Appendix R - Agency Comments Received

This appendix (Appendix R) includes copies of the actual coordination letters received from local, state, and federal agencies during the agency review period. Provided references (in red) direct the reader back to **Appendix P Public and Agency Comments on the Draft EA** where a summary of public and agency comments on the 2022 Draft EA can be found including Airport responses.

For additional public and agency information, see **Appendix O Public Hearing & Public and Agency Involvement** for details on the Public Hearing and agency coordination. See **Appendix Q Public Comments Received** for copies of the actual letters and emails received from the public during the public commenting period with references to find Airport responses to individual comments.

Pittsfield Charter Township
Department of Public Safety
6227 West Michigan Avenue, Ann Arbor, MI 48108
Phone: (734) 822-4911 • Fax: (734) 944-0744
Website: www.pittsfield-mi.gov

Mandy Grewal, Supervisor

Matthew E. Harshberger
Director of Public Safety
Chief of Police
harshbergerm@pittsfield-mi.gov
(734) 822-4921

Sean Gleason
Fire Chief
gleasons@pittsfield-mi.gov
(734) 822-4926

December 12, 2022

Mr. Matthew Kulhanek
Ann Arbor Municipal Airport
801 Airport Drive
Ann Arbor, MI 48108

Re: Public Hearing for the Runway Extension Project at the Ann Arbor Municipal Airport

Dear Mr. Kulhanek,

As outlined in the Notice of Public Hearing for the proposed runway extension project, comments/statements can be submitted by email and/or mail to be included in the transcript of the public hearing. As Pittsfield Charter Township's representative on the Airport Advisory Committee, I wish to submit, on Pittsfield Township's behalf, opposition to the airport runway extension project, as previously documented in the two attached Pittsfield Township Board of Trustees' Resolutions #09-23 (March 24, 2009) and #17-21 (April 12, 2017). As cited in the notice of public hearing, I request that my letter and the two attached resolutions are included in the transcript of the public hearing.

Thank you.

Respectfully,

Matthew E. Harshberger,
Director of Public Safety

Attachments: PCT Res #09-23
PCT Res #17-21

See General response #27

PITTSFIELD CHARTER TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RES #09-23
RESOLUTION OPPOSING PROPOSED EXPANSION OF THE ANN ARBOR MUNICIPAL AIRPORT RUNWAY

MARCH 24, 2009

Minutes of a Regular Meeting of the Township Board of Pittsfield Charter Township, Washtenaw County, Michigan, held at the Township Administration Building located at 6201 W. Michigan Avenue, in said Township, on the 24th day of March, at 6:30 p.m.

Members Present: Grewal, Israel, Scribner, Ferguson, Hunt, Krone, Yi.
Members Absent: None.

The following preamble and resolution were offered by Member Scribner and supported by Member Ferguson.

WHEREAS, the Ann Arbor airport is under the jurisdiction of the City of Ann Arbor and operated by an independent Authority and the land is located within Pittsfield Charter Township immediately adjacent to a residential area; and

WHEREAS, the existing width and length has not posed any substantial safety concerns in the past with only five incidents of landing mishaps out of a total of 600,000 landings in the past eight years; and

WHEREAS, the proposed changes and expansion would shift the runway dangerously close to a busy township roadway (Lohr Road) and closer to dense residential subdivisions; and

WHEREAS, such a runway expansion will significantly increase air traffic volumes and noise pollution experienced by residential subdivisions in the vicinity of the Ann Arbor airport, thereby resulting in a decline of residential home property values; and

WHEREAS, the City of Ann Arbor has not fully demonstrated the economic and safety justifications for undertaking the proposed runway expansion; and

WHEREAS, the City of Ann Arbor appears to have not taken into consideration the negative safety implications such a runway expansion may impose on the surrounding residential subdivisions by expanding a runway closer to residential subdivisions

NOW THEREFORE BE IT RESOLVED, the Pittsfield Charter Township Board of Trustees urges the City of Ann Arbor to reconsider the merits of expanding the Ann Arbor Airport runway in light of the negative implications such an expansion would impose on the residents of Pittsfield Charter Township.

AYES:	Grewal, Israel, Scribner, Ferguson, Hunt, Krone, Yi.
NAYS:	None.
ABSENT:	None.
ABSTAIN:	None.

RESOLUTION DECLARED ADOPTED.

Alan Israel

Alan Israel, Clerk
Pittsfield Charter Township

DATED: March 24, 2009.

See General response #27

PITTSFIELD CHARTER TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RES #17-21
RESOLUTION OPPOSING PROPOSED EXTENSION OF THE ANN ARBOR MUNICIPAL AIRPORT RUNWAY

April 12, 2017

At a Regular Meeting of the Township Board of Pittsfield Charter Township, Washtenaw County, Michigan, held at the Township Administration Building located at 6201 W. Michigan Avenue, in said Township, on the 12[th] day of April, 2017 at 6:30 p.m.

Present: Grewal, Anzaldi, Scribner, Edwards-Brown, Jaffer, Krone, Ralph.
Absent: None.

The following preamble and resolution were offered by Treasurer Scribner, and supported by Trustee Ralph.

WHEREAS, the Pittsfield Township Board of Trustees first adopted a resolution opposing the proposed runway expansion/extension on March 24, 2009 that expressed concerns centered around safety and decline in property values (Resolution #09-23); and

WHEREAS, in the eight (8) years since the adoption of Resolution No. 09-23, Pittsfield Township has not only steadfastly opposed the runway extension, it has fostered a strong partnership with the Committee for Preserving Community Quality, established by Pittsfield Township residents also opposed to the runway extension at the Ann Arbor Municipal Airport; and

WHEREAS, it is readily apparent that any runway extension will increase the viability of passenger and commercial jet aircraft usage at the Ann Arbor Municipal Airport thereby not only significantly compromising public safety and property values but also increasing air pollution and potential groundwater contaminants and, furthermore, this extension will detract from the considerable monetary and community investments made in the last few years by Washtenaw County, Ann Arbor SPARK and others toward the revitalization of the east side of Washtenaw County, specifically in and around the Willow Run airport; and

WHEREAS, Pittsfield Township and the Committee for Preserving Community Quality have extensively and specifically documented (officially by way of responses to the Environment Assessments and otherwise) our reasons for opposing the runway extension, which include, but are not limited to: (1) planes landing to the East on an expanded runway just 93 feet over Pittsfield homes, posing danger to residents; (2) Ann Arbor has not justified a proper Purpose and Need for the expansion, and the minimum required operations for expansion have not been met; (3) the Environmental Assessments do not acknowledge the potential dangers resulting from the presence of large numbers of Canada geese surrounding the airport through much of the year; (4) the expansion would attract larger and heavier aircraft closer to the population center, likely in violation of the Pittsfield Noise Ordinance; (5) any pilot could land any type of plane – no matter how large -- at any time because it is a municipal airport funded with federal tax dollars; (6) and that these risks could pose dangers to the safety of water in wells located on airport property, for which the airport property was originally acquired almost a century ago for water rights, wells which provide drinking water to Ann Arbor and an aquifer that flows throughout Pittsfield Township; and

WHEREAS, the City of Ann Arbor has, despite the very significant safety and environmental concerns noted above, included the proposed runway extension in their capital improvement plan; and

WHEREAS, the second Environmental Assessment (conducted because of egregious flaws of the first one), that includes over 200 public comments with only seven (7) in support of the proposed extension, is currently in the review process by the Federal Aviation Administration; and

WHEREAS, the Pittsfield Township Board of Trustees wants to not only reiterate our continued and steadfast opposition to the runway expansion/extension, we want to expressly and officially request a test by the United States Environmental Protection Agency) (EPA) of the aquifer located at the Ann Arbor Municipal Airport, since the 2016 Ann Arbor Municipal Airport Draft Environmental does not report any water testing data; and

WHEREAS, the City of Ann Arbor has worked with the EPA to retroactively address water quality issues as related to the Dixoane Plume, Pittsfield Township would like to request the EPA to proactively address negative impacts to water quality (that is consumed by City of Ann Arbor and Pittsfield Township residents) that may result from the proposed extension of the runway at the Airport;

NOW THEREFORE BE IT RESOLVED, the Pittsfield Charter Township requests Congresswoman Debbie Dingell, State Senator Rebekah Warren, State Representative Adam Zemke and County Commissioner Felicia Brabec to advocate on this matter with the EPA and request that EPA conduct a test of the aquifer located at the Ann Arbor Municipal Airport; and

BE IT FURTHER RESOLVED that copies of this resolution shall be provided to Congresswoman Debbie Dingell, State Senator Rebekah Warren, State Representative Adam Zemke and County Commissioner Felicia Brabec, and City of Ann Arbor councilmembers.

ROLL CALL VOTE:

AYES: Grewal, Anzaldi, Scribner, Edwards-Brown, Jaffer, Krone, Ralph.
NAYS: None.
ABSENT: None.
ABSTAIN: None.

RESOLUTION DECLARED ADOPTED.

Mandy Grewal, Supervisor
Pittsfield Charter Township

DATED: April 13, 2017

CERTIFICATE

I, Michelle L. Anzaldi hereby certify that the foregoing is a true and complete copy of a resolution adopted by the Township Board of Pittsfield Charter Township, County of Washtenaw, State of Michigan, at a Regular Meeting held on April 12, 2017, and that said meeting was conducted and public notice of said meeting was given pursuant to and in full compliance with the Open Meetings Act, being Act 267, Public Acts of Michigan, 1976, and that the minutes of said meeting were kept and will be or have been made available as required by said Act.

Michelle L. Anzaldi

Michelle L. Anzaldi, Clerk
Pittsfield Charter Township

DATED: April 13, 2017

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON
BOULEVARD CHICAGO, IL
60604-3590

January 17, 2022

REPLY TO THE ATTENTION OF:
Mail Code R-19J

VIA ELECTRONIC MAIL ONLY

Sean Doyle
Great Lakes Deputy Regional Administrator
Federal Aviation Administration
Detroit Airports District Office, DET-ADO-600
11677 South Wayne Road, Suite 107
Romulus, Michigan 48174

Steve Houtteman, Environmental Specialist
Planning and Development
Michigan Department of Transportation
Office of Aeronautics
2700 Port Lansing Road
Lansing, Michigan 48906-2160

Re: Ann Arbor Airport – Runway 6/24 Draft Environmental Assessment, Ann Arbor, Washtenaw County, Michigan

Dear Messrs. Doyle and Houtteman:

The U.S. Environmental Protection Agency has reviewed the November 2022 Draft Environmental Assessment (Draft EA) for proposed upgrades at Ann Arbor Airport (Airport). Our comments in this letter are provided in accordance with our responsibilities under the National Environmental Policy Act (NEPA), the Council on Environmental Quality's NEPA Implementing Regulations (40 CFR 1500-1508), and Section 309 of the Clean Air Act.

The Draft EA indicates the proposed project includes:

- extending Runway 6/24 by 720 feet at the approach end of Runway 6 to provide 4,225 feet of runway length,
- shifting Runway 6/24 to the southwest by adding an additional 150 feet on the Runway 6 end and removing 150 feet on the Runway 24 end,
- extending Taxiway A parallel to the southwest to match the Runway 6/24 length,
- relocating Taxiway A1 150 feet to the southwest and reconstructing to correct a taxiway intersection with Runway 6/24,
- constructing new connector taxiway at the end of Runway 6, and
- relocating Taxiway D 150 feet to the southwest and reconstructing.

The Draft EA analyzes the impacts from two alternatives: no build and the proposed build alternative. After reviewing the Draft EA and appendices, EPA has the following comments pertaining to water and air impacts, construction debris, wildlife hazards, and project commitments.

Water Impacts

The Draft EA indicates surface water runoff is directed to the Airport's existing drainage system. However, the Draft EA is silent as to whether de-icing chemicals are used at the Airport. If planes are de-iced, EPA recommends considering biofiltration to remove chemicals before they reach the drainage system and local streams. See Water Resources/Water Quality response #5

Air Impacts

EPA acknowledges the recommendations to reduce temporary air quality impacts for both workers and the surrounding area found in Section 3.4 of the Draft EA. Additional applicable measures to reduce impacts outlined in the enclosed "*Construction Emission Control Checklist*" should become commitments in the Finding of No Significant Impact (FONSI).

See Air Quality response #5

Wildlife Hazards

The Draft EA indicates white-tailed deer and birds have been struck at the Airport. Appendix K, Wildlife Site Visit, recommends building a deer fence and installing grates in the two culverts leading into the airfield to prevent access. However, the Draft EA is silent as to whether fencing and grates will be installed. EPA strongly recommends the recommendations found in Appendix K become project commitments if a FONSI is signed for the prosed project.

Additionally, EPA recommends using Wildlife Control K-9s to proactively manage wildlife and increase aviation safety. Cherry Capitol Airport successfully made use of this program in the past. See Wildlife response #1, Safety/Health responses #1 and #8

Construction Debris

Removing pavement presents opportunities for reuse and recycling of materials, which benefits the environment and preserves valuable landfill capacity. The Draft EA is silent regarding the potential for reuse and/or recycling of pavement materials. EPA recommends applicable practices from EPA's Sustainable Management of Construction and Demolition Materials webpage[1] and EPA's Large-Scale Residential Demolition webpage[2] are identified and incorporated into contract language for bid packages. Additionally, the potential for the use of recycled materials in pavement applications and replacement of carbon-intensive Portland Cement in concrete should be considered. See General response #30

Commitments to Reduce Impacts

The Draft EA includes best management practices (BMPs) that should be considered to prevent and minimize impacts (Table 3-7). However, the Draft EA does not indicate whether these best management practices will be included in project design/implementation if a FONSI is signed. EPA strongly recommends BMPs included in the Draft EA, as well as applicable measures found

[1] https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials
[2] https://www.epa.gov/large-scale-residential-demolition

in EPA's "*Construction Emission Control Checklist,*" become project commitments as part of a FONSI.

See General response #31

The National Archives and Records Administration and the Office of Management and Budget have mandated that Federal agencies transition business processes and recordkeeping practices to fully electronic environments. Please help achieve this goal by eliminating paper mail as much as possible and send a copy of the Finding of No Significant Impact for this project electronically. If you have any questions, please contact Kathy Kowal, the lead reviewer for this project, at kowal.kathleen@epa.gov. Ms. Kowal is also available at 312-353-5206.

Sincerely,

Kathy Triantafillou
Acting Deputy Director
Tribal and Multi-media Programs Office
Office of the Regional Administrator

Enclosure: Construction Emission Control Checklist

cc via email:
Matt Kulhanek, Airport Manager, Ann Arbor Municipal Airport
William Ballard, Mead & Hunt, Inc.
Melissa Letosky, Michigan Department of Environment, Great Lakes, and Energy

U.S. Environmental Protection Agency
Construction Emission Control Checklist

Diesel emissions and fugitive dust from project construction may pose environmental and human health risks and should be minimized. In 2002, EPA classified diesel emissions as a likely human carcinogen, and in 2012 the International Agency for Research on Cancer concluded that diesel exhaust is carcinogenic to humans. Acute exposures can lead to other health problems, such as eye and nose irritation, headaches, nausea, asthma, and other respiratory system issues. Longer term exposure may worsen heart and lung disease.[3] We recommend the following applicable protective measures become commitments for Ann Arbor Airport improvements.

Mobile and Stationary Source Diesel Controls

Purchase or solicit bids that require the use of vehicles that are equipped with zero-emission technologies or the most advanced emission control systems available. Commit to the best available emissions control technologies for project equipment in order to meet the following standards.

- On-Highway Vehicles: On-highway vehicles should meet, or exceed, the EPA exhaust emissions standards for model year 2010 and newer heavy-duty, on-highway compression-ignition engines (e.g., long-haul trucks, refuse haulers, shuttle buses, etc.).[4]
- Non-road Vehicles and Equipment: Non-road vehicles and equipment should meet, or exceed, the EPA Tier 4 exhaust emissions standards for heavy-duty, non-road compression-ignition engines (e.g., construction equipment, non-road trucks, etc.).[5]
- Low Emission Equipment Exemptions: The equipment specifications outlined above should be met unless: 1) a piece of specialized equipment is not available for purchase or lease within the United States; or 2) the relevant project contractor has been awarded funds to retrofit existing equipment, or purchase/lease new equipment, but the funds are not yet available.

Consider requiring the following best practices through the construction contracting or oversight process:

- Establish and enforce a clear anti-idling policy for the construction site.
- Use onsite renewable electricity generation and/or grid-based electricity rather than diesel-powered generators or other equipment.
- Use electric starting aids such as block heaters with older vehicles to warm the engine.
- Regularly maintain diesel engines to keep exhaust emissions low. Follow the manufacturer's recommended maintenance schedule and procedures. Smoke color can signal the need for maintenance (e.g., blue/black smoke indicates that an engine requires servicing or tuning).
- Where possible, retrofit older-tier or Tier 0 nonroad engines with an exhaust filtration device before it enters the construction site to capture diesel particulate matter.
- Replace the engines of older vehicles and/or equipment with diesel- or alternatively-fueled engines certified to meet newer, more stringent emissions standards (e.g., plug-in hybrid-electric vehicles, battery-electric vehicles, fuel cell electric vehicles, advanced technology locomotives, etc.), or with zero emissions electric systems. Retire older vehicles, given the significant contribution of vehicle emissions to the poor air quality conditions. Implement

[3] Carcinogenicity of diesel-engine and gasoline-engine exhausts and some nitroarenes. *The Lancet.* June 15, 2012
[4] http://www.epa.gov/otaq/standards/heavy-duty/hdci-exhaust.htm
5 https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-nonroad-engines-and-vehicles

programs to encourage the voluntary removal from use and the marketplace of pre-2010 model year on-highway vehicles (e.g., scrappage rebates) and replace them with newer vehicles that meet or exceed the latest EPA exhaust emissions standards, or with zero emissions electric vehicles and/or equipment.

Fugitive Dust Source Controls

- Stabilize open storage piles and disturbed areas by covering and/or applying water or chemical/organic dust palliative, where appropriate. This applies to both inactive and active sites, during workdays, weekends, holidays, and windy conditions.
- Install wind fencing and phase grading operations where appropriate and operate water trucks for stabilization of surfaces under windy conditions.
- When hauling material and operating non-earthmoving equipment, prevent spillage and limit speeds to 15 miles per hour (mph). Limit speed of earth-moving equipment to 10 mph.

Occupational Health

- Reduce exposure through work practices and training, such as maintaining filtration devices and training diesel-equipment operators to perform routine inspections.
- Position the exhaust pipe so that diesel fumes are directed away from the operator and nearby workers, reducing the fume concentration to which personnel are exposed.
- Use enclosed, climate-controlled cabs pressurized and equipped with high-efficiency particulate air (HEPA) filters to reduce the operators' exposure to diesel fumes. Pressurization ensures that air moves from inside to outside. HEPA filters ensure that any incoming air is filtered first.
- Use respirators, which are only an interim measure to control exposure to diesel emissions. In most cases, an N95 respirator is adequate. Workers must be trained and fit-tested before they wear respirators. Depending on the type of work being conducted, and if oil is present, concentrations of particulates present will determine the efficiency and type of mask and respirator. Personnel familiar with the selection, care, and use of respirators must perform the fit testing. Respirators must bear a NIOSH approval number.

William Ballard

From: Sadler, Taunia (DNR) <SadlerT@michigan.gov>
Sent: Tuesday, January 17, 2023 9:28 AM
To: William Ballard
Cc: Sadler, Taunia (DNR); Whitcomb, Scott (DNR)
Subject: DNR Comments on Proposed Runway Extension - Ann Arbor Municipal Airport
Attachments: WL 22 EXE00129 I Ballard.pdf

You don't often get email from sadlert@michigan.gov. Learn why this is important

Dear Mr. Ballard:

Thank you for the opportunity to comment on the proposed runway extension at Ann Arbor Municipal Airport. Fisheries and Wildlife Division staff have reviewed (emails are below) and have no concerns.

If you require anything else, please let us know.

Sincerely,

Taunia Sadler
Executive Assistant to Deputy Directors Scott Whitcomb and Kristin Phillips
Michigan Department of Natural Resources
517-930-4989

From: Tison, Dennis (DNR) <TisonD@michigan.gov>
Sent: Tuesday, January 10, 2023 11:24 AM
To: Robison, Joseph (DNR) <RobisonJ@michigan.gov>
Cc: Nagy, Vickie (DNR) <NAGYV@michigan.gov>; McFadden, Terrence (DNR) <McfaddenT@michigan.gov>
Subject: FW: EXE00129/Ballard/Review of Ann Arbor Environmental Assessment draft - Proposed Extension of Runway 6-24

I have reached out to Sara Thomas with Fisheries, and she has already sent her comments to Taunia, but I have also attached them in case you need them.

After my review of this document, I feel there would be little impact on wildlife as current habitat is already mowed and severely degraded by invasives species. My only concern would have been nesting season with Henslow's Sparrow, but they addressed this in the document with the agreement in place with Audubon and the mowing restrictions.

See Wildlife response #1

From: Thomas, Sara (DNR) ThomasS35@michigan.gov
Sent: Thursday, January 5, 2023 2:18 PM
To: Sadler, Taunia (DNR) SadlerT@michigan.gov

Subject: FW: EXE00129/Ballard/Review of Ann Arbor Environmental Assessment draft - Proposed Extension of Runway 6-24

Hi Taunia,

Any impacts to fisheries resources from this expansion will be negligible. Fisheries Division has no objections to the preferred alternative state in the Environmental Assessment.

See Water Resources/Water Quality response #8

Thanks,

Sara Thomas

Sara Creque Thomas (she/her/hers)
Michigan DNR – Fisheries
Waterford Fisheries Station
Lake Erie Unit Manager
7806 Gale Rd.
Waterford, MI 48327

Work cell: 734-718-0474 ***please note new number***

February 21, 2023

VIA EMAIL

William Ballard, AICP
Mead and Hunt, Inc.
2605 Port Lansing Road
Lansing, Michigan 48909

Dear William Ballard:

SUBJECT: Early Coordination Review of Proposed Extension of Runway 6/24;
Ann Arbor Municipal Airport, Ann Arbor, Michigan
Washtenaw County, T03S R06E Sections 17, and 18; Pittsfield Township
Michigan Department of Environment, Great Lakes, and Energy (EGLE)
Water Resources Division (WRD)

Thank you for your December 15, 2022, early coordination letter regarding the development of a Draft Environmental Assessment (EA) for the extension of Runway 6/24 at the Ann Arbor Municipal Airport, Ann Arbor, Michigan.

The scoping information provided indicates that the Federal Aviation Administration (FAA), and Michigan Department of Transportation (MDOT) Aeronautics have authorized the airport to explore alternatives designed to meet current and future fleet mix needs. Specifically, the preferred alternative, Alternative 2, includes the proposed improvements:

- Extend Runway 6/24 720 feet at the approach end of Runway 6 to provide 4,225 feet of runway length;

- Shift Runway 6/24 to the southwest by adding an additional 150 feet on the Runway 6 end and removing 150 feet on the Runway 24 end;

- Taxiway A - Extend parallel to the southwest to match the Runway 6/24 length;

- Taxiway A1 – Relocate 150 feet to the southwest and reconstruct to comply with FAA Advisory Circular (AC) 150/5300-13B, Section 4.8.1 to correct the taxiway intersection with Runway 6/24 to connect at a right angle;

- Taxiway A4 – Construct new connector taxiway at the Runway 6 end;

• Taxiway D – Relocate 150 feet to the southwest and reconstruct to comply FAA AC 150/5300-13B, Section 4.3.5 which prohibits direct access from an apron to a runway without requiring a turn by aircraft prior to reaching the runway;

The WRD can offer the following comments regarding statutes administered by our program:

a) Wood Outlet Drain is present along the western, and southern boundaries of Ann Arbor Municipal Airport. Proposed Runway 6/24 extension will encroach upon this drain, especially the enclosed portion of the drain at the southwestern limits of the project. Any construction below the ordinary high water mark of this drain, modification of the existing drain enclosure, additional enclosure of the drain, or relocation of the drain will require a permit under Part 301, Inland Lakes and Streams, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA). Stream mitigation may be required for unavoidable stream impacts as a result of this project. See Water Resources/Water Quality response #8

b) There may be a floodplain present associated with Wood Outlet Drain that is regulated under state law. Any filling, occupation, or grading within the 100-year floodplain of Wood Outlet Drain, if it has a drainage area of two square miles or more, will require a permit under the State's Floodplain Regulatory Authority, found in Part 31, Water Resources Protection, of the NREPA. See Water Resources/Water Quality response #8

c) Available wetland inventories indicate the presence of wetland throughout the southern portion of the Ann Arbor Municipal Airport property, including within portions of the property actively maintained by mowing, and at the southwest end of the proposed Runway 6/24 extension. Any tree or shrub removal, excavation, filling, grading, or construction that occurs in these wetlands will require a permit under Part 303, Wetlands Protection, of the NREPA. All wetland areas within the project limits should be delineated by a professional wetland consultant, and then submitted to Transportation Review Unit (TRU) for verification. Our recommendation is to submit a Voluntary Preliminary Review (VPR) request form in MiEnviro for verification of wetland delineations, and discussion of permitting requirements and limitations. Mitigation may be required for any unavoidable wetland impacts, as a result of this project. It should be noted that wetland delineations completed by your wetland consultant in 2018, and 2019 have not been verified by WRD. Thus, we recommend requesting a VPR so that those wetland delineations can be reviewed, and verified. See Water Resources/Water Quality response #2

d) A review of our database indicates potential State and/or Federal Threatened and Endangered species Indiana Bat (*Myotis sodalis),* Northern Longeared Bat (*Myotis septentrionalis),* and state listed Henslow's Sparrow (*Ammodramus hanslowii*) within the project area. Henslow's Sparrow has known occurrences within the Ann Arbor Municipal Airport property. It will be required that this project be screened using the U.S. Fish and Wildlife Service's on-line Threatened and Endangered species screening tool, iPAC. The clearance letter generated from this screening process for Indiana Bat and Northern Longeared Bat will need to be provided with your permit application submitted for regulated activities under Parts 31, 301, and 303. Work limitations during the breeding and nesting season of Henslow's Sparrow from spring to mid-summer will be required in conditions included with any permit issued for Part 31, 301, and 303 regulated activities.

See Wildlife response #1

Thank you for the opportunity to comment on this EA. If you have any questions regarding this letter, please contact me at 517-256-1469; SkubinnaJ@Michigan.gov; or EGLE, WRD, Transportation Review Unit, P.O. Box 30458, Lansing, Michigan 48909.

Sincerely,

John Skubinna
Environmental Quality Analyst
Water Resources Division

cc: Steve Houtteman, MDOT

Note:
The 2022 Draft EA was completed as a new effort independent of previous Environmental Assessments to provide a current review of the NEPA-defined environmental categories concerning the proposed extension of Runway 6/24.

Although the 2022 Draft EA is referred to as the "second revised Draft Environmental Assessment" (SRDEA)" throughout this letter, that is incorrect. There is presently only one draft version of the document from this process that may be revised pending comments received from the public outreach process.

LEECHTISHMAN
LEECH TISHMAN FUSCALDO & LAMPL

January 18, 2023

Steven M. Taber
staber@leechtishman.com
(626) 395-7300

VIA USPS AND ELECTRONIC MAIL

Mr. Matthew Kulhanek
Manager, Ann Arbor Municipal Airport
801 Airport Drive
Ann Arbor, Michigan 48108
mjkulhanek@a2gov.org

Mr. Steve Houtteman
MDOT-Aeronautics
2700 Port Lansing Road
Lansing, Michigan 48906
houtteman@michigan.gov

Re: Comments of Pittsfield Charter Township and the Committee for Preserving Community Quality on Michigan Department of Transportations' Second Revised Draft Environmental Assessment for the Extension of the Runway at Ann Arbor Municipal Airport

Dear Mr. Kulhanek and Mr. Houtteman,

These comments are submitted on behalf of The Charter Township of Pittsfield (Pittsfield) and the Committee for Preserving Community Quality (CPCQ) on the second revised Draft Environmental Assessment (SRDEA) dated November 2022, and released to the public on November 13, 2022. The SRDEA was drafted by Mead and Hunt and prepared for the Federal Aviation Administration and Michigan Department of Transportation, Office of Aeronautics (MDOT). These comments are timely because on December 15, 2022, an Agency Coordination letter was sent indicating that all who received the letter could submit comments until January 18, 2023.

Table of Contents

I. Introduction

"The care of human life and happiness and not their destruction is the first and only legitimate object of good government."
- ***Thomas Jefferson, Letter to the Republican Citizens of Washington County Maryland (March 31, 1809)***

"The Federal Aviation Act requires a delicate balance between safety and efficiency, and the protection of persons on the ground."
- ***City of Burbank v. Lockheed Terminal, 411 U.S. 624 (1973*)**

This is the third draft Environmental Assessment that Ann Arbor Municipal Airport (ARB) has put forth for the same the proposed project. The first, dated February 2010, was prepared by JJR, Inc. To which Pittsfield Township submitted public comments on April 19, 2010. Exhibit 1. The second, dated December 2016, was prepared by SmithGroupJJR, to which Pittsfield Township submitted public comments on February 10, 2017. Exhibit 2. None of the previous draft environmental assessments became final. Neither MDOT nor ARB has offered any response to the comments submitted. Appendix N of the SRDEA purports to be responses to the comments submitted to prior draft environmental assessments.

In addition, on January 28, 2013, Pittsfield Township submitted a Petition to Deny Approval and Funding for the Major Runway Extension Project at Ann Arbor Municipal Airport (ARB) Located in Pittsfield Charter Township, Michigan to the Secretary of Transportation. Exhibit 3. Although the FAA responded to the portions that concerned it on December 31, 2013, Pittsfield is awaiting a response from the Department of Transportation to whom the Petition was addressed. To the extent that the Petition was premature, Pittsfield will renew its Petition with the Department of Transportation.

Finally, Pittsfield responded on May 30, 2019, to Mead & Hunt's April 15, 2019, requesting comments on specific issues. Exhibit 4. That letter is not included in the Appendix N of the SRDEA that purports to letters received in response to ARB's "Early Agency Coordination." Nor does the SRDEA address any of the questions and comments raised by Pittsfield's letter. A revised SRDEA should be issued that includes Pittsfield's letter and addresses the comments, concerns, and questions raised in that letter. See General Response #32

Pittsfield incorporates by reference its previous comments, its Petition and its May 30, 2019, letter to Mead and Hunt. Pittsfield also incorporates by reference all other public comments that oppose the construction of the unneeded runway extension. As indicated in the two Resolutions that Pittsfield has passed opposing the extension, Pittsfield reiterates, once again, its continued and steadfast opposition to the runway extension and expansion of the airport.

II. The SRDEA Does Not Meet the Requirements of the State Block Grant Program.

The SRDEA mentions that the Project is being completed under Michigan's State Block Grant Program ("SBGP"), where FAA provides funds to the relevant state agency and that agency then "administers" the program. SRDEA, p. 1-5 – 1-6. There is, however, some question as to whether Michigan Department of Transportation has retained its ability to administer the SBGP. The most recent Memorandum of Agreement, MDOT Contract No. 2010-0204, is dated March 25, 2010 ("2010 Agreement"). Exhibit 5. That Agreement has a term of five years. 2010 Agreement, p.1, § 1 and expired seven years ago.

MDOT has told Pittsfield that there have been no amendments to the Agreement between MDOT and the Federal Aviation Administration (FAA), and a new Agreement has not been executed. Michigan is out of compliance with 49 U.S.C. § 47128 which requires such agreements to be in place before the FAA can fund the state's block grant program. See 49 U.S.C. § 47128(b)(4) and (5). MDOT seems to have lost its ability to fund the Project. See Financial/Economic response #13

When a project is undertaken under the SBGP, federal law requires the Michigan Department of Transportation ("MDOT") to follow "United States Government standard requirements for administering the block grant, including the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.), State and local environmental policy acts, Executive orders, agency regulations and guidance, and other Federal environmental requirements." 49 U.S.C. § 47128(4) (emphasis added).

Thus, as a matter of federal law, in carrying out projects under the SBGP, MDOT must comply not only with NEPA, the Clean Air Act, the Clean Water Act, CERCLA and RCRA, and as all state and local laws, in addition to FAA orders, regulations and guidance.

If the 2010 Agreement is still in effect, the requirement of 49 U.S.C. § 47128 that MDOT follow federal, state, and local law is also a matter of contract, as stated in the 2010 Agreement between the FAA and MDOT.

> In carrying out this program, MDOT will comply with all Federal laws, regulations and executive orders set forth in Attachment B. MDOT also acknowledges awareness of FAA policy and guidance in the form of Orders which have applicability to the state block grant program and are set forth in Attachment B.

2010 Agreement, p.3, Exhibit 5. "Attachment B" lists the federal statutes, rules, and regulations that MDOT must follow when carrying out projects, such as the proposed action.

In addition to federal law, projects under the SBGP must also follow state laws as well. 49 U.S.C. § 47128(4). This means this project must comply with the Michigan Environmental Protection Act ("MEPA"). MCL.324.1701 – 1705. MEPA prohibits state agencies, such as MDOT, from authorizing projects that will result in the "pollution, impairment, or destruction of the air, water, or other natural resources, or the public trust in these resources." MCL 324.1705(2). There is no indication in the SRDEA that it follows Michigan environmental laws, regulations, and standards. MEPA indicates that it is incumbent on MDOT to show that "there is no feasible and prudent alternative" to the Project and that its conduct is consistent with "the promotion of the public health, safety, and welfare in light of the state's paramount concern for the protection of its natural resources from pollution, impairment, or destruction." MCL 324.1703(1). If MDOT approval of this project allows conduct that harms the air and water, and increases noise pollution, and invades the public trust in these resources, which it does, it does not comply with MEPA. See General response #28

In proposing the Project, MDOT's project must also follow local ordinances as well. 42 U.S.C. § 47128. there is no indication in the SRDEA it will comply, for example, with Pittsfield Township's Noise Ordinance. Pittsfield Township, within which ARB is located, has a long-standing noise ordinance making it unlawful for "any person to create, assist in creating, permit, continue, or permit the continuance of any unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace, or safety of others within the limits of the township." Exhibit 6. MDOT and the SRDEA must make sure that Pittsfield Township's citizens' health, safety and property are protected from "unreasonably loud, disturbing, unusual or unnecessary noise" created by the Project. *Id*. In addition, Pittsfield contracted with the City of Ann

Arbor regarding ARB. Exhibits 7 & 8. There is no indication in the SRDEA, ARB and MDOT will follow the Agreement between Pittsfield and the City of Ann Arbor.

See Noise response #1, #4, & #13

III. The SRDEA Does Not Support Its Purpose and Need Because There Is No Purpose or Need for the Project

An environmental assessment (EA) must include a discussion of the purpose and need for the proposed action which must "specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action." 40 C.F.R. § 1502.13; see also, 40 C.F.R. § 1502.14; *Nat'l Parks & Conservation Ass'n v.BLM*, 606 F.3d 1058, 1070 (9th Cir. 2010); *Westlands Water Dist. v. United States*, 376 F.3d 843, 865, 867 (9th Cir. 2004). In addressing the Purpose and Need section of an EA, FAA Order 1050.1F provides that the Purpose and Need section "presents the problem being addressed and describes what the FAA is trying to achieve with the proposed action. The purpose and need for the proposed action must be clearly explained and stated in terms that are understandable to individuals who are not familiar with aviation or commercial aerospace activities." FAA Order 1050.1F, ¶ 6-2.1c. The SRDEA's Purpose and Need accomplishes none of these goals.

The "need" is the problem, and the "purpose" is the proposed solution to the problem. The Purpose (*i.e.,* the Project) is supposed to resolve the Need (*i.e.,* the problem). Here, it is the opposite, one large tenant's desire (AvFuel Corp.) to extend the runway is driving the proposed action. This is a case of a Purpose looking for a Need. It is a project looking for a problem to justify its existence.

See General responses #3 and #14.

A. Neither the Purpose nor the Need justify the harm done to the communities surrounding ARB

In this third iteration of the environmental assessment, MDOT and ARB have abandoned any pretense that extending the runway at ARB is for safety reasons. Instead, the purpose of the runway extension is simply to "improve operational utility of the airport by meeting the takeoff and landing runway length requirements of aircraft that currently operate at the airport and are projected to steadily increase over time." SRDEA, p. 1-7. The SRDEA states that the Project is needed "because the Runway 6/24 was designed to serve primarily small piston driven aircraft; [sic] however, the Airport receives regular use by small turboprop aircraft and occasional business jet aircraft that require a longer runway to operate at a greater payload than they do today." Neither the purpose nor the need justifies the harm to the public health and safety of the surrounding neighborhoods that the extension to the runway will create. After reviewing the SRDEA and the "Runway Justification Study," it is apparent that the "purpose and need" for the Project is to allow a handful of larger aircraft operators at ARB to operate with full payloads on a couple of hot, humid days.

See General responses #3 and #14; Safety/Health responses #3 and #9; and Safety/Health responses #11 and #15.

1. The SRDEA incorrectly categorizes B-II as the "critical aircraft" for Runway 6/24

The SRDEA claims that the critical aircraft at ARB is "B-II." "B-II" denotes an aircraft with an approach speed of 91 nautical miles per hour ("NMPH"), but less than 121 NMPH, (Aircraft Approach Code of "B"), wingspan of 49 ft., but less than 79 ft., and a tail height of 20 ft., but less than 30 ft. (Aircraft Design Group "II").

To determine the "critical aircraft," the SRDEA states that it "may be a single type of aircraft or a grouping of types of aircraft with similar characteristics that conducts at least 500 annual operations at an airport." SRDEA, Appendix C, p.19. It claims that the "B-II" grouping of aircrafts represent the "critical aircraft" at ARB. *Id.* The SRDEA claims that in 2019 there were 679 B-II operations, *Id.,* and, therefore, B-II is the "critical aircraft" for Runway 6/24.

FAA's AC 150/5000-17, *Critical Aircraft and Regular Use Determination*, however, states that in determining the "critical aircraft" for the airport, "an operations count by aircraft make and model is required for the **most recent 12-month period of activity** that is available." AC 150/5000-17, p.2-1 (emphasis added). Since the Runway Justification Study was run in February 2021, the "most recent 12-month period of activity" would have been from February 1, 2020, until January 31, 2021. According to the FAA, there were 383 B-II operations at ARB during that period. *FAA Traffic Flow Management System Counts,* *https:/aspm/faa.gov/tfms/sys/Airport.asp*. The last full calendar year of data available to MDOT in February 2021 showed that in 2020 there were 424 B-II operations from ARB. *Id.* If one were to use the date that SRDEA was issued (November 13, 2022), one arrives at 469 annual B-II operations. *Id.* The SRDEA provided no justification for using data from 2019, which is not allowed using FAA's criteria in its Advisory Circular. See Technical response #8 and #10

To cover up the failure to reach the required 500 annual operations within the previous 12-month period, SRDEA uses false numbers to bolster its argument that B-II is the "critical aircraft" at ARB. Table 1-0 in the SRDEA (p.1-8), for example, which shows the number of B-II flights is wrong. When compared to the chart in the Appendix C, the "annual operations" numbers in Table 1-0 are wrong.

Representative Aircraft	**Annual Ops 2019 in Table 1-0 of SRDEA**	**Actual Annual Ops from FAA TFSMC Database**
TBM8 (Socata TBM 850)	150	90
BE20 and B350 (Beechcraft King Air)	966	264
C56X (Cessna Excel XLS)	263	161
E55P (Embraer Phenom 300)	97	77
C172 (Cessna 172)	2,876	709
EC55 (EC-155)	84	82

This verifiably false information in the SRDEA calls into question the veracity of all data in the SRDEA and is a violation of NEPA. *See* 40 C.F.R. § 1502.24. Because of this, MDOT cannot be trusted to present correct data about the situation at ARB based on its willingness to use false data for such a critical issue.

Therefore, the SRDEA's conclusion that "B-II" aircraft are the "critical aircraft" for Runway 6/24 at ARB is wrong. Because the Airport Reference Code "B-II" is not the critical aircraft, the runway does need not be lengthened to accommodate that size of aircraft. See Technical response #11

2. Use of the lengthened runway would rarely be required, but would pose substantial risks to the surrounding community every day

a. After over twelve years, MDOT and ARB still have presented no evidence of "undue concessions"

The SRDEA claims that an extended runway is needed because for small turboprops and jets "to conduct operations on the existing runway, undue concessions in reduced fuel, passengers and/or cargo loads are often needed." SRDEA, p. 1-7. This has been the primary justification for extending the runway since 2007. However, none of the inventories, assessments, analyses, or studies required by FAA Order 1050.1F are present in the SRDEA that would confirm this need. FAA Order 1050.1F, ¶ 6-2.1c. As the FAA pointed out in an earlier draft of the SRDEA, "[t]he rate of users taking weight restrictions has not been documented (at least in the justification report)." Exhibit 13. Neither the SRDEA nor the Runway Justification Study (Appendix C of the SRDEA) provide any documentation regarding the weight restrictions experienced by any aircraft at ARB. In response to the FAA and community concerns, MDOT and ARB simply brush the issue off by claiming that because they have gathered no data, they can provide no documentation about this critical issue. See SRDEA, Appendix N, p. 18, ("There is no information available on the number of aircraft operations that have needed to make weight and/or fuel concessions to operate at ARB. This is because there are no publicly available databases with this information. Likewise, there are no methods to obtain an accurate count of this number since all pilots would need to be willing to participate in an interview/survey effort to share this information"). There is no evidence or discussion in the SRDEA that operating with weight restrictions is an issue at ARB for anyone except the pilot of the Citation XLS.

Although no evidence indicates that airport users are taking "undue concessions," MDOT leans heavily on this purported "need" in the SRDEA. MDOT frequently mentions it throughout the SRDEA as the justification for extending the runway. Yet, although this has been an issue for over twelve years, neither MDOT nor ARB has tried to gather the information requested by the FAA and the surrounding communities. MDOT and ARB have even failed to gather this information from the two aircraft that account for most of the B-II flights. Without that evidence or other support, the statements made by MDOT regarding the purported "need" are unreliable and self-serving and must be dismissed as arbitrary and capricious.

Even B-II aircraft must take weight restrictions on a "regular basis," MDOT still has not answered FAA's logical and reasonable question from 2016: "Why do they base at ARB instead of another close airport if they cannot use the aircraft to its max capability?" (Comment No. 15, October 2016 MDOT AERO/Applicant Ann Arbor comments in response to FAA questions) Exhibit 9. Why, indeed.

As mentioned above, MDOT claims that the Project is needed "because the Runway 6/24 was designed to serve primarily small piston driven aircraft; [sic] however, the Airport receives regular use by small turboprop aircraft and occasional business jet aircraft that require a longer runway to operate at a greater payload than they do today." Exhibit 13. This putative need, however, presumes that such critical aircraft cannot already operate at such capabilities regularly. Again, the SRDEA presents no evidence that aircraft currently operating at ARB have incurred weight penalties. On the few occasions that a longer runway is needed, Willow Run Airport (YIP) is a short 12 statute miles from ARB (about 15 minutes by car). YIP has three runways (7500, 7300 and 6000), 24-hour tower, 24-hour fire and rescue, de-icing, and robust general aviation and business aviation facilities. Thus, the Airport's argument that the runway needs to be lengthened so a handful of aircraft pilots and passengers need not drive an extra 12 miles to get to/from the airport on the few days that a weight restriction would be required is ludicrous when compared to the damage the increase in jet operations will do to surrounding communities.

This issue of justification of the need to lengthen the runway has been problematic since the idea was first raised in 2007. Even the FAA has questioned the need for an extended runway. In May 2010 comments on the 2010 Draft Environmental Assessment (DEA), the FAA asked, "[h]as it been documented that the current B-II 'small' users operate with load restrictions? If so, how often does this occur and what are the quantifiable impacts to their operations?" Exhibit 10. In the ensuing 12 years, ARB has never answered the FAA's question from 2010 by providing that documentation. In addition, in a separate question, the FAA asked, "the conclusion for the implementation for the preferred alternative states that a positive result of improvements is the ability of business owners to achieve improved fleet efficiency for critical aircraft by maximizing their passenger and/or cargo loads. How has this statement been substantiated? What records exist that current users at ARB are not operating at maximum passenger and/or cargo loads? What has been the economic impact of the reduction of loads if they are occurring?" To paraphrase the FAA's questions, if there is no established, substantiated loss of passenger or cargo load opportunities, or established current negative economic impact, there is no Need. These questions must be answered before any project to lengthen the runway is even considered by MDOT. The SRDEA does not have answers to these questions. Since these questions have been pending for 13 years

It is also worth noting that MDOT's federal block grant status could be at risk if it does not enforce the requirements under FAA Order 1050.1F in terms of requiring applicants to provide supporting data, inventories, assessments, analyses, or studies to support its proposed expansions, even though MDOT has not traditionally done so. Since this question is so important to the justification for lengthening Runway 6/24 at ARB, without evidence to support the statement that existing aircraft are taking weight penalties "on a regular basis," any decision to move forward with the Project is arbitrary and capricious. See Technical response #7

b. "Contaminated runway" is not a justification for lengthening it

The SRDEA also claims that the runway extension is needed because "[d]iversions to other airports are also commonly needed when the runway surface is wet, or during the summer months when higher temperatures reduce aircraft performance." SRDEA, p. 1-7. This is contrary to the Runway Justification Study, which states in Section 6.3 that "The inclusion of the contaminated runway length distances cannot be used to justify runway length under FAA funding requirements …" SRDEA, Appendix C, p. 26. FAA also pointed this out in its comments, stating "[r]ecommend clarifying that contaminated runways are not used in the runway length requirements." FAA Comments, p.1-5. MDOT ignored both the Runway Justification Study and the FAA and included the sentence as part of the justification for the "need" for the Project. See Technical response #7

c. A longer runway is not needed to accommodate the existing aircraft that use ARB

The "purpose and need" of the Project comes under additional scrutiny when one considers that the take-off/landing distances specified for the various B-II aircraft that regularly use ARB. Since the "need" is to allow airport users to conduct operations without "undue concessions in reduced fuel, passengers and/or cargo loads," (SRDEA, p. 1-7), it is important to understand what are the "operational performance characteristics" for B-II aircraft that regularly use ARB. The following table is a table of the Take-Off Distance and the Landing Distances for the B-II identified in the Appendix C of the SRDEA.

Aircraft Model	No. of 2019 Operations	Take-off Distance (MTOW, Sea Level, ISA) (feet)	Landing Distance (feet)
Gulfstream Jetprop Commander 1000	4	2,131	2,186
Beech Super King Air 350	123	3,300	2,692
Beech 200 Super King Air	141	2,579	2,074

Raytheon 300 Super King Air	2	3,300	2,692
Beech F90 King Air	2	2,775	
Cessna 208 Caravan	100	2,053	1,624
Cessna Citation CJ4	5	3,180	2,770
Cessna Conquest	2	2,465	1,875
Cessna Citation II/Bravo	8	3,450	2,078
Cessna Excel/XLS	161	3,590	2,909
Cessna Citation Sovereign	28	3,530	2,600
Embraer Phenom 300	77	3,199	2,430
Pilatus PC-24	21	2,930	2,375

SRDEA, Appendix C

While the Cessna Citation Excel and the Cessna Citation Sovereign may not be able to operate at their maximum weight on an average day, they could operate at about 90% of their maximum weight. All other "B-II" aircraft can use ARB's 3,505-foot runway with little or no weight restrictions on most days. The Beechcraft King Air 200 can use ARB's 3,505-foot runway on most days without weight restrictions. The entire runway expansion project is specifically designed to benefit a single aircraft: AvFuel's Cessna XLS. See Technical response #2

As stated above, ARB has long claimed that an extended runway is needed because the small turboprop and jet aircraft operating out of ARB "on a regular basis" suffer "undue" weight penalties due to the length of the runway. While neither MDOT nor ARB have provided any data about how often this occurs, it is possible to provide a rough statistical analysis based on usage data of how the expanded runway might be necessary. FAA Advisory Circular 150/5325-4B *Runway Length Requirements for Airport Design,* Exhibit 11, aids an airport in determining the recommended runway length. AC 150/5325-4B, has a runway length curve used with temperatures at 86ºF (30ºC) or above, and an ARB elevation of 839 feet to meet the mean daily temperature during the hottest month at ARB. ARB had 76,430 total operations in 2019, of which, MDOT claims (at least in Appendix C, if not in the text of SRDEA) 679 were category B-II operations. SRDEA, Appendix C, pp. 8, 19. An analysis of data from the National Oceanic and Atmospheric Administration Weather Station at ARB shows that in 2019 there were 66 days in which the temperature was 86ºF or above. ARB has a based population of 164 aircraft, of which 14 are category B-II aircraft.

With these data, a calculation of potential need of an expanded runway based on maximum potential need can be made. If, on every day on which the temperature reached or exceeded 86 degrees, every aircraft in the B-II fleet attempted to operate at its maximum take-off weight – a highly unlikely possibility – and required the expanded runway to take-off, based on the ARB fleet population the need for the expanded runway would be 0.0154, or 15 in 1,000 (66/365 x 14/164). This means that for every 1,000 operations at ARB on a day over 86º, only 15 operations would be B-II aircraft. This is based on the number of days with temperatures exceeding 86 degrees and the proportion of the total ARB fleet that is Category B-II.

However, if this calculation were based on the more realistic actual usage in the operational year used by MDOT (2019), on every day the temperature reached 86 degrees or above, the actual need for an expanded runway would be 0.0016 – or about 1.6 B-II operations for every 1,000 operations (66/365 x 679/76,430) – the number of B-II operations relative to the total operations in SRDEA's study year 2019. In addition, weight penalties are more of a concern for take-offs, rather than landings. So, the issue would apply primarily to one-half of the "total operations" for B-II aircraft, or about 340 operations per year. This lowers the actual "need" for the runway extension to 8 B-II operations for every **10,000 operations** on a day over 86º (66/365 x 340/76,430). See Technical response #4 & #5 and General response #3 and #14

Thus, operational need for an expanded runway would be rare. Based on statistical analysis the expanded runway would be necessary for about 42 operations per year, at most. Yet, it would place citizens in the surrounding community at risk hundreds of times more often because aircraft would take off and land 950 feet closer to residential areas, and larger and heavier aircraft will be attracted to ARB by the expanded runway. The area to the west and south of the Airport – just off the most frequently used end of the runway – is heavily residential. The Airport is not in a rural setting and more homes are being constructed close to the Airport. These risks are exacerbated because of the potential dangers posed by aircraft that would land just 93 feet over homes in an area heavily populated with Canada geese just west of the airport, and by the reduced margins of safety if an aircraft suffers an engine failure on or just after takeoff. Such aircraft can lose their climbing power with an engine loss and could crash into the heavily populated neighborhood. The risk of – and liability from – such a potential accident has not been studied and should be as part of any assessment about the purpose and need of extending the runway at the Airport.

See Noise response #3 & Safety/Health responses #1, #2, and #3

3. The lengthened runway would primarily benefit a handful of rich, well-connected aircraft operators.

AvFuel, a Pittsfield Township-based national aviation fuel supplier that counts ARB as one of its customers, would be the primary beneficiary of any runway expansion as owner and operator of B-II aircraft based at ARB. AvFuel provided a letter of support in the SRDEA, claiming that, "most flights departing ARB require concessions to fuel and/or passenger loads with a stop for fuel before reaching their intended destination due to runway length limitations at ARB. When runway 6/24 is contaminated with snow or ice, AvFuel often needs to divert to another airport, which delays or cancels flight plans until pavement surface conditions at ARB improve, since braking distance is reduced when water, snow, or ice is present," SRDEA, Appendix C, p. B2, although no specific data on any such impacts were provided.

In addition, a further analysis based on aircraft performance data provided in the SRDEA's Runway Justification Analysis confirms that the Citation-class aircraft, including AvFuel's Cessna Citation XLS jet, could operate 90% of the time on the existing 3,505-foot runway. The Citation XLS performance data shows only a 3,500-foot runway is required until temperatures exceed 85 degrees F., which would let the AvFuel jet operate at 90% capacity. SRDEA, Appendix C, pp. E13-14. Also, in response to claims of the need for a longer runway to combat wet runway conditions, the FAA noted that under such circumstances, "Safety is maintained by the pilot adjusting their mission (payload, etc.) to the available runway length, not by the addition of a longer runway."

To further support the claimed need for the extension, the SRDEA explains that the 4,649 instrument flight rules (IFR) operations at ARB in 2019, indicating the aircraft involved required eliminating weight concessions that would let aircraft operate at greater capacity, thus resulting in a "more efficient operating environment." However, further analysis of the supporting data showed that all but an estimated 48 Citation XLS class jet flights of the 4,525 IFR airplane operations could be conducted on the current 3,505-foot runway without penalty.

Finally, if operating the aircraft to fullest extent of its capabilities is such a concern, then the owners of the aircraft should move their aircraft to YIP – just a few miles from ARB. While that may be inconvenient for the owners of the handful of aircraft it would affect, that inconvenience pales when compared to the damage that would be done to the public's health and safety should the runway be lengthened.

See General response #3, #13, and #14

4. Support for Need for Economic Need and Increase in Jet Operations Comes at a Cost.

In support of the presumed need, and alluding to a connection between the airport and the Ann Arbor-area business community, the SRDEA also reported that the area surrounding Ann Arbor was home to "many prominent businesses and institutions with the University of Michigan being the area's largest employer. Manufacturing, health care, automotive, information technology, and biomedical research companies account for major employers in the surrounding area." SRDEA, pp. 1-1. The SRDEA added that with many such technology-driven industries, "[t]here is often a need for air transportation to bring workers, clients, suppliers, customers, and time sensitive parts / supplies to and from the region." SRDEA, p. 1-2. However, no data were provided to support the implied claims of any connection to or the vitality of ARB to support such vast economic and operational activity, save for particulars on the AvFuel XLS Citation jet. In addition, the SRDEA does not address the fact that YIP can satisfactorily address the needs of the surrounding area, since there are very few "businesses and institutions" that are not also within a short drive from YIP. See Financial/Economic response #12

The SRDEA suggests that the University of Michigan's six/seven home football weekends each year and the two annual NASCAR racing events at nearby Michigan International Speedway are examples that bring increased aircraft activity to airports in the region, suggesting that "should Runway 6/24 be extended, additional aircraft activity could occur at ARB due to its proximity to special event venues surrounding the Ann Arbor area." Again, any need for more airport capacity can be (and has been) satisfactorily met by YIP. For example, according to Google Maps, YIP is just 8.8 miles further from Michigan International Speedway (ARB is 33.9 miles away, and YIP is 42.7). Even the comparative distance between the two airports and Michigan Stadium is inconsequential. While ARB is 3.6 mile (or 4.3 miles) from the stadium, YIP is only 13.6 miles away from the stadium. It is not apparent from the SRDEA why residents in the surrounding communities would have suffer health impacts just so a few wealthy aircraft owners can shave 5 minutes off their drive to downtown Ann Arbor or Brooklyn, Michigan. See Technical response #3

An earlier draft of the SRDEA projected an immediate tripling of annual jet operations if the ARB runway were extended to over 1,000 operations per year, with another 500-665 operations from jets, which use nearby Willow Run Airport, possibly moving to an expanded ARB. That earlier draft SRDEA suggested that up to 40% of the current 9,313 annual small and medium jet operations at nearby Willow Run Airport "would likely shift to ARB if additional runway length were available," thus increasing jet operations from the 360 in 2019 to upwards of 3,660 jet operations per year – a 10-fold increase, ultimately turning ARB into a jetport. This is not an organic increase in jet operations. This is a shift of operations from YIP to ARB. This indicates that the extension of the runway would not increase air traffic in the region – thereby increasing the economic benefit to the region – but merely shift jet operations from YIP to ARB. Even AvFuel Chief Pilot suggests that, indicating that AvFuel would shift its aircraft currently based at YIP to ARB. Were YIP operating at capacity or near capacity, this would be a benefit to the region. But it is not. YIP has the available capacity to safely and efficiently handle any aircraft that cannot take-off or land at ARB due to "operational capabilities," now and in the future.

In short, the "need" expressed in the SRDEA is being already being met by YIP. There is no need for ARB to extend its runway. See Technical response #4

IV. The Use of Willow Run Airport Is a "Reasonable Alternative" that Has Not Been Fully Considered.

The National Environmental Policy Act ("NEPA") (42 U.S.C. §§ 4321 *et seq.*) requires that federal agencies examine all reasonable alternatives in preparing environmental documents. 42 U.S.C. § 4332(c)(iii). An agency preparing an EA should develop a range of alternatives that could reasonably achieve the need that the proposed action is intended to address. The Council on Environmental Quality ("CEQ") Regulations ("NEPA Regulations"), which implement NEPA, require that Federal agencies "[u]see the NEPA process to identify and assess the reasonable alternatives to the proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment" 40 C.F.R. § 1500.2(e), and that "agencies shall . . . (a) Rigorously explore and objectively evaluate all reasonable alternatives…." 40 C.F.R. § 1502.14(a). Courts have consistently held that the "existence of reasonable but unexamined alternatives renders an EIS inadequate." *See*, *e.g.*, *Friends of Southeast's Future v. Morrison*, 153 F.3d 1059, 1065 (9th Cir. 1998). The FAA and MDOT must act if an environmental assessment is limiting the choice of reasonable alternatives. "If the FAA is . . . aware that the applicant is about to take an action within the agency's jurisdiction that would have an adverse environmental impact or limit the choice of reasonable alternatives, the responsible FAA official will promptly notify the applicant that the FAA will take appropriate action to ensure that the objectives and procedures of NEPA are achieved" 1050.1F, 2-3.1. Because the SRDEA fails to explore all reasonable alternatives to the Preferred Alternative selected, it is inadequate.

The SRDEA does not address using Willow Run Airport (YIP) as alternative. The SRDEA bases its conclusion that ARB is a more "desirable" location on the assumption that B-II aircraft operators using ARB instead of YIP "demonstrates that a large number of operators of business aircraft value the close proximity of ARB to their corporate offices and business contacts over the larger facility at Willow Run." SRDEA, Appendix N. This is a baseless assumption since it is equally likely that the fact that B-II aircraft still land at ARB instead of YIP because the weight restrictions posed by the short runway ARB are non-existent or not significant, otherwise these users would land at YIP instead.

Although the FAA raised this point in its October 2016, comments, the SRDEA chose not to address it. FAA October 2016, Comments, No. 62. Exhibit 9. Instead, ARB waves the argument off by stating that the Airport "cannot dictate which airfield a pilot uses" – an argument that applies equally to the SRDEA's argument that rejects the YIP alternative.

However, using YIP instead of ARB meets the purpose and need of the project thereby making it a reasonable alternative that must be considered in the Environmental Assessment. That is, the operational requirements of all of the aircraft at ARB can be met by using YIP instead of ARB. As the SRDEA points out, YIP has the runway length and facilities to accommodate the aircraft that may be weight-restricted from using ARB. The only reason that the SRDEA does not consider YIP as a reasonable alternative is that it is located and mere 12 miles from ARB and that it is slight inconvenience to the corporations who want to use ARB instead of YIP. Even if lengthening the runway would benefit more than one or two aircraft, this is not an appropriate reason to dismiss an alternative from further consideration in an Environmental Assessment. If an alternative is "reasonable" (*i.e.,* it meets the purpose and need) then it must be considered in the Environmental Assessment alongside the preferred alternative and the no action alternative. *Friends of Southeast's Future v. Morrison,* 153 F.3d 1059, 1065 (9th Circ. 1998). Since using YIP instead of ARB would achieve the purpose and need of allowing "critical aircraft" to take-off and land without weight restrictions, it is a reasonable alternative and must be considered as part of the Environmental Assessment process. The SRDEA must be considered inadequate, arbitrary, and capricious on this basis alone.

See General responses #5 & #10 and Financial/Economic response #11

V. ENVIRONMENTAL IMPACTS

United Stated federal law states at 49 U.S.C. § 47101(a)(6) that it is "the policy of the United States . . .that airport development under this subchapter [which includes the SBGP] provide for the protection and enhancement of natural resources and the quality of the environment of the United States." NEPA, the NEPA regulations, caselaw, other applicable environmental laws, state, and local law provide the framework for carrying out this policy. At a bare minimum, an environmental assessment must describe the impact the proposed project will have on a variety of environmental resources. The Project will have a significant impact on the environment not only on the airport, but throughout the surrounding communities. Since it is Pittsfield's duty and responsibility to protect the environment within its boundaries and to protect its residents from significant environmental impacts, it has serious concerns about the environmental impact the Project will have on the community.

See Safety/Health responses #11 and #15, Water Resource/Water Quality response #1, and Air Quality response #1

A. NEPA requires that a Health Risk Assessment be drafted for the Project

NEPA requires agencies to analyze the direct and indirect environmental consequences that a proposed action might have on public health and safety. 40 C.F.R. §§ 1501.3(B)(2)(III), 1502.16(a) – (b), 1508.1(g). An agency normally meets this statutory requirement by preparing a health risk assessment ("HRA") or other comparable study that is subject to a public comment and review process to ensure all "likely health effects" are "adequately disclosed." *Natural Resources Defense Council, Inc. v. U.S Dept. of Transp.*, 770 F.3d 1260, 1272 (9th Cir. 2014); *see also Beverly Hills Unified School District v. Federal Transit Administration*, No. CV- 12-9861-GW (SSX) 2016 WL 4650428, at *61 (C.D. Cal., Feb. 1, 2016). The SRDEA fails to take a hard look at the Project's environmental impacts by failing to include an

HRA or any comparable analysis and provides no support for the health and safety conclusions made in SRDEA § 3.15.3. See Safety/Health response #17

As a threshold issue, the SRDEA's analysis is improperly constrained to consideration only of health impacts to children. See SRDEA § 3.15.3. NEPA does not limit an agency's health impact analysis to just children, however. Rather, it mandates an agency consider "the degree of [a proposed action's] effects on public health and safety." 40 C.F.R. § 1501.3(b)(2)(iii), emphasis added. The Environmental Protection Agency's ("EPA's") guidance advises agencies to assess health impacts for all "population groups of concern." See Safety/Health response #4

An HRA for a proposed action of this size and scope should include, at least, emissions estimations of hazardous air pollutants ("HAPs"), exposure assessments, dose-response assessments, and a potential health risk measurement. This requires consideration of all construction and operational sources of emissions, including on- and off-road equipment, and emissions/toxins associated with construction. In addition, the SRDEA does not mention whether firefighting foam was or is used at ARB that may contain per- and polyfluoroalkyl substances (PFAS) and/or other toxic materials, such as perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA), and perfluoroctanesulfonic acid (PFOS). If it was or is used at ARB, those substances may be in the soil unearthed as of part of the Project and is now in the groundwater. Likewise, the aviation gas that is stored at ARB contains lead, among other hazardous components, yet the SRDEA does not analyze whether disturbing the soil will cause lead to leach into the ground. In addition, the soil underneath and around the Airport likely contain other federally regulated substances, such as volatile organics, semi-volatile organics, PCBs, metals, pesticides, and petroleum hydrocarbons. The task of removing and remediating this contamination, alone, should be subject to an HRA-style analysis before the construction phase begins.

See Air Quality responses #1 & #2; Water Resources/ Water Quality responses #1 & #4

Nearly all of the over twenty individual exhaust constituents are regulated as HAPs by the Federal Clean Air Act. 42 U.S.C. § 7412(b). The SRDEA should include an HRA that analyzes potential health impacts from construction activities, on-going airport ground operations (ground support equipment, emergency generators, truck deliveries, etc.) and aircraft operations. Exhaust from these sources contains benzene, formaldehyde, PAH's, naphthalene, acetaldehyde, acrolein, 1,3-butadiene, chlorobenzene, propylene, xylene, ethyl benzene, arsenic, cadmium, chromium, lead, manganese, mercury, nickel, and selenium. These toxic contaminants must be analyzed in the SRDEA in relation to human health.

See Air Quality responses #1, #3, and #4

The SRDEA, to be transparent and informative as required by NEPA, should have an HRA that includes the aforementioned sources and associated risks to human health. An HRA is critical for ensuring an adequate disclosure of the Project's health effects to the public and decisionmakers. *Natural Resources Defense Council, supra*, 770 F.3d at p.1272.

When preparing the HRA for the Project, the study area should be expanded to include a broader range of sensitive receptors. A two-mile radius to pick up additional sensitive receptors such as schools, hospitals, and parks should be used. Construction-related emissions such as diesel construction trucks and soil hauling would be expected to impact areas over two miles away because of their operational characteristics and haul routes. And aircraft exhaust and noise from the increase in aircraft operations and change in the type of aircraft using the Airport will also affect an area considerably larger than the project area.

A Health Impact Assessment or similar public health analysis should be part of the ARB environmental analysis. Failing to include a Health Risk Assessment would render the environmental assessment arbitrary and capricious.

B. Noise from aircraft, particularly high-performance jets has not been sufficiently analyzed by MDOT.

1. Technical and Scientific Data Support the Finding that Aircraft Noise is Detrimental to Public Health and Welfare.

a. Aircraft noise has caused health risks to people living under flight paths.

i. Aircraft noise causes an increased risk of cardiovascular disease, hospitalizations, and mortality.

The causal connection between aircraft noise and this increased health risk is well-supported by a growing body of scientific evidence. Two large studies have found associations between aircraft noise and heart disease and stroke. In a 2013 Harvard University study, researchers examined hospitalization rates in 6 million adults aged 65 years and over living near 89 US airports. The study concluded there is a statistically significant association between exposure to aircraft noise and risk of hospitalization for cardiovascular diseases among older people living underneath flight paths.[1] A second 2013 study examined hospitalization and mortality in a population of 3.6 million potentially affected by aircraft noise from London Heathrow airport.[2] The conclusion in that study was that aircraft noise was associated with increased risks of stroke, coronary heart disease, and cardiovascular disease for both hospital admissions and mortality.

Two additional studies discussed below have found connections between aircraft noise and heart disease and stroke. In one study, using data collected between 2004 and 2006 on 4,712 participants who lived underneath flight paths in six European countries, researchers concluded that individuals exposed to aircraft noise over many years showed an increased risk of heart disease and stroke.[3]

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[1] Correia AW, Peters JL, Levy N, Melly S, Dominici F., *Residential exposure to aircraft noise and hospital admissions for cardiovascular diseases: multi-airport retrospective study,* 347 BMJ f5561, (October 8, 2013). Exhibit 14.

[2] Hansell AL, Blangiardo M, Fortunato L, Floud S, de Hoogh K, Pecht D, et al., *Aircraft noise and cardiovascular disease near Heathrow airport in London: Small area study*, 347 BMJ f5432 (October 8, 2013). Exhibit 15.

[3] Floud S, Blangiardo M, Clark C, Babisch W, Houthuijs D, Pershagen G, et al., *Reported heart disease and stroke in relation to aircraft and road traffic noise in six European countries - The HYENA study*, 23 Epidemiology 39 (2012). Exhibit 16.

Likewise, a census-based study of 4.6 million individuals in Switzerland concluded that aircraft noise was associated with mortality from myocardial infarction.[4] The study noted that the association does not seem to be "explained by exposure to particulate matter air pollution, education, or socioeconomic status of the municipality."

ii. Aircraft noise causes an increased risk of hypertension.

Besides causing cardiovascular disease, aircraft noise is also linked to an increase in hypertension among those exposed. Two meta-analyses[5] relating to seven epidemiological studies found a correlation between aircraft noise exposure and hypertension in adults.[6] A 2008 field study of 140 individuals living near four European airports found increases in blood pressure during the night sleeping period related to aircraft operations.[7] Short-term experimental studies in healthy

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[4] Huss A, Spoerri A, Egger M, Roosli M. *Aircraft noise, air pollution, and mortality from myocardial infarction,* 21 Epidemiology 829 (2010). Exhibit 17.

[5] Meta-analyses combine evidence from several studies and are considered to provide the highest ranked research and to provide stronger evidence than single studies.

[6] *See* Babisch W, Kamp I., *Exposure-response relationship of the association between aircraft noise and the risk of hypertension*. 11 Noise Health 161 (2009). Exhibit 18. *See also* Huang D, Song X, Cui Q, Tian J, Wang Q, Yang K., *Is there an association between aircraft noise exposure and the incidence of hypertension? A meta-analysis of 16784 participants*, 17 Noise Health 93 (2015). Exhibit 19.

[7] Haralabidis AS, Dimakopoulou K, Vigna-Taglianti F, Giampaolo M, Borgini A, Dudley ML, et al., *Acute effects of night-time noise exposure on blood pressure in populations living near airports,* 29 Eur. Heart J. 658 (2008). Exhibit 20.

adults[8] and those with existing cardiovascular disease[9] have found links between aircraft noise at night and next-morning blood pressure and blood vessel functions.

iii. Aircraft noise increases the risk of dementia in older individuals.

Besides an increased risk of cardiovascular disease and hypertension, a recent study confirms that aircraft noise also causes an increased risk of developing dementia later in life.[10] "These findings suggest that within typical urban communities in the United States, higher levels of noise may impact the brains of older adults and make it harder for them to function without assistance. This is an important finding since millions of Americans are currently impacted by high levels of noise in their communities," said senior author Sara D. Adar, ScD, of the University of Michigan School of Public Health, Ann Arbor.[11] Professor Adar added that "although noise has not received a great deal of attention in the United States to date, there is a public health opportunity here as there are interventions that can

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[8] Schmidt FP, Basner M, Kroger G, Weck S, Schnorbus B, Muttray A, et al., *Effect of nighttime aircraft noise exposure on endothelial function and stress hormone release in healthy adults*, 34 Eur. Heart J. 3508 (2013). Exhibit 21.

[9] Schmidt F, Kolle K, Kreuder K, Schnorbus B, Wild P, Hechtner M, et al., *Nighttime aircraft noise impairs endothelial function and increases blood pressure in patients with or at high risk for coronary artery disease* 104 Clin. Res Cardiol. 23 (2015). Exhibit 22.

[10] Weuve J, D'Souza J, Beck T, Evans DA, Kaufman JD, Rajan KB, Mendes de Leon CF, Adar SD, *Long-term community noise exposure in relation to dementia, cognition, and cognitive decline in older adults,* Alzheimer's & Dementia: The Journal of the Alzheimer's Association (October 20, 2020). Exhibit 24.

[11] https://www.eurekalert.org/pub_releases/2020-10/w-cnm101920.php (last accessed December 23, 2020).

reduce exposures both at the individual and population level." *Id.* This study underscores the need for FAA to reduce exposure to aircraft noise to better protect older adults living in Pittsfield Township. See Safety/Health response #11 & #15

b. Aircraft Noise Causes Sleep Disturbance for Those Who Live Under the Flight Paths.

"Sleep undoubtedly counts as one of life's basic needs," the court concluded in *Harper v. Showers*, 174 F.3d 716, 720 (5th Cir. 1999). The Second Circuit agreed that "[n]o reasonable person would disagree that "sleep is critical to human existence." *Walker v. Schult*, 717 F.3d 119, 126 (2d Cir. 2013). Sleep is a biological imperative, and an active process that serves several vital functions for human life. Undisturbed sleep of sufficient length is essential for daytime alertness and performance, quality of life, and health.[12] The epidemiologic evidence that chronically disturbed or curtailed sleep is associated with negative health outcomes (such as obesity, diabetes, and high blood pressure) is overwhelming. Aircraft noise-

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[12] Fritschi L, Brown AL, Kim R, Schwela DH, Kephalopoulos S, editors. *Burden of Disease from Environmental Noise*. Bonn, Germany: World Health Organization (WHO); 2011. Exhibit 25. *See also* EU Parliament Directive 2002-49-EC. Exhibit 26. (The WHO has adopted the underlying principles of European Parliament's Directive 2002 in this publication. *See* the "introduction" section to the WHO publication: *Burden of Disease from Environmental* Noise. In recognition of the significant environmental risk from noise pollution, European Parliament and Council adopted Directive 2002/49/EC of 25 June 2002 to manage environmental noise. *Id.* In turn, the EU Parliament has mandated all EU Member States to develop a noise map and action plan to manage noise as evidence regarding the health effects of environmental noise has mounted in the recent years. *Id.*).

Muzet A, *Environmental noise, sleep, and health*, 11 Sleep Med. Rev. 135 (2007). Exhibit 27.

induced sleep disturbance is considered the most deleterious non-auditory effect of aircraft noise.

In 2012, researchers conducted a systematic review to clarify the causal link between aircraft noise exposure and sleep disturbance.[13] The researchers reviewed 12 studies that dealt with sleep disturbances. Of those studies surveyed, four were found to be of high quality, five were considered of moderate quality and three were considered of low quality. All moderate- to high-quality studies showed a link between aircraft noise events and sleep disturbances such as awakenings, decreased slow wave sleep time or use of sleep medication.

Four years later, in 2016, researchers investigated the relationship between sleep disturbance and exposure to aircraft noise on almost 4,000 residents living near an airport.[14] The study concluded that the prevalence of insomnia and daytime hypersomnia (excessive daytime sleepiness) was higher in the aircraft noise exposure group, as compared to the control group. The study concluded there is a causal relation between exposure to aircraft noise and sleep disturbances.

Research has shown a relationship between aircraft noise exposure and sleep disturbance and a link between noise-induced sleep disturbance and long-term

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[13] Perron S, Tétreault LF, King N, Plante C, Smargiassi A, *Review of the effect of aircraft noise on sleep disturbance in adults*, 14 Noise & Health 58 (2012). Exhibit 28.
[14] Kyeong Min Kwak, Young-Su Ju, Young-Jun Kwon, Yun Kyung Chung, Bong Kyu Kim, Hyunjoo Kim, Kanwoo Youn, *The effect of aircraft noise on sleep disturbance among the residents near a civilian airport: a cross-sectional study*, 28 Annals of Occupational and Environmental Medicine 38 (2016). Exhibit 29.

health consequences. The residents underneath flight paths are now waiting for the policymakers to help mitigate the effects of aircraft noise on their sleep.

See Safety/Health response #12 & #15

c. Aircraft Noise Has an Impact on Children's Learning and Low Weight at Birth.

The aircraft noise generated by aircraft flying above Pittsfield Township will affect children living underneath flight paths. Recent studies show that children born to mothers living underneath flight paths are born with lower-than-normal birth weight. See Safety/Health response #4

i. Chronic exposure to aircraft noise negatively affects children's ability to learn.

Reviews of how noise, and in particular aircraft noise, affect children's learning have concluded that aircraft noise exposure at school or at home is associated with children having poorer reading and memory skills.[15] There is also increasing evidence suggesting that children exposed to chronic aircraft noise at school have poorer performance on standardized achievement tests, compared with children who are not exposed to aircraft noise. The RANCH study (Road traffic and Aircraft Noise and children's Cognition & Health) is a large-scale cross-sectional study of 2,844 children aged 9–10 years from 89 schools around London Heathrow, Amsterdam Schiphol, and Madrid Barajas airports. It found a causal link between

[15] Clark C., *Aircraft Noise Effects on Health: Report Prepared for the UK Airport Commission. Report Number 150427*. London: Queen Mary University of London, (2015). Exhibit 30.

aircraft noise and poorer reading comprehension and poorer recognition memory.[16] These associations were not explained by air pollution.[17] Children's aircraft noise exposure at school and that at home are often highly correlated.[18] In the RANCH study, night-time aircraft noise at the child's home was also associated with impaired reading comprehension and recognition memory.[19] See Safety/Health response #4

ii. Chronic aircraft noise exposure is linked to low birth weight.

Health economists from Lehigh University, Lafayette College and the University of Colorado, Denver, pinpointed a causal link between aircraft noise and low birth weight.[20] This study focused on the effects of aircraft noise on babies' health at birth, specifically low birth weight born to mothers living near Newark Liberty International Airport after implementing NextGen flight procedures at the airport. The study concluded that low birth weight was tied to implementing

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[16] Stansfeld SA, Berglund B, Clark C, Lopez-Barrio I, Fischer P, Ohrstrom E, et al. *Aircraft and road traffic noise and children's cognition and health: A cross-national study,* 365 Lancet 1942 (2005). Exhibit 31.

[17] Clark C, Crombie R, Head J, van Kamp I, van Kempen E, Stansfeld SA., *Does traffic-related air pollution explain associations of aircraft and road traffic noise exposure on children's health and cognition? A secondary analysis of the United Kingdom sample from the RANCH project,* 176 Am. J. Epidemiol. 327 (2012). Exhibit 32.

[18] Clark C, Martin R, van Kempen E, Alfred T, Head J, Davies HW, et al., *Exposure-effect relations between aircraft and road traffic noise exposure at school and reading comprehension - The RANCH project*, 163 Am. J. Epidemiol. 27 (2006). Exhibit 33.

[19] **Stansfeld SA, Hygge S, Clark C, Alfred T., *Nighttime aircraft noise exposure and children's cognitive performance,* 12 Noise Health 255 (2010). Exhibit 34.**

[20] Argys, L.M., Averett, S.L., Yang, M., *Residential noise exposure and health: Evidence from aviation noise and birth outcomes*, 103 Journal of Environmental Economics and Management 102343 (2020). Exhibit 35.

NextGen flight procedures. The flight procedures over Pittsfield Township are also NextGen flight procedures. One economist, Muzhe Yang of Lehigh University stated that "[o]ur findings have important policy implications regarding the trade-off between flight pattern optimization and human health. This is especially important given the long-term negative impact of low birth weight on a range of later-life outcomes such as lifetime earnings, educational achievement, and long-term health."[21] See Safety/Health response #4

d. Aircraft noise causes poorer mental health.

Studies have also been conducted to show the link between aircraft noise exposure and poorer well-being, lower quality of life, and psychological ill health. In a 2020 study, researchers determined that noise annoyance, particularly from aircraft, is associated with depression, anxiety, and sleep disturbance over a five-year period.[22] The research concluded that over the five-year period, general noise annoyance remained stable and that "daytime noise annoyance predicted new onset of depressive, anxiety symptoms (also nighttime annoyance) and sleep disturbance." These results "indicate the need to provide regulatory measures in affected areas to prevent mental health problems." These results confirmed the findings in a 2010

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[21] https://www2.lehigh.edu/news/muzhe-yang-how-airplane-noise-affects-fetal-health (last accessed December 23, 2020). Exhibit 36.

[22] Beutel, M.E., Brähler, E., Ernst, M., *Noise annoyance predicts symptoms of depression, anxiety, and sleep disturbance 5 years later. Findings from the Gutenberg Health Study*. 30 European Journal of Public Health, 487 (2020). Exhibit 37.

study of 2,300 residents near Frankfurt airport that annoyance was associated with self-reported lower quality of life.[23]

See Noise response #1 and
Safety/Health response #11

e. Aircraft Noise Has Increased the Community's Annoyance with Environmental Noise.

i. International Organization for Standardization creates standards to address elevated levels of community annoyance from aircraft noise.

Community annoyance refers to evaluating the disturbing aspects or nuisance of a noise situation by a "community" or group of residents, combined in a single outcome. To help with comparisons and data pooling, members of the International Commission on Biological Effects of Noise proposed a standardized annoyance question[24] that was adopted by International Organization for Standardization ("ISO") as TS 15666.[25] The percentage of highly annoyed respondents is considered the main indicator of community annoyance. Using a common question has allowed researchers to compare studies from around the globe.

[23] Schreckenberg D, Meis M, Kahl C, Peschel C, Eikmann T., *Aircraft noise and quality of life around Frankfurt Airport,* 7 Int. J. Environ. Res. Public Health 3382 (2010). Exhibit 38.
[24] Fields JM, De Jong RG, Gjestland T, Flindell IH, Job RF, Kurra S, et al., *Standardized general-purpose noise reaction questions for community noise surveys: Research and a recommendation*, 242 J. Sound Vibr. 641 (2001). Exhibit 39.
[25] IS Organization, *ISO TS 15666: Acoustics- Assessment of Noise Annoyance by Means of Social and Socio-Acoustic Surveys* (2003). Exhibit 40.

Because of this step forward, in 2016, the ISO published a new standard to assess community annoyance because of environmental noise, such as aircraft noise. ISO 1996-1:2016, *Acoustics – Description, measurement, and assessment of environmental noise*, Exhibit 41, helps policymakers in predicting the potential annoyance response of a community to long-term exposure to several types of environmental noises, including aircraft noise. Although the U.S. has approved ISO 1996-1:2016 as being "state of the art," and ready for use in the United States, FAA has refused to use it in assessing aircraft noise in communities. Use of this tool in developing flight procedures would allow FAA to better evaluate and manage aircraft noise exposure. See pp. 35-40, *infra* for complete discussion of ISO 1996-1:2016.

See Noise response #1, #4, and #5.

ii. Community annoyance from aircraft noise is increasing.

In 2017, the United Kingdom Civil Aviation Authority undertook a survey of "noise attitudes." The study examined evidence on attitudes to aircraft noise around airports in England, including the effects of aircraft noise on annoyance, well-being, and health. It found that the level of noise exposure that leads to significant community annoyance has fallen from 57 dB L_{Aeq} (in an earlier survey) to 54 dB L_{Aeq}.

In 2016, the long-term German study entitled, "Noise-Related Annoyance, cognition, and Health" (NORAH) concluded there has been a change in annoyance responses: people are now more highly annoyed by aircraft noise than 30 years ago.[26] The NORAH study examined noise responses following the opening of a new runway, and implementation of a night curfew. The NORAH study mentions that several attempts are being made at trying to explain the variance within the annoyance response, using modelling to calculate the weight of non-acoustic factors. The NORAH study concluded that more people were "highly annoyed" when they experienced an increase in aircraft noise and that annoyance remains through the years. People do not habituate to aircraft noise.

Annoyance with aircraft noise amongst the affected population is increasing, not decreasing. The authors of 2011 report looked at datasets from separate airports in various parts of the world, including the U.S. from 1967 until 2005.[27] The results suggested there has been a significant increase in annoyance over the years. Instead of a gradual increase, the study showed increased levels of annoyance from

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[26] Schreckenberg, D. et al. *Effects of aircraft noise on annoyance and sleep disturbances before and after the expansion of Frankfurt Airport – results of the NORAH Study WP1 'Annoyance and Quality of Life',* Internoise Congress, Hamburg (2016). Exhibit 42.
[27] Janssen, S. et al., *Trends in aircraft noise annoyance: the role of study and sample characteristics,* 129 J. Acoust. Soc. Am. 1953 (2011). Exhibit 43.

1996 onward. This is despite FAA's self-congratulatory declarations that aircraft noise is decreasing.[28] See Noise response #1, #2, and #4.

iii. FAA's recent Neighborhood Environmental Survey underscores growing community annoyance with aircraft noise.

The method for representing the community response to noise is known as the "Schultz Curve," which is a dose-response curve developed in the 1970's. The noise thresholds used for current FAA noise policy are informed by the "Schultz Curve." While the "Schultz Curve" remains the accepted standard for describing transportation noise exposure-annoyance relationships, its original supporting scientific evidence and social survey data were based on information from the 1970s. The last in-depth review and revalidation of the Schultz Curve was conducted in 1992 by the Federal Interagency Committee on Noise ("FICON Report"). More recent analyses have shown that aviation noise results in annoyance levels higher than other modes of transportation. Recent international social surveys have also generally shown higher annoyance than predicted by the Schultz Curve. These analyses and survey data indicate that the Schultz Curve may not reflect the current U.S. public perception of aviation noise.

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[28] "By one measure, it has been a success: over the last four decades, the number of people in the U.S. exposed to aviation noise has dropped substantially, even as the number of flights has soared." https://www.faa.gov/regulations_policies/policy_guidance/noise/ (last accessed December 23, 2020).

In 2015 and 2016, FAA conducted a nationwide survey to measure the relationship between aircraft noise exposure and annoyance in communities underneath flight paths. This survey captured the community response to a modern fleet of aircraft as they are being flown today and it used best practices in terms of noise analysis and data collection. This survey has been called the "Neighborhood Environmental Survey" (NES). See Exhibit

For the NES, FAA surveyed over 10,000 residents living near 20 representative airports via a mailed questionnaire. The questionnaire asked the recipients about various environmental concerns that bothered, disturbed, or annoyed them. Noise from aircraft was one of the thirteen environmental concerns that the survey covered. Since the aircraft noise question was one of 13 environmental concerns listed, the recipient did not know whether this was an airport community noise survey. This was the largest survey of this type undertaken at one time. The data from the survey was used to calculate the new "National Curve" to replace the "updated Schultz Curve" in use by the FAA and provides a contemporary picture of community response to aircraft noise exposure. A follow up phone survey was also offered to the 10,000 mail survey respondents, and just over 2,000 elected to participate. The phone survey provided additional insights on how the mail survey respondents felt about aircraft noise.

The results of the survey showed that the updated Schultz Curve, as used in the FICON Report, was antiquated, and no longer reflected the public's response to aircraft noise exposure. Comparison of the FICON Report prepared using the updated Schultz Curve and NES prepared using the National Curve showed the following percentage of population highly annoyed by exposure to transportation noise:

- At a noise exposure level of DNL 65 dB, the FICON Report indicated 12.3% of people were highly annoyed, compared to between 60.1% & 70.9% from the NES.

- At a noise exposure level of DNL 60 dB, the FICON Report indicated that 6.5% of people were highly annoyed, compared to between 43.8% & 53.7% from the NES.

- At a noise exposure level of DNL 55 dB, the FICON Report indicated that 3.3% of people were highly annoyed, compared to between 27.8% & 36.8% from the NES.

- At a noise exposure level of DNL 50 dB, the FICON Report indicated that 1.7% of people were highly annoyed, compared to between 15.4% & 23.4% from the NES.

Extrapolating from the FAA's current "thresholds of significance," one concludes that the new "threshold of significance" should be around DNL 45 dB.

See Noise response #1, #2, and #4

iv. WHO Environmental Noise Guidelines for European Region (October 2018) establish new, science-based thresholds of significance.

In October 2018, the World Health Organization (WHO) Regional Office for Europe published its Environmental Noise Guidelines for the European Region ("WHO Guidelines") Exhibit 44. Those Guidelines found that aviation noise was connected to higher incidence of ischemic heart disease, hypertension, "prevalence of 'highly annoyed'" population, and a delay in reading skills and oral comprehension in children. WHO Guidelines. WHO strongly recommended that average levels of noise produced by aircraft be reduced below 45 dB DNL, as aircraft noise above this level is associated with adverse health effects. WHO Guidelines, pp. xvii, 61.

WHO also strongly recommended that noise levels produced by aircraft be reduced during nighttime below 40 dB DNL, as aircraft noise above this level is associated with adverse effects on sleep. WHO strongly recommended that to reduce health effects policymakers implement "suitable measures to reduce noise exposure from aircraft in the population exposed to levels above the guideline values for average and night noise exposure." WHO Guidelines, pp. xvii, 61.

See Noise response #1, #2, #5, and #10.

2. MDOT and ARB must protect the surrounding community from aviation noise.

It is "the policy of the United States … that aviation facilities be constructed and operated to minimize current and projected noise impact on nearby communities." 49 U.S.C. § 47101(a)(2). Part of the FAA's mission, and therefore

MDOT's mission, is to ensure that the communities surrounding airports are not hurt by noise from aircraft at airports. This mission is expressed in 49 U.S.C. § 47101(c), which states that "[i]t is in the public interest to recognize the effects of airport capacity expansion projects on aircraft noise. Efforts to increase capacity through any means can have an impact on surrounding communities. Noncompatible land uses around airports must be reduced and efforts to mitigate noise must be given a high priority." Thus, if noncompatible land uses around airports cannot be reduced, then the capacity of nearby airports should not be increased or else the FAA and the airport sponsor would violate federal law. ARB and MDOT seem aware that increases in capacity at the airport will affect the noise levels in Pittsfield, because they studiously have avoided the topic. Noise impacts of the increase in jet operations at ARB have not been analyzed or account for in the SRDEA. See Noise response #1, #3

MDOT has the legal duty to protect residents and property owners from the deleterious effects of aircraft noise. Federal law establishes the absolute duty of the government to protect both people and property from aircraft noise. "[T]he Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare." 42 USC § 4901(b). MDOT's statutory duty to protect people and property on the ground from the deleterious effects of aircraft noise goes beyond its duty under NEPA to determine what it believes to be "significant" or "reportable" under FAA Order 1050.1F. Legally speaking, the MDOT cannot conclude that a proposed MDOT action purportedly not "reportable" under 1050.1F, § 14.5e or that purportedly does not have a "significant impact" under 1050.1F, § 14.3, is not subject to review and regulation under 42 USC § 4901(b), 49 U.S.C. § 40103(b)(2) and 49 U.S.C. § 44715(a)(1)(A). Those statutory obligations require that the lead agency address aircraft noise separate from its duties under NEPA because the lead agency's proposed action will create aircraft noise that will have a deleterious effect on the public health and welfare. See Noise response #1, #3, an #4.

3. ARB and MDOT incorrectly assume that extending the runway will not significantly increase the number of air operations, the fleet mix, or other growth-inducing effects of the Project.

When considering an airport project for federal funding, the FAA must evaluate not merely the direct impacts of a project, but also its indirect impacts, including those "caused by the action and later in time but still reasonably foreseeable." 40 C.F.R. § 1508.8(b). Indirect impacts include a project's growth-inducing effects, such as changes in patterns of land use and population distribution associated with the project (40 C.F.R. § 1508.8(b)) and increased population, increased traffic, and increased demand for services. *City of Davis v. Coleman*, 521 F.2d 661, 675 (9th Cir. 1975). The "growth-inducing effects of [an] airport project appear to be its *raison d'etre*." *California v. U.S. D.O.T.*, 260 F.Supp.2d at 978, citing *City of Davis, supra*, 521 F.2d at 675. Even though the Project is virtually defined by its growth-inducing impacts, ARB and MDOT have ignored this requirement completely – not only in the SRDEA, but in the public participation parts of the Project as well. There is substantial evidence to indicate that the Project will cause a significant increase in both night and jet operations.

See Noise response #2, #3, and #14

As indicated above, the runway need not be extended for most of ARB's "critical aircraft" to operate at the airport without weight restrictions. For example, it is clear that the "load restrictions" referenced in the SRDEA will apply to the higher category aircraft (jets in the C-I and C-II ARC categories) even with a 4,225-foot runway. Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel, which discourages these aircraft from conducting operations at ARB. A Cessna Citation II (Category B-II), for example, requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day, and, most days, can operate at unrestricted weight from ARB's existing 3,505-foot runway. A Lear 35 (Category C-I), on the other hand, requires 5,000 feet for takeoff at maximum certificated gross weight on a standard day. While extending the runway to 4,225 feet would not facilitate unrestricted operations by the Lear 35, the required weight reduction would be substantially diminished. Therefore, the runway extension to 4,225 feet would operationally benefit the Category C-I Lear

35, but would provide little or no operational benefit to the Category B-II Citation jet, which the SRDEA claims is a "critical aircraft." Thus, with the runway extension ARB does not become any more or any less attractive to the operator of the Citation II, but becomes much more attractive to the operator of the Lear 35. This would cause an increase in usage of ARB by the Lear 35, but the same usage by the Citation II. This is not reflected in the SRDEA's noise analysis or in the Runway Justification Study, which relies on the FAA's Terminal Area Forecast.

The primary reason ARB is so keen on extending the runway is to facilitate the loading of additional passengers and baggage on high performance jet aircraft outside of what ARB considers to be its "critical aircraft." Also, the ability to carry more fuel may mean that, in certain cases, costly and time-consuming intermediate fuel stops will become unnecessary. If the runway is lengthened to 4,225 feet, it is reasonably foreseeable that ARB will become much more attractive to operators of higher performance jet aircraft, such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II), who could then operate at ARB instead of driving to and from Willow Run Airport, a mere 12.3 mile car trip, where there are ample facilities for large aircraft. In an earlier draft of the Runway Justification Study, MDOT indicated that it believed that jets currently based at YIP may move their operations to ARB if the runway is extended. These additional ARB-based jets are not included in the forecasts on which both the Runway Justification Study and the SRDEA's noise analysis is based.

See General response #5; Noise responses #1 & #2; and Technical responses #2, #7, #8, #9

4. The RDEA does not analyze the fact that night and jet operations will increase because of the Project.

It is reasonably foreseeable that the fleet mix at ARB will change in favor of a higher percentage of jet operations as compared to the current level of light single and multi-engine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft currently account for a high percentage of ARB operations. B-II aircraft account for a low percentage of ARB operations. Because of the availability of a longer runway, it is therefore reasonably foreseeable that the number of night operations will increase as the number of arrivals of longer haul business jets often occur in the evening hours due to the longer time duration of their trips. Since one of the stated "benefits" of the Project is to increase interstate commerce (SRDEA, Appendix N, p. 9), this is not merely an indirect, but also a direct effect, that the Project will have on the surrounding community. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions. Because there is a potential of an increase in the number of operations, it must be analyzed thoroughly.

The evidence is clear that the Project will cause an increase in both jet and night operations. It is also reasonably foreseeable that these added high-performance jet aircraft operations and night operations will come with significant noise and air quality impacts. Still, ARB and MDOT have not acknowledged, let alone analyzed, these reasonably foreseeable impacts caused by expansion of airport physical facilities and operational profile and, thus, the Project should not be approved for funding. See Noise response #3, #10, and #14

5. Increased jet aircraft and nighttime operations were not included in the noise modeling used by ARB and MDOT.

The SRDEA states it used FAA's Aviation Environmental Design Tool (AEDT) to model annual operations for the 2019 "base" or existing condition in the SRDEA, to develop 65, 70 and 75 DNL noise contours for the Project. SRDEA, Appendix L. The RDEA states that "the 65 DNL contour remains completely within ARB owned property or over commercial property not considered noise sensitive under all noise scenarios." SRDEA, Appendix L, p. 7. The SRDEA noise analysis assumes that both the time of day of the operations and the fleet mix remain constant. See SRDEA, Appendix L, pp. 3-5.

During the period modeled, jet operations accounted for about 2 percent of total operations at ARB, and nighttime operations accounted for 4.2 percent of total operations. https://aspm.faa.gov/tfms/sys/ Airport.asp. Because of the increase in the length of the runway the Project will facilitate an increased number of night operations, and a change in fleet mix that will include many more higher performance jet aircraft. DNL calculations depend on, among other things, forecast numbers of operations, operational fleet mix and times of operation (day versus night). SRDEA, Appendix L, pp. 2-3. However, ARB and MDOT have failed to model or assess future increased night operations and fleet mix changes resulting from the Project. See Noise response #1, #3, and #5

FAA Order 1050.1F requires an EA's noise analysis to include, among other things: (1) noise contours at the DNL 75 dB, DNL 70 dB and DNL 65 dB levels; (2) analysis within the proposed alternative DNL 65 dB contour to identify noise sensitive areas where noise will increase by DNL 1.5 dB ; and (3) analysis within the DNL 60-65 dB contours to identify noise sensitive areas where noise will increase by DNL 3dB, if DNL 1.5 dB increases as documented within the DNL 65 dB contour. FAA Order 1050.1F, Appendix A, p. A-62, & 14.4d. As the noise modeling failed to account for the foreseeable increases in nighttime and jet aircraft operations at ARB, the questions of whether the future DNL 65 dB contour will be increased, and to what extent, and whether increased noise levels within the DNL 65 dB contour would require designation of a DNL 60 dB contour remain unanswered. See Noise responses #1, #5, and #10

6. **Federal law and NEPA required that MDOT use ISO to calculate the noise impact of the runway extension in the community surrounding ARB.**

The NEPA regulations mandate that federal agencies "insure the professional integrity, including scientific integrity, of the discussions and analyses in environmental impact statements." 40 C.F.R. § 1502.24.[29] In addition, the Data Quality Act (also called the Information Quality Act, Section 515 of the Consolidated Appropriations Act, 2001 (Pub. L. 106-554)) requires that agencies to use the best scientific methods in technical matters. ISO 1996-1:2016, entitled "Acoustics -- Description, measurement and assessment of environmental noise -- Part 1: Basic quantities and assessment procedures," which was published in March 2016, defines the basic qualities to be used for the description of noise in community environments and describes basic assessment procedures. ISO 1996-1:2016 predicts the potential annoyance response of a community to long-term exposure to noise based on characteristics of the community rather than based on the noise created. As a product of the International Organization for Standardization, ISO 1996-1:2016 represents the best science for assessing the impact of noise on affected communities. Therefore ISO 1996-1:2016 must be used to avoid a violation of NEPA and the Data Quality Act. See Noise responses #1, #5, and #10

7. The Levels used in NES and the WHO Guidelines Should Have Been Used.

[29] The courts have applied this standard to EAs as well as EISs. *See, e.g.*, *Idaho Sporting Congress v. Thomas*, 137 F.3d 1146, 1152 (9th Cir. 1988)

Both the FAA's "Neighborhood Environmental Study" and the World Health Organization's Guidelines, indicate that it is imperative that levels well below 65 DNL need to be examined for their impact on public health and safety. It is also imperative that this study be done now, not be in the future after the runway extension is built. Both the NES and Guidelines indicate that 45 DNL is a more appropriate threshold of significance than 60 DNL. Because MDOT fails to analyze to these levels, the SRDEA is inadequate and incomplete.

See Noise responses #1, #5, and #10

C. Air

1. Aircraft Emissions have caused health risks to people living under flight paths.

Besides the health risks of aircraft noise, substantial research has been performed on the health risks posed by air toxics and particulate matter emissions from airports. This includes a 2014 study that showed that concentrations of particulate matter, black carbon, and nitrogen oxides (NO2) are elevated fourfold within six miles downwind of the airport and twofold within 10 miles from airport emissions. Hudda et al. *Emissions from an International Airport Increase Particle Number Concentrations 4-fold at 10 km Downwind*, Environmental Science & Technology, 2014 48(12), pp.6628-6635. Exhibit 45. In that study, researchers from University of Southern California's Keck School of Medicine conducted the analysis in a region near Los Angeles International Airport over 29 days, usually during times of onshore westerly winds in the late morning and afternoon. But measurements also were taken in early mornings and late nights when air traffic and onshore winds are lower. They found chemical concentrations to be up to five times higher than background pollution levels of an area within nine square miles of the airport. Within two miles east of the airport, levels of dangerous particulates were 10 times higher than in areas not affected by the airport's emissions. As a result, residents living downwind and to the east of the airport could inhale hazardous levels of nitrogen oxides and fine particulates that could contribute to inflammation, blocked arteries, asthma, heart conditions and other health issues.

The results from LAX were confirmed in a 2016 study at Boston's Logan Airport[30] where it was determined that aviation activities affected ambient ultrafine particle number concentrations ("PNC"). The study concluded there is a correlation between aviation activity and concentrations of ultrafine particulate matter and NO2. Two years later, in 2018, the same research group found that ultrafine particles from aviation activity penetrate indoors:[31]

> Overall, our results indicate that aviation-related outdoor PNC infiltrate indoors and result in significantly higher indoor PNC. Our study provides

[30] N. Hudda et al., *Aviation-Related Impacts on Ultrafine Particle Number Concentrations Outside and Inside Residences near an Airport,* February 7, 2018, Environmental Science & Technology. Exhibit 46.

[31] N. Hudda et al., *Aviation-Related Impacts on Ultrafine Particle Number Concentrations Outside and Inside Residences near an Airport,* February 7, 2018, Environmental Science & Technology. Exhibit 46.

> compelling evidence for the impact of aviation-related emissions on residential exposures.

These findings were confirmed in 2020.[32] Likewise, in 2020, it was reported that pregnant mothers exposed to aircraft emissions resulted in preterm births.[33] This analysis evaluated whether ultrafine particulate matter (UFPs) from jet aircraft emissions are associated with increased rates of preterm birth (PTB) among pregnant mothers living downwind of Los Angeles International Airport (LAX). The result was that *in utero* exposure to aircraft-origin ultrafine particles was positively associated with preterm births. This led the researchers to conclude that:

> emissions from aircraft play an etiologic role in PTBs [pre-term births], independent of noise and traffic-related air pollution exposures. These findings are of public health concern because UFP exposures downwind of airfields are common and may affect large, densely populated residential areas.

One of the perceived difficulties in assessing aircraft emissions was put to rest in a February 21, 2021, report that distinguished between roadway particle pollution and aircraft particle pollution.[34] The Mobile ObserVations of Ultrafine Particles (UFP) study found that key differences existed in the particle size distribution and

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[32] N. Hudda et al., *Impacts of Aviation Emissions on Near-Airport Residential Air Quality*, June 23, 2020, Environmental Science & Technology/. Exhibit 47.
[33] S. Wing et al., *Preterm Birth among Infants Exposed to In Utero Ultrafine Particles from Aircraft Emissions*, April 2, 2020, Environmental Health Perspective. Exhibit 48.
[34] E. Austin et al., *Distinct Ultrafine Particle Profiles Associated with Aircraft and Roadway Traffic*, February 21, 2021, Environmental Science & Technology/. Exhibit 49.

the black carbon concentration for roadway and aircraft features. These differences can help distinguish between the spatial impact of roadway traffic and aircraft UFP emissions using a combination of mobile tracking and standard statistical methods.

Particulate pollution is not the only concern. In 2008 the Airport Cooperative Research Program produced an analysis entitled "Aircraft and Airport-Related Hazardous Air Pollutants: Research Needs and Analysis," which was funded through the FAA. That analysis provides direction on how airports should be able to address the requests from states and "communities surrounding airports to analyze the health impacts of aircraft and other airport-related sources of air toxics, also known as hazardous air pollutants (HAPs), in National Environmental Policy Act (NEPA) and state-level documents." Indeed, the health effects of emissions of air toxics from airports on the surrounding communities has been studied regarding large California airports under state law. The conclusion is inescapable: the HAPs emitted by airports create health risks to the surrounding communities and any project that increases the emission of HAPs into the air should be analyzed.

At the very least, the MDOT should require a Hazardous Air Pollutants inventory under FAA's guideline set out in *Guidance for Quantifying Speciated Organic Gas Emissions from Airport Sources*, (Ver. 1, September 2, 2009) ("HAP

Guidance") Exhibit 50.[35] According to the FAA, the HAP Guidance "provides an approach to, and technical guidance for, preparing speciated OG/HAP emission inventories in support of environmental documents prepared by, or on behalf of, the FAA under the National Environmental Policy Act (NEPA)." With the establishment of HAP Inventory, there would be, at least, a baseline for future health risk assessments showing the deleterious effect that airport emissions have on the surrounding communities. See Safety/Health response #17 and Air Quality response #4

While establishing a HAP Inventory is a step in the right direction, what is needed is a study that quantifies the substantial health risks that HAP emissions resulting from the SoCal Metroplex project present to surrounding communities. Toward that end, a more significant finding is the May 8, 2009, article *Between-airport heterogeneity in air toxics emissions associated with individual cancer risk thresholds and population risks*, by Ying Zhou and Jonathan I. Levy. Exhibit 51. In that article, the authors conclude:

> Using state-of-the-art four-dimensional emissions characterization and atmospheric dispersion modeling, we demonstrated that both the emission rate contributing to a 10^{-6} maximum individual risk and the total population exposure within 50 km of the airport per unit emissions vary substantially across airports *but can be predicted with reasonable precision using easy to*

[35] In addition, the FAA and the EPA has published the *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines* which details joint efforts between the FAA and the EPA to update OG/HAP speciation profile data from these types of aircraft.

> *obtain variables, such as distance from the airport, total population, and mixing height.* These results provide a method to quickly but reasonably determine the likelihood of public health impacts of concern for airport modifications or expansions.

Zhou Levy Article, p.10 (emphasis added). In developing their conclusions about air toxics at airports, Zhou and Levy used the AERMOD high resolution atmospheric dispersion model, which is an FAA–approved model.

Because of the increase in aircraft flying at low altitudes directly over Pittsfield Township, ultrafine particulate matter and various contaminants have increased in the air above Pittsfield Township. Consequently, the citizens of Pittsfield Township are breathing in more particulate matter and inhaling contaminants that can lead to serious health effects. See Safety/Health response #4

The significant harms to human health of poor ambient air quality are well known. Extensive correlations have been demonstrated in diverse illnesses, affecting all segments of the population. Air quality related illnesses include breast cancer, brain tumors, asthma and non-smoking COPD, heart attacks, poor cognition, Sudden Infant Death Syndrome (SIDS), neonatal ICU admissions and preterm delivery. Recent data linking Traffic Related Air Pollution (TRAP) to Pregnancy related complications such as preeclampsia and gestational hypertension, is alarming given the maternal mortality crisis occurring nationwide. A well-designed study documented airport delays and taxiing time to an increased incidence of hospitalizations for asthma and heart attacks. Data is now emerging regarding the specific risk of UFPs. UFPs cause unique risk to health because their small size allows passage across tissue barriers, including the difficult to permeate blood-brain barrier. Recent NIH studies have shown UFP exposure related brain tumors, childhood cancers, asthma, heart attacks, mental health issues, including teen ER visits for anxiety and suicidal ideation, and various pregnancy complications, specifically preterm birth. Babies and children may be susceptible because they accumulate UFPs at relative concentrations higher than adults. Recent COVID-19 related public health trends, specifically decreased asthma admissions and preterm birth and increased COVID-19 mortality for residents in areas of poor air quality, are tangible examples of the real-time consequences of air quality. One recent study showed an increase by only 1 μg/m3 of PM2.5 is associated with an 8% increase in the COVID-19 death rate. It is imperative we quantify the emissions pollutant volume and dispersal patterns regarding public health and environmental justice.

See Safety/Health response #4 and Air Quality response #1

D. Water

1. SRDEA fails to adequately consider water issues.

The SRDEA consistently understates the significance of water resources. SRDEA, pp. 3-32 – 3-45. The principal use of the grounds where the airport is located is for the collection and pumping of water for the City of Ann Arbor.

However, water quality must be taken much more seriously than the SRDEA takes it. As FAA Order 1050.1F points out, the significance threshold is breached when the action would “contaminate an aquifer used for public water supply such that public health **may** be adversely affected.” FAA Order 1050.1F, p. 4-12. The 1050.1F Desk Reference elaborates that “[i]f there is the potential for contamination of an aquifer designated as an EPA-designated sole source aquifer for the area, the FAA must consult with the EPA regional office as required by Section 1424(e) of the SDWA.” That is the case here, but there is no indication in the SRDEA that MDOT consulted with EPA. See Water Resources/Water Quality response #5

The Airport is located on a porous sand/gravel formation that yields a large amount of water for pumping. The land where the airport is located was originally acquired by the City of Ann Arbor for water rights in 1921. Currently, about 25% of Ann Arbor’s water supply come from the three wells on Airport property. The paving that the Project will require increases not only the impervious area on top of the aquifer, but also increases the risk of contamination, particularly from PFAS contamination that may exist in the soil from firefighting foam that may have been used at ARB for firefighting and for training. This, in turn, reduces the infiltration of water that feeds the aquifer/City water supply. Adding 950 feet to the end of the runway adds another 71,250 square feet of impervious area over an aquifer vital to the City of Ann Arbor. See General response #6, Water Resources/Water Quality response #1

So critical is drinking water from the airport wells to the city that de-icing is prohibited on the airport. Due to the 'unmaintained nature' of the airport vegetation, it is acting as a buffer around the wellheads," the water faces many potential threats from a lengthened runway. Those threats become more critical because of the potential for lead to contaminate Ann Arbor's water supply. Most of the fuel used at ARB is consumed by piston-driven aircraft, which mostly use leaded AvGas. Any risk to the aquifer underlying the airport could pose a threat of lead contamination. With Ann Arbor's other water resources affected by dioxane risks caused by the "Gelman spill," the Airport well-field has taken on a much more significant role. The SRDEA, however, gives this issue only passing mention. See SRDEA, pp. 3-41 – 3-44. Notably absent from their coordination efforts is the EPA or its Regional Office regarding water resource issues.

See Water Quality/Water Resources response #1 and #7

Because the wells on ARB property is a principal source of Ann Arbor's water supply, the Washtenaw County Water Resources Commissioner raised serious issues about the Project in the past. In response to the draft 2010 EA, the Washtenaw County Water Resources Commissioner pointed out:

> It is noted in the [draft EA] that: "The amount of impervious surface on site would increase slightly due to the extension of the runway and taxiway from the existing 7 percent of the 837 acres to 7.4 percent." This slight increase noted equates to an additional 3.348 acres or 145,839 square feet. This increase in impervious surface is considered by this office to be significant

> and not slight particularly knowing that the additional runoff from this area will discharge to the Wood Outlet Drain.

Exhibit 52, p.2. This, coupled the City owning and operating four water wells on ARB's property, caused deep concern with the County.

This issue has become even more important since the draft EA was published back in 2010. In May 2012, for example, it was reported that the water table in the Ann Arbor area, has risen substantially. As pointed out in the Ann Arbor Chronicle, "[t]he only hard data that the city has collected on the water table is at the municipal airport, and there the water table measures between 2-7 feet below the surface now, compared to 15 feet below the surface 50 years ago." Exhibit 53. This is not an insubstantial problem. With the water table at the airport now being 2-7 feet below the ground surface instead of 15 feet, when the drinking water wells were first dug, the groundwater is even more vulnerable to contamination because there is much less soil for any surface pollution to filter through or attach to soil particles before it reaches the water table. This dramatic change in the water table may also alter groundwater data from the past. That is, the rise in the water table may have altered the direction of groundwater flow, or there may now be some barrier blocking the traditional pathway for the water to flow, which would cause Ann Arbor's principal drinking water supply to be contaminated.

See Water Resources/Water Quality response #1

In the past the Washtenaw County Water Resources Commissioner raised additional significant concerns that have yet to be addressed by either ARB or MDOT.

> 3. It is indicated that the preferred alternative does not impact the stream that is existing on the site. [Draft EA, p.4-18]. Using GIS measurements it appears that the stream is less than 1,000 linear feet from the existing runway. The runway extension would bring this infrastructure within 50 linear feet or less of the stream. In addition to this the grading limits shown in Appendix D-7 clearly extend into and beyond the location of the stream. Based on this information *it is not understood how it has been concluded that there are no impacts to the stream*.
>
> 4. It is indicated that the preferred alternative does not impact the floodplain for the stream that is existing on the site. It is indicated that proposed grading for the expansion would not occur within the designated floodplain boundary. [Draft EA, p.4-24]. Based on the floodplain boundary shown on FEMA Community-Panel Number: 260623 0010 C these statements are incorrect. Not only do the grading limits indicated for the preferred alternative extend into the floodplain boundary but the runway extension itself will extend into this floodplain boundary. Based on this information it is *not understood how it has been concluded that there are no impacts to the floodplain.*
>
> ….
>
> 6. It is noted in the report that: "Implementation of appropriate best management practices (BMPs) would continue to control the rate of stormwater runoff and maintain water quality standards." [Draft EA, p.4-18]. It is unknown by this office as to what the control rate of stormwater is currently being implemented or whether this rate meets county standards. *The additional volume created by this increase in imperviousness is not spoken to at all by the report. The type or locations of the appropriate BMPs indicated are not identified.*

Exhibit 52, pp.1-2 (emphasis added). Pittsfield Township has the same concerns about how water resources will be managed by ARB should this Project move forward. If there has been a change to the Project that addresses these concerns, they should have been addressed in the SRDEA. As such, these issues have not been sufficiently addressed by the SRDEA.

MDOT and ARB have a responsibility under the law to ensure the safety of the water in Ann Arbor's wells. Further, although Pittsfield does not receive its drinking water from these wells, water from the same aquifer filling these wells is the source of water for many Pittsfield Township waterways, including the several ponds in the Stonebridge Community. Thus, beyond ensuring applicant Ann Arbor's compliance with the law, Pittsfield has a vested interest in ensuring the water in the aquifer be maintained to the highest possible quality level.

See Water Resources/Water Quality response #8

8. The EA Fails to Address Standards and Requirements Under the Michigan Safe Drinking Water Act

The Michigan Safe Drinking Water Act, Public Act 399, as amended, was enacted in 1976 and enables the Michigan Department of Environment, Great Lakes, and Energy (EGLE) to maintain direct control over the public drinking water program in the state.

Rule 325.10812, promulgated under the Michigan Safe Drinking Water Act, MCL 325.1001 *et seq*., provides that:

> R 325.10812 Location of wells; major sources of contamination. Rule 812. **Wells serving type I and type IIa public water supplies shall be located a minimum distance of 2,000 feet, and wells serving type IIb and type III public water supplies shall be located a minimum distance of 800 feet, from known major sources of contamination**, including large scale waste disposal sites, land application of sanitary wastewater or sludges, sanitary landfills, and chemical or waste chemical storage or disposal facilities. The department may require an increase or approve a decrease in the 2,000 foot distance for type I or type IIa public water supplies or the 800 foot distance for type IIb or type III public water supplies based on a study of hydrogeological conditions or other methods approved by the department for identifying the capture zone of a well. [Emphasis Added]

As acknowledged in the SRDEA, there are several water wells on ARB property. SRDEA, 3-42; Figure 3.9. Further, the ARB property is within a wellhead protection area, which represent the land surface area that contributes ground water to wells serving public water supply systems throughout Michigan. EA, 3-42; Figure 3.10. Specifically, the Steere Farm wells on ARB property provide a substantial portion of the public water supply to the surrounding community.

While the SRDEA sets forth certain actions and Best Management Practices ("BMPs") that "should be considered" because ARB is within a wellhead protection area, the SRDEA fails to address or analyze compliance with the minimum well isolation distances provided for under the Michigan Safe Drinking Water Act and the rules promulgated by the EGLE, nor does it identify the distances from the Project Area to the various wells located on ARB property.

See Water Resources/Water Quality response #9

Further, the EA's failure to address or analyze the requirements under the Michigan Safe Drinking Water Act leaves the public unable to fully assess whether the Project is subject to challenge under the Michigan Environmental Protection Act (MEPA), Part 17 of NREPA, MCL 324.1701-.1706. MEPA authorizes any person to bring an action "for the protection of the air, water, and other natural resources and the public trust in these resources from pollution, impairment, or destruction." MCL 324.1701(1), and prohibits conduct that "has polluted, impaired, or destroyed or is likely to pollute, impair, or destroy the air, water, or other natural resources or the public trust in these resources. MCL 324.1703(1); MSA 13A.1703(1)." *City of Jackson v. Thompson-McCully Co., L.L.C.*, 239 Mich. App. 482, 487-88, 608 N.W.2d 531, 535 (2000). The SRDEA fails to address MEPA, nor does it provide sufficient information to evaluate the applicability of potential action under MEPA, and consequently additional analysis related to compliance with the Michigan Safe Drinking Water Act and MEPA is required.

The Project should not be approved by MDOT until these requirements regarding water quality have been complied with fully.

See Water Resources/Water Quality response #9

VI. MDOT has not given the communities' interests "fair consideration" as required under federal law.

i.

The aviation statutes of the United States make it incumbent on MDOT to give the interests of the surrounding communities fair consideration. *See* 49 U.S.C. § 47106(b)(2). That statute requires that before any federal funding, including funds from the SBGP, of an airport development project takes place, "the interests of the community in or near which the project may be located have been given fair consideration." 49 U.S.C. § 47106(b)(2). Thus, before the Project moves forward, MDOT and FAA must ensure that Pittsfield Township's interests have been given fair consideration. See General response #2

A. The Expansion at Ann Arbor Municipal Airport Does Not Comply with Planning in the Surrounding Communities.

MDOT has a duty under the law and by contract to ensure that federal funds are used properly for airport development projects. It is imperative that the concerns and issues of the surrounding communities are considered *prior* to approval of a project. This policy is reflected not only in the statutes that the FAA (and MDOT, through its SBGP Contract) is bound to uphold, but in its regulations and guidance documents it has issued. One place this policy is shown is in the assurances that airport sponsors, owners and operators are bound to follow upon accepting federal funds for airport development. Grant assurances 6 and 7 state:

6. Consistency with Local Plans. The project is reasonably consistent

with plans (existing at the time of submission of this application) of public agencies that are authorized by the State in which the project is located to plan for the development of the area surrounding the airport.

7. Consideration of Local Interest. It has given fair consideration to the interest of communities in or near where the project may be located.

FAA Airport Sponsor Grant Assurances, Exhibit 54. ARB is bound by these assurances and must comply with them. Thus, approval of this project without the approval by Pittsfield Township would violate ARB's grant assurances.

See General response #2 and #15

B. ARB's and the City of Ann Arbor's Goals Are Different from Pittsfield's Goals.

While Pittsfield Township recognizes the "operational needs" presented in the SRDEA, it is less sympathetic with growth-inducing aspects of the project which would subject both the government of Pittsfield and the people of Pittsfield to untold potential future damage. This damage would come in the form of both safety risks and in economic loss because of repeated flights of low flying, heavy jet aircraft. Pittsfield and its residents would have no choice but to seek recovery in the event of a tragic accident or inverse condemnation class action proceedings, from the City potentially leaving Pittsfield victims without an effective remedy at law.

See Noise response #1 and #3, Safety response #2, and Financial/Economic response #1, #2, and #4

1. The Project would increase safety concerns of low-flying aircraft near surrounding densely populated communities

Petitioners would be subjected to a perfect storm of potential risks from low-flying aircraft in heavily populated neighborhoods also occupied by wildlife, including many Canada geese, during much of the year. *See* Exhibit 55 for map of ponds surrounding the airport that support Canada Geese. This is confirmed by a study conducted by MDOT and Ann Arbor's own airport architects (URS Corporation), which was excluded from the draft EA, and visualized on a projection of what the approach to an expanded Runway 6 would look like relative to the close proximity to area homes, which was corrected for accuracy. Exhibit 56.
The safety of having an airport so close to a densely populated area is not an unfounded fear. In June 2009, a small single-engine plane attempting to land at ARB instead made an emergency landing 1,200 yards short of Runway 6/24 on a Stonebridge Golf Club fairway in Pittsfield after its engine died at low altitude on final approach. Exhibit 57. The pilot said if there had been people on the fairway, he would have "crashed into the trees," which would have been fatal for him and his grandson, whom he was instructing. *Id*. In Fall 2022, a single-engine plane was forced to make an emergency landing in the ARB-owned agricultural field to the west of the airport after losing its engine on take-off. While that resulted in no

damage or injury, with an expanded runway that aircraft may have had nowhere to "ditch" other than in the heavily populated Stonebridge neighborhood across from the agricultural field. It is not insignificant that between 1973 and 2001 nine people died from accidents flying in the Ann Arbor Airport traffic pattern within three miles of the airport. Exhibit 58.

With Runway 6/24 extended 950 feet farther to the southwest and even closer to hundreds of homes, as proposed, and planes still lower on approach – and planes heavier, larger, carrying greater payloads, and more people – this poses a risk too grave to bring to a heavily populated community as well as to the users of ARB.

See Noise response #1; Wildlife response #1; and Safety/Health response #1, #2, #3, #5, & #6

9. Because of the Project ARB will attract more and heavier aircraft, which will increase the safety risk to the surrounding community as well lower their property values.

Extending Runway 6/24 by 950 feet will attract more and heavier jets (as well as larger multi-engine turboprop aircraft) while bringing them closer to heavily populated residential areas. ARB estimates that jets would be within 600 yards and at altitudes of 93 feet above rooftops of homes, or lower, on a regular basis. Aircraft landing on Runway 6 would pass Lohr Road below 90 feet, which is the site of a non-motorized bike path, the Lohr-Textile Greenway Project. Thus, low-flying, heavy jets would land just feet over people traversing this non-motorized trail.

This is especially dangerous with heavier aircraft because, in the event of any common multi-engine aircraft mishaps – such as an engine failure on takeoff, a bird strike on takeoff, climb out, or approach, or similar incident – with aircraft in very close proximity to homes, the risk could be grave – a perfect storm of environmental or human risk. For example, a twin- engine jet losing one of its engines would lose 80 percent of its climb performance. At low altitudes that could be tragic. Likewise, losing an engine in a light twin-engine aircraft would be catastrophic since the aircraft could not continue to climb on one engine in takeoff configuration. Neither could it turn back toward the airport at low altitude in takeoff configuration.

Such impacts and safety implications on political jurisdictions where airports are located and where the airport decision-making bodies are devoid of local citizens and local governments must be investigated carefully and thoroughly by the governmental entities empowered to protect the safety of all concerned. MDOT must protect the health and well-being of the people on the ground as well as those in the air from the inherent risks of aviation.

See Noise response #1 & #3, Safety/Health response #6, and Financial/Economic response #2

10. Expanding the Runway Will Result in an Increase in Violations of Pittsfield Township's Ordinances and Planning Procedures

a. Noise Ordinance

Pittsfield Township, within which ARB is located, has a long-standing noise ordinance making it unlawful for "any person to create, assist in creating, permit, continue, or permit the continuance of any unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace, or safety of others within the limits of the township." Pittsfield Township has a duty to protect its citizens' health, safety, and property from "unreasonably loud, disturbing, unusual or unnecessary noise." Exhibit 6.

How the lengthening of the runway will affect the enforcement of this ordinance has not been examined, as required by NEPA, NEPA Regulations and FAA Order 1050.1F. If the ARB runway were expanded to the west, as proposed, and the noise impacts on Pittsfield residents were to change, this ordinance would face demands from citizens for more strenuous enforcement. Therefore, all aircraft flying in and out of ARB are subject to Pittsfield's noise ordinance and fines can be levied on the aircraft owners for operating their aircraft if they create an "unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace, or safety of others within the limits of the township."

Justice Rehnquist, in the landmark case *City of Burbank v. Lockheed Air Terminal Inc.*, 411 U.S. 624 (1973) stated that the legislative history of the 1968 noise control amendment to the Federal Aviation Act, and the subsequent 1972 Noise Control Act, provided for local land use planning to control the noise impacts on communities surrounding airports. *Burbank*, 411 U.S. at 643. Justice Rehnquist further noted that the House Committee on Interstate and Foreign Commerce specifically advocated the cooperation of state and local governments in achieving noise control. *Id.* Justice Rehnquist concluded from the legislative history that Congress intended only that the FAA regulate the "source" of noise, specifically the "mechanical and structural aspects of jet and turbine aircraft design." *Id.,* at 650. The statute did not, however, limit the states and local authorities from "enacting every type of measure, which might have the effect of reducing aircraft noise . . ." *Id.,* at 650-651. Justice Rehnquist, thus, suggests that so long as local or state governments do not regulate aircraft noise emissions directly, for example by requiring aircraft to meet certain noise standards or requiring certain technical modifications to jet engine design, they may regulate noise for the common benefit.

Therefore, all aircraft flying in and out of ARB are subject to Pittsfield's noise ordinance and fines can be levied on the aircraft owners for operating their aircraft such that they create an "unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace, or safety of others within the limits of the township."

See Noise response #13

b. Violation of Agreements between the City of Ann Arbor and Pittsfield Township.

ARB and Pittsfield Township have a long and contentious history. In 1979 Pittsfield Township and the City of Ann Arbor, the owner of ARB, reached an agreement intended to resolve issues at the Airport. Exhibit 7. In 2009, a new agreement was reached that incorporated the 1979 Agreement and sought to instill a sense of cooperation between the City of Ann Arbor and Pittsfield Township on issues regarding the Airport. Exhibit 8. The 2009 Agreement is automatically renewed, unless one party opts out.

Pittsfield Township's position is that extending the runway at ARB violates the 2009 Agreement, if not to the letter of the agreement, at least to the spirit of the agreement. The 2009 Agreement was drafted to foster cooperation between the City of Ann Arbor and Pittsfield Township on issues related to ARB. However, ARB's insistence on extending the runway over the strong opposition of Pittsfield Township is not being "cooperative." The runway extension violates the Agreement between the City of Ann Arbor and Pittsfield Township.

See General response #29

11. Runway expansion could cause Pittsfield Township to lose millions of dollars from reduced taxes.

There is extensive research to suggest an extension of the runway could cause severe economic losses to several communities surrounding the airport, including Pittsfield Township, in reduced real estate values and, reduced property and school taxes based on assessed property values. This reduction in home values is attributable to aircraft noise and emissions. How and to what extent the noise and emissions created by the Project will damage property values is not addressed in the SRDEA. Extensive research based on other communities in which airport runways have been extended – Atlanta, Reno-Tahoe, Chicago O'Hare, the Greensboro-High Point-Winston Salem metroplex, 23 cities in Canada, among others – show property values decline as runways are expanded. The most respected such study, *The Announcement Effect of an Airport Expansion on Housing Prices*, G.D. Jud & D.T. Winker, (2006), JOURNAL OF REAL ESTATE FINANCE AND ECONOMICS, 33, 2, 91-103, Exhibit 59, suggests house prices decline by about 9.2 percent within a 2.5-mile band of the airport, and, beyond that, in the next 1.5-mile band, prices decline another percent once an announcement – without extraneous influences – was made.

The lengthy hold up of the proposed ARB expansion has represented an extraneous influence since the initial announcement in 2007, but that if approved, these effects would occur at ARB. To further support this claim, a literature search could find no published, peer-reviewed research study where residential real estate values continued to rise in areas immediately surrounding an airport after runways were expanded. A decrease in property values in the areas surrounding ARB would have important consequences for the governmental bodies that benefit from property tax collections. In the corridors referenced in the Jud & Winker study noted above, there are:

- 6,239 Pittsfield Township parcels of land within the 2.5-mile area surrounding the airport; and
- 4,168 parcels within the 2.5-mile to 4-mile area.

These parcels will be subjected to a decline in real estate values of 9.2 percent and 5.7 percent, respectively due to the expanded runway. Using those facts, the following is the estimated value of what the potential **annual** losses in property tax revenue would be for various governmental bodies based on their tax collections in the year following the extension of the runway:

- $1.5 million less for the Ann Arbor School District;
- $1.4 million less for the Saline School District;
- $850,000 less for Pittsfield Charter Township; and,
- $810,000 less for Washtenaw County.

This estimate is only for property in Pittsfield Township. These numbers understate the decline in tax revenues, because they do not consider the potential effects of property in Lodi Township, the City of Saline, (both of which could affect the Saline School District's revenues), or property in the City of Ann Arbor. Thus, governmental bodies could stand to lose millions of dollars in operating funds annually from a runway expansion project that has yet to show any real economic benefit. See Financial/Economic response #2

12. MDOT must consider the interests and decisions of the surrounding communities

ii.

Both Pittsfield Township, where ARB is located, and neighboring Lodi Township have passed Resolutions opposing an expansion of the runway at ARB. Pittsfield passed two resolutions opposing the extension of the runway. The first was passed on March 24, 2009 (Exhibit 60), and the second was passed on April 12, 2017 (Exhibit 61). Lodi Township passed its resolution on May 12, 2009 (Exhibit 62). The Resolutions oppose the expansion because of the risks from Canada geese in areas surrounding the airport, low-flying aircraft on the approaching newly expanding runway, and that 99 percent of the based aircraft can operate at their full weight capacity on the existing runway. More important, though, the Resolutions seek to protect the health and property rights of their citizens. The Airport has ignored these Resolutions in the past and will do so again unless FAA or MDOT take them seriously when conducting an environmental assessment.

Ignoring the resolutions violates NEPA, NEPA Regulations and FAA Order 1050.1F, it is also a violation of ARB's federal grant assurances, exposing the City of Ann Arbor to litigation liability and potential loss of all federal funding for ARB. Going forward with the project without Pittsfield's sign-off is not being a good neighbor or keeping with the spirit of cooperation regarding Airport issues.

Given Pittsfield's and Lodi's resolutions of opposition, the expansion of the runway contradicts the will of those governing bodies. The expansion would benefit a minute number of airport users while placing at risk thousands of members of the Pittsfield and Lodi communities with added larger and heavier aircraft, flying much closer to their homes, at lower altitudes, in an area heavily populated by Canada geese, and in an increasingly dense residential area.

The consideration of the wishes of these local communities must be weighed, evaluated, and given "fair consideration" as required by the FAA's grant agreement with Ann Arbor. In the twelve years since the proposed expansion has been pending, for example, not even one study on the potential safety effects of the expansion on the residents of Pittsfield has been conducted. ARB and MDOT have consistently ignored the interests of communities surrounding ARB.

See Financial/Economic response #2, Wildlife response #1, Noise response #1, Safety/Health response #1 & #6, and General response #2 & #29

13. Any Environmental Assessment Must Properly Consider the Intensity of the Impacts on the Surrounding Community.

NEPA Regulation 40 C.F.R. § 1508.27 requires that the Project be placed in context with the surrounding society so the Project's impact on the affected region, the affected interests, and the locality can be rigorously evaluated. Any environmental document undertaken by MDOT must adequately address this aspect before the Project can be approved. This aspect of the environmental assessment process is often called "Intensity," and it requires consideration of:

> (1) Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that the effect will be beneficial.
> (2) The degree to which the proposed action affects public health or safety.
> (4) How much the effects on the quality of the human environment are likely to be highly controversial.
> (5) How much the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
> ….
> (10) Whether the action threatens a violation of Federal, State, or **local law** or requirements imposed for protecting the environment.

40 C.F.R. § 1508.27 (emphasis added). *See also* FAA Order 1050.1F, § 4-3.2, p.4-3.

The National Environmental Protection Act under which the SRDEA was prepared, and the due process clauses of the Fifth and Fourteenth Amendments to the United States Constitutions all provide legal protections to the residents living west of the Ann Arbor Municipal Airport. The citizens living in areas that surround the airport believe the airport expansion represents an arbitrary denial of their life, liberty, or property in violation of the Fifth and Fourteenth Amendments. These rights cannot be restricted except for a valid governmental purpose. *Bolling v.*

Sharpe, 347 U.S. 497 (1954). Critical is that any decision to move forward on the runway expansion must be made by a neutral decision-maker. Goldberg *v. Kelly*, 397 U.S. 254, 267 (1970). This is an important distinction because for four decades, MDOT has shown itself to be an advocate for expansion of the ARB primary runway, and not a neutral party. Typically, when a law or other act of government is challenged as a violation or potential violation of individual liberty under the due process clause, courts balance the importance of the governmental interest and the appropriateness of the government's method of implementation against the resulting infringement of individual rights. Where state authorities, such as MDOT, are involved, the United States Supreme Court has held that ". . . we cannot leave to the States the formulation of authoritative . . . remedies designed to protect people from infractions by the States of federally guaranteed rights." *Chapman v. California*, 386 U.S. 18, 22 (1967). Thus, MDOT may be forced to recuse itself from any decision in the Ann Arbor Municipal Airport expansion case, an expansion project which poses significant potential risks to citizens living in neighborhoods surrounding the airport.

This proposed project has a statistically small benefit, and yet would attract larger and heavier jet aircraft in closer proximity to homes in areas heavily populated with Canada geese, potentially jeopardizing residents if an accident occurs – accidents that the FAA contends are the third most frequent that occur in terms of incidents with hazardous wildlife in aviation. The risk to public safety may far outweigh any established benefit, which has not been substantiated. Added risks in terms of additional noise and night flights have not been established, but with arrival traffic traveling just 93 feet over rooftops on an expanded runway, it could have a controversial and negative impact on the human environment of citizens in Pittsfield Township, in violation of that township's noise ordinance and resolution, and in violation of federal law.

See Noise response #1 & #13, Wildlife response #1, Safety/Health response #1, and Safety/Health #2, #3, #5, & #6

VII. Conclusion

These comments detail why the SRDEA is inadequate and fails to meet the requirements of federal law, NEPA, the NEPA regulations, FAA Order 1050.1F as well as State and local laws. For the reasons stated above, the Project proposed by ARB should not be approved by either MDOT or the FAA because:

- The SRDEA does not state a valid Purpose and Need, rather, ARB attempts to justify its desire for an extended runway by creating a non-existent problem (or, at least, a problem that affects a picayune portion of the aircraft operating at ARB).

See Noise responses #1 & #3, Safety/Health responses #7 & #16, and General responses #3 & #14.

- The SRDEA does not establish by convincing evidence that the "critical aircraft" at ARB is a "B-II" type aircraft. In order to push its agenda, ARB has cherry-picked a year where operations of B-II aircraft exceeded 500 operations, but it ignores the fact that FAA regulations require there to be over 500 operations in 12 months preceding the environmental assessment. This fact obviates the "need" for an extended runway.

See Technical response #8 and #10

- The SRDEA does not address the fact that the proposed expansion brings potential risks to residents living near the airport by attracting larger and heavier jets, having aircraft take off 850 feet closer to population areas, and aircraft land just 93 feet over homes to the west of the airport.

See Noise response #1 & #3; Safety/Health response #6

- The SRDEA does not address the fact that the proposed expansion will have both noise and public safety impacts, violating a local Pittsfield Township noise ordinance. See Noise response #1, #4, and #13

- The SRDEA does not address the fact that both Pittsfield and Lodi Townships have passed resolutions oppose expanding the Ann Arbor Airport runway. This puts the proposed expansion at odds with 40 C.F.R. § 1508.27(2), (4), (5) and (10). See General response #29 and #33

- By carrying out the preferred alternative, ARB will be in violation of its FAA grant assurances which require it to consider the local interests of these communities, which there is no evidence presented in the SRDEA that it has done. See General response #5 and #18

In keeping with the above, if this proposed expansion is not rejected based on these above arguments, we ask that the following changes to the RDEA be required before the project moves forward:

(1) Compliance with Pittsfield Township's Noise Ordinance must be considered as a required part of the project.

(2) The SRDEA must address the fact that the preferred alternative is in direct opposition of Resolutions passed by both Pittsfield Township, the jurisdiction in which ARB is located, and Lodi Township, the adjacent jurisdiction. This puts the City of Ann Arbor at risk for litigation since it has signed grant agreements that state that the project must comply with local laws.

(3) The Alternative of using Willow Run Airport (YIP) to meet the RDEA's Purpose and Need must be fully considered as a "reasonable alternative" under NEPA and FAA Order 1050.1F.

(4) An updated noise study must be conducted that includes the effects of larger and heavier jet aircraft that an expanded runway will attract at night, and the health effects of such potential noise from positioning the runway 950 feet closer to the population center on citizens living near the airport.

(5) A Health Risk Assessment must be drafted to assess the public health risk as a result of the Project.

(6) The drinking water from wells on the airport property must be evaluated and provisions for further consultation with federal and state officials required (FAA Order 1050.1E (Pages A-76-76, 17.4a).

If you have any questions or comments, please feel free to call me at (626) 396-7300 or send me an email at staber@leechtishman.com.

Sincerely,

LEECH TISHMAN FUSCALDO & LAMPL

Steven M. Taber

Steven S. Taber

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CHEVALIER, ALLEN & LICHMAN LLP
Attorneys at Law
Aviation Law & Litigation • Environmental Law & Litigation • Commercial Litigation
www.calairlaw.com | www.aviationairportdevelopmentlaw.com

Gary M. Allen, Ph.D.
John Chevalier, Jr.*
Berne C. Hart
Barbara E. Lichman, Ph.D.
Jacqueline E. Serrao, LL.M.◊
Steven M. Taber○△
Anita C. Willis◊

*Retired
○Admitted in Illinois
△Admitted in Florida
◊Of Counsel

695 Town Center Drive, Suite 700
Costa Mesa, California 92626
Telephone (714) 384-6520
Facsimile (714) 384-6521
E-mail cal@calairlaw.com

April 19, 2010

By E-Mail
lamrouexm@michigan.gov

Molly Lamrouex
Airports Division
MDOT Bureau of Aeronautics and Freight Services
2700 Port Lansing Road
Lansing, Michigan 48906-2160

Re: Comments by The Charter Township of Pittsfield on the Environmental Assessment for Ann Arbor Municipal Airport

Dear Ms. Lamrouex:

The following comments are submitted on behalf of The Charter Township of Pittsfield on the February 2010 Environmental Assessment for Ann Arbor Municipal Airport ("EA").

I. THE PROJECT'S STATED PURPOSE AND NEED IS UNSUPPORTED BY THE EVIDENCE.

An EA must include a discussion of the purpose and need for the proposed action which must "specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action." [40 C.F.R. § 1502.13]. In addressing the Purpose and Need section of an EA, FAA Order 1050.1E provides that: "This discussion identifies the problem facing the proponent (that is, the need for an action), the purpose of the action (that is, the proposed solution to the problem), and the proposed timeframe for implementing the action." FAA Order 1050.1E, ¶ 405c. The EA accomplishes none of these goals.

A. The EA Supports Neither the Problem it Aims to Solve Nor its Purported Solution.

First, the EA defines the *purpose* of the Project[1] as "to provide facilities that more effectively and efficiently accommodate the *critical aircraft* that presently use the airport, as well as to enhance the operational safety of the airport." [EA, p. 2-4]. The EA defines "critical aircraft" as "the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport," *Id.*, and states that a 2009 MDOT Airport User Survey "has confirmed that the critical aircraft classification for ARB is 'B-II Small Aircraft.'" *Id.*

To effectuate the stated purpose, the EA purports to support the construction of a runway extension from 3,505 feet to 4,300 feet. However, the extant evidence is clear that no "B-II Small Aircraft" require a 4,300 foot long runway. All B-II Small Aircraft are capable of operating on the existing 3,505 feet long runway without weight restriction. *See*, attached Williams Aviation Consultants Report [incorporated herein by reference]. In fact, the representative B-II Small Aircraft cited in the EA, the Beechcraft King Air 200, requires only 2,579 feet of runway to take-off fully loaded, and 2,845 feet to land. *See*, http://www.hawkerbeechcraft.com/beechcraft/ king_airb200gt/specifications.aspx. Thus, the statement that "[d]evelopment of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small Aircraft to operate at their optimum capabilities (without weight restrictions)" [p. 2-4], although true, is misleading. There is no need to extend Runway 6/24 to allow B-II aircraft to operate at ARB. They can operate on a 3,505 foot runway without weight restrictions. Therefore, the statement that interstate commerce would be negatively impacted by B-II Small weight restrictions does not state a valid need, and the purported purpose of "provid[ing] facilities that more effectively and efficiently accommodate the *critical aircraft* that presently use the airport" is an unnecessary solution to a nonexistent problem.

B. The EA Incorrectly Relies on ***Total*** Annual Operations to Support the Proposed Runway Extension.

The EA states, "[t]he critical aircraft, or grouping of aircraft are generally the largest, most demanding types that conduct at least 500 operations per year at the airport" [EA, p. 2-7], and concludes that the proper Airport Reference Code ("ARC") for ARB is "B-II Small", based on a total of "750 actual annual operations by B-II category critical aircraft from survey data year

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[1] The proposed improvements described at page 2-1 of the EA are referred to herein as the "Project."

2007." [EA, p. 2-9]. However, the EA's use of "annual operations" differs markedly from the FAA criteria for selecting runway lengths and widths set forth in FAA Order 5090.3C:

> 3-4. AIRPORT DIMENSIONAL STANDARDS
>
> Airport dimensional standards (such as runway length and width, separation standards, surface gradients, etc.) should be selected which are appropriate for the critical aircraft that will make substantial use of the airport in the planning period. Substantial use means either 500 or more annual ***itinerant*** operations, or scheduled commercial service. FAA Order 5090.3C, p. 21 (emphasis added).

(FAA Order 5090.3C does not state that critical aircraft must be the "largest.")

The FAA divides General Aviation operations into two categories, "local" and "itinerant." Itinerant operations are defined as "an operation performed by an aircraft, either IFR, SVFR, or VFR, that lands at an airport, arriving from outside the airport area, or departs an airport and leaves the airport area." [U.S. DOT JO 7210.695, p. 5]. Local operations are defined as "those operations performed by aircraft that remain in the local traffic pattern, execute simulated instrument approaches or low passes at the airport, and the operations to or from the airport and a designated practice area within a 20-mile radius of the tower." *Id*.

The EA, without reference to this distinction, relies on "annual operations" and "total annual operations" not "itinerant operations," *see,* EA, Table 2-1, p. 2-10. Separating itinerant and local operations at ARB would result in a dramatic reduction in the number of annual critical aircraft operations at the airport. For example, data from the website City-Data.com shows that there were 29,322 itinerant operations and 43,573 local operations at ARB in 2007, the year used by MDOT in the EA. *See*, http://www.city-data.com/airports/Ann-Arbor-Michigan.html. In that itinerant operations account for approximately 40% of the total operations at ARB, itinerant B-II operations for 2007 would be in the neighborhood of 300 operations per year [40% of 750 total operations], substantially below the FAA's threshold of 500 annual operations to constitute "substantial use." Moreover, the Airport User Survey shows only 293 annual B-II Small operations at ARB in 2007. [EA Appendix A-1, p. 7]. Thus, the FAA Order 5090.3C airport dimensional standards for B-II small aircraft do not apply.

C. Shifting Runway 6/24 150 Feet to the Southwest Will Not Achieve an Additional Margin of Safety.

The EA states as part of its purpose to "[e]nhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road." [EA, p. 2-5]. Operational safety in low visibility conditions will not be enhanced by providing a clear 34:1 approach surface to Runway 24. The EA is correct in stating that shifting the Runway 24 threshold 150 feet west would enhance safety by effectively removing the current obstruction to line-of-site vision (hangar) of the parallel taxiway for ATCT personnel. [EA, p. 2-5]. However, in the next paragraph the EA states, "The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles." [EA, p. 2-5]. This statement lacks support in either the Instrument Approach Procedure (IAP) design or Terminal Instrument Procedures ("TERPS") Obstruction Standards.

Both the 20:1 and the 34:1 surfaces exist simultaneously for every published IAP, and are defined as "Obstacle Identification Surfaces" which do not establish obstacle clearance safety margins, but rather only define instrument approach visibility minimums. The FAA does not require either of these two surfaces to be free of penetration by obstacles, and thus "providing an additional margin of safety," as stated in the EA, does not apply in the case of these two surfaces. Other TERPS surfaces (Obstacle Clearance Surfaces) are established which do ensure clearance from obstructions, and the FAA requires that these Obstacle Clearance Surfaces be clear of structures and terrain. The current IAPs to Runway 24 were designed by the FAA to accommodate all existing obstructions. Thus, shifting the runway 150' southwest would not enhance safety. Assuming that the EA is correct in the assertion that shifting the Runway 24 threshold would eliminate obstruction penetrations to the existing 34:1 Obstacle Identification Surface, the effect would not be a safety improvement, but would result only in a reduction in the required approach visibility minimums. [*See*, attached Williams Aviation Consultants Report]

II. THE EA DOES NOT CONSIDER ALL REASONABLE ALTERNATIVES.

The National Environmental Policy Act ("NEPA") [42 U.S.C. §§ 4321 *et seq.*] requires that federal agencies examine all reasonable alternatives in preparing environmental documents. [42 U.S.C. § 4332(c)(iii)]. An agency preparing an EA should develop a range of alternatives that could reasonably achieve the need that the proposed action is intended to address. The Council on Environmental Quality ("CEQ") Regulations ("NEPA Regulations"), which implement NEPA, require that Federal agencies "[u]se the NEPA process to identify and assess the reasonable alternatives to the proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment" 40 C.F.R. § 1500.2(e), and that "agencies shall . . . (a) Rigorously explore and objectively evaluate all reasonable alternatives . . ." 40 C.F.R. § 1502.14(a). The EA fails to explore all reasonable alternatives to the Preferred Alternative selected.

The EA [p. 2-5] lists five objectives of the proposed project:

- Enhance interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions.
- Enhance operational safety by improving the FAA ATCT line-of-sight issues.
- Enhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road.
- Reduce the occurrence of runway overrun incidents by small category A-I aircraft (local objective).
- Relocate and potentially upgrade the Runway 24 Approach Light System.

As shown in Section I above, enhancing interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions is not a valid need. Further, lengthening Runway 6/24 is not necessary to achieve the remaining four objectives. Those objectives could be met by simply shifting Runway 6/24 150 feet to the southwest, *i.e.*, removing 150 feet from the approach end of Runway 24 and adding 150 feet to the departure end of Runway 24. Runway length would remain 3,505 feet.

Section 2.2.1 of the EA states that a 150-foot shift of the Runway 24 threshold to the west would (1) enhance the safety of ground operations by taxiing aircraft; (2) enhance operational safety, and possibly prevent runway incursions, by expanding the view of the hold area and parallel taxiway to ATCT personnel; (3) allow for a clear 34:1 approach surface to the east end of the runway, providing an added margin of safety between approaching aircraft and ground-based obstacles, which is particularly beneficial when aircraft are operating in low-visibility conditions; and (4) include relocation and replacement of the existing runway approach light system with newer Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF). [EA, pp. 2-5, 2-6]. Shifting Runway 6/24 150 feet to the southwest without lengthening the runway would also accommodate future widening of State Road. Nevertheless, this reasonable alternative was not considered in the EA.

An Environmental Assessment "shall include brief discussions of . . . alternatives . . ." 40 C.F.R. § 1508.9(b).[2] Absent an analysis of an alternative based on a 150-foot southwesterly shift of the runway, without lengthening the runway, the EA is inadequate.

III. THE EA FAILS TO ADEQUATELY ANALYZE OR DISCLOSE THE PROJECT'S AIR QUALITY IMPACTS WHERE IT FAILS TO ADDRESS OR DETERMINE THE PROJECT'S CLEAN AIR ACT CONFORMITY.

Section 7506 of the Federal Clean Air Act [42 U.S.C. §§ 7401 *et seq.*] mandates that "[n]o department, agency, or instrumentality of the Federal Government shall engage in, support in any way or provide financial assistance for, license or permit, or approve, any activity which does not conform to [a State Implementation Plan] after it has been approved or promulgated under [42 U.S.C. § 7410]." The Environmental Protection Agency (EPA) has promulgated regulations implementing Section 7506 (the "Conformity Provision") in 40 C.F.R. §§ 93.150 *et seq.* ("General Conformity Rule"). The General Conformity Rule requires, in part, that Federal agencies first determine if a project is either exempt from conformity analysis or presumed to conform. If it is neither, the agency must conduct a conformity applicability analysis to determine if a full conformity determination is required. *See*, *Air Quality Procedures for Civilian Airports and Air Force Bases*, p. 13.

The project area, *i.e.*, Washtenaw County, is in attainment for five of the seven criteria pollutants [p. 4-17], and marginal nonattainment for Ozone [p. C-3].[3] The area is designated as in nonattainment for $PM_{2.5}$. [EA, p. C-4]. Therefore, one of the following must apply: (1) the Project is exempt from conformity; or (2) the Project is presumed to conform; or (3) the agency must conduct a conformity applicability analysis to determine if a conformity determination for $PM_{2.5}$ is required. The EA does not indicate that any of the required actions was performed.

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2 Courts have consistently held that the "existence of reasonable but unexamined alternatives renders an EIS inadequate." *See, e.g., Friends of Southeast's Future v. Morrison*, 153 F.3d 1059, 1065 (9th Cir. 1998).

3 The original six criteria pollutants are Ozone (O3), Particulate Matter (PM_{10}), Carbon Monoxide (CO), Nitrogen Oxides (NO2), Sulfur Dioxide (SO2) and Lead (Pb). FAA Order 1050.1E ("Environmental Impacts; Policies and Procedures"), p. A-3, ¶ 2.1b, includes both PM_{10} and $PM_{2.5}$ under the category Particulate Matter. On April 5, 2010 the EPA published Revisions to the General Conformity Regulations Final Rule [75 Fed. Reg. 17254-279 (2010)] which, among other things, added $PM_{2.5}$ to the list of criteria pollutants in 40 C.F.R. § 93.153(b).

As a threshold matter, the EA is internally inconsistent with regard to whether the Project is exempt or presumed to conform. At page C-4, the EA states unequivocally that "[f]or this analysis it will be assumed that the project is neither exempt nor presumed to conform." [Emphasis added.] However, at page C-5 the EA states ". . . a conformity determination is not required and the proposed project is presumed to conform to the state implementation plan." [Emphasis added.] Under either scenario, however, the EA is deficient and fails to meet the "public disclosure" requirement under the National Environmental Policy Act ("NEPA"), 42 U.S.C. §§ 4321 *et seq*.

A. The EA Fails to Establish That the Project Is Exempt.

A federal agency has two options to determine that a project is exempt from conformity analysis: (1) if the project is included in the list of exempt actions listed in § 93.153(c)(2); or (2) if the project's total of direct and indirect emissions are below the emissions levels specified in § 95.153(b) of the Conformity Regulations ("*de minimis*"). § 93.153(c)(1).

The first option does not apply here because runway and taxiway extension projects such as the one described in the EA [p. 2-1] are not included in the exempt actions listed in § 93.153(c)(2). Nor does the EA establish that the Project can be considered exempt as *de minimis* under 40 C.F.R. § 93.153(c)(1). The EA instead relies on a 1996 MDOT Bureau of Aeronautics Air Quality Study of seven general aviation airports (which notably do not include ARB) for the conclusion that "typical GA airports generate a low level of pollutants." [EA, p. 4-17]. From that nonspecific conclusion, the EA further generalizes to the assertion that, because ARB is comparable in size and activity to the seven airports studied, it can be assumed that emissions resulting from the Project will not exceed the conformity threshold levels and, on that basis, concludes that a conformity analysis is not required.

This assumption is fatally flawed, however, for at least two reasons: (1) the EA does not quantify $PM_{2.5}$ emissions from flight operations at ARB at all, relying exclusively on the 1996 Study; and (2) because there is no quantification, there is also no comparison with the explicit *de minimis* thresholds established in 40 C.F.R. § 93.153(c)(1). It is correct that the original version of 40 C.F.R. § 93.153(c)(1) did not establish explicit thresholds for $PM_{2.5}$, as distinguished from PM_{10}. However, the newly implemented revised General Conformity Rule does establish that distinction, and now serves as the template for the air quality analysis required in the EA. Moreover, FAA Order 1050.1E, Appendix A, p. A3, § 2.16 includes both PM_{10} and $PM_{2.5}$ in "particulate matter."

B. The EA Fails to Establish That the Project Is Presumed to Conform.

The second option, the presumption of conformity does not apply here either. In July, 2007, the FAA published a "Federal Presumed to Conform Actions Under General Conformity Final Notice" [72 Fed.Reg. 41,565-580 (July 2007)] in which the FAA listed fifteen Airport Project categories which the FAA presumes to conform to applicable SIPs. The runway and taxiway extension project described in the EA does not fall within any of those presumed to conform categories. Therefore, the FAA cannot rely on the Presumed to Conform Final Notice to presume that the Project is in conformity.

C. The EA Fails to Establish the Project's Conformity Status.

Finally, even if, for argument's sake, the study of airports other than ARB were adequate for air quality analysis of ARB in the EA (which it is not), the 1996 Study would be an inadequate substitute for the required analysis. 40 C.F.R. § 93.159 requires that analyses under the General Conformity Rule be based on, among other things: (1) "the latest planning assumptions," § 93.159(a); and (2) "the latest and most accurate emissions estimation techniques available," § 93.159(b). The 1996, 14-year old, Study patently fails to fall within either, let alone both, of these parameters.

In summary, the EA fails to establish the existence of any of the necessary components of the required finding of conformity for a Federal project, and, thus, is inadequate under both NEPA and the Clean Air Act.

IV. THE EA FAILS TO ACCOUNT FOR WELLS ON AIRPORT PROPERTY.

While Section 4.5.2 of the EA purports to address "Geology, Groundwater, and Soils" affected by the Project, it understates the significance of the fact that water resources are a principal use of the grounds where the airport is located.

"If there is the potential for contamination of an aquifer designated by the [EPA] as a sole or principal drinking water resource for the area, the responsible FAA official needs to consult with the EPA regional office, as required by section 1424(e) of the Safe Drinking Water Act, as amended." FAA Order 1050.1E, pp. A-74, 75, ¶ 17.1c. "When the thresholds indicate that the potential exists for significant water quality impacts, additional analysis in consultation with State or Federal agencies responsible for protecting water quality will be necessary. *Id.*, pp. A-75, A-76, ¶ 17.4a. "If the EA and early consultation [with the EPA] show that there is a potential for exceeding water quality standards [or] identify water quality problems that cannot be avoided or mitigated . . . an EIS may be required. *Id.*, pp. A-75, ¶ 17.3.

There are two issues raised by the Project that require further examination in the EA. First, there is the issue of contamination from the Airport. The Airport is the location of a porous sand/gravel formation that yields a large amount of water for pumping Historically, the land where the Airport is located was originally acquired by the City of Ann Arbor for water rights in 1929. Until recently, 15% of Ann Arbor's water supply came from the three wells located on Airport property. Water Quality Report, 2008, City of Ann Arbor, p. 2 (available at http://www.a2gov.org/government/publicservices/water_treatment/documents/ccr.pdf). Due to the importance of the water supply at ARB, the EA needs to have more than a few passing words ("Based on coordination with the City of Ann Arbor, the proposed runway extension would not impact the water supply wells or the new water supply line (Bahl, 2009)"). [EA, p. 4-20].

Second, paving the area for a runway, roads, *etc.* increases the impervious area on the aquifer. This in turn reduces the infiltration of water that feeds the aquifer/City water supply. Adding 950 feet to the end of the runway adds another 71,250 square feet of impervious area over an aquifer that it vital to the City of Ann Arbor. Further environmental review should provide detailed analyses of the impact of this increase in impervious surface, as well as the possibility of contamination, currently unexplored in the EA.

V. <u>THE EA FAILS TO ANALYZE THE PRESENCE OF HAZARDOUS WILDLIFE NEAR THE AIRPORT AND FAILS TO PRESENT ANY MANDATORY MITIGATION MEASURES</u>.

FAA Advisory Circular 150/5200-33B ["Hazardous Wildlife Attractants on or Near Airports"] contains standards for land uses that have the potential to attract hazardous wildlife on or near public-use airports. The standards are applicable to airport development projects, including airport construction, expansion and renovation. Airports that have received Federal grant-in-aid assistance must use these standards. [*See,* AC 150/5200-33B, p. ii]. The FAA recommends separation distances of 5,000 feet at airports that do not sell Jet-A fuel, and 10,000 feet at airports that sell Jet-A fuel for hazardous wildlife attractants. [AC 150/5200-33B, p.1]. ARB sells Jet-A fuel.

The FAA also "recommends a distance of 5 statute miles between the farthest edge of the airport's AOA [Air Operations Area] and the hazardous wildlife attractant if the attractant could cause hazardous wildlife movement into or across the approach or departure airspace." [AC 150/5200-33B, p. 1]. Finally, AC 150/5200-33B provides that "[a]irport operators should identify hazardous wildlife attractants and any associated wildlife hazards during any planning process for new airport development projects" [p. 17] and "[t]he FAA will not approve the placement of airport development projects pertaining to aircraft movement in the vicinity of hazardous wildlife attractants without appropriate mitigating measures." [pp. 17-18].

The FAA ranks geese as number three [3] in a list of the relative hazard to aircraft for 25 species groups. [AC 150/5200-33B, Table 1, p. iii]. However, the EA does not disclose that the area surrounding the airport is a prime habitat for large numbers of Canada Geese. EA Appendix F lists 38 species of birds that have either been observed, or for which there has been confirmed or probable breeding in Airport fields during 2006 through 2008. The list does not include Canada Geese. Canada Geese populate waterways on a golf course, in business parks and in neighboring wetlands located west and southwest of the Airport, well within the separation distances prescribed by the FAA.

The preferred alternative (Build Alternative 3) would extend Runway 6/24 950 feet to the southwest. The extension would allow aircraft landing on Runway 6 and departing on Runway 24 to overfly areas populated by Canada Geese at altitudes of less than 100 feet. The EA does not consider this hazardous condition. Even though they are not designated as "special concern", "threatened" or "endangered," the presence of Canada Geese in the Airport area poses a hazard to aircraft operational safety, and should be identified and analyzed in the EA, along with proper mitigation measures.

VI. <u>THE EA DOES NOT ACKNOWLEDGE OR ANALYZE THE PROJECT'S MANIFEST GROWTH-INDUCING IMPACTS</u>.

A Federal agency is required to evaluate not merely the direct impacts of a project, but also its indirect impacts, including those "caused by the action and later in time but still reasonably foreseeable." 40 C.F.R. § 1508.8(b). Indirect impacts include a project's growth-inducing effects, such as changes in patterns of land use and population distribution associated with the project [40 C.F.R., § 1508.8(b)] and increased population, increased traffic, and increased demand for services. *City of Davis v. Coleman*, 521 F.2d 661, 675 (9th Cir. 1975). "The growth-inducing effects of [a] project appear to be its raison d'etre." *Id*. The EA ignores this requirement, even though the Project is virtually defined by its growth-inducing impacts. Despite the fact that the EA assumes that the "percent of night and jet operations would remain constant between the existing condition and the future years" [EA, p. 4-2], there is substantial evidence to indicate that the Project will cause a large increase in both types of operations.

As indicated above, there are no weight restrictions that must be lifted to allow the EA's "critical aircraft" to operate at ARB without weight restrictions. The "load restrictions" referenced on page 2-12 refer not to category B-II aircraft, but to higher category aircraft (jets in the C-I and C-II categories) which must currently operate at reduced weights in order to use the 3,505-foot runway. (Required takeoff length is the primary restrictor.) Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel, all of which discourage these aircraft from conducting operations at ARB.

For example, a Cessna Citation II (Category B-II) requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day, and can operate at unrestricted weight from the existing 3,505 foot runway. A Lear 35 (Category C-I), on the other hand, requires 5,000 feet for takeoff at maximum certificated gross weight on a standard day. While extending the runway to 4,300 feet would not facilitate unrestricted operations by the Lear 35, the required weight reduction would be less than is currently required. Therefore, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide no operational benefit to the Category B-II Citation jet, which the EA states is a "critical aircraft."

The longer runway will facilitate the loading of additional passengers and baggage on high performance jet aircraft. Also, the ability to carry additional fuel may mean that, in certain cases, costly and time consuming intermediate fuel stops will become unnecessary. If the runway is lengthened to 4,300 feet, it is reasonably foreseeable that ARB will become much more attractive to operators of higher performance jet aircraft, such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II), who could then operate at ARB instead of driving to and from Willow Run Airport.

Contrary to the unsupported assertions in the EA [EA, p. 42; Appendix B-1, p. B-4], it is reasonably foreseeable that the fleet mix will change in favor of a higher percentage of jet operations, as compared to the current level of light single and multi-engine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft account for a high percentage of ARB operations. B-II aircraft account for a low percentage of ARB operations.

It is, therefore, reasonably foreseeable that the number of night operations will increase as the number of arrivals of longer haul business jets often occur in the evening hours due to the longer time duration of their trips. Since one of the stated purposes of the EA is to increase interstate commerce, this is not merely an indirect, but also a direct effect, the Project will have on the surrounding community. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

Thus, the evidence is clear that the Project will cause an increase in both jet *and* night operations. It is also reasonably foreseeable that these added high-performance jet aircraft operations and night operations will be accompanied by significant noise and air quality impacts. Nevertheless, the EA fails to acknowledge, let alone analyze, these reasonably foreseeable impacts caused by expansion of Airport physical facilities and operational profile and, thus, is inadequate.

VII. NOISE MODELING FOR THE PROJECT FAILED TO INCLUDE INCREASED JET AIRCRAFT AND NIGHTTIME OPERATIONS IN DEVELOPING NOISE CONTOURS.

The FAA's Integrated Noise Model ("INM") was used to model annual operations for the 2009 existing condition, *i.e.*, April 2008 through March 2009 [EA Appendix B-1, p. B-4] and develop 65, 70 and 75 DNL noise contours for the Project. [EA, p. 4-3]. The EA states that "[t]he existing 65 DNL contour does not extend beyond airport property." [EA, p. 4-3]. During the time modeled, jet operations accounted for approximately 2 percent of total operations at ARB, and nighttime operations accounted for 4.2 percent of total operations. [EA, p. 4-2]. The EA states: (1) "[t]he percent of night and jet operations would remain constant between the existing condition and the future years"; (2) "fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives would remain static" [EA, p. 4-2; Appendix B-1, p. B-4]; and "[t]he ARB 2014 proposed project alternative DNL 65 dBA noise contour does not extend beyond airport property." [EA, p. B-6].

However, as shown in Section VI above, the Project will likely facilitate an increased number of night operations, and a change in fleet mix, which will include higher performance jet aircraft. DNL calculations depend on, among other things, forecast numbers of operations, operational fleet mix and times of operation (day verses night). [EA, Appendix B-2, p. B-16]. However, the EA fails to model or assess future increased night operations and fleet mix changes resulting from the Project.

The FAA is required to use INM to produce, among other things: (1) noise contours at the DNL 75 dB, DNL 70 dB and DNL 65 dB levels; (2) analysis within the proposed alternative DNL 65 dB contour to identify noise sensitive areas where noise will increase by DNL 1.5 dB[4]; and (3) analysis within the ***DNL 60-65 dB contours*** to identify noise sensitive areas where noise will increase by DNL 3dB, ***if*** DNL 1.5 dB increases as documented within the DNL 65 dB contour. [FAA Order 1050.1E, Appendix A, p. A-62, ¶ 14.4d].

As the noise modeling failed to take into account the foreseeable increases in nighttime and jet aircraft operations at ARB, the questions of whether the future DNL 65 dB contour will be increased, and to what extent, and whether increased noise levels within the DNL 65 dB contour would necessitate designation of a DNL 60 dB contour remain unanswered.

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[4] A significant noise impact would occur if analysis shows that the proposed action will cause noise sensitive areas to experience an increase in noise of DNL 1.5 dB or more at or above DNL 65 dB noise exposure when compared to the no action alternative for the same timeframe." [FAA Order 1050.1E, Appendix A, P. A-61, ¶ 14.3]

VIII. THE EA FAILS TO CONSIDER THE POLITICAL JURISDICTIONS AFFECTED BY THE PROJECT.

FAA Order 5050.4B, paragraph 706 provides a format for integrating the NEPA process with special purpose laws outside the scope of NEPA in preparing environmental assessments. Paragraph 706.e.(4) requires that an environmental assessment address "[p]olitical jurisdiction(s) the proposed action would affect." The EA fails to do that. The EA does not disclose that Pittsfield Township, the political jurisdiction in which the Project is located, and neighboring Lodi Township have both passed resolutions opposing the Project. The EA also fails to identify or analyze the effect that environmental impacts, which are certain to result from the Project (*e.g.*, noise, air quality, safety, economic impacts, *etc.*), will have on those political jurisdictions.

IX. CONCLUSION.

Given the Project's many potential significant environmental impacts that have not been identified or analyzed in the EA, a full Environmental Impact Statement (EIS) is required prior to approval and implementation of the Project. "No matter how thorough, an EA can never substitute for preparation of an EIS, if the proposed action could significantly affect the environment." *Anderson v. Evans*, 371 F.3d 475, 494 (9th Cir. 2004).

Sincerely,

CHEVALIER, ALLEN & LICHMAN, LLP

BC Hart
for Barbara E. Lichman, Ph.D.

Attachment (1)

Williams Aviation Consultants

Williams Aviation Consultants, Inc. was retained by the law firm of Chevalier, Allen & Lichman, LLP to review and comment on Chapters 1 and 2, and Appendices A and B of the DRAFT Ann Arbor Municipal Airport Environmental Assessment (DEA), February, 2010. The following are our comments on the DEA.

A. Accommodating the Critical Aircraft at Ann Arbor Municipal Airport (ARB)

As stated in paragraph 2.2.7, "*The proposed shift and extension of primary Runway 6/24 at ARB would provide a runway configuration that more effectively accommodates the critical aircraft that presently use the facility.* (Emphasis added)

In particular, the proposed project would provide the following benefits:

- *Enhance business aviation and interstate commerce by providing sufficient runway length to allow the majority of category B-II Small critical aircraft that currently use ARB to operate without load restrictions (i.e. reduction in passengers, cargo, and fuel associated with aircraft range).* (Emphasis added)

According to paragraph 2.2, Purpose and Need, "The purpose of the proposed improvements at ARB is to provide facilities that more effectively and efficiently *accommodate the critical aircraft* that presently use the airport, as well as to enhance the operational safety of the airport. (Emphasis added)

The critical aircraft is defined by the FAA as the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport. In cases where the critical aircraft weigh less than 60,000 lbs, a classification of aircraft is used rather than a specific individual aircraft model. A recent Airport User Survey has confirmed that the critical aircraft classification for ARB is "*B-II Small Aircraft.*" (Emphasis added)

Also stated under "Purpose and Need" "*Development of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small classification aircraft to operate at their optimum capabilities (without weight restrictions).* (Emphasis added)

WAC Comment: There are no aircraft in the B-II Small aircraft classification that require a runway length of 4,300 feet to conduct normal operations. All B-II Small Aircraft are capable of operating out of the current runway (3,505 feet long) without the need to reduce weight by off-loading passengers, baggage or fuel.

Regarding the establishment of the <u>critical aircraft</u>, ARB lacks the required number of 500 annual operations by B-II Small Aircraft, so they have added larger aircraft such as B-II Large, Category C-I and C-II operations to meet the 500 classification requirement. It is the Category C-I and C-II aircraft which would benefit by the runway extension to 4,300 feet, not

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those aircraft that fall within the definition of Category B-II Small Aircraft. The current runway length of 3,500 feet is sufficient to handle all Category B-II Small Aircraft.

B. Lengthening Runway 6/24 to 4,300 Feet: The Impact on Aircraft Load Restrictions and Fleet Mix

The "load restrictions" referenced above in paragraph 2.2.7 refer to the fact that the higher category aircraft (primarily jets in the C-I and C-II categories) must currently operate at reduced weights in order to operate out of the current 3,500 foot runway (required takeoff length is the primary restrictor). Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel; all of which discourage these aircraft from conducting operations out of ARB.

For example: A Cessna Citation II (Category B-II) requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day and may therefore operate unrestricted as to weight from the current 3,500 foot runway. A Lear 35 (Category C-I) requires 5,000 feet for takeoff at maximum certificated gross weight on the same standard day.

The Category B-II Citation II can conduct unrestricted operations from the current 3,500 foot runway. Whereas extending the runway to 4,300 feet would not facilitate unrestricted operations by the Category C–I, Lear 35, the required weight reduction would be less than is currently required. In this way, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide no operational benefit to the Category B-II Small Citation jet, or any other Category B-II Small aircraft.

All Category B-II Small aircraft, i.e. the ARB critical design aircraft, are currently accommodated on the existing 3,500 foot runway. Contrary to what is stated in the DEA, lengthening the runway to 4,300 feet WOULD NOT "provide a runway configuration that more effectively accommodates the critical aircraft that presently use the facility."

If the runway is lengthened to 4,300 feet, other jets such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II) may be able to operate out of ARB with minor reductions in takeoff weight. This will impact the community as it could reasonably be expected that the longer runway will attract more of the larger, higher performance jet aircraft to the airport.

These added high performance jet aircraft operations will be accompanied by noise and air quality impacts. Many of these operations will take place at night, thereby negatively affecting the general quiet of the surrounding community.

C. **Shifting Runway 6/24 150 Feet to the West While Maintaining the Current Runway Length of 3,500 Feet: The Impact on Load Restrictions, Future Fleet Mix and Safety of Operations**

Load Restrictions

Maintaining the current runway length of 3,500 feet would mean that the Category C-1 and C-II aircraft would continue to suffer significant load restrictions. These load restrictions would thereby continue to serve as a deterrent to these aircraft operating out of ARB.

Future Fleet Mix

Maintaining the current runway length would serve to maintain the current fleet mix. Category B-II Small jet aircraft include lower powered models such as the smaller versions of the Cessna Citation (Category B-I/II) and the Mitsubishi Diamond jet (Category B-I). Higher powered jet aircraft such as the Lear 25 (Category C-I), Lear 35 (Category C-I), IAI Astra (Category C-I) and Cessna Citation III (Category C-II) may be generally discouraged from flying into Ann Arbor and would generally, with few exceptions choose to land at Detroit and drive the 40 miles to Ann Arbor.

Safety of Operations

2.2.1 Safety Enhancements:

In the first paragraph, the consultant is correct in stating that shifting the Runway 24 threshold 150 feet west would enhance safety by effectively removing the current obstruction to line-of-site vision (hangar) of the parallel taxiway for ATCT personnel.

However, in the next paragraph the consultant states, "The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles."

This statement betrays a lack of understanding by the consultant of Instrument Approach Procedure (IAP) design and TERPS Obstruction Standards. Regarding the 20:1 and the 34:1 surfaces; it is not either/or, but both/and. Both the 20:1 and the 34:1 surfaces exist simultaneously for every published IAP and are defined as "Obstacle Identification Surfaces" which do not establish obstacle clearance safety margins but rather only define instrument approach visibility minimums. The FAA does not require either of these two surfaces to be free of penetration by obstacles, and thus "providing an additional margin of safety" as stated by the consultant does not apply in the case of these two surfaces.

Other TERPS surfaces (Obstacle Clearance Surfaces) are established which do ensure clearance from obstructions and the FAA requires that these Obstacle Clearance Surfaces be clear of structures and terrain. The current IAPs to Runway 24 were designed by the

FAA to accommodate all existing obstructions. In this respect, shifting the runway 150' to the west would not enhance safety.

Summary: Assuming that the consultant is correct in their assertion that shifting the threshold would eliminate obstruction penetrations to the existing 34:1 Obstacle Identification Surface, the effect would not be a safety improvement but would only result in a reduction in the required approach visibility minimums.

D. Appendix B Noise Analysis Report
B-1 Noise Impact Analysis
B.1.3 Data
Flight Operations

The consultant states "INM-modeled annual operations for the 2009 existing condition, consisting of operations from April 2008 through March 2009, totaled 61,969 operations, which is approximately 169 daily operations. Jet operations accounted for approximately 2 percent of the total operations. Nighttime operations accounted for 4.2 percent of the total operations."

2014 future condition aircraft operations were obtained from the 2008 FAA TAF for ARB. Modeled annual operations for the 2014 condition totaled 69,717 operations, or approximately 191 daily operations. *It is assumed that the percent of night and jet operations will remain constant between the existing condition and the future years. In addition, it is also assumed that the fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives will remain static.* The existing and future fleet mix with annual operations is shown in Table B-2." (Emphasis added)

The consultant wrongly assumes that the percent of night and jet operations will remain constant, and that the fleet mix will remain static if Runway 6/24 is lengthened to 4,300 feet.

The longer runway will make ARB much more attractive to larger and higher performance jet aircraft as the added runway length will facilitate the loading of additional passengers and baggage on to these aircraft. Also, being able to carry additional fuel may mean that, in certain cases, costly and time consuming intermediate fuel stops will become unnecessary. As ARB becomes more attractive to higher performance jet aircraft, these larger aircraft may then consider operations to/from ARB in lieu of landing at Detroit and driving to Ann Arbor.

As more high performance jet aircraft begin operations at ARB, the fleet mix will change in favor of a higher percentage of jet operations as compared to the current level of light single and multiengine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft currently reflect a high percentage of ARB operations. B-II Small aircraft (the critical design aircraft) reflect a low percentage of ARB operations. Recall that Category B-II Large and Category C aircraft had to be added to the currently operating Category B-II Small aircraft design group in order to meet the 500 operation requirement for establishing the critical aircraft and thereby justify the runway extension.

The number of night operations also has the strong potential to increase as the number of arrivals of the larger, longer haul business jets often occur in the evening hours due to the longer time duration of their trips. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

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VIA EMAIL AND USPS EXPEDITED MAIL

10 February 2017

houttemanS@michigan.gov

Steve Houtteman
Environmental Specialist
MDOT-Office of Aeronautics
2700 Port Lansing Road
Lansing, MI 48906-2160

Re: Comments of Pittsfield Charter Township and the Committee for Preserving Community Quality on Michigan Department of Transportation's revised Draft Environmental Assessment for the Extension of the Runway at Ann Arbor Municipal Airport.

Dear Mr. Houtteman:

The following comments are submitted on behalf of The Charter Township of Pittsfield and the Committee for Preserving Community Quality (CPCQ) on the revised Draft Environmental Assessment (RDEA) dated October, 2016, but not released and published for public comment until January, 2017, prepared for the City of Ann Arbor ("City"), the Michigan Department of Transportation, Aeronautics Division (MDOT) and the Federal Aviation Administration (FAA).

The RDEA became necessary when MDOT failed to proceed to a final Environmental Assessment in a timely fashion. The original Draft Environmental Assessment (DEA), which was published on February 28, 2010, contained numerous problems and issues that were identified in comments by Pittsfield Township, CPCQ, Washtenaw County and the Federal Aviation Administration, among others. While the RDEA addresses some of

1 LEAGUE, #60036 | IRVINE, CA 92602 | TEL 949.735.8217 | FAX 714.707.4282 | staber@taberlawgroup.com

the issues raised in those comments, it fails to address all concerns that were raised previously while creating additional problems. The RDEA is seriously flawed for numerous reasons detailed below and it should not be approved.

I. THE RDEA DOES NOT SUPPORT ITS PURPOSE AND NEED: THERE IS NO PURPOSE OR NEED FOR THE PREFERRED ALTERNATIVE.

An environmental assessment (EA) must include a discussion of the purpose and need for the proposed action which must "specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action." 40 C.F.R. § 1502.13. In addressing the Purpose and Need section of an EA, FAA Order 1050.1F provides that the Purpose and Need section "presents the problem being addressed and describes what the FAA is trying to achieve with the proposed action. The purpose and need for the proposed action must be clearly explained and stated in terms that are understandable to individuals who are not familiar with aviation or commercial aerospace activities. To provide context while keeping this section of the EA brief, the FAA may incorporate by reference any supporting data, inventories, assessments, analyses, or studies." FAA Order 1050.1F, ¶ 6-2.1c. The RDEA's Purpose and Need accomplishes none of these goals.

A. The RDEA Cannot Support Its Assertion That ARB Is a "B-II" Airport or that the Runway Expansion Is Needed by Aircraft that Make Substantial Use of the Airport.

The RDEA does not present a convincing case that "B-II" aircraft are the "critical aircraft" for ARB. Moreover, any lengthening of the runway would substantially serve only a couple of aircraft that currently use ARB, while attracting larger and noisier aircraft.

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1. In Four of the Last Five Years the 500 Operations Has Not Been Met.

Recommended runway lengths for airports are contained in MDOT's Michigan Airport Survey Program (MASP) (the most current version of which is 2008) or FAA Advisory Circular 150/5300-13 *Airport Design.* In either case, the recommended runway length is established by the "critical aircraft" for the airport in question. The RDEA states, without attribution, that a "critical aircraft" is "defined by the FAA as the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport." RDEA, p.12. However, that is incorrect. FAA Order 5090.3C, *Field Formulation of the National Plan of Integrated Airport Systems (NPIAS)* states:

> 3-4. AIRPORT DIMENSIONAL STANDARDS Airport dimensional standards (such as runway length and width, separation standards, surface gradients, etc.) should be selected which are appropriate for the **critical aircraft that will make substantial use of the airport in the planning period.** Substantial use means either 500 or more annual itinerant operations, or scheduled commercial service. **The critical aircraft may be a single aircraft or a composite of the most demanding characteristics of several aircraf**t. The critical aircraft (or composite aircraft) is used to identify the appropriate Airport Reference Code for airport design criteria. Design criteria (such as dimensional standards and appropriate pavement strength) are contained within AC 150-5300-13, Airport Design.

FAA Order 5090.3C, p.21 (emphasis added). The RDEA has claimed that the critical aircraft for ARB is "B-II." That is, aircraft with an approach speed of 91 NMPH but less than 121 NMPH, a wingspan of 49 ft., but less than 79 ft., and a tail height of 20 ft., but less than 30 ft. However, in four of the last eight years, B-II aircraft have not used ARB for over 500 operations, the threshold for determining whether there is "substantial use."

Using the FAA's Traffic Flow Management System Counts[1], it is apparent that since 2009, only four years have exceeded the 500 operations for B-II aircraft (both small and large). Since the original DEA was published in 2010, there have been only two years that exceeded the 500 operations threshold.

Year	Number of B-II Operations
2009	553
2010	554
2011	512
2012	444
2013	481
2014	538
2015	429
2016	447

Source: FAA Traffic Flow Management System Counts https:/aspm/faa.gov/tfms/sys/Airport.asp

Therefore, it is incorrect to conclude that "B-II" aircraft is the "critical aircraft" for ARB. Because the aircraft classification "B-II" is not the critical aircraft, the runway does not need to be lengthened to accommodate that size of aircraft.

2. The operating specifications for one aircraft is driving ARB's push to lengthen the primary runway.

Since 2009, approximately two-thirds of all "B-II" operations come from two aircraft: a Cessna Citation XLS[2] and a Beechcraft King Air 200.

[1] MDOT uses FAA's Traffic Flow Management System Counts (TFMSC) for its 2014 "User Survey." TFMSC is available to the public at https://aspm/faa.gov/tfms/sys/Airport.asp.
[2] Most, if not all, of the "pilot quotes" regarding the need for the expansion of the runway come from the corporate pilot of the Cessna Citation Excel.

Year	No. of Citation XLS Flights	Percentage of All B-II Flights	No. of Beechcraft King Air 200 Flts	Percentage of All B-II Flights	King Air & XLS Flights as % of All B-II Flts
2016	153	34%	127	28%	63%
2015	188	44%	108	25%	69%
2014	158	29%	167	31%	60%
2013	148	31%	113	24%	54%
2012	164	37%	120	27%	64%
2011	197	38%	151	30%	68%
2010	179	32%	201	36%	69%
2009	198	36%	152	27%	63%

Source: FAA Traffic Flow Management System Counts https:/aspm/faa.gov/tfms/sys/Airport.asp

Thus, the Project primarily benefits two aircraft out of the entire fleet of aircraft that are based and/or use ARB on a regular basis. The question becomes whether this is a proper "purpose and need" to expend over $3 million in federal funds on a Project[3] that primarily benefits two aircraft.

The "purpose and need" of the Project comes under additional scrutiny when one considers the take-off/landing distances specified for the various B-II aircraft that use ARB on a regular basis. Since the "need" is "to allow the critical aircraft to safely operate at their optimum capabilities without weight restrictions due to lack of suitable runway length" (RDEA, p.12) it is important to understand what the "optimum capabilities" for "critical aircraft" are.

[3] As used in these comments, the term "Project" means what the RDEA identifies as the "preferred alternative."

Aircraft Model	**No. of 2014 Operations**	**Take-off distance (MTOW, Sea Level, ISA)**	**Landing Distance**
B-II Small			
Aero Commander 500	1	1,916	2,235
Gulfstream Jetprop Commander 1000	3	2,131	2,186
Beechcraft King Air 90	67	2,856	2,275
Beechcraft King Air 100	34	2,694	2,679
Beechcraft King Air 200	167	2,579	2,074
Cessna 441 Conquest II	5	2,465	1,875
Cessna Citation CJ2 (C25A)	2	3,360	2,980
B-II Large			
Beechcraft King Air 300	5	3,300	2,692
Beechcraft King Air 350	16	3,300	2,692
Cessna Citation CJ3 (C25B)	4	3,180	2,770
Cessna Citation II (C550)	2	3,450	2,078
Cessna Citation V (C560)	46	3,160	2,230
Cessna Citation Excel (C56X)	158	3,590	2,909
Embraer Phenom 300	28	3,199	2,430

Multiple Sources

Therefore, extending the runway is necessary for the Cessna Citation Excel and for the Cessna Citation II. All other B-II aircraft can use ARB's 3,500-foot runway with little or no weight restrictions. The Beechcraft King Air 200 can use ARB's 3,500-foot runway on most days with little or no weight restrictions. The entire runway expansion project will primarily benefit a single aircraft. Therefore, either the project is intended to allow an increase in the number of larger aircraft operations at ARB, which the RDEA claims is not the case, or it is meant to primarily benefit a single aircraft.

B. RDEA's "Need" Is Not Supported by Evidence in the RDEA

Beyond this, the problem being addressed – Need – is not supported by any substantive evidence in the RDEA. None of the inventories, assessments, analyses, or studies required by FAA Order 1050.1F are present in the RDEA. FAA Order 1050.1F, ¶ 6-2.1c. No actual evidence of economic losses because of weight restrictions are provided. In fact, there is no evidence, except for a single quote from the Cessna Citation XLS pilot, that operating a B-II aircraft at ARB requires the use of weight restrictions. MDOT relies entirely on its findings that ARB is a "B-II" airport. Both the MASP 2008 and the FAA advisory circular **recommend** a runway length of 4,300 and 4,200 (respectively) for B-II aircraft. There is no discussion in the RDEA that operating with weight restriction is an issue at ARB for anyone except with the pilot of the Citation XLS.

It is understood that the distances listed above are at sea level (which ARB is not) and on a "standard day." However, without more information from ARB regarding weight restrictions faced by the current users, it is the best information we have to examine ARB's claims that weight restrictions are "frequently" imposed on B-II aircraft. MDOT maintains that it is desirable to allow critical aircraft to operate at their optimum capabilities, yet MDOT does not provide any information about how often critical aircraft cannot operate at their optimum capabilities or even what those optimum capabilities are. Until that information is provided, the Project must not be approved.

ARB has consistently maintained that it need not quantify load restrictions or answer any questions about how often load restrictions occur at ARB because no other airport in Michigan has been required to do so. However, ARB has made "operating without load restrictions" a critical component of its purpose and need, so it should also have to reveal how big a factor this really is and show that the Project will not primarily benefit a single aircraft.

Also, MDOT is aware that, according to the National Weather Service, temperatures exceed 40 degrees Fahrenheit nine months out of the year in Ann Arbor (Exhibit 1). This fact suggests that instead of an expensive and potentially dangerous runway expansion, a more appropriate solution is that the single aircraft in question be based at another larger airport (Willow Run is just 12 miles away). Even the FAA queried: "[t]his example seems to be an extreme case. . .Why do they base at ARB instead of another close airport if they cannot use the aircraft to it's (sic) max capability above 40 degree F?" (Comment No. 15, October 2016 MDOT AERO / Applicant Ann Arbor comments in response to FAA questions.) And in a related question (Comment No. 8), the FAA asked, ". . .how often is the runway length affecting users?" – a question that went unanswered by RDEA.

C. Lengthened Runway Would Be Rarely Required, But Could Pose Risks to the Surrounding Community Every Day.

While the RDEA does not provide any data on B-II operational usage in terms of the number of days when aircraft suffered actual weight penalties, number of aircraft involved, or the actual penalties suffered on the current runway, it is possible to provide an analysis based on usage data of how frequently the expanded runway might be necessary. A statistical analysis makes such a determination possible. FAA Advisory Circular 150/5325-4B *Runway Length Requirements for Airport Design* aids an airport in determining the recommended runway length. AC 150/5325-4B, contains a runway length curve that was utilized with temperatures at 83 degrees Fahrenheit or above, and an ARB elevation of 839 feet, criteria to which MDOT stipulated meet the mean daily temperature during the hottest month at ARB. RDEA, Appendix K, Response No. 75. ARB also had 57,370 total operations in 2014, of which, it claims, 551 were category B-II operations. RDEA, Table 1-1. An analysis of data from the National Oceanic and Atmospheric Administration Weather Station at ARB shows in the most recent year (2015) there were 42

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days in which the temperature was 83 degrees Fahrenheit or above. ARB currently has a based population of 183 aircraft, of which 14 are category B-II aircraft. RDEA, § 1.2, ¶ 2.

With these data, a calculation of potential need of an expanded runway based on maximum potential need can be made. If, on every day on which the temperature reached or exceeded 83 degrees, every aircraft in the B-II fleet operated at its maximum take-off weight – a highly unlikely possibility – and required the expanded runway to take-off, based on the ARB fleet population the need for the expanded runway would be 0.0088, or less than 1 in 100 (42/365 x 14/183). This is based on the number of days with temperatures exceeding 83 degrees and the proportion of the total ARB fleet that is Category B-II. However, if this calculation were based on the more realistic actual usage that took place in the most recent operational year (2014) used in the RDEA, based on the same criteria, on every day the temperature reached 83 degrees or above, the actual need for an expanded runway would be 0.00110 – or about 1 in 1,000 (42/365 x 551/57,370) – the number of B-II operations relative to the total operations in the most recent year of 2014.

Thus, operational need for an expanded runway would be quite rare, at best – if at all. Based on statistical analysis the expanded runway would be used for approximately 50 operations per year, at most. Yet, it would place citizens in the surrounding community at risk hundreds of times more frequently. This is due to the fact that aircraft would be taking off and landing 950 feet closer to residential areas, and larger and heavier aircraft, which undoubtedly will be attracted to ARB by the expanded runway.[4] These risks are exacerbated because of the potential dangers posed by aircraft that would be landing just 93 feet over homes in an area heavily populated with Canada geese just west of the airport, and by the reduced margin of safety in the event a heavy twin-engine aircraft suffers an engine failure on or just after takeoff. Such aircraft can lose their climbing power with an engine loss and could

[4] MDOT and ARB consistently assume that the fleet mix and number of annual operations by larger, faster aircraft will remain the essentially the same after the runway has been lengthened. This is a false assumption. *See infra* IV.B.2, p.30.

crash into the heavily populated neighborhood. The risk of – and liability from -- such a potential accident has not been thoroughly studied, and is not assessed in the RDEA.

D. The RDEA Conflates Purpose and Need.

The RDEA stated the document was prepared to conform to the requirements of FAA Order 1050.1F, "Environmental Impact: Policies and Procedures." Section 6-2.1(c) of Order 1050.1F defines need (the problem being addressed) and purpose (the proposed solution to the problem), saying they must be "clearly explained and stated in terms that are understandable to individuals who are not familiar with aviation or commercial airspace activities." The Order further recommends incorporating "by reference any supporting data, inventories, assessments, analyses, or studies." The Order clearly distinguishes Purpose and Need. The Purpose (*i.e.,* the Project) is supposed to resolve the Need (*i.e.,* the problem). Here, the desire for the Project is what is driving the Project. As such, this is a case of a Purpose looking for a Need. That is, it is a project looking for a problem to justify its existence.

The RDEA does not fulfill the requirements of FAA Order 1050.1F. The RDEA is flawed in stating in § 1.4 on Purpose and Need that a problem actually exists, and by using confusing language to conflate Need and Purpose as a result. The claimed Need lacks substantive evidence. Section 1.4 of the RDEA states "Need of the proposed actions is to allow the critical aircraft to safely operate at their optimum capabilities without weight restrictions (i.e. reductions in passengers, cargo, and fuel associated with cargo range) due to suitable runway length." RDEA, p.12, ¶ 7. But that presumes that such critical aircraft cannot already operate at such capabilities. The only purported evidence to support such a claim contained in the RDEA is the comment from the Cessna Citation XLS pilot who claimed, "…we are forced to reduce our departure weight with any temperature above 40 degrees Fahrenheit…which in many cases causes us an additional fueling stop which could be avoided with a longer runway…" RDEA, p.13, ¶ 6. In responding to

FAA's October 2016 comments, MDOT claimed that the pilot uses ARB due to the "proximity" of ARB to the user's business which offers "a significant time savings over other local airports." Since Willow Run Airport (YIP) is a short 12 miles from ARB (15 minutes by car), it is hard to imagine how using ARB would offer a "significant time savings." Thus, MDOT is arguing that the runway needs to be lengthened so that one pilot does not have to drive an extra 12 miles to get to/from his office on the handful of days that a weight restriction would be required.

The remaining evidence presented to support the Need claim relies on resolving an operational safety line-of-sight issue involving the FAA Air Traffic Control Tower. However, that issue could be resolved by the much shorter proposed 150-foot shift alone, described elsewhere in the RDEA (RDEA, § 2.1.4, "150-Foot Runway Shift Only"), not requiring the larger 800-foot runway expansion in addition to the 150-foot shift, which was not even fully studied as an alternative.

MDOT then attempts to explain the Purpose of the expansion to "fully accommodate the operational requirements of critical aircraft currently using the airport," while at the same time enhancing safety. For this, the applicant relies on FAA Advisory Circular 150/5325-4B, *Runway Length Requirements for Airport Design*, which suggests a runway of the length proposed for its determination of the recommended B-II classification of the critical aircraft for ARB. However, in utilizing the Advisory Circular and no supporting documentation as the primary justification for the proposed expansion, the RDEA establishes a Purpose to solve a problem for which a Need has not been substantially established.

This issue of Need justification was also problematic in the original DEA, which was issued in 2010, causing the FAA to also question the Need issue. In its May, 2010 comments on the 2010 DEA, the FAA asked, "[h]as it been documented that the current B-II 'small' users operate with load restrictions? If so, how often does this occur and what are the quantifiable impacts to their operations?" RDEA, Appendix J, FAA Letter dated 5-13-10, p.6, ¶ 5). In addition, in a separate question, the FAA asked, "the conclusion for the implementation for the preferred alternative states that a positive result of improvements is the ability of business owners to achieve improved fleet efficiency for critical aircraft by maximizing their passenger and/or cargo loads. How has this statement been substantiated? What records exist that current users at ARB are not operating at maximum passenger and/or cargo loads? What has been the economic impact of the reduction of loads if they are occurring?" RDEA, Appendix J, FAA Letter dated 5-13-10, p.7, ¶ 6.). None of these questions have been answered. They must be answered before the project is approved.

MDOT and ARB respond by again conflating Purpose and Need. In Comment No. 48 of the RDEA (RDEA, Appendix K), MDOT and ARB detail AC 150/5325-4B justification for aircraft family groupings of similar performance characteristics, as well as attempting to justify an explanation for its recommended proposal to expand ARB's primary runway to a 4,300-foot length based on runway length curves contained in the AC. The response concludes that "…load factors are only considered in the development of recommended runway lengths for critical aircraft groupings and individual aircraft models in the 'large' weight category. Load factor analysis is not a requirement for determining the recommended runway length at small general aviation airports such as ARB, with critical aircraft models in the B-II 'small' category. Since the FAA's methodology of determining the recommended runway length at ARB does not consider load factors, no in-depth analysis of aircraft loading was conducted as part of this study…" *Id.*, ¶ 7; *see also* Response to FAA's October, 2016, Comments, No. 8.

MDOT goes on to emphasize that "no other small general aviation airport in Michigan has ever had load factors analyzed as part of developing justification for extension of their primary runway to the length recommended in the FAA AC." RDEA, Appendix K, Comment 48, ¶ 7. The fact that this has never been required by MDOT is not a justification for avoiding answering the FAA's questions regarding the sufficiency of the existing ARB runway and the assumed Need for runway expansion, or adhering to the recommended procedures in the FAA AC. For more than two decades, MDOT had served as the FAA's agent in Michigan under the federal block grant program (49 U.S.C. § 47128), but its precedents may not always affirm the most proper enforcement of FAA-intended policies. A more rigorous agent might have pursued more thorough and complete standards and analyses with respect to ARB's critical usage and justification for expansion. It is also worth noting, as an aside, that MDOT's federal block grant status could be at risk if it does not more fully enforce the requirements under FAA Order 1050.1F in terms of requiring applicants to provide supporting data, inventories, assessments, analyses, or studies to support their proposed expansions, even though MDOT has not traditionally done so.

The point is that the "Need" must be justified in keeping with the full requirements of FAA Order 1050.1F to avoid taxpayer dollars being wasted on airport runway construction that may not be necessary or justified, which could lead to unnecessary spending across America if the Order were not fully and properly enforced.

If the Purpose and Need requirement has not been fully and properly enforced for the 20-plus years MDOT has served as the FAA's agent in Michigan, that is insufficient justification to allow such negligence to serve as a precedent. This example, for instance, presumes the only reason for the FAA's questions would be to substantiate Purpose. And yet that defies logic on its face because the FAA issues an Advisory Circular with advice on runway length development to satisfy any Purpose requirement for B-II airports. It is a much more reasonable conclusion to assume the FAA's questions pertain to Need. To paraphrase the FAA's questions, to-wit, if there is no established, substantiated loss of passenger or cargo load opportunities, or established current negative economic impact, there is no Need. Thus, the only way the applicant Ann Arbor could establish Need was to conflate it with Purpose, as it has done in the current RDEA, further confusing readers by attempting to justify the claimed Need based on an FAA Advisory Circular rather than the requirements of an FAA Order. This does not establish a proper Need for the proposed expansion.

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E. While Claims of Enhancements to Interstate Commerce Are overstated, Runway expansion Could Cost Local Authorities Millions in Losses from Reduced Taxes.

The RDEA claims an expanded runway would provide enhancements to interstate commerce by "removal of operational weight restrictions on critical category aircraft." RDEA, § 1.8.4. But the RDEA does not establish through specific operational statistical evidence that current critical aircraft suffer interstate commerce penalties causing economic hardship. In fact, elsewhere in the RDEA, when asked directly by the FAA to provide evidence on how the project would enhance interstate commerce in response to the 2010 DEA (RDEA, Appendix K, Response No. 30, ¶ 1), MDOT stated that "the need for the project is not based on the enhancement of interstate commerce. . .Enhancement of interstate commerce is a benefit of providing a runway long enough to avoid weight restrictions to critical aircraft. . ." Thus, the only condition that provides for a claim of enhanced interstate commerce is the same one that provides for the flawed one of satisfying Purpose and Need – conflating both, and then utilizing the FAA's Advisory Circular on recommended runway length curves to infer a loss of interstate commerce. Indeed, there is nothing to suggest that the "enhancement of interstate commerce" would simply mean moving the "interstate commerce" from YIP to ARB.

However, while there is no legitimate economic justification for the runway expansion, there is extensive research to suggest such an expansion could cause economic losses to several communities surrounding the airport, in the form of reduced real estate values and, consequently, reduced property and school taxes based on assessed property values. Extensive research based on other communities in which airport runways have been extended – Atlanta, Reno-Tahoe, Chicago O'Hare, the Greensboro-High Point-Winston Salem metroplex, 23 cities in Canada, among others – show property values decline as runways are expanded. The most respected such study. *The Announcement Effect of an Airport Expansion on Housing Prices*, G.D. Jud & D.T. Winker, (2006),

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JOURNAL OF REAL ESTATE FINANCE AND ECONOMICS, 33, 2, 91-103, suggests house prices decline by about 9.2 percent within a 2.5-mile band of the airport, and, beyond that, in the next 1.5-mile band, prices decline another 5.7 percent once an announcement – without extraneous influences – moved forward. The lengthy hold up of the proposed ARB expansion has represented an extraneous influence since the initial announcement eight years ago, but that if approved, these effects would occur, as well, at ARB. To further support this claim, a literature search could find no published, peer-reviewed research study where residential real estate values continued to rise in areas immediately surrounding an airport after runways were expanded. Further adding credence to this statement, the sales manager of the largest real estate firm in the Ann Arbor area has said he would no longer accept residential house sales listings in the area surrounding ARB if the runway extension is approved.[5]

A decrease in property values in the areas surrounding ARB would have important consequences for the various governmental bodies that benefit from property tax collections. In the corridors referenced in the Jud & Winker study noted above, there are:

- 6,239 Pittsfield Township parcels of land within the 2.5-mile area surrounding the airport; and
- 4,168 parcels within the 2.5-mile to 4-mile area.

These parcels will be subjected to a decline in real estate values of 9.2 percent and 5.7 per cent, respectively due to the expanded runway. Using those facts, the following is the estimated value of what the potential **annual** losses in property tax revenue would be for various governmental bodies based on their tax collections in 2016:

- $1.5 million less for the Ann Arbor School District;
- $1.4 million less for the Saline School District;

[5] Frank McVeigh, Charles Reinhart Company, personal communication.

- $850,000 less for Pittsfield Charter Township; and,
- $810,000 less for Washtenaw County.

This estimate is only for property located in Pittsfield Township. These numbers vastly understate the decline in tax revenues, because they do not consider the potential effects of property in Lodi Township, the City of Saline, (both of which could impact the Saline School District's revenues), or most importantly, property in the City of Ann Arbor. Thus, governments could stand to lose millions of dollars in operating funds annually from a runway expansion project that has yet to demonstrate any real economic benefit.

II. ALL REASONABLE ALTERNATIVES WERE NOT CONSIDERED IN THE RDEA.

The National Environmental Policy Act ("NEPA") (42 U.S.C. §§ 4321 *et seq*.) requires that federal agencies examine all reasonable alternatives in preparing environmental documents. 42 U.S.C. § 4332(c)(iii). An agency preparing an EA should develop a range of alternatives that could reasonably achieve the need that the proposed action is intended to address. The Council on Environmental Quality ("CEQ") Regulations ("NEPA Regulations"), which implement NEPA, require that Federal agencies "[u]se the NEPA process to identify and assess the reasonable alternatives to the proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment" 40 C.F.R. § 1500.2(e), and that "agencies shall . . . (a) Rigorously explore and objectively evaluate all reasonable alternatives…." 40 C.F.R. § 1502.14(a). Courts have consistently held that the "existence of reasonable but unexamined alternatives renders an EIS inadequate." *See*, *e.g*., *Friends of Southeast's Future v. Morrison*, 153 F.3d 1059, 1065 (9th Cir. 1998). Because the RDEA fails to explore all reasonable alternatives to the Preferred Alternative selected, it is inadequate.

Moreover, the FAA and MDOT, are required to take action if an environmental assessment is limiting the choice of reasonable alternatives. "If the FAA is . . . aware that the applicant is about to take an action within the

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agency's jurisdiction that would have an adverse environmental impact *or limit the choice of reasonable alternatives*, the responsible FAA official will promptly notify the applicant that the FAA will take appropriate action to ensure that the objectives and procedures of NEPA are achieved" 1050.1F, 2-3.1 (emphasis added).

A. The Use of Willow Run Airport Is a "Reasonable Alternative" that Has Not Been Fully Considered.

The RDEA summarily dismisses using Willow Run Airport (YIP) as an alternative because "[i]t was determined that using other airports is neither suitable based on runway lengths nor desirable based on proximity to corporate offices or business needs. Consequently, this alternative was removed from further consideration." RDEA, p.28. Since the not "suitable based on runway lengths" applies only to airports other than YIP, the sole reason why using YIP was dismissed as a "reasonable alternative" is due to its not being "desirable based on proximity to corporate offices or business needs." These are not valid reasons to not consider an alternative in an Environmental Assessment and in violation of NEPA, NEA regulations, and FAA Order 1050.1F.

The RDEA bases its conclusion that ARB is a more "desirable" location on the assumption that B-II aircraft operators using ARB instead of YIP "demonstrates that a large number of operators of business aircraft value the close proximity of ARB to their corporate offices and business contacts over the larger facility at Willow Run." This is a baseless assumption on the part of the RDEA, since it is equally likely that the fact that B-II aircraft still land at ARB instead of YIP demonstrates that the weight restrictions posed by the short runway are non-existent or not significant, otherwise these users would land at YIP instead. Although the FAA raised this point in its October, 2016, comments, the RDEA chose not to address it. FAA October, 2016, Comments, No. 62. Instead, ARB waves the argument off by stating that the Airport "cannot dictate which airfield a pilot uses" – an argument that applies equally as well to the RDEA's argument that rejects the YIP alternative.

However, using YIP instead of ARB meets the purpose and need of the project thereby making it a reasonable alternative that must be considered in the Environmental Assessment. As the RDEA points out, YIP has the runway length and facilities to accommodate the aircraft that may be weight-restricted from using ARB. *See* RDEA, p.27. The only reason that the RDEA gives to dismiss it from further consideration is the fact that it is located 12 miles from ARB and that it is an "inconvenience" to the corporations who want to use ARB instead of YIP. Even if lengthening the runway would benefit more than one or two aircraft, this is not an appropriate reason to dismiss an alternative from further consideration in an Environmental Assessment. If an alternative is "reasonable" (*i.e.,* it meets the purpose and need) then it must be considered in the Environmental Assessment alongside the preferred alternative and the no action alternative. *Friends of Southeast's Future*, at 1065. Since using YIP instead of ARB would achieve the purpose and need of allowing "critical aircraft" to take-off and land without weight restrictions, it is a reasonable alternative and must be considered as part of the Environmental Assessment process. The RDEA must be deemed inadequate on this basis alone

In its response to the FAA's comments in October, 2016, ARB adds additional criteria for dismissing the YIP Alternative by stating that the "proposed project would also result in ARB achieving full compliance with all AERO basic development standards outlined in the MASP 2008 for category B-II airports." However, it is far from clear that ARB is a "B-II" airport since there have not been over 500 itinerant operations of B-II aircraft for the past two years and four of the last five years (*see infra* pp.4-6). Moreover, both the MASP's and the FAA's design standards are recommendations, not requirements, and the FAA has told MDOT that meeting the recommended standards in its advisory circular is not a legitimate basis for lengthening a runway using federal funds. Finally, "achieving full compliance with AERO basic development standards" is *not* part of the Need. Although that may be raised in an environmental assessment as a reason to prefer the preferred alternative over the YIP Alternative, it is not a reason to eliminate the YIP Alternative from further consideration.

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B. Line-of-Sight Shift Only.

The RDEA lists four "benefits" of the Project:

1. Provide sufficient runway length to allow the majority of category B-II Small critical aircraft that currently use ARB to operate without load restrictions (*i.e.* reduction in passengers, cargo, and fuel associated with aircraft range);

2. Enhance the safety of ground operations, and lessen the chances of a runway incursion, by expanding the view of the parallel taxiway and aircraft hold area to ATCT personnel;

3. Improve the all-weather capability of ARB and enhance operational safety in low visibility conditions by providing a clear 34:1 approach slope to Runway 24; and

4. Address the local objective of decreasing the number of runway overruns by small category A-I aircraft by providing approximately 795 feet of additional runway pavement.

RDEA, p.26

As shown below, providing sufficient runway length to allow category B-II critical aircraft that currently use ARB to operate without load restrictions is not a valid need without providing additional information. Further, lengthening Runway 6/24 is not necessary to achieve the remaining three benefits. Those benefits could be achieved by simply shifting Runway 6/24 150 feet to the southwest, *i.e.*, removing 150 feet from the approach end of Runway 24 and adding 150 feet to the departure end of Runway 24. Runway length would remain 3,505 feet.

This RDEA does not fully evaluate the 150-foot shift alone as a potential alternative to resolving all of the issues that ARB is facing, as noted in § 2.1.4 of the RDEA. The rationale provided for not fully considering this alternative is that ". . . it does not meet the purpose of providing an overall safe, efficient and useable facility at ARB, it does not meet the need to allow the majority of critical aircraft to safely operate at their design capabilities, it does not satisfy the FAA design objectives for the critical aircraft at the airport, and it does not achieve full compliance with the basic development standards outlined in the MASP 2008 for category B-II airports." RDEA, Page 29, Paragraph 3).

However, with regard to safety, (1) the 150-foot shift would resolve any ATCT line-of sight issues with respect to Runway 24, and any prospective problems with local runway overrun issues; (2) there is no evidence provided in the RDEA that the "majority" of critical aircraft cannot already operate safely to their design capabilities at the present airport; (3) FAA design objectives for the airport are based only on an Advisory Circular and are not a matter of law or formal FAA rule and are not part of the "Need;" and (4) the MASP is arbitrary and capricious in its application to ARB, not having been independently evaluated in terms of potential risks.

Further, because the issues of Purpose and Need have been challenged above as not being satisfied, and the legitimacy of the 500-operations have been questioned over multiple years, it is not established that current users of ARB have an established economic need for an expanded airport. There are established arguments to be "proactive in enhancing safety" for not expanding the primary runway at ARB, and for limiting any runway project to the proposed 150-foot shift, which was not fully explored as an alternative (RDEA, § 2.1.4). That alternative should be fully explored, which could lead to it being a preferred alternative resolving all pertinent safety issues. Meanwhile, the current preferred alternative must not be pursued until this 150-foot shift can be fully and properly considered as an alternative.

III. THE RDEA DOES NOT ADEQUATELY CONSIDER THE AFFECTED ENVIRONMENT AND THEREFORE IT IS INADEQUATE.

A. Ann Arbor May Have Violated Its Contractual Grant Assurances in not Considering the Interests of Local Communities.

By proceeding with the Project despite strong opposition of Pittsfield and Lodi Townships, ARB is in violation of its federal grant assurances.

As reported in CPCQ's comments on the DEA (Committee for Preserving Community Quality, DEA Comments, 4-19-10, p.12, ¶ 4), both Pittsfield Township, where ARB is located, and neighboring Lodi Township have passed Resolutions, (March 24, 2010, and May 12, 2009, respectively) opposing the proposed runway expansion. Those Resolutions are contained in the current RDEA as Appendices H and J. The Resolutions basically oppose the expansion because of the risks from Canada geese in areas surrounding the airport, low-flying aircraft on the approaching newly expanding runway, and the fact that 99 percent of the based aircraft can operate at their full weight capacity on the existing runway. Further, the Resolutions described the importance of protecting the property rights of their citizens from degradation. MDOT has ignored these Resolutions and proceeded with the Runway expansion despite the opposition of the jurisdiction ARB is located and the jurisdiction adjacent. Not only is this a violation of NEPA, NEPA Regulations and FAA Order 1050.1F, it is also a violation of the City's federal grant assurances, thereby exposing the City to litigation liability and potential loss of all federal funding for ARB.

On April 16, 2012, the Ann Arbor City Council voted to accept a $45,000 federal Airport Improvement Program planning grant as part of this ARB expansion program, with city officials executing Terms and Conditions of Accepting Airport Improvement Program Grants as a condition of that grant. Two such contractual conditions to which city officials agreed as part of those grant assurances require:

> 6. Consistency with Local Plans: The project is reasonably consistent with local plans (existing at the time of submission of this application) of public agencies by the state in which the project is located to plan for the development of the area surrounding the airport.
>
> 7. Consideration of Local Interest: It has given fair consideration to the interests of communities in or near where the project may be located. (FAA Terms and Conditions of Accepting AIP Program Grants.)

Not only would moving forward with the expansion be inconsistent with these grant assurances to which the City is already contractually bound, but it may violate those grant assurances, opening the City of Ann Arbor to potential litigation under 14 C.F.R., Part 16. Further, the City would be required to make further assurances as part of gaining further millions of dollars in federal AIP funds to move forward with any proposed expansion under the current proposal.

This is even before the manifest conflicts that exist between the communities over airport expansion are examined. It is curious, for example, that Ann Arbor is purchasing greenbelt space and other farmland outside the city throughout Washtenaw County as part of its environmental preservation program. At the same time, the city proposes to destroy natural spaces by expanding a runway unnecessarily in neighboring Pittsfield Township in opposition to its neighbors' wishes, reflecting insensitivity to its next-door community in the process. Such a move of destroying greenspace may be inconsistent with the spirit of Ann Arbor's own master plan. Plus, given Pittsfield and Lodi's Resolutions of opposition, the expansion is clearly not consistent with the will of those governing bodies. As noted in the section on Purpose and Need, the expansion would benefit a minute number of airport users – at best – for a Need that has not been substantiated, while placing at risk thousands of members of the Pittsfield and Lodi communities with added larger and heavier aircraft, flying much closer to their homes, and at lower altitudes, in an area heavily populated by Canada geese. There is no evidence presented in the RDEA that the consideration of the wishes of these local communities have been weighed and seriously evaluated in the RDEA, let alone to the standard of "fair consideration" required by the grant agreement the City signed. In the eight years since the proposed expansion has been pending, for example, not even one study on the potential safety effects of the expansion on the residents of Pittsfield has been conducted. ARB and MDOT have consistently ignored the interests of communities surrounding ARB.

B. Expanding the Runway Will Result in an Increase in Violations of Pittsfield Township's Noise Ordinance

Pittsfield Township, within which ARB is wholly located, has a long-standing noise ordinance making it unlawful for "any person to create, assist in creating, permit, continue, or permit the continuance of any unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace, or safety of others within the limits of the township." Pittsfield Township Noise Ordinance. How the lengthening of the runway and the change in glideslope will affect the enforcement of this ordinance has not been examined, as required by NEPA, NEPA Regulations and FAA Order 1050.1F. Moreover, if the ARB runway were to be expanded to the west, as proposed, and the noise impacts on Pittsfield residents were to change, this ordinance would begin to face demands from citizens for more strenuous enforcement.

Justice Rehnquist, in the landmark case *City of Burbank v. Lockheed Air Terminal Inc.*, 411 U.S. 624 (1973) stated that the legislative history of the 1968 noise control amendment to the Federal Aviation Act, and the subsequent 1972 Noise Control Act, provided for local land use planning as a means of controlling the noise impacts on communities surrounding airports. *Burbank*, 411 U.S. at 643. Justice Rehnquist further noted that the House Committee on Interstate and Foreign Commerce specifically advocated the cooperation of state and local governments in achieving noise control. *Id.* Justice Rehnquist concluded from the legislative history that Congress intended only that the FAA regulate the "source" of noise, specifically the "mechanical and structural aspects of jet and turbine aircraft design." *Id.,* at 650. The statute did not, however, limit the states and local authorities from "enacting every type of measure, which might have the effect of reducing aircraft noise . . ." *Id.,* at 650-651. Justice Rehnquist, thus, suggests that so long as local or state governments do not regulate aircraft noise emissions directly, for example by requiring aircraft to meet certain noise standards or requiring certain technical modifications to jet engine design, they are free to regulate noise for the common benefit.

Therefore, all aircraft flying in and out of ARB are subject to Pittsfield's noise ordinance and fines can be levied on the aircraft owners for operating their aircraft such that they create an "unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace, or safety of others within the limits of the township."

C. The RDEA Fails to Properly Consider the Intensity of the Impacts on the Surrounding Community.

NEPA Regulation 40 C.F.R. § 1508.27 requires that the Project be placed in context with the surrounding society so that the Project's impact on the affected region, the affected interests, and the locality can be properly evaluated. The RDEA has failed to adequately address this aspect of the environmental assessment and must do so before the Project can be approved. This aspect of the environmental assessment process is often called "Intensity," and it requires consideration of:

(1) Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial.

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(2) The degree to which the proposed action affects public health or safety.

(4) The degree to which the effects on the quality of the human environment are likely to be highly controversial.

(5) The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.

….

(10) Whether the action threatens a violation of Federal, State, or **local law** or requirements imposed for the protection of the environment."

40 C.F.R. § 1508.27 (emphasis added). *See also* FAA Order 1050.1F, § 4-3.2, p.4-3.

This is critical because this CFR, the National Environmental Protection Act under which the RDEA was prepared, and the due process clauses of the Fifth and Fourteenth Amendments to the United States Constitutions all provide legal protections to the residents living west of the Ann Arbor Municipal Airport.

The citizens living in areas that surround the airport, part of the human environment feel the airport expansion represents an arbitrary denial of their life, liberty, or property in violation of the Fifth and Fourteenth Amendments. These rights cannot be restricted except for a valid governmental purpose. *Bolling v. Sharpe*, 347 U.S. 497 (1954). Critical is that any decision to move forward on the runway expansion must be made by a neutral decision-maker. *Goldberg v. Kelly*, 397 U.S. 254, 267 (1970). This is important because for four decades, MDOT has shown itself to be an advocate for expansion of the ARB primary runway, and not a neutral party. Typically, when a law or other act of government is challenged as a violation or potential violation of individual liberty under the due process clause, courts balance the importance of the governmental interest and the appropriateness of the government's method of implementation against the resulting infringement of individual rights. In cases where state authorities, such as MDOT, are involved, the United States Supreme Court has held that ". . . we cannot leave to the States the formulation of authoritative . . . remedies designed to protect people from infractions by the States of federally guaranteed rights." *Chapman v. California*, 386 U.S. 18, 22 (1967). Thus, MDOT may be forced to recuse itself from any decision in ARB expansion case, an expansion project which poses significant potential risks to citizens living in neighborhoods surrounding the airport.

As we contend and documented above, this proposed project has a statistically small benefit (.00110), at best, and yet would attract larger and heavier jet aircraft in closer proximity to homes in areas heavily populated with Canada geese, potentially jeopardizing residents in the event of an accident – accidents that the FAA contends are the third most frequent that occur in terms of incidents with hazardous wildlife in aviation. This is even more critical given the proposed flatter approach slope now being proposed. The Purpose and Need have not been substantiated. The risk to public safety may far outweigh any established benefit, which has not been substantiated in the RDEA. Added risks in terms of additional noise and night flights have not been established, but with arrival traffic traveling just 93 feet over rooftops on an expanded runway, it could have a controversial and negative impact on the human environment of citizens in Pittsfield Township, in violation of that township's noise ordinance and in violation of federal law.

IV. THE EXTENSION OF THE RUNWAY WILL CAUSE SIGNIFICANT ENVIRONMENTAL IMPACTS ON THE SURROUNDING COMMUNITIES.

United States federal law states at 49 U.S.C. § 47101(a)(6) that it is "the policy of the United States - - that airport development under this subchapter provide for the protection and enhancement of natural resources and the quality of the environment of the United States." The Project will have a significant impact on the environment not only on the airport, but throughout the surrounding community. Since it is Pittsfield Township's duty and responsibility to protect the environment within its boundaries and protect its citizens from significant environmental impacts, it has serious concerns about the environmental impact the Project will have on the community.

A. The Data Used to Justify the Project Is Not Current.

1. RDEA must update the required correspondence with all federal, state and local agencies.

The RDEA fails to update its required correspondence with other federal, state and local agencies and fails to update its environmental evaluations thereby making the RDEA in violation of NEPA and FAA regulations. ARB last sent out correspondence to federal, state and local agencies in 2009. This is a requirement under NEPA and FAA regulations. Under FAA Order 1050.1F and the National Environmental Protection Act Implementing Instructions for Airport Actions (FAA Order 5050.4B) and the National Environmental Policy Act (42 U.S.C. §§ 4321-4347), applicants for airport improvement program funds are required to provide supporting documentary evidence from interested and affected public agencies. Further, the FAA specifies that elements of Environmental Assessments remain valid for only three years with respect to "the affected environment, environmental impacts, and mitigation" and that evaluating officials must determine the extent to which substantial changes are needed. FAA Order 1050.1F.

Numerous such public agency letters are contained in the RDEA (RDEA, Appendix D) from agencies including the Michigan Department of Natural Resources, the U.S. Department of Interior Fish and Wildlife Service, the Michigan Department of Agriculture, the Michigan Department of Environmental Quality, the U.S. Environmental Protection Agency, the United States Department of Agriculture, the Michigan Department of History, Arts, and Libraries, and the Little Traverse Bay Bands of Odawa Indians. However, all the correspondence is from the years 2009-2010 when the project was first proposed – prior to the first DEA. The RDEA is relying on correspondence from public agencies that is seven to eight years old. Conditions have substantially changed for some or all of these agencies in terms of their evaluation of the proposed alternative in the substantial periods since these letters of evaluation were written.

The FAA agreed with this position, stating in its May, 2016 correspondence with the applicant the need to "update letters from 2009 for preferred alternative (Department of Natural Resources instructions that may have changed)" (Comment No. 111, October 2016, MDOT/City comments in response to FAA questions). MDOT and ARB responded by stating that, "As soon as this draft EA is finalized, the regulatory agencies will be contacted in writing and given the opportunity to review, comment and/or update the instructions" (MDOT and ARB response to Comment No. 111). This is unacceptable. The public has a right to know if the public agencies have changed their evaluation of the Project and have a right to comment on the agencies' evaluations as part of the public comment period. To do otherwise would open the door to premature project approval if conditions have changed. All of these conditions must be re-evaluated and the letters updated to comply with FAA Order 1050.1F before the project can be approved.

2. **RDEA must update its environmental evaluations and reports it used to assess the environmental effects of the alternatives.**

The RDEA must also update its evaluations of the environmental effects the Project will have on the environment. Instead of performing additional tests, processes or modeling, the RDEA makes a desktop survey and states whether the eight- to ten-year old test it performed should still be valid. This is unacceptable and in violation of NEPA, NEPA regulations and FAA Order 1050.1F. Even when the draft EA first came out almost seven years ago, Pittsfield Township had issues about the timeliness of the data presented. The data that the Airport relied upon was almost three years old when it was used in the 2010 draft EA. Moreover, it is the FAA's policy to use timely data instead of data that is stale, like the data used to justify the Project.

For example, new noise modeling should be run to assess noise impacts, since the previous one is now eight years old and the FAA no longer uses the Integrated Noise Model, which was used in the original DEA. Indeed, the "future years" scenario in the original DEA was 2014, which is now three years in the past. Many things have changed in the past eight years that may (or may not) have affected the environment surrounding ARB. ARB has a duty under NEPA to investigate what those changes might be and not assume that nothing has changed.

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B. The Project Does Not Account for the Noise Impact of the Project on the Surrounding Community.

1. MDOT and ARB have a statutory duty to protect the surrounding community from aviation noise.

As stated above, it is "the policy of the United States - - that aviation facilities be constructed and operated to minimize current and projected noise impact on nearby communities." 49 U.S.C. § 47101(a)(2). Part of the FAA's mission, and therefore MDOT's mission, is to ensure that the communities surrounding airports are not adversely impacted by noise from aircraft at airports. This mission is expressed in 49 U.S.C. § 47101(c), which states that "[i]t is in the public interest to recognize the effects of airport capacity expansion projects on aircraft noise. Efforts to increase capacity through any means can have an impact on surrounding communities. Noncompatible land uses around airports must be reduced and efforts to mitigate noise must be given a high priority." Thus, to the extent that noncompatible land uses around airports cannot be reduced, then the capacity of nearby airports should not be increased or else the FAA and the airport sponsor would be in violation of federal law. ARB and MDOT seem to be aware of the fact that increases in capacity at the airport will affect the noise levels in Pittsfield, because they studiously avoid the topic.

MDOT, as the agent for the FAA, has a statutory duty to protect residents and property owners from the deleterious effects of aircraft noise.

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Federal law clearly establishes the absolute duty of the government to protect both people and property from aircraft noise. "[T]he Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare." 42 USC § 4901(b). In developing the RDEA, MDOT ignored its statutory and regulatory duty to control and abate "aircraft noise and sonic boom." MDOT's statutory duty to protect people and property on the ground from the deleterious effects of aircraft noise goes beyond its duty under NEPA to determine what it believes to be "significant" or "reportable" under FAA Order 1050.1F. Legally speaking, the MDOT cannot draw the conclusion that a proposed MDOT action that is purportedly not "reportable" under 1050.1F, § 14.5e[6] or that purportedly does not have a "significant impact" under 1050.1F, § 14.3[7], is not subject to review and regulation pursuant to 42 USC § 4901(b), 49 U.S.C. § 40103(b)(2) and 49 U.S.C. § 44715(a)(1)(A). Those statutory obligations require that the lead agency address aircraft noise separate and apart from its duties under NEPA because the lead agency's proposed action will create aircraft noise that will have a deleterious effect on the public health and welfare.

2. ARB and MDOT incorrectly assume that extending the runway will not increase the number of air operations, the fleet mix or other growth-inducing effects of the Project.

When considering an airport project for federal funding, the FAA is required to evaluate not merely the direct impacts of a project, but also its indirect impacts, including those "caused by the action and later in time but still reasonably foreseeable." 40 C.F.R. § 1508.8(b). Indirect impacts include a project's growth-inducing effects, such as changes in patterns of land use and population distribution associated with the project (40 C.F.R. § 1508.8(b)) as

[6] *See also* 1050.1F B-1.4, p.B-4.

[7] *See also* 1050.1F, Table 4-1, p.4-8

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well as increased population, increased traffic, and increased demand for services. *City of Davis v. Coleman*, 521 F.2d 661, 675 (9th Cir. 1975). The "growth-inducing effects of [an] airport project appear to be its *raison d'etre*." *California v. U.S. D.O.T.*, 260 F.Supp.2d at 978, citing *City of Davis, supra*, 521 F.2d at 675. Even though the Project is virtually defined by its growth-inducing impacts, ARB and MDOT have ignored this requirement completely – not only in the draft EA, but in the public participation aspects of the Project as well.

Contrary to ARB and MDOT's unsupported assertions in the draft EA (*see e.g.* RDEA, p. 42; Appendix B-1), it is reasonably foreseeable that the fleet mix at ARB will change in favor of a higher percentage of jet operations as compared to the current level of light single and multi-engine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft account for a high percentage of ARB operations. B-II aircraft account for a low percentage of ARB operations. Because of the availability of a longer runway, it is therefore reasonably foreseeable that the number of night operations will increase as the number of arrivals of longer haul business jets often occur in the evening hours due to the longer time duration of their trips. Since one of the stated "benefits" of the Project is to increase interstate commerce, this is not merely an indirect, but also a direct effect, that the Project will have on the surrounding community. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

As indicated above, the runway need not be extended in order for most of ARB's "critical aircraft" to operate at the airport without weight restrictions. For example, the "load restrictions" referenced in the RDEA will apply to the higher category aircraft (jets in the C-I and C-II categories). Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel, all of which discourage these aircraft from conducting operations at ARB. A Cessna Citation II (Category B-II), for example, requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day, and, most days, can operate at unrestricted weight from ARB's existing 3,505-foot runway. A Lear 35 (Category C-I), on the other hand, requires 5,000 feet for takeoff at maximum certificated gross weight on a standard day. While extending the runway to 4,300 feet would not facilitate unrestricted operations by the Lear 35, the required weight reduction would be less than is currently required. Therefore, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide little or no operational benefit to the Category B-II Citation jet, which the RDEA states is a "critical aircraft." Thus, with the runway extension ARB does not become any more or any less attractive to the operator of the Citation II, but becomes more attractive to the operator of the Lear 35 thereby causing an increase in usage of ARB by the Lear 35, but the same amount of usage by the Citation II.

Even the RDEA admits that there will be an increase in operations. Tucked away in its discussion of "Energy Supply and Natural Resources," the RDEA states that "[d]evelopment of the Preferred Alternative would have the potential to increase the amount of air traffic utilizing ARB, which can potentially result in an increase in the amount of airplane fuel distributed by the airport and used by aircraft at the facility." RDEA, p.67. Because there is a potential of an increase in the number of operations, it must be analyzed thoroughly.

The primary reason why ARB is so keen on extending the runway is to facilitate the loading of additional passengers and baggage on high performance jet aircraft outside of what ARB considers to be its "critical aircraft." Also, the ability to carry additional fuel may mean that, in certain cases, costly and time consuming intermediate fuel stops will become unnecessary. If the runway is lengthened to 4,300 feet, it is reasonably foreseeable that ARB will become much more attractive to operators of higher performance jet aircraft, such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II), who could then operate at ARB instead of driving to and from Willow Run Airport, a mere 12.3 mile car trip, where there are ample facilities for large aircraft.

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The evidence is clear that the Project will cause an increase in both jet and night operations. It is also reasonably foreseeable that these added high-performance jet aircraft operations and night operations will be accompanied by significant noise and air quality impacts. Nevertheless, ARB and MDOT have failed to acknowledge, let alone analyze, these reasonably foreseeable impacts caused by expansion of airport physical facilities and operational profile and, thus, the Project should not be approved for federal funding.

3. Increased jet aircraft and nighttime operations were not included in the noise modeling used by ARB and MDOT.

The only noise modeling done for the RDEA was performed in 2009. The RDEA claims to have "re-evaluated" the 2009 results and claims that they still apply. On its face, its "re-evaluation" is insufficient to meet FAA standards. The FAA's Integrated Noise Model (INM) was used to model annual operations for the 2009 existing condition in the draft EA, *i.e.*, April 2008 through March 2009 and develop 65, 70 and 75 DNL noise contours for the Project. RDEA, p.41, Appendix B-1. The RDEA states that "[t]his 65 DNL contour does not extend beyond airport property." RDEA, p. 41. However, during the time period modeled, jet operations accounted for approximately 2 percent of total operations at ARB, and nighttime operations accounted for 4.2 percent of total operations. RDEA, p. 41. The draft EA states: (1) "[t]he percent of night and jet operations would remain constant between the existing condition and the future years;" (2) "fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives would remain static"; and (3) "[t]he ARB 2014 proposed project alternative DNL 65 dBA noise contour does not extend beyond airport property." RDEA, p. 40; Appendix B-1. Since the time that the original DEA was published, the FAA now requires the use of the Aviation Environmental Design Tool (AEDT) for noise modeling instead of the Integrated Noise Model (INM). Because of the change in models, the RDEA must use AEDT to produce the noise modeling for ARB.

None of these assertions are based on facts or the reality of the situation that exists at ARB. As shown above, because of the increase in the length of the runway the Project will likely facilitate an increased number of night operations, and a change in fleet mix that will include higher performance jet aircraft. DNL calculations depend on, among other things, forecast numbers of operations, operational fleet mix and times of operation (day versus night). RDEA, Appendix B-2. However, ARB and MDOT have failed to model or assess future increased night operations and fleet mix changes resulting from the Project.

Thus, ARB must use AEDT to produce among other things: (1) noise contours at the DNL 75 dB, DNL 70 dB and DNL 65 dB levels; (2) analysis within the proposed alternative DNL 65 dB contour to identify noise sensitive areas where noise will increase by DNL 1.5 dB ; and (3) analysis within the DNL 60-65 dB contours to identify noise sensitive areas where noise will increase by DNL 3dB, if DNL 1.5 dB increases as documented within the DNL 65 dB contour. FAA Order 1050.1F. As the noise modeling failed to account for the foreseeable increases in nighttime and jet aircraft operations at ARB, the questions of whether the future DNL 65 dB contour will be increased, and to what extent, and whether increased noise levels within the DNL 65 dB contour would necessitate designation of a DNL 60 dB contour remain unanswered.

4. Noise from aircraft, particularly high performance jets, remains a very real concern for communities that surround ARB.

The FAA last reviewed the technical bases for its noise policies in 1992. For example, 65 DNL as the "threshold of significant impact" under NEPA and the level below which land uses are deemed compatible has been used by the FAA without substantial change since *1978* (it was "re-affirmed" by FICAN in 1992). It is safe to say that the FAA's policy no longer reflects the best scientific evidence of the effects of aircraft noise exposure. This failure on the part of the FAA to update its policy undermines the trust that the public places in the FAA in their pursuit to understand noise exposure and its effects.

This is particularly true since substantial research done on the measurement and effect of aircraft noise on the communities surrounding airports has come from sources outside the United States. For example, the Hypertension & Exposure to Noise Near Airports (HYENA) study evaluated the effects of aircraft noise on 4,861 persons residing near 7 European airports between 2002 and 2006. The 2002 RANCH study from London studied the effect of aircraft and road traffic noise on 2,844 children's cognition and health. Both of these studies came out with rather startling results concerning the effect aircraft noise has on the quality of human life. Finally, WHO Europe issued "Night Noise Guidelines," which were based on research done by the European Union. This type of study has largely been absent in the United States.

The emerging research suggests that current standards used by the FAA are outdated and underestimate the significant health risks posed by aircraft noise. The current understanding of the health effects of aircraft noise goes beyond mere annoyance and sleep disturbance, which the current DNL protocols were meant to address. The new research shows a strong correlation between aircraft noise and significant, serious health outcomes, such as hypertension and heart disease. Four studies from Europe have shown this connection:

1. Haralabidis AS, Dimakopoulou K, Velonaki V, Barbaglia G, Mussin M, Giampaolo M, Selander J, Pershagen G, Dudley ML, Babisch W, Swart W, Katsouyanni K, Järup L; for the HYENA Consortium. Can exposure to noise affect the 24 h blood pressure profile? Results from the HYENA study. *J Epidemiol Community Health*. 2010 Jun 27.

2. Haralabidis AS, Dimakopoulou K, Vigna-Taglianti F, Giampaolo M, Borgini A, Dudley ML, Pershagen G, Bluhm G, Houthuijs D, Babisch W, Velonakis M, Katsouyanni K, Jarup L; for

the HYENA Consortium. Acute effects of night-time noise exposure on blood pressure in populations living near airports. *Eur Heart J*. 2008 Feb 12

3. Jarup L, Babisch W, Houthuijs D, Pershagen G, Katsouyanni K, Cadum E, Dudley M-L, Savigny P, Seiffert I, Swart W, Breugelmans O, Bluhm G, Selander J, Haralabidis A, Dimakopoulou K, Sourtzi P, Velonakis M, VignaTaglianti F, on behalf of the HYENA study team. Hypertension and Exposure to Noise near Airports - the HYENA study. *Environ Health Perspect* 2008; 116:329-33

4. Jarup L, Dudley ML, Babisch W, Houthuijs D, Swart W, Pershagen G, Bluhm G, Katsouyanni K, Velonakis M, Cadum E, Vigna-Taglianti F for the HYENA Consortium. Hypertension and exposure to noise near airports (HYENA) - Study design and noise exposure assessment. *Environ Health Perspect* 2005; 113:1473-8.

This is not to say that there has not been any research done in the United States on this issue. In March 2007, for example, Lisa Goines and Louis Hagler published their article entitled "Noise Pollution: A Modern Plague" in the *Southern Medical Journal*. While it did not concentrate solely on aircraft noise, the article concluded that

> [n]oise produces direct and cumulative adverse effects that impair health and that degrade residential, social, working, and learning environments with corresponding real (economic) and intangible (well-being) losses. It interferes with sleep, concentration, communication, and recreation. The aim of enlightened governmental controls should be to protect citizens from the adverse effects of airborne pollution, including those produced by noise. People have the right to choose the nature of their acoustical environment; it should not be imposed by others.

ARB and MDOT are imposing the nature of their "acoustical environment" on Pittsfield and its citizens, rather than having the citizens choosing for themselves.

In addition, several "findings" have been issued by governmental or quasi-governmental sources. The Federal Interagency Committee on Aviation Noise (FICAN) has issued two findings: *FICAN Recommendation for use of ANSI Standard to Predict Awakenings from Aircraft Noise* (2008) and *Findings of the FICAN Pilot Study on the Relationship between Aircraft Noise Reduction and Changes in Standardized Test Scores* (2007). Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER), a collaboration among the FAA, NASA and TransportCanada, issued in July 2010, its *Review of the Literature Related to Potential Health Effects of Aircraft Noise*, (prepared by Hales Swift). That review concluded that "[p]otentially serious health outcomes have been identified in studies involving transportation noise exposure in a population. These include heart disease and hypertension and the observed effects seem to be related especially to nighttime noise exposure although similar daytime exposure effects have also been identified." PARTNER 2010, p.62. PARTNER has also issued several other reports:

• Sonic Boom and Subsonic Aircraft Noise Outdoor Simulation Design Study. Victor W. Sparrow, Steven L. Garrett. A PARTNER Project 24 report. May 2010. Report No. PARTNER-COE-2010-002.

• Passive Sound Insulation: PARTNER Project 1.5 Report. Daniel H. Robinson, Robert J. Bernhard, Luc G. Mongeau. January 2008. Report No. PARTNER-COE-2008-003.

• Vibration and Rattle Mitigation: PARTNER Project 1.6 Report. Daniel H. Robinson, Robert J. Bernhard, Luc G. Mongeau. January 2008. Report No. PARTNER-COE-2008-004.

• Low Frequency Noise Study. Kathleen Hodgdon, Anthony Atchley, Robert Bernhard. April 2007. (Report No. PARTNER-COE-2007-001) PARTNER Project 1, Low Frequency Noise Study, final report.

• Land Use Management and Airport Controls: A further study of trends and indicators of incompatible land use. Kai Ming Li, Gary Eiff. September 2008. Report No. PARTNER-COE-2008-006

• En Route Traffic Optimization to Reduce Environmental Impact: PARTNER Project 5 Report. John-Paul Clarke, Marcus Lowther, Liling Ren, William Singhose, Senay Solak, Adan Vela, Lawrence Wong. July 2008. Report no. PARTNER-COE-2008-005

• Land Use Management and Airport Controls: Trends and indicators of incompatible land use. Kai Ming Li, Gary Eiff, John Laffitte, Dwayne McDaniel. December 2007. (Report No. PARTNER-COE-2008-001) PARTNER Project 6 final report.

Thus, there is no shortage of relevant, topical information for ARB to use in assessing the health risks and impacts of noise on the communities surrounding ARB. It is readily apparent that the current system does not fully account for the increased health risks communities surrounding airports are subject to due to the increased noise levels. ARB needs to re-evaluate its noise modeling and insist that health risks to the surrounding communities be assessed prior to ARB receiving federal funds for any expansion that will result in an increase in aviation operations.

C. Air Quality: The RDEA Fails to Take Into Account the Effects the Project Will Have on Air Pollution in the Surrounding Community.

Section 7506 of the Federal Clean Air Act (42 U.S.C. § 7401 et seq.) mandates that "[n]o department, agency, or instrumentality of the Federal Government shall engage in, support in any way or provide financial assistance for, license or permit, or approve, any activity which does not conform to [a State Implementation Plan] after it has been approved or promulgated under [42 U.S.C. §7410]." The Environmental Protection Agency (EPA) has promulgated regulations implementing § 7506 (the "Conformity Provision") in 40 C.F.R. § 93.150 *et seq.* ("General Conformity Rule"). The General Conformity Rule requires, in part, that federal agencies first determine if a project is either exempt from conformity analysis or presumed to conform. If it is neither, the agency must conduct a conformity applicability analysis to determine if a full conformity determination is required. *See Air Quality Procedures for Civilian Airports and Air Force Bases*, p. 13.

The project area, *i.e.*, Washtenaw County, is in attainment for five of the eight criteria pollutants, and maintenance for Ozone, PM_{10} and $PM_{2.5}$. Exhibit 2. A conformity determination is required for criteria pollutants in maintenance areas. 40 C.F.R. § 93.153(b). Therefore, one of the following applies:(1) the project is exempt from conformity; (2) the project is presumed to conform; or (3) the agency must conduct a conformity applicability analysis to determine if a conformity determination for Ozone, PM10 and $PM_{2.5}$ is required. ARB has not indicated that any of the required actions has been performed even though required by NEPA and FAA Order 1050.1F. The RDEA does not provide any guidance as to whether the Project is exempt or presumed to conform

1. The RDEA fails to establish that the Project is exempt.

There are two options in determining that a project is exempt from conformity analysis: (1) if the project is included in the list of exempt actions listed in § 93.153(c)(2); or (2) if the project's total of direct and indirect emissions are below the emissions levels specified in § 95.153(b) of the Conformity Regulations ("*de minimis*"), § 93.153(c)(1).

The first option does not apply here because none of the actions to be undertaken as part of the Project are included as "exempt actions" §

93.153(c)(2). Nor does the Project qualify as exempt because of *de minimis* emissions under 40 C.F.R. § 93.153(c)(1) because no air quality analysis was performed. The RDEA assumes that because Washtenaw County is no longer in non-attainment for a particular criteria pollutant, it is not required to perform an air quality analysis. This assumption, however, does not comply with federal law for at least two reasons. First, the RDEA does not quantify Ozone, PM_{10} and $PM_{2.5}$ emissions from flight operations at ARB. Second, because the RDEA fails to quantify the emissions, there can be no comparison with the *de minimis* thresholds established in 40 C.F.R. § 93.153(c)(1).

2. The RDEA fails to establish that the project is "presumed to conform."

The second option, the presumption of conformity, does not apply here either. In order for a federal action to be "presumed to conform," the Project has to fall within a category of actions predetermined by the responsible federal agency to carry a presumption of conformity. *See* 40 C.F.R. § 93.154(f) – (h). In July, 2007, the FAA published its *Federal Presumed to Conform Actions Under General Conformity Final Notice*, 72 Fed.Reg. 41,565-580 (July 2007), in which the FAA listed fifteen Airport Project categories that the FAA presumes to conform to applicable SIPs. None of the actions to be undertaken by the Project fall within any of those presumed to conform categories. The RDEA cannot unilaterally presume that the Project is in conformity.

3. The RDEA fails to establish the Project's conformity status under the Clean Air Act.

Finally, 40 C.F.R. § 93.159 requires that analyses under the General Conformity Rule be based on, among other things: (1) "the latest planning assumptions" (§ 93.159(a)); and (2) "the latest and most accurate emissions estimation techniques available" (§ 93.159(b)) none of which are covered in the RDEA.

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D. The RDEA Fails to Take Into Account the Effect the Project Will Have on Water Resources in the Surrounding Communities.

The RDEA consistently understates the significance of the effect that the Project will have on water resources and water quality. The principal and longest use of the grounds where the airport is located has been for the collection and pumping of water for the City.[8] Before the first aircraft landed on the property of what is now ARB, Ann Arbor was using the property to supply its drinking water.[9] However, the RDEA fails to take water quality seriously. As FAA Order 1050.1F points out "[i]f there is the potential for contamination of an aquifer designated by the [EPA] as a *sole or principal drinking water resource* for the area, the responsible FAA official needs to consult with the EPA regional office, as required by section 1424(e) of the Safe Drinking Water Act, as amended." FAA Order 1050.1F, p.4-12 (emphasis added). Likewise, "[w]hen the thresholds indicate that the potential exists for significant water quality impacts, additional analysis in consultation with State or Federal agencies responsible for protecting water quality will be necessary. *Id.*, pp. A-75, A-76, & 17.4a. Finally, in situations such as this, "[i]f the EA and early consultation [with the EPA] show that there is a potential for exceeding water quality standards [or] identify water quality problems that cannot be avoided or mitigated . . . an EIS may be required." *Id.*, pp. A-75, & 17.3. Based on these requirements, the RDEA is inadequate. As expressed in NEPA, the NEPA Regulations, and FAA Order 1050.1F, drinking water

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[8] The land where that grass runway now exists was purchased by Ann Arbor in 1921, seven years prior to the first aircraft landing, when the Steere Water Farm was acquired for water rights, not aviation. The purpose was to sink wells to support the growing city's drinking water needs.

[9] In fact, Ann Arbor attempted to annex the airport grounds in 1976, but that annexation was ruled illegal and vacated by the court (Charter Township of Pittsfield v. City of Ann Arbor, Washtenaw County Circuit Court, Judge Campbell, 77-12619-CZ, 12-22-76, Summary Judgment) later that year.

contamination is too important of an issue to rely on outdated reports that are based on conjecture instead of data.

The Airport is the location of a porous sand/gravel formation that yields a large amount of water for pumping. Historically, the land where the airport is located was originally acquired by the City of Ann Arbor for water rights in 1921. Until recently, 15% of Ann Arbor's water supply came from the three wells located on Airport property. Exhibit 3, Water Quality Report, 2015, City of Ann Arbor, p.2. The paving that the Project will require increases not only the impervious area on top of the aquifer, but also increases the risk of contamination. This in turn reduces the infiltration of water that feeds the aquifer/City water supply. Adding 950 feet to the end of the runway adds another 71,250 square feet of impervious area over an aquifer that is vital to the City. However, the RDEA gives this issue only passing mention: "[b]ased on coordination with the City of Ann Arbor, the proposed runway extension would not impact the water supply wells or the new water supply line (Bahl, 2009)." RDEA, p.60. Notably absent from their coordination efforts is the EPA, its Regional Office, the Michigan Department of Environmental Quality, and Washtenaw County with respect to water quality issues.

So critical is drinking water from the airport wells to the city that de-icing is prohibited on the airport. And despite the claim in response to comments to the 2010 DEA (RDEA, Appendix K, Page 2, Paragraph 1) that, "drainage from airport pavements sheet flows through hundreds of feet of vegetation before infiltrating. Due to the 'unmaintained nature' of the airport vegetation, it is acting as a buffer around the wellheads," the water faces many potential threats from a lengthened runway. Those threats become more critical because of how lead contaminated the water supply in nearby Flint. This is relevant here because the majority of fuel utilized at ARB is consumed by piston-driven aircraft, which mostly use leaded AvGas. Any risk to the aquifer underlying the airport could pose a lead threat, which is in addition to the potential dioxane risks to Ann Arbor's only other drinking water source on the Huron River because of nearby contamination that has not been fully resolved, locally referred to as the "Gelman spill." The RDEA further claims that the airport wells are within a "wellhead protection zone" and that Ann Arbor's Water Treatment Plant Manager "indicated the preferred alternative will not result in adverse impact to the wellhead protection area" (RDEA, Appendix K, Response 81, Paragraph 2.) However, that report, like others based on expert sources, was based on 2009 information, and only speculation – not any actual testing.

Because the wells on ARB property is a principal source of Ann Arbor's water supply, the Washtenaw County Water Resources Commissioner – another entity with whom ARB and MDOT should have been consulting from the very beginning – raised serious issues about the Project. In response to the draft EA, the Washtenaw County Water Resources Commissioner pointed out:

> It is noted in the [draft EA] that: "The amount of impervious surface on site would increase slightly due to the extension of the runway and taxiway from the existing 7 percent of the 837 acres to 7.4 percent." This slight increase noted equates to an additional 3.348 acres or 145,839 square feet. This increase in impervious surface is considered by this office to be significant and not slight particularly knowing that the additional runoff from this area will discharge to the Wood Outlet Drain.

RDEA, Appendix K. This, coupled with the fact that the City owns four and operates three water wells on ARB's property, causes deep concern with the County.

This issue has become even more important since the draft EA was published back in 2010. In May, 2012, it was reported that the water table in the Ann Arbor area, has risen substantially. As pointed out in the Ann Arbor Chronicle, "[t]he only hard data that the city has collected on the water table is at the municipal airport, and there the water table measures between 2-7 feet below the surface now, compared to 15 feet below the surface 50 years ago."

Exhibit 4.[10] This is not an insubstantial problem. With the water table at the airport now being 2-7 feet below the ground surface instead of 15 feet, when the drinking water wells were first dug, the groundwater is even more vulnerable to contamination because there is much less soil for any surface pollution to filter through or attach to soil particles before it reaches the water table. This dramatic change in the water table may also alter ground water data from the past. That is, the rise in the water table may have altered the direction of groundwater flow, or there may now be some barrier blocking the traditional pathway for the water to flow, which would cause Ann Arbor's principal drinking water supply to be contaminated.

The Washtenaw County Water Resources Commissioner raised additional significant concerns that have yet to be addressed by either ARB or MDOT.

3. It is indicated that the preferred alternative does not impact the stream that is existing on the site. [Draft EA, p.4-18]. Using GIS measurements it appears that the stream is less than 1,000 linear feet from the existing runway. The runway extension would bring this infrastructure within 50 linear feet or less of the stream. In addition to this the grading limits shown in Appendix D-7 clearly extend into and beyond the location of the stream. Based on this information *it is not understood how it has been concluded that there are no impacts to the stream*.

4. It is indicated that the preferred alternative does not impact the floodplain for the stream that is existing on the site. It is indicated that proposed grading for the expansion would not occur within the designated floodplain boundary. [Draft EA, p.4-24]. Based on the floodplain boundary shown on FEMA Community-Panel Number: 260623 0010 C these statements are incorrect. Not only do the grading limits indicated for the preferred alternative extend into the floodplain boundary but

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.[10] By contrast, the draft EA relies on data at least 15 years old. Since there is more current data, that should be used instead of outdated data. *See* RDEA, pp.59-60.

> the runway extension itself will extend into this floodplain boundary. Based on this information it is *not understood how it has been concluded that there are no impacts to the floodplain*.
>
> ….
>
> 6. It is noted in the report that: "Implementation of appropriate best management practices (BMPs) would continue to control the rate of stormwater runoff and maintain water quality standards." [Draft EA, p.4-18]. It is unknown by this office as to what the control rate of stormwater is currently being implemented or whether this rate meets county standards. *The additional volume created by this increase in imperviousness is not spoken to at all by the report. The type or locations of the appropriate BMPs indicated are not identified.*

RDEA, Appendix K (emphasis added). Pittsfield Township has the same concerns about how water resources will be managed by ARB should this Project move forward. These issues have not been sufficiently addressed by the RDEA.

ARB has a responsibility under this law to ensure the safety of the water in Ann Arbor's wells. Further, although Pittsfield Township does not receive its drinking water from these wells, water from the same aquifer filling these wells is the source of water for numerous Pittsfield Township waterways, including the several ponds in the Stonebridge Community. Thus, beyond ensuring applicant Ann Arbor's compliance with the law, Pittsfield Township and CPCQ have a vested interest in ensuring the water in the aquifer be maintained to the highest possible quality level.

This project should not be approved by MDOT until these requirements regarding water quality have been complied with fully.

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E. Wildlife Hazards Remain Undetermined.

1. Risk of Canada Geese strikes requires Wildlife Hazard Assessment before any further AIP grants may be awarded to ARB.

The RDEA responds to comments to the 2010 DEA regarding risks because of large numbers of Canada geese surrounding ARB, which become a greater risk because the larger number of jets that would be attracted to a lengthened runway, because such jets travel at higher speeds than traditional piston-driven aircraft. Our comments to the 2010 DEA raised the risk of the large number of Canada geese and provided photographic evidence to support the claim (Committee for Preserving Community Quality, 4-19-10, pp. 9-10, and Exhibit 3 photographs). However, the response to those numerous comments in the current RDEA (RDEA, Appendix K, Page 1) state that, "…MDOT staff has been monitoring the Stonebridge ponds and farm field along Lohr Road since the project was initiated in the spring of 2009. Groups of geese (less than 10 total) have been observed at various times in and around Stonebridge ponds. No geese have been observed in the farm field east of Lohr Road by MDOT during this time. Based on these observations and those from airport staff, there has been no indication hazardous wildlife conditions exist on or in the immediate vicinity of ARB.

"However, during the course of the public comment period Ann Arbor Municipal Airport (ARB) has received numerous letters alleging significant populations of geese in the Lohr Road farm field and the Stonebridge ponds. If these allegations are true, these populations are within 5,000 feet of the existing runway end and therefore, would be considered an existing hazardous wildlife situation.

"Relocating the runway end would neither increase nor decrease the potential for adverse wildlife interaction since the approach is already over these areas (92% of strikes occur at less than 3,000 feet above ground level, FAA). Therefore, ARB will consider this issue independently from the proposed runway project and will retain the services of a qualified wildlife biologist to perform a Wildlife Hazard Assessment and provide recommendations" (Paragraphs 5-8). This is unacceptable and contrary to federal law.

Applicant Ann Arbor had provided these same responses in submissions to the FAA three years earlier in 2014 received under the Freedom of Information Act (FAA FOIA No. 2016-003646GL), but in the ensuing years – based on no updates or changes in the content of the current 2017 RDEA – ARB has apparently done nothing to retain the wildlife biologist discussed and conduct the Wildlife Hazard Assessment it committed to doing. However, the RDEA reports (RDEA, Page 65, Paragraph 2) that an endangered species specialist has confirmed that "no new species are reported and the original data were substantially valid" from eight years ago. The fact that Canada geese are not endangered and that this assessment was conducted by an "endangered species specialist" rather than as a broader Wildlife Hazard Assessment could well have been because significant Canada geese were discovered as part of that assessment. Given that, attached as exhibits are recent photographs of substantial Canada geese on or near airport flyways and on Stonebridge ponds (Exhibits 5 and 6) in Fall 2016, and on the farm field west of the airport (Exhibit 7).

FAA Advisory Circular 150/5200-33B discusses Hazardous and Protected Wildlife Attractants on or Near Airports and ranks geese as No. 3 in causing damage to aircraft. It discusses how golf courses, such as the one within 1,500 feet of the proposed expanded runway end, are particularly attractive to Canada geese. This alone, with the two large ponds at Stonebridge, is one reason for the continued sightings of large numbers of Canada geese on the flightpaths of ARB. And the potential risks that these Canada geese could cause, especially if large numbers of jets are attracted to a lengthened runway at ARB, underscore the urgency of conducting such a Wildlife Hazard Assessment before this project can proceed. Moreover, the lengthened runway will put the aircraft lower and closer to the areas where Canada geese congregate. To make matters worse, by changing the glideslope from the current 20:1 slope to a 34:1 slope, aircraft on approach to ARB will be exposed to the Canada Geese flyways for a longer period of time thereby increasing the risk of a bird strike.

Further, the Migratory Bird Act of 1918 (16 U.S.C. § 703-712) makes it illegal to kill a Canada goose or harm their nests or eggs. So not only do Canada geese pose a potential risk of causing an aviation accident, but they are also protected, causing what should be a dual concern to the applicant. This is compounded by the fact that mute swans, a species even larger than Canada geese, also inhabit the Stonebridge area just west of ARB, and could pose a further accident risk. As a result, a Wildlife Hazard Assessment must be completed before the proposed runway expansion project can move forward.

2. Presence of Canada Geese pose safety risks and mandates further study prior to lengthening runway.

The documented risk from Canada geese requires applicant Ann Arbor to conduct an immediate Wildlife Hazard Management Assessment (14 C.F.R. § 139.337(b)(4)), which specifies that such an assessment must be conducted *immediately* when any of the following events occurs on or near the airport:

> (4) Wildlife of a size, or in numbers, capable of causing an event described in paragraphs (b)(1), (b)(2), or (b)(3) of this section is observed to have access to any airport flight pattern or aircraft flight pattern or aircraft movement area.

14 C.F.R. § 139.337(b)(4). The "events described in paragraphs (b)(1) – (3)" are wildlife strikes, engine ingestion of wildlife, and/or substantial damage to aircraft from striking wildlife.

Even the up to 10 Canada geese sighted that applicant Ann Arbor stipulated to in Appendix K, Page 1, would be sufficient to warrant such incidents and, hence, such a Wildlife Hazard Assessment. And the fact that the applicant did not undertake such a study on its own, as it committed to doing, since the issue was first recognized and discussed in the draft of this

RDEA submitted to the FAA in 2014, but only an updated endangered species assessment, is sufficient evidence that the Wildlife Hazard Management Assessment must be mandated to be completed and acted upon before any further federal AIP fund grants can be awarded to the applicant. Further, that completed Wildlife Hazard Management Assessment must be submitted to, evaluated, and approved by the FAA administrator before any further action on the proposed project can proceed. 14 C.F.R. § 139.337(e)(2).

V. SAFETY ISSUES DO NOT JUSTIFY RUNWAY EXPANSION AND INCREASE DANGERS TO SURROUNDING COMMUNITIES.

The RDEA frequently emphasizes the issue of safety, but only with regard to the airport, its airplanes, and their fliers -- not once in the 428-page document is there a single reference to the concern for the safety of citizens in the communities surrounding the airport. This is especially troublesome given two recent small jet crashes nearby – one on a runway comparable to that proposed for an expanded ARB, a crash which could have been catastrophic had it occurred here.

A. Runway Overruns Do Not Justify Runway Expansion, But Related Runway Excursions Could Be Deadly.

The RDEA further describes a goal of reducing runway overruns, claiming 11 such previous such overruns by smaller category A-1 aircraft (RDEA Section 1.8.3). The RDEA states that curbing overrun incidents is a goal of the Project, concluding, "[t]here is no evidence in the incident reports that any of the aircraft which overran the end of the existing 3,505-foot runway exceeded the limits of the 300-foot-long turf Runway Safety Area (RSA). Therefore, in each of these cases, the proposed 4,300-foot runway would have provided sufficient length for the small category A-1 aircraft to safely come to a stop while still on the runway pavement, without running off the runway end." RDEA, p.25. However, our review of the 11 runway overrun incidents shows they were all the result of pilot error or mechanical problems – one as careless as the lack of marking construction areas on the runway itself by the airport operator, so the pilot was unaware of a construction berm. The FAA agreed that these incidents did not support runway expansion, concluding in its comments to the 2010 DEA, "…[t]he local objective of reducing runway overrun incidents appears to conclude that if the added runway length were present, all the incidents would have been avoided. Based on the information presented, the FAA does not necessarily come to the same conclusion. There are many factors that go into any overrun incident and if additional runway length were present this may have only prolonged the overrun incident. The A-1 category of aircraft involved with the overrun incidents do not appear to have needed any length beyond the existing runway length to operate at full capacity and in a safe manner." RDEA, Appendix J, FAA letter dated 5-13-10, pp. 5-6, ¶¶ 7 (p.5) and (p.6).

While the RDEA raises the issue of overruns to support expanding the runway erroneously, there is evidence that expanding the runway could lead to *additional* runway excursions. This is a result of the potential dangers created by attracting more business jets because of the extended runway length. On February 11, 2016, the National Business Aviation Association reported that runway excursions by business jets on landings cause about one-third of all runway excursions, making them the most common business aviation accident, occurring about twice weekly somewhere in the world at a cost of about $900 million annually. These incidents are frequently caused by not aborting landings when pilots should, landing at unfamiliar airports, and landing too fast and too far down the runway. The added risk for ARB is that these larger jet aircraft, with larger fuel payloads, could pose added challenges to firefighters in the event of an emergency. Those firefighters are not based on the ARB airport, which does not actually provide on-site fire and rescue services – and are provided by Pittsfield Township. These risks have not been considered or evaluated in this RDEA.

One such excursion occurred quite recently -- just 20 miles northwest of Ann Arbor on January 16, 2017, at the Livingston County Spencer J. Hardy Airport (OZW) in Howell, when just such an unfamiliar pilot attempted to land his Cessna Citation 525 CJ4, but crashed on landing, destroying the aircraft and injuring the pilot, with a broken back. The pilot, who was the only one aboard the 10-passenger, twin-engine jet, apparently lost control on landing, skidding off the end of the runway, through a fence, across a road, and striking a clump of trees, tearing the wings from the fuselage, and causing a fire. Witnesses helped the pilot from the wreckage before emergency crews could arrive (L.T. Hansen, "Report: Plane with single occupant crash-lands at Livingston County Airport," *MLive.com*). The distance from the end of the runway to the trees is about 1,800 feet.

This is important because while the Livingston County airport runway is 5,000-feet long – 700 feet longer than the proposed ARB extended runway – the aircraft would have been more than capable of landing on an expanded ARB runway of 4,300-feet. And, as discussed below, the Runway Safety Zones (RSZs) and Runway Protection Zones (RPZs) frequently mentioned by MDOT as protecting neighborhoods surrounding airports from the effects from potential aircraft accidents, afforded no such benefits in this case. In fact, if a similar incident were to have occurred at an expanded ARB, with a high-speed jet crashing, skidding not just 1,800 feet, but 2,500 feet – because the Livingston County airport runway was longer -- beyond the end of an expanded 4,300-foot ARB runway, and burning, it could have ended up in homes across Lohr Road from the end of the runway, which could have been deadly!

These same type of Cessna jets have crashed on takeoff into two Great Lakes – an organ transplant team from the University of Michigan departing from Milwaukee about a decade ago (into Lake Michigan), killing six, and a family returning from a Cleveland Cavaliers basketball game that crashed on takeoff, killing all six on board (into Lake Erie) last December. The National Transportation Safety Board (NTSB) released a preliminary report on the Cleveland crash in January 2017, reporting that the owner-pilot of the Cessna Citation CJ4 had only been certified to operate the aircraft for three weeks ("NTSB Posts Preliminary Report on Cleveland CJ Crash," R. Mark, *Flying,* 24 January 2017). The report shows the aircraft turned right after takeoff, climbed to an altitude about 1,000 feet higher than assigned, then entered a descending right turn before crashing two minutes after takeoff, less than two miles from the airport, into the lake.

The NTSB has reported on the significant danger of crashes in private and charter airplanes vs. commercial aircraft, the type of aircraft likely to be attracted to an expanded ARB. Between 2000 and 2015, the NTSB found there were five times more fatal accidents in the U.S. involving private and chartered corporate planes than airlines. Investigators cited pilot error in 88 percent of the crashes, noting crews skipping safety checks, working long days, missing rest periods, overlooking ice on wings, or trying to land when they could not see the runway as among the causes of crashes ("Private Jets Have More Fatal Accidents than Commercial Planes," A. Levin, May 15, 2015, *Bloomberg News*).

"I was constantly hearing stories of corporate pilots who don't get enough rest or who are always concerned about being pressured to press on," Stuart Matthews, former president of the Flight Safety Foundation, told Bloomberg News.

Between 2000 and 2015, there were 62 reported fatal accidents involving the most sophisticated models of corporate-style jets and turboprops operated by professional pilots, compared with 13 such accidents by passenger airlines, with 107 fatalities since 2007 in the private-charter crashes compared with 50 deaths in airline crashes.

"Nobody's paying attention," said former NTSB member Kitty Higgins, a board member from 2006 to 2009. NTSB Chairman Christopher Hart added that more regulations would not help: "A lot of times we're talking about people who aren't following the regulations anyway, so I'm not sure that more regulation is the answer" (*Bloomberg News*, May 15, 2015).

And the record may be even worse for hobbyist pilots such as those who crashed in Cleveland and in Livingston County, because their primary occupations are not as pilots, but in doing other things, such as operating their businesses. Such hobbyist pilots may not have sufficient experience and reaction times for high-speed jets when problems develop, especially at airports close to population centers. But even if such pilots are to fly jets, they might be better advised to do so into larger airports – such as Willow Run and Cleveland Hopkins, which provide more operating room and degrees of freedom to recover in emergencies. However, these pilots cannot be kept away from airports close to population centers such as ARB. Consequently, the larger airports were not utilized in the accident cases discussed above, and smaller airports were used – Cleveland Lakefront and Livingston County, possibly exacerbating the accidents that occurred.

In short, the best way for an ARB surrounded by population centers to avoid such potential tragic problems is to not expand the existing airport and invite such larger and heavier jet aircraft to impose such dangers and risks given the small, if any, benefit any expansion would provide. The current airport is safe and presents no such dangers.

B. Changing the Runway Approach Slope Is Unjustified and Creates Additional Safety Issues that Have not Been Considered.

The RDEA proposes, as part of the Project, to flatten the approach slope to ARB's Runway 24 from the current 20:1 slope to 34:1 slope. RDEA, § 1.8.2, p.24, ¶ 6. According to the RDEA, this would provide "an additional margin of safety" from ground based obstacles. The lower, flatter approaches, however, would also expose aircraft to Canada geese for a longer period of time, raising the potential risk of accident, while providing no appreciable benefit. While the RDEA suggests this shift in the slope provides an added margin of safety, it presents a greater margin of risk given the high risk caused by Canada geese that inhabit the wetlands to the east of the airport -- especially given the likelihood of increased jet traffic a lengthened runway would attract. There is no justification for such a slope change established in the RDEA. The risks of such a slope change far outweigh any benefits.

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C. Line-of-Sight Concern Raises Controversial Issue to Justify 150-Foot Runway Shift.

As part of the Project, the RDEA proposes a 150-foot shift of the northeast end of Runway 24 to the southwest to "enhance the safety of ground operations by taxiing aircraft" on Runway 24. RDEA, § 1.8.1. The RDEA goes on to support this recommendation by claiming that two separate buildings currently block the view from the Air Traffic Control Tower (ATCT) to the taxiway hold area on Runway 24. The RDEA reports that the resulting area of restricted visibility has been designated as a "hot spot" by the FAA. Although not an immediate hazard, this situation can "…lead to a confusing condition which may be compounded by miscommunication between a pilot and controller. . ." RDEA, § 1.8.1, ¶ 1. Section 1.8.1 of the RDEA concludes by suggesting that the proposed shift would enhance operational safety, and possibly prevent a runway incursion by expanding the view of the hold area and parallel taxiway to ATCT personnel.

The RDEA goes on to discuss the fact that other alternatives had been considered "initially," but were dismissed as not being reasonable – such as removing and reconstructing the structures, or raising the ATCT, or constructing it elsewhere. But while these details were summarized in the RDEA and in response to an FAA question to the 2010 DEA (RDEA, Appendix K, Response No. 55, ¶ 5), no specific financial estimates were provided. In the end, since any spending will be done with federal Airport Improvement Program dollars, these alternatives must be examined and denominated in dollars, so that the FAA can make the best-informed decision as to both the spending of these funds and the best location of its ATCT. Relatedly, in examining alternatives to the Runway 24 line-of-sight issue, apparently, no alternative as simple as installing a series of cameras was even considered, which could provide sufficient visibility to the Runway 24 hold area for the ATCT. This certainly would be much cheaper and more practical than adding 150 feet of runway.

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Finally, although such a thorough study has not been conducted, this 150-foot shift has been recommended. In responding to questions from the 2010 DEA, ARB states, "[w]hile we are not aware of any incursions that have actually occurred as a result of this condition, we believe it is appropriate to address this condition while the runway condition is being considered . . .**MDOT would rather be proactive in enhancing the safety** of this situation prior to a potentially catastrophic runway incursion taking place, rather than waiting for one to take place and reacting to it afterwards." RDEA, Appendix K, Response 34, ¶¶ 2-4 (emphasis added).

D. MDOT Logic of Being Proactive to Enhance Safety Has Multiple Applications.

Just as MDOT's proactive approach to enhancing safety (mentioned in the above paragraph) may have application to the proposed 150-foot shift in the case of the ATCT, so, too, does that proactive approach apply to the entire proposed runway expansion and the risks it poses to the surrounding community. MDOT wrongly assumes that all aviation accidents related to takeoffs and landings are contained within those areas provided for in FAA Advisory Circular design specifications, such as elaborated on in AC 150/5325/4B, which details Runway Safety Zones (RSAs), Object Free Areas (OFAs), and Runway Protection Zones (RPZs), as it suggests in response to Comment 145 in the 2010 DEA (RDEA, Appendix K, Response 145). But these are only designed areas in runway design that are required to allow for safely aborted takeoffs or similar incidents; they in no way are intended to account for *all* potential aviation accidents in and around airports. For example, of the nine fatalities that have occurred within the ARB operational area, *none* have taken place within these designated runway areas. Thus, in responding to Comment 145 by stating that an expanded ARB, "…will continue to meet and/or exceed all FAA and State of Michigan safety standards. . .," that does not mean populated areas around the airport will be free from potential risk of incidents after takeoff, bird strikes with Canada geese, or other potential tragic incidents. It is important to remember that there have been no incidents or injuries from any of these line-of-sight incidents on the airport grounds, but that nine people have been killed over the years from aircraft crashes within two miles of ARB.

For that reason, just as, "MDOT would rather be proactive in enhancing the safety of this situation prior to a potentially catastrophic" event taking place regarding the line-of-sight issue discussed above, we recommend that the proposed 800-foot runway expansion should be denied, just as MDOT believes the 150-foot shift should be permitted. The importance of MDOT's standard of being "proactive in enhancing the safety of this situation prior to a potentially catastrophic" event holds equal weight in both circumstances, for the safety of people living near the airport as well as fliers.

VI. CONCLUSION

These comments detail why this RDEA is inadequate and fails to meet the requirements of NEPA, the NEPA regulations and FAA Order 1050.1F. For the reasons stated above, the project proposed by ARB should not be approved by either MDOT or the FAA because:

- The RDEA does not state a valid Purpose and Need, rather, ARB attempts to justify its desire for an extended runway by creating a non-existent problem (or, at least, a problem that affects a picayune portion of the aircraft operating at ARB).
- The RDEA does not establish by convincing evidence that the "critical aircraft" at ARB is a "B-II" type aircraft. In order to push its agenda, ARB has cherry-picked a few years where operations of B-II aircraft exceeded 500 operations, but it ignores the fact that in 5 out of the 8 years and 2 out of the last three years, B-II operations did not exceed 500 operations. This fact obviates the "need" for an extended runway.
- The RDEA does not address the fact that the proposed expansion brings potential risks to residents living near the airport by attracting larger and heavier jets, having aircraft take off 950 feet closer to population areas, and aircraft land just 93 feet over homes to the west of the airport.

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- The RDEA does not address the fact that the proposed expansion will have both noise and public safety impacts, violating a local Pittsfield Township noise ordinance.
- The RDEA does not address the fact that both Pittsfield and Lodi Townships have passed resolutions oppose expanding the Ann Arbor Airport runway. This puts the proposed expansion at odds with 40 C.F.R. § 1508.27(2), (4), (5) and (10).
- By carrying out the preferred alternative, ARB will be in violation of its FAA grant assurances which require it to consider the local interests of these communities, which there is no evidence presented in the RDEA that it has done.
- Further, MDOT has asserted a desire to be "proactive in enhancing the safety of ground operations by taxiing aircraft," in addressing the issue of the proposed 150-foot runway shift, emphasizing that, "MDOT would rather be proactive in enhancing the safety of this situation prior to a potential catastrophic runway incursion taking place, rather than waiting for one to take place and reacting to it afterwards." We support and agree with that logic – agreeing that the same logic should be applied to not expanding the Ann Arbor Airport primary runway as proposed because of the potential risk such an expansion could cause to citizens living around the airport in the event of an accident – employing the philosophy that, "MDOT would rather be proactive in enhancing the safety of this situation prior to a potential catastrophic" incident taking place. Proactive safety should support the 150-foot shift as the only construction that is approved for federal funding.

In keeping with the above, if this proposed expansion is not rejected based on these above arguments, we ask that the following changes to the RDEA be required before the project moves forward:

(1) Compliance with Pittsfield Township's Noise Ordinance must be considered as a required part of the project.

(2) The RDEA must address the fact that the preferred alternative is in direct opposition of Resolutions passed by both Pittsfield Township, the jurisdiction within which ARB is located, and Lodi Township, the adjacent jurisdiction. This puts the City of Ann Arbor at risk for litigation since it has signed grant agreements that state that the project must comply with local laws.

(3) The Alternative of using Willow Run Airport (YIP) to meet the RDEA's Purpose and Need must be fully considered as a "reasonable alternative" under NEPA and FAA Order 1050.1F

(4) The Alternative of adding 150 feet of runway and shifting the end of Runway 24 must be fully considered as a "reasonable alternative" under NEPA and FAA Order 1050.1F.

(5) All federal and state agency correspondence contained in Appendix D of the RDEA must be updated and that the public must be given the opportunity to comment on such updated federal and state agency correspondence prior any approval of the project.

(6) An updated noise study must be conducted that includes the effects of larger and heavier jet aircraft that an expanded runway will attract at night, and the health effects of such potential noise from positioning the runway 950 feet closer to the population center on citizens living near the airport.

(7) A Clean Air Act conformity analysis must be performed to ensure that the Project does not interfere with the State of Michigan's and the USEPA's State Implementation Plans for ozone, PM_{10} and $PM_{2.5}$.

(8) The evaluation of drinking water from wells on the airport property must be updated, and provisions for further consultation with federal and state officials required (FAA Order 1050.1E (Pages A-76-76, 17.4a).

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(9) A Wildlife Hazard Assessment that addresses the risk from Canada Geese must be drafted, approved and submitted for public comment before the project moves forward because of the risk from Canada geese surrounding the airport. This Wildlife Hazard Assessment must be approved by the FAA Administrator before the project can proceed. 14 C.F.R. § 139.337(e)(2).

If you have any questions or comments, please feel free to call me at (949) 735-8217 or send me an e-mail at staber@taberlawgroup.com.

Yours very truly,

TABER LAW GROUP, P.C.

Steven M. Taber

Steven M. Taber

Exhibit 1

Climate Ann Arbor - Michigan

°C | °F

	Jan	Feb	Mar	Apr	May	Jun
Average high in °F:	31	35	46	60	71	80
Average low in °F:	18	20	27	38	48	58
Av. precipitation in inch:	2.6	2.4	2.68	3.23	3.43	3.66
Days with precipitation:	-	-	-	-	-	-
Hours of sunshine:	-	-	-	-	-	-
Average snowfall in inch:	16	13	9	3	0	0

	Jul	Aug	Sep	Oct	Nov	Dec
Average high in °F:	83	81	74	61	48	35
Average low in °F:	62	61	53	42	33	23
Av. precipitation in inch:	3.62	3.7	3.46	2.83	3.07	2.87
Days with precipitation:	-	-	-	-	-	-
Hours of sunshine:	-	-	-	-	-	-
Average snowfall in inch:	0	0	0	0	3	13

Climate data for ann arbor univ of mich, Longitude: -83.7108, Latitude: 42.2947
Average weather Ann Arbor, MI - 48108 - 1981-2010 normals

Jan: January, Feb: February, Mar: March, Apr: April, May: May, Jun: June, Jul: July, Aug: August, Sep: September, Oct: October, Nov: November, Dec: December

Ann Arbor weather averages

Geo Ann Arbor - Michigan

Country:	United States
State:	Michigan
County:	Washtenaw

City	Ann Arbor
Zip code	48108
Longitude:	-83.7108
Latitude:	42.2947
Altitude - Elevation:	899 feet
ICAO:	KARB
IATA:	ARB
Local Time:	10:19
Sunrise:	07:42
Sunset:	17:56
Day / Night:	Day
Timezone:	EST - Eastern Standard Time
Timezone DB	America/New_York

EXHIBIT 1 – ANN ARBOR WEATHER / TEMPERATURE DATA

Exhibit 2

EPA United States Environmental Protection Agency

You are here: EPA Home > Air Quality Implementation Plans > SIP Status Reports > Status of Michigan Designated Areas

Status of Michigan Designated Areas

Michigan Areas by NAAQS
As of 01/29/2017

Jump to Michigan section for: CO (1971) Lead (1978) Lead (2008) NO2 (1971) Ozone-1Hr (1979) Ozone-8Hr (1997) Ozone-8Hr (2008) PM-10 (1987) PM-2.5 (1997) PM-2.5 (2006) PM-2.5 (2012) SO2 (1971) SO2 (2010)

Michigan CO (1971) Areas

Return to map

Click on the Area name to view SIP Required Elements Area	Status	Designation Date	Classification	2010 Population (state portion)	Meets NAAQS Basis	Design Value Annual (ppm) (entire area)	Meets NAAQS	SIP Requirements Original/ Approved	Clean Air Determination Citation Effective Date Click to view FR notice	Redesignation Request Date	Redesignation Citation Effective Date Click to view FR notice
Detroit Area	Maintenance	11/15/1990	Not Classified	1,382,239	2015	1.7	Yes	1 / 1	08/30/1999 64 FR 35017	03/18/1999	08/30/1999 64 FR 35017

Michigan Lead (1978) Areas

Return to map

No designated areas for this pollutant.

Michigan Lead (2008) Areas

Return to map

Click on the Area name to view SIP Required Elements Area	Status	Designation Date	Classification	2010 Population (state portion)	Meets NAAQS Basis	Design Value Annual (μg/m^3) (entire area)	Meets NAAQS	SIP Requirements Original/ Approved	Clean Air Determination Citation Effective Date Click to view FR notice	Redesignation Request Date	Redesignation Citation Effective Date Click to view FR notice
Belding	Nonattainment	12/31/2011		1,890	2013-2015	0.06	Yes	6 / 0	09/22/2015 80 FR 43956	01/12/2016	

Michigan NO2 (1971) Areas

Return to map

No designated areas for this pollutant.

Michigan Ozone-1Hr (1979) Areas

Return to map

Click on the Area name to view SIP Required Elements Area	Status	Designation Date	Classification	2010 Population (state portion)	Meets NAAQS Basis	Design Value Annual (ppm) (entire area)	Meets NAAQS	SIP Requirements Original/ Approved	Clean Air Determination Citation Effective Date Click to view FR notice	Redesignation Request Date	Redesignation Citation Effective Date Click to view FR notice
Detroit-Ann Arbor Area	Maintenance (NAAQS revoked)	11/15/1990	Moderate	4,704,743	2013-2015	0.094	Yes	23 / 23	04/06/1995 60 FR 12459	11/01/1993	04/06/1995 60 FR 12459
Grand Rapids Area	Maintenance (NAAQS revoked)	11/15/1990	Moderate	866,423	2013-2015	0.087	Yes	23 / 23	06/21/1996 61 FR 31831	03/09/1995	06/21/1996 61 FR 31831
Muskegon Area	Maintenance (NAAQS revoked)	11/15/1990	Moderate	172,188	2013-2015	0.091	Yes	23 / 23	10/18/2000 65 FR 52651	03/09/1995	10/18/2000 65 FR 52651

Michigan Ozone-8Hr (1997) Areas

Return to map

Click on the Area name to view SIP Required Elements Area	Status	Designation Date	Classification	2010 Population (state portion)	Meets NAAQS Basis	Design Value Annual (ppm) (entire area)	Meets NAAQS	SIP Requirements Original/ Approved	Clean Air Determination Citation Effective Date Click to view FR notice	Redesignation Request Date	Redesignation Citation Effective Date Click to view FR notice
Allegan County Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	111,408	2013-2015	0.075	Yes	4 / 1	09/24/2010 75 FR 58312	05/12/2010	09/24/2010 75 FR 58312
Benton Harbor Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	156,813	2013-2015	0.073	Yes	4 / 0	05/16/2007 72 FR 27425	06/13/2006	05/16/2007 72 FR 27425
Benzie County Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	17,525	2013-2015	0.068	Yes	4 / 0	05/16/2007 72 FR 27425	05/09/2006	05/16/2007 72 FR 27425
Cass County Area	Maintenance (NAAQS revoked)	06/15/2004	Subpart 2/Marginal	52,293	2013-2015	0.068	Yes	3 / 0	05/16/2007 72 FR 27425	06/13/2006	05/16/2007 72 FR 27425
Detroit-Ann Arbor Area	Maintenance (NAAQS revoked)	06/15/2004	Subpart 2/Marginal	4,804,635	2013-2015	0.072	Yes	3 / 2	06/29/2009 74 FR 30950	03/06/2009	06/29/2009 74 FR 30950

Flint Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	514,109	2013-2015	0.067	Yes	4 / 0	05/16/2007 72 FR 27425	06/13/2006	05/16/2007 72 FR 27425
Grand Rapids Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	866,423	2013-2015	0.068	Yes	4 / 0	05/16/2007 72 FR 27425	05/09/2006	05/16/2007 72 FR 27425
Huron County Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	33,118	2013-2015	0.065	Yes	4 / 0	05/16/2007 72 FR 27425	05/09/2006	05/16/2007 72 FR 27425
Kalamazoo-Battle Creek Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	462,735	2013-2015	0.067	Yes	4 / 0	05/16/2007 72 FR 27425	05/09/2006	05/16/2007 72 FR 27425
Lansing-East Lansing Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	464,036	2013-2015	0.065	Yes	4 / 0	05/16/2007 72 FR 27425	05/09/2006	05/16/2007 72 FR 27425
Mason County Area	Maintenance (NAAQS revoked)	06/15/2004	Former Subpart 1	28,705	2013-2015	0.068	Yes	4 / 0	05/16/2007 72 FR 27425	05/09/2006	05/16/2007 72 FR 27425
Muskegon Area	Maintenance (NAAQS revoked)	06/15/2004	Subpart 2/Marginal	172,188	2013-2015	0.074	Yes	3 / 0	05/16/2007 72 FR 27425	06/13/2006	05/16/2007 72 FR 27425

Michigan Ozone-8Hr (2008) Areas

Return to map

No designated areas for this pollutant.

Michigan PM-10 (1987) Areas

Return to map

Click on the Area name to view SIP Required Elements Area	Status	Designation Date	Classification	2010 Population (state portion)	Meets NAAQS Basis	Design Value (entire area)	Meets NAAQS	SIP Requirements Original/ Approved	Clean Air Determination Citation Effective Date Click to view FR notice	Redesignation Request Date	Redesignation Citation Effective Date Click to view FR notice
Wayne County; (part)	Maintenance	11/15/1990	Moderate	713,777	2013-2015		Yes	3 / 3	10/04/1996 61 FR 40516	07/24/1995	10/04/1996 61 FR 40516

Michigan PM-2.5 (1997) Areas

Return to map

Click on the Area name to view SIP Required Elements Area	Status	Designation Date	Classification	2010 Population (state portion)	Meets NAAQS Basis	Design Value Annual (µg/m^3) (entire area)	Meets NAAQS	SIP Requirements Original/ Approved	Clean Air Determination Citation Effective Date Click to view FR notice	Redesignation Request Date	Redesignation Citation Effective Date Click to view FR notice
Detroit-Ann Arbor	Maintenance	04/05/2005	Former Subpart 1	4,704,743	2013-2015	11.4	Yes	5 / 1	12/06/2012 77 FR 66545	07/05/2011	08/29/2013 78 FR 53272

Michigan PM-2.5 (2006) Areas

Return to map

Area designated nonattainment for the 24-hour standard

Click on the Area name to view SIP Required Elements Area	Status	Designation Date	Classification	2010 Population (state portion)	Meets NAAQS Basis	Design Value 24-Hr (µg/m^3) (entire area)	Meets NAAQS	SIP Requirements Original/ Approved	Clean Air Determination Citation Effective Date Click to view FR notice	Redesignation Request Date	Redesignation Citation Effective Date Click to view FR notice
Detroit-Ann Arbor	Maintenance	12/14/2009	Former Subpart 1	4,704,743	2013-2015	26	Yes	6 / 0	08/29/2013 78 FR 53272	07/05/2011	08/29/2013 78 FR 53272

Michigan PM-2.5 (2012) Areas

Return to map

No designated areas for this pollutant.

Michigan SO2 (1971) Areas

Return to map

No designated areas for this pollutant.

Michigan SO2 (2010) Areas

Return to map

Click on the Area name to view SIP Required Elements Area	Status	Designation Date	Classification	2010 Population (state portion)	Meets NAAQS Basis	Design Value Annual (ppb) (entire area)	Meets NAAQS	SIP Requirements Original/ Approved	Clean Air Determination Citation Effective Date Click to view FR notice	Redesignation Request Date	Redesignation Citation Effective Date Click to view FR notice
Detroit	Nonattainment	10/04/2013		254,079	2013-2015	64	Yes	6 / 0			
St. Clair	Nonattainment	09/12/2016			2013-2015		No Data	6 / 0			

We have made our best effort to ensure that the data contained in these reports is accurate. We note that there may be brief delays in updating the reports as we receive new state submissions and we take rulemaking action on plans. In order to assist us in providing accurate information, we request that you contact us by clicking on the "Contact Us" link near the top of this page with any comments regarding or corrections to the posted information, including concerns about whether the entries reflect the most recent status.

Current and historical design value data can be found on the EPA Air Quality Design Values website and the EPA Green Book contains comprehensive nonattainment area, designation status, and historical information.

2017-01-29

Exhibit 3

2015 ANNUAL CITY OF ANN ARBOR

water QUALITY REPORT

INSIDE

FROM SOURCE TO TAP | MARCH 2016

a2gov.org/A2H2O

Water Plant 1938

Dear Valued Customer:

The City of Ann Arbor Water Treatment Services Unit is pleased to share with you our annual drinking water quality report, which is a requirement of the Safe Drinking Water Act (SDWA).

This report will tell you where your drinking water comes from, what's in it, and how to keep our water supply safe.

In the wake of the water crisis in Flint, it is understandable that our customers are concerned about their own water quality. We have a qualified staff of water utility professionals who understand the importance that the water supply plays in the overall quality of life for our community. We are dedicated to providing our customers with the best quality drinking water possible and we continue to meet or exceed all State and Federal regulatory requirements.

We work hard to provide you with safe, reliable, cost-effective drinking water and outstanding customer service

Twenty-five years ago, the City began removing the only lead components remaining in our system. These components, called "goosenecks" were used before 1950 to connect the iron water main and the galvanized iron service lines. Today there are about 100 goosenecks remaining, and the City is committed to removing them. In the meantime, these connections are covered by a protective layer of scale that prevents lead from entering the drinking water. On pages 6-7 of this report you will find a summary of the City's lead testing data and some additional facts and information about healthy plumbing.

The most recent data from Ann Arbor homes indicates that the lead level in our drinking water is well below the established action levels.

We work hard to provide you with safe, reliable, cost-effective drinking water and outstanding customer service, and we are committed to constantly improving our services and operations. Continuing to reinvest in our infrastructure is one important component of our efforts to meet your service expectations. A significant portion of the City's Water Treatment Plant dates back to 1938 and is still in service. As we begin to plan for its replacement, the City will need to adjust its drinking water rates to ensure it is in position to finance this reinvestment.

This reinvestment helps to ensure a reliable water system today and for future generations.

If you have questions about this report, or drinking water quality in the City of Ann Arbor, please contact us at (734) 794-6426 or visit us on the web at www.a2gov.org/departments/water-treatment.

Sincerely,

Brian Steglitz, PE
Manager of Water Treatment Services

Did you know...

Storm drains lead directly to the river, without treatment?

Dumping waste into storm drains, ditches, or waterways contaminates drinking water supplies, recreational areas, and wildlife habitats. Plus, it is illegal!

We need your help!

Report any dumping, spills, or construction site runoff into the stormwater system to City officials.

Sources of Drinking Water

The sources of drinking water - both tap water and bottled water - include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants that may be present in source water include:

- **Microbial contaminants**, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.
- **Inorganic contaminants**, such as salts and metals, which can be naturally-occurring or result from urban stormwater runoff, industrial, or domestic wastewater discharges, oil and gas production, mining, or farming.
- **Pesticides and herbicides**, which may come from a variety of sources such as agriculture, urban stormwater runoff, and residential uses.
- **Organic chemical contaminants**, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban stormwater runoff, and septic systems.
- **Radioactive contaminants**, which can be naturally-occurring or be the result of oil and gas production and mining activities.

Protecting Water Quality

Source Water Assessment Program

All sources of drinking water may be susceptible to contamination. Federal regulations require states to develop and implement Source Water Assessment Programs (SWAP) to compile information about any potential sources of contamination to their source water supplies. This information allows us to better protect our drinking water sources. In 2004, the MDEQ performed a Source Water Assessment on our system. To obtain a copy of the assessment, request one by calling (734) 794-6426.

Using the information from the assessment, a susceptibility rating for each water source was determined by considering the number and location of all potential sources of contamination to our source water. The Huron River was rated “high” and the wells were rated “moderate”. These ratings do not mean that source water contamination has or will occur in our water supply; rather, they indicate a need for us to continue to carefully monitor and protect our drinking water sources.

Where does my water come from?

The City of Ann Arbor’s source water is comprised of both surface and ground water sources. About 85% of the water supply comes from the Huron River with the remaining 15% provided by multiple wells. The water from both sources is blended at the Water Treatment Plant.

Are you at risk?

Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. EPA/CDC guidelines on appropriate means to lessen the risk of infection by Cryptosporidium and other microbial contaminants are available from the Safe Drinking Water Hotline at (800) 426-4791.

Cryptosporidium

Cryptosporidium is a microbial pathogen found in surface water throughout the U.S. Although filtration removes Cryptosporidium, the most commonly-used filtration methods cannot guarantee 100 percent removal. Current test methods do not allow us to determine if the organisms are dead or if they are capable of causing disease. Ingestion of Cryptosporidium may cause cryptosporidiosis, an abdominal infection. Symptoms of infection include nausea, diarrhea, and abdominal cramps. Most healthy individuals can overcome the disease within a few weeks. However, immuno-compromised people, infants and small children, and the elderly are at greater risk of developing life-threatening illness. We encourage immuno-compromised individuals to consult their doctor regarding appropriate precautions to take to avoid infection. Cryptosporidium must be ingested to cause disease, and it may be spread through means other than drinking water. Our monitoring indicates the presence of these organisms in our source water, but not in the finished water.

TERMS USED IN THIS REPORT

- **Action Level (AL):** The concentration of a contaminant, which, if exceeded, triggers treatment, or other requirements, which a water system must follow.
- **Grains per Gallon (gpg):** A unit of water hardness defined as 1 grain (64.8 milligrams) of calcium carbonate dissolved in 1 US gallon of water (3.785 L). This is a term often used by appliance manufacturers.
- **Maximum Contaminant Level (MCL):** The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.
- **Maximum Contaminant Level Goal (MCLG):** The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.
- **Maximum Residual Disinfectant Level (MRDL):** The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- **Maximum Residual Disinfectant Level Goal (MRDLG):** The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- **N/A:** Not Applicable
- **Not Detected (ND):** Not detected at or above the minimum reporting level - laboratory analysis indicates that the constituent is not present.
- **Nephelometric Turbidity Units (NTU):** Turbidity is a measure of the cloudiness of the water. We monitor it because it is a good indicator of the effectiveness of our filtration system.
- **pCi/L:** picocuries per liter (a measure of radioactivity).
- **Treatment Technique (TT):** A required process intended to reduce the level of a contaminant in drinking water.
- **1 part per million (ppm) or milligrams per liter (mg/L):** corresponds to one minute in two years or a single penny in $10,000. 1 ppm = 1000 ppb
- **1 part per billion (ppb) or micrograms per liter (µg/L):** corresponds to one minute in 2,000 years, or a single penny in $10,000,000.

Now It Comes With A List of Ingredients!

During the past year, we have taken thousands of water samples. This report includes information on all regulated drinking water parameters detected during calendar year 2015. Many more parameters were tested, but not detected, and are not included in this report.

REGULATED CONTAMINANTS THAT WERE DETECTED

Parameter Detected	Your Water Results		Regulatory Requirements		Likely Source
	Highest Level Detected	Results Range	EPA LIMIT MCL, TT, or MRDL	EPA GOAL MCLG or MRDLG	
Disinfection Byproducts, Disinfectant Residuals, and Disinfection Byproduct Precursors					
Bromate	6.8 ppb [1]	2.9 – 14.0 ppb	10	0	Byproduct of ozone disinfection
Chloramines [3]	2.4 ppm [1]	0.03 – 3.5 ppm	MRDL: 4	MRDLG: 4	Disinfectant added at Water Plant
Haloacetic Acids (HAA5) [3]	5.5 ppb [2]	1.7 – 11.0 ppb	60	N/A	Byproduct of disinfection
Total Organic Carbon (TOC)	54% removed [1]	47 – 64% removed	TT: 25% minimum removal	N/A	Naturally present in the environment
Total Trihalomethanes (TTHM) [3]	3.6 ppb [2]	ND – 6.4 ppb	80	N/A	Byproduct of disinfection
Radioactive Contaminants (tested in 2014)					
Radium 226 and 228	2.21 ±0.87 pCi/L	N/A	5	0	Erosion of natural deposits
Inorganic Contaminants					
Barium	10 ppb	N/A	2000	2000	Erosion of natural deposits
Chromium (total)	ND	N/A	100	100	Discharge from steel and pulp mills; erosion of natural deposits
Fluoride	0.85 ppm	0.58 – 0.85 ppm	4	4	Erosion of natural deposits; water additive which promotes strong teeth
Nitrate	0.8 ppm	0.5 – 0.8 ppm	10	10	Runoff from fertilizer use; leaching from septic tanks and sewage
Microbiological Contaminants					
Total Coliform [3]	0.7% in Oct out of 137 tested	0 – 0.7%	≤ 5% positive per month	0 positive	Naturally present in the environment
Turbidity	0.16 NTU	100% of samples ≤0.3 NTU	1 NTU and 95% of samples ≤0.3 NTU	N/A	Naturally present in the environment

[1] highest running annual average [2] highest locational running annual average [3] measured in the distribution system

Contaminants in Water

In order to ensure that tap water is safe to drink, EPA prescribes regulations which limit the amount of certain contaminants in water provided by public water systems. FDA regulations establish limits for contaminants in bottled water which must provide the same protection for public health. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the EPA's Safe drinking Water Hotline at (800) 426-4791.

Is There Lead in My Water?

Water that comes out of the City's drinking water plant has no detectable lead, however, test results from homes in our community show there can be low levels of lead and copper in tap water, primarily caused by corrosion of household pipes, solder, and faucets.

The City adjusts the chemistry of the water leaving the plant to minimize the amount of corrosion that can occur, thus helping to reduce the risk to you!

MORE ABOUT LEAD

2014 LEAD AND COPPER RESULTS

Parameter Detected	Units	Your Water Results		Regulatory Requirements		Likely Source
		Concentration at 90th Percentile	Number of sites above Action Level	Action Level	MCLG	
Lead	ppb	2	0 out of 52	15	0	Corrosion of household plumbing
Copper	ppb	70	0 out of 52	1300	1300	Corrosion of household plumbing

2015 SPECIAL MONITORING

Parameter Detected	Units	Your Water Results		Likely Source
		Average level detected	Range	
1,4-dioxane	ppb	ND	N/A	Groundwater contamination from manufacturing process and landfills
N-Nitrosodimethylamine (NDMA)	ppb	0.0029	N/A	Byproduct of disinfection
Perchlorate	ppb	0.09	N/A	Nitrate fertilizer runoff; contamination from industrial manufacturing process
Sodium	ppm	60	48 – 67	Erosion of natural deposits; road salt and water softeners

OTHER WATER QUALITY PARAMETERS OF INTEREST

Parameter Detected	Units	Your Water Results	
		Average level detected	Range
Alkalinity, total	ppm as $CaCO_3$	51	30 – 94
Aluminum	ppm	0.022	N/A
Ammonia as N	ppm	0.13	ND – 0.30
Arsenic	ppb	ND	N/A
Calcium	ppm	32	23 – 66
Chloride	ppm	115	98 – 147
Conductivity	μmhos/cm	607	497 – 737
Hardness (calcium carbonate)	ppm	132	100 – 176
	gpg	7.7	5.8 – 10.3
Iron	ppm	ND	N/A
Lead	ppb	ND	N/A
Magnesium	ppm	24	10 – 33

Parameter Detected	Units	Your Water Results	
		Average level detected	Range
Manganese	ppb	ND	N/A
Mercury	ppb	ND	N/A
Nitrite as N	ppm	0.02	ND – 0.06
Non-Carbonate Hardness	ppm	80	44 – 123
pH	S.U.	9.3	9.0 – 9.4
Phosphorus, total	ppm	0.24	0.08 – 0.40
Potassium	ppm	3.4	N/A
Sodium	ppm	60	48 – 67
Sulfate	ppm	58	41 – 82
Temperature	°C	14.9	6.3 – 24.9
Total solids	ppm	369	321 – 447
Zinc	ppb	ND	N/A

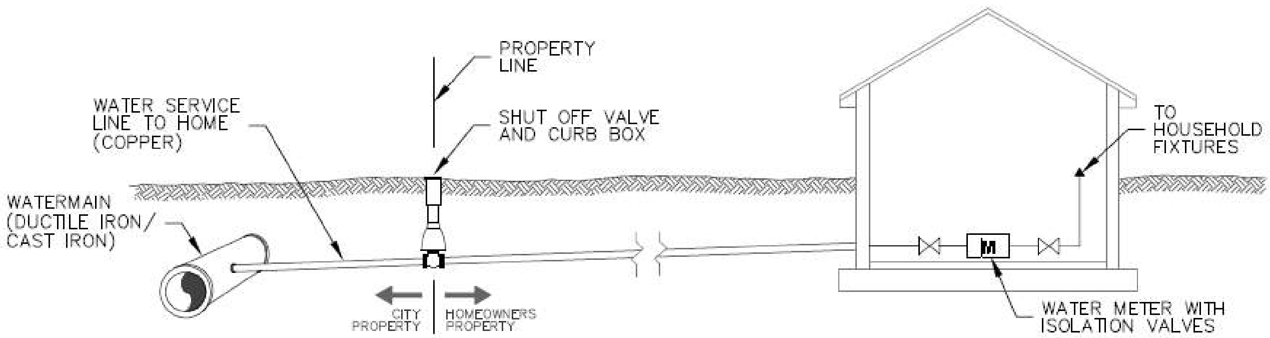
Lead Awareness in Our Community

There has been a lot of recent news coverage about lead in the Flint drinking water system. To address any local concerns, we would like to provide some information that helps to clarify how the Ann Arbor drinking water system is different.

The unfortunate situation in Flint was caused, in part, when they switched their drinking water supply source, did not use any corrosion control, and lowered the pH of the water. This caused the lead pipes and fittings in their water system to lose their protective coating and then corrode, releasing lead and iron into the water. Our water supply has been softened since 1938 and this process has optimized corrosion control. By controlling the corrosivity of the water, the amount of lead in your drinking water is kept to a minimum.

A diagram has been included below to illustrate a typical residential service line installation.

Typical Residential Service Line Installation



Healthy Household Plumbing

What you can do to minimize lead in your home:

- **Flush your pipes before drinking.** Anytime the water in a faucet has not been used for six hours or longer, flush your cold-water pipes by running the water until it becomes noticeably cold.
- **Do not cook with or drink water from the hot water tap.** Hot water can dissolve lead more quickly than cold water. If you need hot water, draw water from the cold tap and heat it on the stove or in the microwave.
- **Remove and clean your faucet screen and aerator.** Rinse out any debris then reattach them. Doing this once a month will reduce the possibility that small particles that may contain lead will build up in your faucet.
- **Consider replacing lead-containing plumbing fixtures.** A new law came into effect in 2014 limiting the amount of lead in brass faucets and plumbing.

Important information about lead

If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. The City of Ann Arbor is responsible for providing high quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline at (800) 426-4791 or at http://water.epa.gov/drink/info/index.cfm.

Water Quality Word Search

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r d r r g l x h c n m t x b f k j d j d
e s m e a n f p y s v u a t s r m q o p
t r m g d m i f l u o r i d e u y n g k
a s a u d n q r u u t s h d i m t l i f
w w c l t e i t o o m y u m o f i c t h
e j j a c c q b n t t b o b l s d p x t
c k k t l y i p q i i r i u f n i p t p
a e v i m a o r l j h n s n h i b m p u
f o v o z n p a t c p h o o g t r b h h
r g d n d q u t k e m m n m f r u v e t
u w r s d q o b x e m g w l a a t i r a
s l x o r m u i d i r o p s o t p y r c
m g l e u m u i r a b f l i i e r m i c
j k t e w n c d i s i n f e c t a n t v
f a w m a a d t e c y l f j h b n t q r
w z w k t d e w t q d h f f w p w l v e
d y v i c s l c a m b w d s n k e b k p
i t o b n u g y v t p u u f o z o n e p
d n l u a x z g b r e v i r n o r u h o
s t s o g y w k q h g r c a w t e p e c
```

barium
barton pond
chromium
copper
cryptosporidium
disinfectant
don’t flush medications
fluoride
groundwater
huron river
intake
lead
monitoring
nephelometric
nitrate
ozone
plumbing
ppb
ppm
regulations
sodium
sunset
surface water
turbidity
water quality

Exhibit 4

the ann arbor chronicle
it's like being there

Commission OKs FY 2013 Parks Budget

Also: Windemere tennis court problems; drain project at Veterans

BY MARY MORGAN APRIL 27, 2012 at 8 am

Ann Arbor park advisory commission meeting (April 17, 2012): The action items at this month's PAC meeting focused on the upcoming fiscal year, with parks-related budget recommendations for July 1, 2012 through June 30, 2013. Sam Offen, who chairs PAC's budget and finance committee, observed that the FY 2013 budget is in better shape than in recent years.

At left is city councilmember Christopher Taylor (Ward 3), who also serves as an ex officio member of the Ann Arbor park advisory commission. To the right is Sam Offen, chair of PAC's budget and finance committee. (Photos by the writer.)

This is the second year of a two-year budget cycle, and commissioners had recommended approval of budgets for both years at their April 2011 meeting. The recent recommendations for FY 2013 include: (1) increasing the frequency of the mowing cycle from every 19 days to every 14 days; (2) increasing seasonal staffing between April 15–October 15 to maintain active recreation areas better; (3) establishing three seasonal park steward/supervisor positions to improve park maintenance and enforcement; and (4) increasing seasonal staffing at the ice arenas to improve facility cleanliness.

Fee increases at several parks and rec facilities are also part of the budget recommendations, but most have already been implemented in the current fiscal year.

The April 17 meeting included a public hearing on the renewal of the city's park maintenance and capital improvements millage, which will likely be on the November 2012 ballot. No one spoke at the hearing. In general, "there seems to be a great deal of relative silence" about the millage, parks and rec manager Colin Smith told commissioners. Few people have attended the recent public forums held by parks staff. The final forum is set for Thursday, April 26 from 6:30-7:30 p.m. at the Ann Arbor District Library's Traverwood branch, 3333 Traverwood Drive.

Parks staff gave an update on deteriorating conditions at Windemere Park's two tennis courts, and provided an initial estimate on costs to replace one or both courts at that location. No formal recommendation has been made, but options include moving the courts to another park. Commissioners discussed the need to assess the distribution and conditions of all of the city's public courts – including ones in the public school system – as well as their overall usage, to get a better idea of where the greatest needs are.

Another update came from an engineer at the Washtenaw County water resources commissioner's office, who described a drain replacement project that will affect Veterans Memorial Park later this year. Also related to Veterans Memorial, the request for proposals (RFP) for a skatepark there has been issued. [.pdf of skatepark RFP] The goal is to solicit proposals for a consultant to handle design and oversee construction of the skatepark, which will be located on city-owned property.

During public commentary, commissioners were given an update on the nonprofit Project Grow, which has several gardens located in city parks and is celebrating its 40th anniversary this year. Another speaker urged commissioners to take control of the parking lots in city parks, and possibly increase revenues by installing metered parking.

Parks & Rec Budget Recommendation

Park commissioners considered two resolutions related to the city's fiscal year 2013 budget, for the year beginning July 1, 2012 through June 30, 2013. It's the second year of a two-year budget planning cycle. PAC had previously recommended approval of budgets for both years at its April 2011 meeting. The parks budget is part of the city's overall budget, which city administrator Steve Powers proposed at the April 16 meeting of the Ann Arbor city council.

Most of these changes have already been implemented, as part of the current year's budget. Colin Smith, the city's parks and rec manager, reminded commissioners that there will be no increase in budgeted expenses. These changes will be made within the budget plan that was discussed last year for FY 2013, when the FY 2012 budget was formally adopted. [.pdf of budget resolution adopted by council for FY 2012, including parks-related items]

The portion of the city budget relating to parks is separated into two parts: (1) park operations; and (2) parks and recreation.

Sam Offen, who chairs PAC's budget and finance committee, noted that the budget is in better shape than in recent years. He joked that it makes his job much easier.

Parks & Rec Budget Recommendation: Parks Operations Budget

PAC was asked to approve recommendations for the FY 2013 parks operations budget, which includes the following proposed changes: (1) increasing the frequency of the mowing cycle from every 19 days to every 14 days; (2) increasing seasonal staffing between April 15–October 15 to maintain active recreation areas better; (3) establishing three seasonal park steward/supervisor positions to improve park maintenance and enforcement; and (4) increasing seasonal staffing at the ice arenas to improve facility cleanliness. [.pdf of parks operations budget recommendation]

There was considerable discussion about whether to change the wording on the recommendation for the mowing cycle. Tim Doyle initially felt it sounded too much like a dictate rather than an objective, and preferred deferring to staff's judgement on the exact number of days in the cycle. After some wordsmithing on a possible amendment, Christopher Taylor – PAC's ex officio member who also serves on city council – was asked whether his council colleagues would understand the intent. "Contextually, it's plain enough," he said.

Ultimately, PAC reached a consensus not to change wording on the recommendation.

Outcome: Commissioners voted unanimously to recommend approval of the FY 2013 parks operations budget.

Parks & Rec Budget Recommendation: Parks & Rec Budget

In a separate resolution, PAC was asked to recommend approval of the FY 2013 parks and recreation budget. The resolution commended parks staff for its work, and made several general recommendations: (1) reduce energy expenses to reflect the benefit of infrastructure energy improvements at recreational facilities, including Cobblestone Farm and Mack Pool; (2) reduce materials and supplies used to maintain various facilities as a result of recent improvements; (3) reduce water usage expense to reflect actual usage better; (4) eliminate unnecessary software installations where appropriate; (5) increase revenue by initiating additional programming at the Argo Cascades; and (6) increase revenue by increasing fees for admission to swimming pools. [.pdf of parks & rec budget recommendation] [.pdf of fee increases]

Most of these items have been started in the current fiscal year, Offen noted, and will continue into FY 2013.

Outcome: Commissioners unanimously recommended approval of the FY 2013 parks and recreation budget.

Parks Millage Renewal: Public Hearing

No one spoke during a public hearing on the renewal of the city's park maintenance and capital improvements millage, which will likely be on the November ballot.

Park commissioners had been briefed by staff about the millage renewal at PAC's March 20, 2012 meeting.

John Lawter, PAC's vice chair who was presiding over the meeting in the absence of chair Julie Grand, noted that two of the four public informational forums regarding the millage had been held.

[The third forum took place on Monday, April 23. The final one is set for Thursday, April 26 from 6:30-7:30 p.m. at the Ann Arbor District Library's Traverwood branch, 3333 Traverwood Drive.]

Colin Smith, parks and rec manager, noted that Grand had wanted to schedule some of the public forums prior to the public hearing at PAC, and prior to a vote by PAC on whether to recommend millage renewal. That way, PAC could respond if any issues arose. However, Smith added, "there seems to be a great deal of relative silence," and nothing has come up to indicate that the city is on the wrong track in seeking renewal. [At an April 11 forum held at Cobblestone Farm, several city parks staff, PAC commissioners, city councilmember Jane Lumm, and two members of the media – from The Chronicle and WEMU – showed up. But only one member of the public came: Eric Meves, a board member at Project Grow who also spoke during public commentary at the April 17 PAC meeting (see below).]

From left: Greg McDonald, assistant manager of city operations for Community Television Network (CTN), explains a camera problem to Colin Smith, the city's parks and recreation manager. The controller that allows CTN staff technicians to remotely control cameras in city council chambers wasn't working during the April 17 park advisory commission meeting. CTN staff instead adjusted the cameras manually prior to the meeting, to capture wide angle views of the proceedings.

Gwen Nystuen observed that it's hard to get people excited now about a vote that won't happen until November. She said she hadn't heard anything unfavorable about the millage, and that people in Ann Arbor are very supportive of parks. "I'm optimistic," she said.

Sam Offen asked whether there were any significant comments or feedback from the first two forums. Lawter reported that the one person at the forum he attended was supportive. [That person was Meves.] Nystuen praised the staff – she said they had done a good job of answering questions at the first forum about how the budget was prepared.

Informational handouts are being distributed, and Smith pointed out that information about the millage renewal is also available on the city's website.

Windemere Park Tennis Courts

Parks planner Amy Kuras gave a presentation on the tennis courts at Windemere Park, a nearly four-acre parcel on the city's northeast side, north of Glazier Way between Green and Earhart roads. There was no action requested of PAC at this meeting – the staff just wanted to update commissioners on the situation.

The courts were initially built in 1986, then color coated in 2007. Repairs to cracks in the court were attempted in 2009, Kuras said, but failed because of poor soil conditions. The city also attempted to install new net posts in 2009, but that also failed.

In 2010, the city took soil borings in five parts of the park. The borings revealed saturated organic soil and fill, particularly in areas located near the tennis courts in the west part of the park.

Part of the problem is a high water table, Kuras said. In fact, the parks staff have noted higher water tables throughout the city, she added. The only hard data that the city has collected on the water table is at the municipal airport, and there the water table measures between 2-7 feet below the surface now, compared to 15 feet below the surface 50 years ago. Jen Lawson, the city's water quality manager, attributed the change to a variety of factors, Kuras reported, including climate change and more impervious surfaces in the city.

Kuras presented a chart showing cost estimates to replace either one or both courts at the current location. She based her estimates on work done for tennis courts at Veterans Memorial Park and West Park. The total would be $181,377 for two courts at Windemere, or $107,408 for one court. [Link to chart of itemized replacement costs.]

The options to consider, Kuras said, include: (1) replacing both tennis courts at the current location, (2) replacing the courts in another part of Windemere Park, (3) replacing only one court, (4) removing

the courts, or (5) possibly putting the courts in another park.

Matt Warba, the city's acting field operations manager, told commissioners that he's frustrated by the situation. The staff has attempted several repairs, but with water at just two feet below the surface, it's difficult. There's a likelihood that having tennis courts at that location isn't reasonable, he said. But he understands the value to the neighborhood, and the staff is still working on getting some firm numbers and options to consider. There's no easy or quick solution, he said, but they're working on it.


Cracked pavement at the Windemere Park tennis court. (Image provided by city staff in a slide presentation to PAC.)

Windemere Park Tennis Courts: Public Commentary

Jeff Alson told commissioners that he has lived near the park since the late 1970s. He bought his home there in part because of the park. There are a lot of tennis players in the neighborhood, and there are a lot of young children in the area so demand could grow. But because of water issues there's only one court that can be used. Last summer, he hardly played there at all. Alson said he understood that there are problems with water that make maintenance of the courts more expensive. But he emphasized that the courts have held up well for at least the last 10 years, and he would consider it a good investment. It would be disappointing to him if the courts were removed. Alson concluded by thanking commissioners for their service to the city.

Windemere Park Tennis Courts: Commission Discussion

David Barrett asked whether the water table is the same throughout the park. Yes, Kuras said, but the soil composition is different at certain locations in the park – that's a factor, too. She clarified that there are water table issues at other parks, but nothing to the degree they're seeing at Windemere.

Barrett recalled that when the city decided to put in rain gardens at Burns Park, they were slow to let the community know about it. He wondered what kind of outreach was happening for the tennis courts at Windemere. Colin Smith, parks and recreation manager, indicated that outreach would occur when the staff had more information to share. If it makes sense to move the tennis courts, the neighborhood would need to be engaged, he said.

Tim Doyle asked is there's evidence of this same kind of problem at other city tennis courts. He said he's encountered it on a similar project he's working on near Honey Creek, on the west side of town. Warba said that certainly there are areas in the parks that are wetter than they've been in the past. But the Windemere courts are the worst by far.

Sam Offen noted that there are a lot of city tennis courts on the west side of town, but he wondered how many there were on the northeast side. Kuras reported that there are three courts in Leslie Park and two in Sugarbush Park, and it might be possible to accommodate new tennis courts somewhere in Foxfire North Park. All of those parks are in northeast Ann Arbor.

Jeff Alston, a resident who'd spoken during public commentary, pointed out that the courts at Sugarbush are too short for adults to play – they hit the back fence with their rackets, he said.

Gwen Nystuen said she didn't know too much about tennis courts, but that it seemed like the city should assess the distribution and conditions of all of its courts, as well as their overall usage, to get a better idea of where the greatest needs are.

Commissioners and staff also discussed the availability of tennis courts at Ann Arbor public schools, noting that certain times of day and certain days of the week those courts are heavily used by students. Tim Berla noted that Ann Arbor Rec & Ed runs tennis leagues, as does the Ann Arbor Area Community Tennis Association. He pointed out that court conditions aren't just a concern for the city parks – a sinkhole developed at the relatively new tennis courts at Skyline High School, putting one of

the courts out of commission. Berla suggested looking at other materials, such as clay, which he said required more maintenance but wouldn't crack.

Assuming there's need for more tennis courts on the northeast side of town, Berla wondered whether the former Pfizer property – now owned by the University of Michigan – could be a possible location for new courts. He noted that there's a lot of unused land there, as well as available parking.

Drain Project at Veterans Memorial Park

Scott Miller, an engineer with the Washtenaw County water resources commissioner's office, was on hand to give a presentation about a drain project that would affect Veterans Memorial Park. He said the county had been petitioned by the city to do this project. It's referred to as the West Park Fairgrounds project, which is the name of the drain that runs through that section of town – on the west side of town, in the former fairgrounds area. Miller acknowledged that it was a bit confusing, given that a park in a different location is called West Park.

Scott Miller of the Washtenaw County water resources commissioner's office describes an upcoming drain project that will affect Veterans Memorial Park.

The upper end of the drain is located in the Maple Village Shopping Center, where Kmart and Plum Market are located. The drain starts out as a 30-inch pipe and quickly transitions to a 54-inch pipe and then a 66-inch corregated metal pipe as it runs toward town. The pipe runs through Veterans Memorial Park, crosses under Dexter Road and heads east, eventually connecting to a pipe that contains another branch of the Allen Creek.

The city conducted video inspection of the pipe and found several sections that are cracked and corroded, resulting in leaks. Portions of the pipe were clogged with debris. [The city council voted at its Sept. 20, 2010 meeting to petition the county water resources commissioner for this project, estimated to cost roughly $2 million. It will be repaid by the city in annual installments over 15 years.]

Miller said the county staff began work last fall, first clearing the debris and then conducting another video assessment. That revealed two sections of the pipe that have a significant sag, and result in water being held in those sections year-round. One sagging section is in the parking area in the shopping center. Another is in the north side of the park's parking lot that's accessed off of Dexter Road. The preliminary design is to dig up the two sections of sagging pipe and replace them. For the rest of the pipe, the plan calls for putting in a cast lining to reinforce the pipe structurally.

The project would cause minimal disruption, he said, but would include some impact to the parking lot and a small portion of the area west of one of the ballfields. The county is coordinating with the city, which is doing road work and water main replacement along Dexter Road, as well as upcoming work to renovate the ballfields in the park.

The project is in the design phase now, Miller said, with construction expected to begin in the fall.

Drain Project at Veterans Memorial Park: Commission Discussion

Gwen Nystuen asked for more details about how much land would be dug up for the project. Miller reported that in the Maple Village lot, a section about 15 feet wide and 150 feet long would be excavated. In Veterans Memorial Park, the work would be about 15 feet wide and 190 feet long.

Nystuen also commented on the confusing name of the project, and Miller agreed: "It's raised confusion at a lot of levels," he said, but they don't have much latitude to change it.

David Barrett pointed out that there's already disruption to the park – a big pile of dirt has been dumped by the ballfield. He wondered if the county had also coordinated with Ann Arbor Rec & Ed, which runs softball leagues in the park. Miller said the drain work hasn't yet started, so the excavated dirt isn't from their project. Matt Warba, the city's acting field operations manager, clarified that it was likely related to road construction there. Parks and rec manager Colin Smith said the parks staff has been coordinating with Rec & Ed since last year regarding work in the park.

Sam Offen asked about the project's timeframe. It will likely take about two months, Miller replied, but more if there's a lot of rain. In response to another query from Offen, Miller said the county is mindful of the potential flooding impact downstream, but noted that this project isn't intended to increase capacity dramatically. There will be more efficient flow, however.


Ann Arbor park advisory commissioner David Barrett.

Tim Berla clarified that Rec & Ed has cancelled its fall season, which starts in August, because of renovation work on the ballfields at three parks, including Veterans. [PAC had recommended those renovations at their February 2012 meeting.] He asked whether it would be possible to do the park portion of the drain project first, to ensure it would be finished by the spring season. Miller said it probably wouldn't matter – the entire project is expected to be done by the spring of 2013 – but he would look into it.

Berla also asked whether the proposed skatepark – to be located in another part of Veterans Memorial Park – would affect the drain project, in terms of adding runoff. Miller said that although the addition of any impervious surfaces would affect runoff, the pipe is underutilized and has the capacity to handle it.

Smith noted that one of the elements of the skatepark design, as reflected in the request for proposals, will be to include stormwater management that meets or exceeds city standards.

Communications & Commentary

Every meeting includes opportunities for public commentary and communications from commissioners and staff.

Comm/Comm: Public Commentary – Parking in Parks

During public commentary, **George Gaston** told commissioners that he recently visited the University of Michigan's Matthaei Botanical Gardens – it's a lovely place, he said. He had noticed that UM now has metered parking there at $1.20 per hour, between 8 a.m. and 8 p.m. Gaston noted that the city leases its Fuller Park parking lot to UM. It was supposed to be a temporary arrangement, but it's been going on for about 20 years. He wondered if the city has considered taking back control of that lot and and making it a metered lot, too. UM hospital employees use it 24/7, Gaston said, but only pay for part of that time. It could be a great revenue source for the city.

Gaston noted that people park their vehicles all day at Island Park and West Park, as two examples. And with UM planning to build a parking structure on Wall Street that would add another 500 spaces to that area, it might be possible to forego leasing the 18 spaces at Riverside Park to UM and adding metered spaces instead. "You might gain real money out of this," Gaston said. There's precedent in the city for 24-hour metered lots – at the Amtrak station on Depot Street, for example. Right now, it seems the city is undercharging the university for parking. With meters, the lots would be available to anyone if they paid. It might make sense to look into this, he concluded.

Comm/Comm: Project Grow – Public Commentary

Eric Meves, a board member of Project Grow, gave commissioners an overview of the nonprofit. He started by referring to Gaston's comments about parking, noting that Project Grow had to buy parking tags at Matthaei for its gardeners there this year. Meves told commissioners that Project Grow is celebrating its 40th anniversary this year, and he's gardened with the group for 39 of those years.

Several Project Grow gardens are in city parks, so he wanted PAC to become familiar with the organization. It's an educational organization, with assistance for low-income residents. Although the nonprofit has received city funding in the past, it no longer receives public money, he noted.

Project Grow doesn't own any land. About a third of the gardens are located in Washtenaw County parks, and a third on Ann Arbor public school property. The remaining third is evenly divided between

UM land, private property, and city of Ann Arbor parks. About 300-350 families have garden plots each year, Meves said. People do it to grow food, but also for outdoor exercise and to be in a pleasant environment, he said. There's also an element of community – being with your fellow gardeners.


Eric Meves, treasurer of the Project Grow board.

The nonprofit grosses about $40,000 to $50,000 annually, Meves said. About 60% of that comes from plot fees – it costs about $130 for a full plot. About 20% of revenues come from fundraising, primarily through an annual plant sale. The remaining 20% comes from an organic gardening class that Project Grow developed for Washtenaw Community College.

Roughly half of those revenues allow Project Grow to have one half-time employee who works out of his house, Meves said. The group relies on volunteers and a working board. The rest of the funds are used to pay for things like water, utilities, insurance and capital improvements. There are about 40 people on a waiting list for gardens now – demand for gardens is about two to three times what Project Grow can provide, he said.

Meves unfurled a map that he said was made with the help of Merle Johnson and Dan Rainey of the city's information technology department. It showed possible additional locations for gardens within the parks system.

Comm/Comm: Project Grow – Manager's Report

Later in the meeting, Colin Smith reported that parks planner Amy Kuras has been working with the Project Grow managing director [Kirk Jones] to draft an agreement that will outline the formal relationship between the city and the nonprofit. It's been a few years since the city funded Project Grow, he said, but because the group uses city parkland, there's still a relationship. The agreement will stipulate what the procedures are for putting gardens into parks. There have been varied reactions to having gardens in the parks, depending on the neighborhood, he noted. Parks staff will share the agreement with PAC when it's ready, he said.

Tim Berla asked if there's anything PAC or the city can do to help Project Grow identify potential locations for more gardens. Kuras said she works with the organization – sometimes she'll be contacted by someone in a neighborhood who's interested, and she'll in turn contact Project Grow, or sometimes Project Grow comes to her. There are certain requirements, she noted. The land needs to be in a sunny area, and have access to a water source. The city also needs to hold a public meeting if a park is being considered for gardens, and sometimes neighbors don't want it, she said.


From left: Park advisory commissioners Tim Berla and John Lawter. Lawter, who chaired the April 17 meeting in the absence of chair Julie Grand, was reviewing procedural rules with Berla before the meeting. Berla's advice: "No one ever did time" for flubbing Robert's Rules.

Smith noted that the agreement with Project Grow will include details about how PAC can be involved in the process of selecting new locations.

Gwen Nystuen said she appreciated that Eric Meves had spoken to PAC during public commentary. She hadn't realized how many people are involved, and how the city provides relatively little land for

the group. It's useful information, she said, especially given the growing interest in the local food movement.

Tim Doyle clarified with Smith that there is no relationship between Project Grow and the city's greenbelt program.

Comm/Comm: Skatepark RFP

Smith reported that the request for proposals (RFP) for a skatepark at Veterans Memorial Park would be issued the following day. [.pdf of skatepark RFP] The goal is to solicit proposals for a consultant to handle design and oversee construction of the skatepark, which will be located on city-owned property.

Tim Doyle asked how the project would be funded. Smith replied that there are three sources for the roughly $1 million cost of the project: (1) private donations – primarily solicited through the Friends of the Ann Arbor Skatepark; (2) a $300,000 state grant; and (3) up to $400,000 in matching funds from the Washtenaw County parks and recreation commission. The Ann Arbor Area Community Foundation is acting as fiduciary for the project.

The city's contribution will be the land and staff time to manage the process, Smith said, not money. It will be a city-owned asset, he said.

In terms of process, a selection committee – which will include members of the Friends of the Ann Arbor Skatepark, as well as city and county representatives – will be relied on to make a recommendation for the designer. That recommendation will be reviewed by PAC. PAC commissioner David Barrett will serve on the committee. Park planner Amy Kuras is the city's point person on the project.

Construction is expected to start in the spring of 2013.

Gwen Nystuen asked about the relocation of pathways that will be required because of the skatepark location. Kuras noted that some pathways in Veterans Memorial Park are being redone as part of the Dexter Avenue improvement project that's currently underway. Paths that connect to the skatepark will be designed as part of the overall skatepark design, she said.

Comm/Comm: Manager's Report – Market Manager

Smith reported that the field had been narrowed to two candidates to replace Molly Notarianni, who left the job of public market manager earlier this year. He said he hoped to have finalized a hire by PAC's May 15 meeting.

Comm/Comm: Manager's Report – Argo Cascades

The same day as the PAC meeting, the consultant who designed the new canoe/kayak bypass by Argo Dam – Gary Lacy of Boulder, Colo. – was testing the series of drop pools along with city staff. Smith said he had hoped that Lacy would have the time to give an update to PAC about the new Argo Cascades, but the morning had been chilly and Lacy had gotten a late start on the testing, so he wasn't able to attend the meeting.

A grand opening of the Argo Cascades is planned for June, but it will be open to the public before that. May 5 is the date for the first trips from the Argo Pond livery to Gallup Park, Smith said.

Present: David Barrett, Tim Berla, Doug Chapman, Tim Doyle, John Lawter, Karen Levin, Gwen Nystuen, Sam Offen, councilmember Christopher Taylor (ex-officio). Also Colin Smith, city parks and recreation manager.

Absent: Julie Grand, councilmember Mike Anglin (ex-officio).

Next meeting: PAC's meeting on Tuesday, May 15, 2012 begins at 4 p.m. in the city hall second-floor council chambers, 301 E. Huron St., Ann Arbor. [confirm date]

Section: Center Column, Govt., Meeting Watch

The following terms describe the content of this article. Click on a term to see all articles described with that term: **Ann Arbor Parks & Recreation**, **drains**, **park maintenance and capital improvements millage**, **parks budget**, **Project Grow**, **skatepark**, **tennis courts**

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One Comment

1. BY TRACEY WENTZ & BLACKMER
   MAY 1, 2012 at 11:54 am | PERMALINK

   We encourage action, soon. This problem has existed for a long time without solution. Just listen to the nearby neighborhoods say the demand is there and fix a community resource. Seems like a sunk cost without adequate maintenance.

   Consider a local bond issue or ~ and do something.

Exhibit 5

EXHIBIT 5 – GEESE (AND A WOLF) ON STONEBRIDGE POND – FALL 2016

Exhibit 6

EXHIBIT 6 – GEESE ON STONEBRIDGE POND – FALL 2016

Exhibit 7

EXHIBIT 7 – GEESE ON AIRPORT FARM FIELD – FALL 2016

BEFORE THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C.

IN RE: PROPOSED MAJOR RUNWAY EXTENSION PROJECT AT ANN ARBOR MUNICIPAL AIRPORT.	)
PITTSFIELD CHARTER TOWNSHIP MICHIGAN, and COMMITTEE FOR PRESERVING COMMUNITY QUALITY, INC.	)
Petitioners.	)

PETITION TO DENY APPROVAL AND FUNDING FOR THE MAJOR RUNWAY EXTENSION PROJECT AT ANN ARBOR MUNICPAL AIRPORT (ARB) LOCATED IN PITTSFIELD CHARTER TOWNSHIP, MICHIGAN

Communications with respect to this document should be sent to Petitioners' Representative:

Steven M. Taber
TABER LAW GROUP, P.C.
P.O. Box 60036
Irvine, California 92602
(949) 735-8217 (phone)
(714) 707-4282 (fax)
staber@taberlaw.com

Counsel for Pittsfield Charter Township and Committee for Preserving Community Quality, Inc.

January 28, 2013

Notice of Petition to:

Honorable Ray LaHood, Secretary
Department of Transportation
1200 New Jersey Avenue SE
Washington, D.C. 20590

Honorable Michael Huerta, Administrator
Federal Aviation Administration
800 Independence Avenue SW
Washington, D.C. 20591

Ms. Christa Fornarotto
Associate Administrator, Airports
Federal Aviation Administration
800 Independence Avenue SW
Washington, D.C. 20591

TABLE OF CONTENTS

I. STATEMENT OF FACTS

A. The Airport.

Ann Arbor Municipal Airport (ARB) is a general aviation airport located entirely within the boundaries of Pittsfield Charter Township, Michigan ("Pittsfield"). According to AirNav.com, ARB has two runways, a concrete runway 3,505 feet long and 75 feet wide, and a turf runway 2,750 feet long and 110 feet wide. Exhibit 1. AirNav also notes that ARB is the base for 166 aircraft, consisting of 137 single engine airplanes, 16 multi-engine airplanes, 1 jet airplane, 11 helicopters and 1 ultralight. *Id*. ARB averages 161 operations per day, 64% of those operations are local general aviation, and 36% are transient general aviation operations.[1] *Id.* Although located outside the city limits of Ann Arbor, the City of Ann Arbor (the "City") owns and operates the airport.[2] Despite the fact that ARB is located entirely within the boundaries of Pittsfield, the township has no voting representation on any committee, council or board tasked with the management or the operation of ARB.[3]

B. The Petitioners.

1. Pittsfield Charter Township.

Pittsfield is a "charter township." Under Michigan law, a "charter township" is a municipal corporation that has been granted a charter, allowing it certain rights and responsibilities of home rule that are generally intermediary in scope between those of a city and a village. A charter township has greater protections against annexation of a township's land by

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[1] These figures are for the 12-month period ending December, 2011.

[2] Official FAA records actually list "Roger W. Fraser" as the owner of ARB without noting that Roger W. Fraser was the City Administrator for the City until 2011. Exhibit 2. The fact that the Airport is actually owned by the City, however, is noted on ARB's website: http://www.a2gov.org/government/publicservices/fleetandfacility/Airport/Pages/default.aspx.

[3] Both Pittsfield and Lodi Township have a non-voting *ex officio* member on the "Ann Arbor Municipal Airport Advisory Committee." *See* Exhibit 3. However, "the purpose of the [Ann Arbor Municipal Airport Advisory Committee] is to make recommendations to the Ann Arbor City Council regarding the construction and operation of the Airport." *Id.*

cities and villages. As a charter township, Pittsfield has established a variety of municipal services, such as a police force, fire department, assessors and is governed by a comprehensive zoning ordinance. Since ARB is within Pittsfield's corporate jurisdiction, the township provides services to ARB, as well as being subject to the township's ordinances limited only by the agreements between Pittsfield and the City.

The City, in the past, expressed an interest in annexing the property on which ARB sits. This resulted in the 1978 agreement between the City and Pittsfield Township regarding the airport. Exhibit 4. This agreement was modified in 2010. Exhibit 5.

2. Committee for Preserving Community Quality, Inc.

The Committee for Preserving Community Quality, Inc. (CPCQ) is a not-for-profit corporation consisting of approximately 400 residents of the Pittsfield and Lodi Townships and the cities of Ann Arbor and Saline. CPCQ was incorporated in April, 2010, as a community action group for residents of the communities surrounding ARB who feel the airport expansion is "both dangerous and unjustified."

C. The Proposed Project.

According to the draft Environmental Assessment[4] ARB has several issues that impact aviation safety. First, there is a "line of sight" issue whereby aircraft waiting to take off in the holding area for Runway 24 may pass out of sight of the control tower. In addition, because the northeast end of Runway 24 is a few hundred feet from State Road, a busy Township road, aircraft have to approach at slope of 20:1 instead of a more optimal 34:1. Moreover, according to the draft EA, State Road will only get bigger and wider, thereby exacerbating the problem.[5] Thus, according to ARB and MDOT, one goal of the proposed project is to move Runway 24

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4 The City of Ann Arbor issued a draft Environmental Assessment in March, 2010. Exhibit 26.

5 The FAA, in its comments to MDOT, noted that the draft EA does not seem to substantiate the need for "a clear 34:1 approach surface to the east end of the runway." Exhibit 18, pp.4-5.

150 feet to southwest, resolving both the line-of-sight issue and the slope issue. The current 150 feet of runway at the northeast end of Runway 24 would remain as a displaced threshold.

If the project had ended there, Pittsfield and CPCQ (collectively, "Petitioners") may not have objected to it since it has a vested interest in the safe operation of the airport. However, the City also wanted to tack on an additional 800 feet at the southwest end of Runway 24 to make the runway 4,300 feet long. This runway extension, ARB and MDOT have argued, is necessary to "[e]nhance interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions." Thus, all told 950 feet of runway would be added to the southwest end of Runway 24 and 150 feet of the current runway would remain as a displaced threshold. However, there is no aviation safety issue connected to the extension of the runway.[6]

This extension of the Runway 24 qualifies as a "major runway extension" as that term has been defined by the FAA and the courts. The runway extension will permit the accommodation of aircraft that would result in an increase in noise of three decibels. *See Suburban O'Hare Commission,* 787 F.2d at 199-200; and *Town of Stratford v. FAA,* 285 F.3d 84, (D.C. Cir. 2002).

D. Petitioners' Opposition to the Proposed Project.

Petitioners' opposition to the proposed project dates back to the first time Ann Arbor proposed to extend the runway to allow bigger and noisier aircraft into ARB. On January 22, 2007, the Ann Arbor City Council unanimously approved Resolution R-31-1-07, formally adopting the airport's previous Airport Layout Plan (ALP) and called for "staff to bring back a

[6] The draft EA attempts to attach a safety concern to the extension, mentioning that aircraft had a tendency to overrun the runway at ARB. Ultimately, though, each of the runway overruns was found to be unrelated to the length of the runway and due to pilot error, a fact that ARB and MDOT admit in their response to FAA's comments. Exhibit 19, pp.14-15.

separate proposal regarding extending the runway within the next 60 days and that notification of the proposal be sent out to citizens in the surrounding area." Exhibit 6; *see also* Exhibit 31. Unfortunately, not only did the City's staff not return to a public council meeting within 60 days with an expanded runway plan, the City's staff also failed to inform "citizens in the surrounding community" of its actions for twenty months. Instead, on February 28, 2007, just 37 days after its initial City Council Resolution order, the City Staff, citing that Resolution as a basis, submitted a proposal for an 800-foot extension of primary Runway 6/24 at ARB to the Michigan Department of Transportation – Aeronautics Division (MDOT). Exhibit 7. No corresponding notice was given to Pittsfield or to the "citizens in the surrounding area."

On September 12, 2007, the proposed ALP was amended at the request of MDOT to allow for the 150-foot southwesterly movement of the entire primary runway,[7] to provide for the widening of State Street-State Road, which MDOT conceded could not be funded for decades.[8] Neither Pittsfield nor the "citizens in the surrounding community" had yet been informed by the applicant or MDOT about the proposed ALP, which calls for an extension of Runway 6/24 on land within Pittsfield's jurisdiction. The ALP finally was approved by MDOT on April 23, 2008, and presented to the Federal Aviation Administration for approval on June 4, 2008.

In a June 23, 2008, letter from David L. Baker, Manager, AIP Programs of MDOT's Airports Division of the Bureau of Aeronautics and Freight Services, MDOT indicated to the City that the FAA concurred with the approval of the ALP. Yet neither MDOT nor FAA informed Pittsfield or the citizens of the surrounding communities of either MDOT's or the FAA's approval of the ALP. In fact, it was not until August 22, 2008, that the City first

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7 In the end, then, the Project consisted of adding 950 feet of runway to the southwestern end of existing Runway 6/24: 150 feet to move the runway away from State Road and 800 for extending the runway to 4,300 feet. The existing 150 feet of runway at the northeastern end of the runway would remain as a displaced threshold.

8 At this point in time, it is unclear whether the road will be widened at all or, if so, to the west or to the east.

officially provided Pittsfield with the plans and notification of the proposed ARB expansion and detailed proposed changes in the ALP. These documents were required to be provided to Pittsfield more than 18 months earlier under both the January, 2007, Ann Arbor City Council Resolution and under a separate 1979 Policy Statement.[9] *See* Exhibit 6 and 4, respectively. This is also contrary to the grant assurances that the City agreed to, which indicate that prior to receiving any federal funds for the Airport Layout Plan, it must give "fair consideration to the interest of communities in or near where the project may be located" (Grant Assurance 7). *See also* Grant Assurance 6. It is noteworthy, that this first notification from Ann Arbor to Pittsfield is dated 59 days after the FAA approved the revised Ann Arbor Airport ALP. Under 49 U.S.C. § 46110, routine appeals of final agency "orders" are barred after 60 days. Thus, Pittsfield was effectively barred from legally objecting to the Ann Arbor ALP before even being notified by Ann Arbor about its revised ALP.

Unable to file a legal action to stop the City from moving forward with its illegal ALP, Pittsfield responded to Ann Arbor's August notice, objecting to the proposed expansion, citing the (1) increased noise that would be generated, (2) larger aircraft that would be attracted, and (3) and greater use by heavier aircraft that could result.[10] Despite Pittsfield's opposition to the proposed expansion of ARB, the Ann Arbor City Council approved the revised Ann Arbor ALP on September 22, 2008, without considering Pittsfield's objections, or those of Lodi Township, another township close to ARB.

[9] The 1979 policy states, *inter alia*, that "[p]lans for municipal construction on Airport lands must be submitted to the Township for review and comment." Exhibit 4, p.3. The 1979 Policy was amended after the modification of the ALP. Exhibit 5. The amendment makes clear what Pittsfield already thought was plainly obvious under the 1979 policy - that the City must notify Pittsfield prior to modifying the ALP. *See* Exhibit 5, p.2, ¶ 4.

[10] It should also be noted that the new ALP raises the weight limit of aircraft at ARB to 45,000 (single axle) and 70,000 (double axle). Exhibit 31. This change was never discussed by the Ann Arbor City Council, who still believes that the weight limit at ARB is 20,000 pounds.

On March 24, 2009, Pittsfield unanimously approved a Resolution Opposing Proposed Expansion of the Ann Arbor Municipal Airport Runway. Exhibit 8. That Resolution cites several reasons why the runway at ARB should not be expanded. Primary among those reasons is the fact that ARB is "immediately adjacent to a residential area" and that the existing "width and length" of the runway "has not posed any substantial safety concerns in the past." *Id.* In addition, the Resolution states that:

- The proposed changes would shift the runway dangerously close to a busy township road (Lohr Road) and closer to dense residential subdivisions;

- The runway expansion will significantly increase air traffic volumes and noise pollution experienced by residential subdivisions in the vicinity of ARB, thereby resulting in a decline of residential home property values and impacting Pittsfield's tax base;

- The City has not fully demonstrated the economic and safety justifications for undertaking the proposed runway expansion;

- The City has not taken into consideration the negative safety implications such a runway expansion may impose on surrounding residential subdivisions by expanding a runway closer to residential subdivisions.

Id. Lodi Township, which is adjacent to Pittsfield on the west side and also impacted by ARB, passed a similar resolution on May 12, 2009. Exhibit 9. Ann Arbor, MDOT and the FAA did not respond to either Pittsfield or Lodi Township's resolution, despite repeated requests to consider the communities' input into the proposed revision of the ALP and the proposed expansion of ARB.

On June 17, 2009, the FAA issued a Notice of Intent to Prepare an Environmental Assessment and Conduct Citizen Advisory Meetings. Exhibit 10. Although the Notice of Intent stated that "[d]uring development of the draft EA, *a series of meetings* to provide for public input will be held to identify potentially significant issues or impacts related to the proposed action that should be analyzed in the EA" (*id.* (emphasis added)) the only real opportunity for any public discussion -- with elected public officials present -- about the proposed expansion plan was before the Ann Arbor City Council, where speakers must call-in to register in advance. Only the first ten callers on the day of Council meetings are permitted to speak. Speakers are limited to three minutes. Such a process typically has a stifling effect on open and candid discussions for subjects as complex as an airport ALP and runway expansion proposal.

Prior to the FAA's issuance of the Notice of Intent, in the Spring of 2009, a "Citizens Advisory Committee" (CAC) was appointed to advise the preparers of the Environmental Assessment. The CAC was initially comprised of:

- The Ann Arbor Airport manager;
- The chairman of Ann Arbor's Airport Advisory Committee;
- An Ann Arbor 4th Ward resident, who is also a member of the Airport Advisory Committee;
- An Ann Arbor 3rd Ward resident, who is also a flight instructor at the airport;
- Another pilot based at the airport, who is also chief pilot of Avfuel, which stands to be the single greatest beneficiary from the runway extension;
- Another airport flight instructor, who is also a member of the airport-based FAA Safety Team;
- A citizen member from Ann Arbor's 5th Ward;
- A representative from Ann Arbor's 2nd Ward, who is also a member of the Ann Arbor City Council;
- A representative of the Washtenaw Audubon Society, which conducted a previous study that found no Canada geese among 38 other species on the airport;
- Lodi Township Supervisor Jan Godek; and,
- Pittsfield Township Deputy Supervisor Barbara Fuller.

Only after extensive political pressure was applied were two additional outside members added to the CAC:

- Shlomo Castell, a commercial passenger airline pilot from the Stonebridge Community Association in Pittsfield Township, and

- Kristin Judge, Washtenaw County Commissioner from District 7, which includes Pittsfield.

For an airport located in Pittsfield Township that most dramatically impacts Pittsfield and Lodi Townships and Ward 4 of Ann Arbor, the CAC was dominated by the City and airport members who stood to benefit from the expansion. It was apparent that ARB intended the CAC to under-represent those immediately outside the airport perimeter whose safety could be placed at greater risk by any expansion. Ultimately, however, the CAC was a powerless committee intended only to provide the façade of public participation in an essentially authoritarian decision-making process. The CAC only met three times, with no opportunity for public participation. According to records available to Petitioners, CAC first met on May 4, 2009, to receive information about the proposed project. Exhibit 11. The second meeting was held on July 20, 2009, at which some of the initial findings were presented by ARB's consultants. Exhibit 12. No members of the public were allowed to attend or ask questions. *Id*. Instead, members of the CAC were expected to interact with their "constituencies" and express to the committee their comments and concerns outside of the CAC. *Id.* The final meeting was held on February 22, 2010, when the executive summary of the draft EA was presented to the CAC. Exhibit 13.

This was not the "series of meetings to provide for public input … held to identify potentially significant issues or impacts related to the proposed action that should be analyzed in the EA" that MDOT and the FAA promised. The public was not invited to participate at the CAC meetings. Instead, the members of the CAC received information from ARB's consultants and were expected to relay it back to their "constituencies." When the CAC had suggestions or recommendations, they were often ignored by ARB staff and consultants. For example, Shlomo Castell, a Delta 747-400 pilot and the only commercial pilot who was a member of the CAC, asked that the consultants request bird strike information from the FAA and study it prior to submitting the draft Environmental Assessment, since he himself had experienced a bird strike and since there is a substantial Canada goose population at and around ARB. However, ARB's consultants ignored that request. In the end, the CAC did not come up with any recommendations or findings to be presented to ARB's consultants. Instead, it operated solely as a method for ARB's consultants to disseminate propaganda about the importance of the expansion, while giving the FAA, MDOT, and the City the cover they needed to state that they were providing "public participation."[11]

The other avenue for the public to influence ARB's and MDOT's decision was through the AAC. But the AAC is also heavily weighted in favor of ARB's interests. Although both Pittsfield and Lodi Township have "*ex officio*" members on the AAC, they have no voting power, and the Mayor of Ann Arbor appoints the remaining members. Even if Pittsfield and/or Lodi Township did have voting powers, the AAC has no decision-making authority, and can only recommend actions be taken. During the period in between the FAA's Initial Notice and the publication of the draft EA, the AAC met five times. However, the AAC also limits the time that the public can speak to only three minutes. Thus, it was impossible for the AAC to receive all of the information it needed to make well-reasoned decisions and recommendations with respect to the extension of Runway 6/24 at ARB.

[11] In fact, public access to the CAC was so limited and tightly controlled that Mr. Castell was falsely accused of using his laptop to record the CAC meeting and broadcast it over Skype, which the rules of the CAC prohibited.

On March 19, 2010, the FAA issued its Notice of Availability of Draft Environmental Assessment concerning the expansion at ARB. Exhibit 14. The FAA's Notice of Availability indicated that written comments would be received by MDOT until 5:00 p.m. EST April 12, 2010. In addition, the FAA's Notice of Availability indicated that there would be a "public hearing to provide information on the draft EA and accept comments from the public" on March 31, 2010. However, the "public hearing" actually was a three-hour "open house" held during the dinner hour period between 4-7 pm, during which individuals could assemble and provide public comments in response to the Environmental Assessment. Local media announcements of the event (AnnArbor.com) encouraged citizens to send comment letters directly to the Airport Manager, rather than MDOT, until Petitioners intervened and requested that MDOT correct the process to restore a semblance of fairness. At the session itself, there was no dais of public officials impaneled to answer the public's numerous questions. There were no open, public statements with the media present. All testimony was given in private rooms to court reporters, to be forwarded to MDOT for later evaluation and, presumably, incorporation into the final EA.

That citizens, not public officials, needed to police the process was the ultimate insult to ensure any semblance of fairness and equity. Because this public hearing process was so restrictive, members of the public were effectively deprived of their due process rights under the 14th Amendment of the U.S. Constitution. Pittsfield and its citizens have not had an opportunity to speak in an open and fair forum for a reasonable amount of time in opposition to the extension of Runway 6/24 at ARB before a public body on an issue that directly impacted their physical and economic well-being. That is because, if the extension proposal goes forward, the Ann Arbor City Council generally restricts all outside speakers to three minutes, which is hardly an adequate time to offer an organized and coherent argument against such a complex proposition as an airport expansion. At the same time, city officials and their surrogates are afforded unlimited time to speak to the City Council to advocate in favor of the runway extension, in clear violation of due process protections. Thus, by closing off the fairness and balance intended by holding this only federally-mandated forum, ARB and MDOT were able to stifle the only open public commentary and dissent regarding the airport in violation of the law.

Both Pittsfield and CPCQ submitted comments to the draft EA on April 19, 2010,[12] outlining in great detail the inadequacy of the draft EA and the need for a proper Environmental Impact Statement instead of an Environmental Assessment. *See* Exhibits 15 and 16. The Washtenaw County Water Commissioner also submitted comments to the draft EA, expressing serious concerns regarding inaccurate statements and the failure of the draft EA to address critical water resources issues with respect to the proposed project. Exhibit 17.

The Washtenaw County Water Commissioner was not alone is having reservations about the Project. On May 13, 2010, the Federal Aviation Administration also submitted comprehensive comments on the draft EA, raising a whole host of serious issues that the draft EA left unaddressed. *See* Exhibit 18. In particular, the FAA expresses its doubts of the Project's qualifying as a "safety" project, when the draft EA does not present any evidence for the need for the safety improvements detailed in the draft EA. These relate to the shifting of the runway 150 feet to the southwest so that sight lines between the Air Traffic Control Tower and the aircraft on the taxiway could be improved as well as allowing for the implementation of 34:1 approach instead of the current 20:1 approach. In its November 15, 2010, response, MDOT seems to abandon all of the safety improvements to the airport as being part of the "purpose and need,"

[12] MDOT and FAA extended the comment period from April 12, 2010, until April 19, 2010.

while still maintaining that 950 feet of impervious surface needs to be added to the southwest end of the Runway 6/24. *See* Exhibit 19.

The issue of lighting at ARB also raised FAA's concern. Since the FAA owns and controls the lighting at ARB, the relocation or replacement of the current approach lighting system as well as the development for future approach procedures for the new runway end locations is solely a federal action not within the scope of MDOT's block grant authority. Yet, the FAA points out, the draft EA fails to cover the environmental impact of the relocation and/or replacement of the approach lighting would have. Exhibit 18, p.1. Because of this fact, an additional environmental assessment has been ordered, but has yet to be completed.

Finally, the FAA requested that additional information be submitted regarding the number of critical aircraft using ARB and how ARB arrived at its conclusion that there were over 500 itinerant operations of the critical aircraft at ARB to justify the extension of the runway. The FAA concluded its comments by stating:

> Since there are several updates/clarifications requested by the FAA contained in this letter and the sponsor's responses may be substantial, it would be prudent to afford the public an additional opportunity to review and comment on the changes that are anticipated to be made for the final draft publication. Most specifically, the document will need to clearly outline the requested local, state and federal actions. Since this was not clearly presented in the initial draft EA, the FAA may consider these changes and clarifications as a material change to the document that should result in solicitation of additional public comment.

Exhibit 18, p.9.

But the story does not end there. There is a growing lack of support by the Ann Arbor City Council for the extension of the runway. The Ann Arbor City Council has removed ARB's expansion project from its Capital Improvement Project list for both 2011 and 2012. In addition, despite the fact that the City's portion of additional consulting work to be performed amounts to the relatively small sum of $1,125, the resolutions approving these expenditures were met with considerable skepticism and opposition by the City Council on the utility of the expansion. One City councilman remarked that he would "vote no on everything. It's taxpayer dollars, whether it's local or federal." Exhibit 20. He continued, stating that his constituents do not want the runway extension and he would vote no on that, too. *Id*. Another Council member allowed that the city's portion of the bill was very small but "what the council would be doing is spending money on something that won't move forward" reiterating the fact that the City Council had removed the project from the CIP, which, the Council member said, "translated into a decision that the council wouldn't move forward [with the extension of the runway]." *Id.*

II. LEGAL BASIS FOR PETITION

A. Statutory Basis for Pittsfield Petitioning the Secretary of Transportation.

Federal law gives communities[13] the right to petition the Secretary of Transportation about proposed airport development projects in their communities. 49 U.S.C. § 47106(c)(1)(A)(ii), states in pertinent part, that:

> (1) The Secretary [of Transportation] may approve an application under this subchapter [49 U.S.C. §§ 47101 *et seq.*] for an airport development project involving the location of an airport or runway or a major runway extension –
>
> (A) only if the sponsor certifies to the Secretary that –
>
> . . . .
>
> (ii) the airport management board has voting representation from the communities in which the project is located *or* has advised the communities that they have the right to petition the Secretary *about* a proposed project[14] . . . .

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[13] Federal law does not define the term "communities." Thus, for purposes of this petition, Petitioners consider both Pittsfield and CPCQ to have standing to petition the Secretary of Transportation under federal law since they are both community organizations.

[14] This does not mean that the right to petition the Secretary does not exist for "communities" that have voting representation on the airport management board, only that the sponsor is not required to certify that it advised such communities that they have a right to petition the Secretary.

49 U.S.C. § 47106(c) (emphasis added). Congress, as part of the Airport and Airway Safety, Capacity, Noise Improvement, and Intermodal Transportation Act of 1992 (Pub. L. 102-581), added subsection (A)(ii) stating "the sponsor of the project certifies to the Secretary that the airport management board either has voting representation from the communities where the project is located or has advised the communities that they have the right to petition the Secretary concerning a proposed project."

The provision, however, is somewhat of an anomaly, since the provision itself does not give the communities the right to "petition the secretary," it states instead that prior to receiving approval of a grant for an "airport or runway or a major runway expansion," the sponsor must advise the communities of their right to petition the secretary "about a proposed project." This provision implies that the statutory "right to petition the secretary" exists beyond the scope of the paragraph, although it is the legal duty of the airport sponsor to inform "the communities" of their statutory right to petition the Secretary regarding the project *prior* to the sponsor receiving funding for the project. That is, this paragraph does not give the communities the right to petition the Secretary, but instead only requires that the sponsor certify that it has informed the communities of that pre-existing right. Thus, the communities' right to petition the Secretary of Transportation is separate from the sponsor's duty to inform the communities of that right.

Moreover, the paragraph also implies that the content of the petition need not solely concern environmental matters. Although the paragraph is entitled "Environmental Requirements," as explained above, the *right* to petition the Secretary exists separate and apart from the sponsor's duty to inform "the communities" of that right as part of the "Environmental Requirements." Indeed, one of the few cases to pass judgment on this statutory provision came to a similar conclusion. In *Communities Against Runway Expansion, Inc. et al. v. Federal Aviation*

Administration, 355 F.3d 678, 689 (D.C. Cir. 2004), the U.S. Circuit Court of Appeals for the District of Columbia held that 49 U.S.C. § 47106(c)(1)(A)(ii) was part of the grant application procedure, not the environmental procedure. On that basis the court rejected petitioners' claim that the Environmental Impact Statement was inadequate because the EIS failed to inform the communities of their right to petition the Secretary of Transportation. Thus, the scope of the petition to the Secretary goes beyond mere environmental analysis and extends to all reasons and issues why a proposed project should or should not be undertaken.

In addition, implicit in the language of the paragraph is the scope of the projects about which "communities" have a right to petition the Secretary. Although the statute states that the sponsor need only certify to the Secretary that "the communities" have been informed of their right to petition the Secretary for airport development projects that involve "the location of an airport or runway or a major extension," the paragraph states that the communities' right to petition extends to "a proposed project." The preceding clause in the paragraph states the certification is not necessary if the "airport management board has voting representation from the communities in which *the* project is located …" 49 U.S.C. § 47106(c)(1)(A)(ii)(emphasis added) *compare* "… has advised the communities that they have the right to petition the Secretary about *a* proposed project" (emphasis added). Had Congress intended that the right to petition the Secretary only extend to projects "involving the location of an airport or runway or a major runway extension," it would have used the definite pronoun "the" to indicate the project that is the "location of an airport or runway or a major extension." Instead, Congress uses the indefinite pronoun "a" coupled with the further distinction "proposed" to indicate a wider category of airport development projects. Thus, Congress must have meant to make a distinction between "in which the project is located" and "about a proposed project." And that distinction can only be that the right to petition the Secretary goes beyond limiting factors expressed in (c)(1).

B. Constitutional and Administrative Procedure Act Bases for Petition.

In addition to the provisions of the Airport and Airway Safety, Capacity, Noise Improvement, and Intermodal Transportation Act of 1992, the United States Constitution and the Administrative Procedures Act also give Petitioners a basis for petitioning the Secretary. The First Amendment of the U.S. Constitution states that "Congress shall make no law . . . abridging . . . the right of the people . . . to petition Government for a redress of grievances." U.S. Const., amend. 1. This right has been upheld numerous times by the courts. The right to petition for redress of grievances is among the most precious of the liberties safeguarded by the Bill of Rights. *United Mine Workers of America, Dist. 12 v. Illinois State Bar Association*, 389 U.S. 217, 222 (1967). It shares the "preferred place" accorded in our system of government to the First Amendment freedoms, and has "a sanctity and a sanction not permitting dubious intrusions." *Thomas v. Collins*, 323 U.S. 516, 530 (1945). "Any attempt to restrict those First Amendment liberties must be justified by clear public interest, threatened not doubtful or remotely, but by clear and present danger." *Id*. The Supreme Court has recognized that the right to petition is logically implicit in, and fundamental to, the very idea of a republican form of government. *United States v. Cruikshank*, 92 U.S. (2 Otto) 542, 552 (1875).

The purposes of the Administrative Procedure Act (5 U.S.C. § 551 *et seq.*) have been generally described as (1) to require agencies to keep the public informed of their organization, procedures and rules; (2) to provide for public participation in the rulemaking process; (3) to establish uniform standards for the conduct of formal rulemaking and adjudication; and (4) to define the scope of judicial review. Since this petition falls within the definition of "rule making" (5 U.S.C. § 551), the Administrative Procedure Act applies to the extent that Airport and Airway Safety, Capacity, Noise Improvement, and Intermodal Transportation Act of 1992 lacks clear direction.

III. NEITHER MDOT NOR THE FAA HAS GIVEN THE COMMUNITIES' INTEREST "FAIR CONSIDERATION" AS REQUIRED UNDER FEDERAL LAW.

The aviation statutes of the United States make it incumbent on the Federal Aviation Administration to ensure that communities are given the opportunity to express their frustration with a process that has explicitly disenfranchised them. *See* 49 U.S.C. § 47106(b)(2). That statute requires that before any federal funding of an airport development project takes place, the "Secretary must be satisfied that …the interests of the community in or near which the project may be located have been given fair consideration." 49 U.S.C. § 47106(b)(2). Thus, Petitioners ask federal intervention to preserve their due process rights, since local government has been afforded no voice in the ultimate decision as to whether the Project proceeds within Pittsfield's jurisdiction.

A. The Expansion at Ann Arbor Municipal Airport Does Not Comply With Planning in the Surrounding Communities.

The FAA has a duty under the law to ensure that federal funds are used properly for airport development projects that are required to fulfill the FAA's mission. Because of the substantial authority given to the Secretary of Transportation by Congress with respect to the development of airports, it is absolutely imperative that the concerns and issues of the surrounding communities are taken into account *prior* to approval of a project. This policy is reflected not only in the statutes that the FAA is bound to uphold, but in its regulations and guidance documents that it has issued. One place this policy is shown is in the assurances that airport sponsors, owners and operators are bound to follow upon accepting federal funds for airport development. In particular, grant assurances 6 and 7 state:

> 6. Consistency with Local Plans. The project is reasonably consistent with plans (existing at the time of submission of this application) of public agencies that are authorized by the State in which the project is located to plan for the development of the area surrounding the airport.
>
> 7. Consideration of Local Interest. It has given fair consideration to the interest of communities in or near where the project may be located.

FAA Airport Sponsor Grant Assurances, Exhibit 21. Thus, approval of this project without the approval by Petitioners would be a violation of ARB's grant assurances.

B. The City's Goals Are Not the Same as Petitioners' Goals.

While Petitioners recognize the safety concerns presented in the draft EA, they are less sympathetic with growth inducing aspects of the project which would subject both the government of Pittsfield and the people of Pittsfield to untold potential future damage. This damage would come in the form of both safety risks and in economic loss because of repeated flights of low flying, heavy jet aircraft. Pittsfield and its residents would have no choice but to seek recovery in the event of a tragic accident or inverse condemnation class action proceedings, from the City potentially leaving Pittsfield victims without an effective remedy at law.

1. The Project would increase safety concerns of low-flying aircraft near surrounding densely populated communities.

Petitioners would be subjected to a perfect storm of potential risks from low-flying aircraft in heavily populated neighborhoods that are also occupied by wildlife, including many Canada geese, during much of the year. *See* Exhibit 22 for map of ponds surrounding the airport that support Canada Geese. This is confirmed by a study conducted by MDOT and Ann Arbor's own airport architects (URS Corporation), which was excluded from the draft EA, and visualized on a projection of what the approach to an expanded Runway 6 would look like relative to the close proximity to area homes, which was corrected for accuracy. Exhibit 23.

The safety of having an airport so close to a densely populated area is not an unfounded fear. In June, 2009, a small single-engine plane attempting to land at ARB instead made an emergency landing 1,200 yards short of Runway 6/24 on a Stonebridge Golf Club fairway in Pittsfield after its engine died at low altitude on final approach. Exhibit 24. The pilot said if there had been people on the fairway at the time, he would have "crashed into the trees," which would have probably been fatal for him and his grandson, whom he was instructing at the time. *Id*. Moreover, it is not insignificant that between 1973 and 2001 nine people died from accidents flying in the Ann Arbor Airport traffic pattern within three miles of the airport. Exhibit 25. With Runway 6/24 extended 950 feet farther to the southwest and even closer to hundreds of homes, as proposed, and planes still lower on approach – and planes heavier, larger, carrying greater payloads, and more people – this poses a risk too grave to bring to a heavily populated community as well as to the users of ARB.

2. As a result of the Project ARB will attract more and heavier aircraft, which will increase the safety risk to the surrounding community as well lower their property values.

Extending Runway 6/24 by 950 feet will attract more and heavier jets (as well as larger multi-engine aircraft) while bringing them closer to heavily populated residential areas. ARB estimates that jets would be within 600 yards at altitudes of 93 feet above rooftops of homes, or lower, on a regular basis. Aircraft landing on Runway 6 would pass Lohr Road below 90 feet, which is the site of a new, planned non-motorized bike path, designated the Lohr-Textile Greenway Project, for which the Washtenaw County Parks and Recreation Commission has awarded Pittsfield a $300,000 Connecting Communities grant. Thus, low-flying, heavy jets would be landing just feet over people traversing a new non-motorized trail.

This is especially dangerous with heavier aircraft because, in the event of any common multi-engine aircraft mishaps – such as an engine failure on takeoff, a bird strike on takeoff, climb out, or approach, or similar incident – with aircraft in very close proximity to homes, the risk could be grave – a perfect storm of environmental or human risk. For example, a twin-engine jet losing one of its engines would lose 80 percent of its climb performance. At low altitudes that could be tragic. Likewise, the loss of an engine in a light twin-engine aircraft would be catastrophic, since the aircraft would not be able to continue to climb on one engine in takeoff configuration. Neither could it turn back toward the airport at low altitude in takeoff configuration.

Such impacts and safety implications on political jurisdictions where airports are located and where the airport decision-making bodies are devoid of local citizens and local governments must be investigated carefully and thoroughly by the governmental entities empowered to protect the safety of all concerned. The Department of Transportation and the FAA must protect the health and well-being of the people on the ground as well as those in the air from the inherent risks of aviation.

IV. THERE IS NO AVIATION SAFETY NEED TO EXTEND RUNWAY 6/24 AT ANN ARBOR MUNICIPAL AIRPORT BY 950 FEET.

The draft EA and the initial statements by ARB and MDOT tend to indicate that the primary purpose of the Project is to increase the safety at ARB. While parts of the Project may, in fact, contribute to an increase in aviation safety at ARB, the extension of Runway 6/24 will not provide any more safety either to those using the airport or to those on the ground.

A. Not All Alternatives That Would Meet the Stated Objectives for the Airport, Yet Still Meet the Stated Objectives and Goals, Were Considered.

As part of the National Environmental Policy Act ("NEPA") (42 U.S.C. §§ 4321 et seq.) process, federal agencies are required to examine all reasonable alternatives in preparing environmental documents. 42 U.S.C. § 4332(c)(iii). An agency preparing an EA should develop a range of alternatives that could reasonably achieve the need that the proposed action is intended to address. The Council on Environmental Quality ("CEQ") Regulations ("NEPA Regulations"), which implement NEPA, require that Federal agencies "[u]se the NEPA process to identify and assess the reasonable alternatives to the proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment" 40 C.F.R. § 1500.2(e), and that "agencies shall . . . (a) Rigorously explore and objectively evaluate all reasonable alternatives . . ." 40 C.F.R. § 1502.14(a). The Project, as presented by ARB, has failed to explore all reasonable alternatives to the Preferred Alternative selected.

1. The draft EA utterly fails to give proper consideration to all reasonable alternatives.

The draft EA on p. 2-5 lists five objectives of the proposed project:

- Enhance interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions.

- Enhance operational safety by improving the FAA ATCT line-of-sight issues.

- Enhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road.

- Reduce the occurrence of runway overrun incidents by small category A-I aircraft (local objective).

- Relocate and potentially upgrade the Runway 24 Approach Light System.

Exhibit 26, p. 2-5. To that end, ARB and MDOT dismissed out of hand the alternatives of "use other airports," "construct new airport," and "extend runway to the east." While Petitioners may agree that constructing a new airport and extending the runway to the east may not be feasible either economically or practically, the alternative "use other airports" should have been given more consideration. In particular, Willow Run Airport (YIP), as the draft EA notes "is capable of accommodating any of the aircraft that currently fly into ARB" and that it is located a mere 12 miles from ARB, or 20 minutes by surface transportation. But because some corporate magnates want to be able to fly in on their corporate jets to be 12 miles closer to their offices, federal taxpayers will have to expend millions of dollars on extending the runway at ARB. Moreover, ARB and MDOT imply that interstate commerce will be "enhanced" by the extension of the runway, when, in fact, it will take business away from Willow Run Airport – which already has the infrastructure and excess capacity in place to accept the larger aircraft that ARB so desperately desires.

The FAA reached the conclusion that some of the alternatives mentioned in the draft EA were not given a complete treatment. For example, the FAA stated that: "[b]ased on the information presented in the draft EA, the FAA has not reached the same conclusion that alternatives 1 and 2 do not meet the stated needs for the project."[15] Exhibit 18, p.7. If that is the case, then the draft EA must examine the environmental impacts of alternatives 1 and 2. Moreover, the FAA pointed out "[a]dditional alternatives that may be considered for evaluation to address the need statements could include a combination of items such as: alternative modes of transportation to address enhancing interstate commerce, removal or relocation of obstructions

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[15] *See also* "… table [3-1] appears to incorrectly dismiss alternative 1 because it does not meet purpose and need. The discussion in 3.3.2 does not support that conclusion." Exhibit 18, p.7.

that limit ATCT line of sight issues, and raising or constructing a new ATCT to address the line of sight issues." *Id.*

2. Even after ARB and MDOT changed the need for the Project after the draft EA was published, they have failed to consider all reasonable alternatives.

However, in response to the FAA's comments, ARB and MDOT jettison their concern for the line-of-sight issue and the need for a 34:1 approach on the east end. MDOT and ARB, in their response to the FAA, specifically state that "[t]here is currently not a 'need' for the 34:1 approach." Exhibit 19, p.10. Indeed, ARB and MDOT restate the need in the November 15, 2010, letter as being "based on the objective of providing a primary runway of suitable length to safely accommodate critical category aircraft without operational weight restrictions." *Id.,* p.8. If that is the case – then Build Alternative 2, extending the existing runway 800 feet to the west (instead of 950 feet), should have been more fully examined in the environmental assessment. According to the draft EA Build Alternative 2 was rejected for further consideration because "[k]eeping the east runway end in its current location would not address the tower line of sight issue or the need for a 34:1 approach on the east end." Exhibit 26, p.3-9. The draft EA is not sufficient if the need purposed is simply providing "a primary runway of suitable length," since it failed to assess properly the environmental impacts of Build Alternative 2. In addition, if the need is simply to provide "a primary runway of suitable length," ARB and MDOT have not yet shown that the need cannot be met by using Willow Run Airport instead of ARB.

On the other hand, if the tower line of sight issue or the need for a 34:1 approach on the east end are, indeed, issues that should be addressed, then ARB and MDOT have failed to take into account yet another alternative. The "need" to address the tower line of sight issue and the "need" for a 34:1 approach on the east end could be met by simply shifting Runway 6/24 150 feet to the southwest, *i.e.*, removing 150 feet from the approach end of Runway 24 and adding 150 feet to the departure end of Runway 24. Runway length would remain 3,505 feet.

Section 2.2.1 of the draft EA states that a 150-foot shift of the Runway 24 threshold to the west would (1) enhance the safety of ground operations by taxiing aircraft; (2) enhance operational safety, and possibly prevent runway incursions, by expanding the view of the hold area and parallel taxiway to ATCT personnel; (3) allow for a clear 34:1 approach surface to the east end of the runway, providing an added margin of safety between approaching aircraft and ground-based obstacles, which is particularly beneficial when aircraft are operating in low-visibility conditions; and (4) include relocation and replacement of the existing runway approach light system with newer Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF). Exhibit 26. Shifting Runway 6/24 150 feet to the Southwest without lengthening the runway would also accommodate future widening of State Road. Nevertheless, this "reasonable alternative" was not considered in the draft EA. An Environmental Assessment "shall include brief discussions of . . . alternatives . . ." 40 C.F.R. § 1508.9(b).1. Absent an analysis of an alternative based on a 150-foot southwesterly shift of the runway, without lengthening the runway, the EA is inadequate and the Project should not be approved.

B. Resolving ARB and MDOT's "Need" Through the Extension of Runway 6/24 Is Unsupported by the Evidence.

An Environmental Assessment must include a discussion of the purpose and need for the proposed action that must "specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action." 40 C.F.R. § 1502.13. In addressing the "purpose and need" section of an EA, FAA Order 1050.1E provides that: "[t]his discussion identifies the problem facing the proponent (that is, the need for an action), the purpose of the action (that is, the proposed solution to the problem), and the proposed timeframe for implementing the action." FAA Order 1050.1E, ¶ 405c. The draft EA accomplishes none of these goals and ARB and MDOT have not discussed or examined what exactly the need for the Project is. Although the draft EA never specifies the need for the Project, it does identify the purpose along with various "objectives." *See supra* pp.25 – 26.

1. The Project is not supported by any reasonable and independent evidence and does not solve the problem it purports to solve.

First, the draft EA defines the purpose of the Project as "to provide facilities that more effectively and efficiently accommodate the critical aircraft that presently use the airport, as well as to enhance the operational safety of the airport." Exhibit 26. After being taken to task by the FAA for its lack of a clear definition of a "need" in the draft EA, ARB and MDOT responded that the need (although nowhere to be found in the draft EA) "for the project is based on the objective of providing a primary runway of suitable length to safely accommodate critical category aircraft without operational weight restrictions."[16] Exhibit 19, p.8. The draft EA defines "critical aircraft" as "the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport," and claims that a 2009 MDOT Airport User Survey "has confirmed that the critical aircraft classification for ARB is 'B-II Small Aircraft.'" Exhibit 26, p.2-4. To effectuate the stated purpose, the draft EA purports to support the construction of a runway extension from 3,505 feet to 4,300 feet. However, the evidence is clear that no "B-II Small Aircraft" require a 4,300 foot long runway. All B-II Small Aircraft are capable of operating on the existing 3,505 feet long runway without weight restriction. In fact, the representative B-II Small Aircraft cited by ARB as justification for the Project, the Beechcraft King Air 200, requires only 2,579 feet of runway to take-off fully loaded, and 2,845 feet to land.

[16] As defined by the FAA in FAA Order 1050.1E, ¶ 405c, this is not a "need" but simply a restatement of the purpose. ARB and MDOT have yet to identify and discuss in any reasonable manner "the problem facing the proponent."

See, http://www.hawkerbeechcraft.com/beechcraft/king_airb200gt/specifications.aspx. Thus, the statement that "[d]evelopment of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small Aircraft to operate at their optimum capabilities (without weight restrictions)," although true, is misleading. Exhibit 26.

There is no need to extend Runway 6/24 to allow B-II aircraft to operate at ARB. They can operate on a 3,505 foot runway without weight restrictions. Therefore, the statement that interstate commerce would be negatively impacted by B-II weight restrictions does not state a valid need, and the purported purpose of "provid[ing] facilities that more effectively and efficiently accommodate the critical aircraft that presently use the airport" is an unnecessary solution to a nonexistent problem.

2. ARB's justification for the Project incorrectly relies on total annual operations to support extending Runway 6/24.

The draft EA states, "[t]he critical aircraft, or grouping of aircraft are generally the largest, most demanding types that conduct at least 500 operations per year at the airport," and concludes that the proper Airport Reference Code ("ARC") for ARB is B-II, based on a total of "750 actual annual operations by B-II category critical aircraft from survey data year 2007." Exhibit 26. However, the draft EA's use of "annual operations" differs markedly from the FAA criteria for selecting runway lengths and widths set forth in FAA Order 5090.3C:

> 3-4. AIRPORT DIMENSIONAL STANDARDS
>
> Airport dimensional standards (such as runway length and width, separation standards, surface gradients, etc.) should be selected which are appropriate for the critical aircraft that will make substantial use of the airport in the planning period. Substantial use means either 500 or more *annual itinerant operations*, or scheduled commercial service.

FAA Order 5090.3C, p. 21 (emphasis added). It should be pointed out that FAA Order 5090.3C does not state that critical aircraft must be the "largest." The FAA divides General Aviation operations into two categories, “local” and “itinerant.” Itinerant operations are defined as “an operation performed by an aircraft, either IFR, SVFR, or VFR, that lands at an airport, arriving from outside the airport area, or departs an airport and leaves the airport area.” U.S. DOT JO 7210.695, p.5. Local operations are defined as “those operations performed by aircraft that remain in the local traffic pattern, execute simulated instrument approaches or low passes at the airport, and the operations to or from the airport and a designated practice area within a 20-mile radius of the tower.” *Id*.

The draft EA, without reference to this distinction, relies on “annual operations” and “total annual operations” not “itinerant operations.” *See* Exhibit 26, Table 2-1, p. 2-10. Separating itinerant and local operations at ARB would result in a dramatic reduction in the number of annual critical aircraft operations at the airport. For example, data from the website City-Data.com shows that there were 25,064 itinerant operations and 44,174 local operations at ARB in 2008. *See*, http://www.city-data.com/airports/Ann-Arbor-Michigan.html. In that itinerant operations account for approximately 36% of the total operations at ARB, itinerant B-II operations for 2007 would be in the neighborhood of 300 operations per year (40% of 750 total operations), substantially below the FAA’s threshold of 500 annual operations to constitute “substantial use.” Moreover, the Airport User Survey shows only 293 annual B-II operations at ARB in 2007. Thus, the FAA Order 5090.3C airport dimensional standards for B-II small aircraft do not apply.

Even if, for argument’s sake, we were to accept the critical aircraft data reported in the Airport User Survey, a detailed analysis shows that a weighted average of 78 percent of those B-II aircraft operations took place within a 450-mile radius of ARB, according to MDOT’s own data analysis. Exhibit 27. These represent areas that are within the flight range of ARB’s current based fleet, according to the User Survey data, from the current-length runway. Thus, by another means of calculus, itinerant operations beyond the range of need are fewer than 200 and the Purpose and Need fails.

Further, MDOT's choice of 2007 as a year of certification for critical aircraft was based on an arbitrary and capricious decision. The year 2007 represents the greatest number of ARB operations in the 5-year period 2004-2009 and was selected, according to the MDOT analyst involved, because "our thoughts were that the current recession could possibly have affected the 2008 operational levels in such a way that 2008 year records would not be a true indicator of a post-recession return to normal operations at the airport. . .." Exhibit 26. Even the FAA suggests ARB will not return to such high operating levels as 2007 for the next 20 years. Thus, MDOT was showing bias and affording Ann Arbor a huge advantage in not even evaluating operational data from any other year, particularly one that is more recent than 2007. Objectively, since its standard is the independent FlightAware data base, MDOT should analyze critical aircraft operational data for the five years 2007-2012 and base its decision on an average of those years' operational data. However, such aircraft operational data should be (1) independent, (2) verifiable, and (3) operationally detailed.

At the FAA's request, ARB examined the aircraft operational data for 2009. However, despite ARB and MDOT's claim that "there were still over 500 annual itinerant operations conducted by category B-II at ARB in 2009" (Exhibit 19, p.13), the data provided by ARB and MDOT could only support 346 critical aircraft (not necessarily itinerant) flights. These were the only flights that were (1) independent, (2) verifiable, and (3) operationally detailed, since they were derived from the FlightAware database. Since this is a critical issue, only operational data meeting these criteria should be used. MDOT's analyst, however, allowed purported additional critical aircraft flights (again, not necessarily itinerant flights) based on a corporate pilot's one-line letter certification. These flights were unsupported by the FlightAware data or other independent criteria. Because these flights are not verifiable, independent or operational detailed they must be excluded from the determination of the critical aircraft category at ARB.

3. Shifting Runway 6/24 150 Feet to the Southwest Will Not Achieve an Additional Margin of Safety.

The draft EA states that part of the Project's purpose is to "[e]nhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road." Exhibit 26. Operational safety in low visibility conditions will not be enhanced by providing a clear 34:1 approach surface to Runway 24. The draft EA is correct in stating that shifting the Runway 24 threshold 150 feet west would enhance safety by effectively removing the current obstruction to line-of-site vision (hangar) of the parallel taxiway for ATCT personnel. Exhibit 26. However, in the next paragraph the draft EA states, "The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles." Exhibit 26. This statement lacks support in either the Instrument Approach Procedure (IAP) design or Terminal Instrument Procedures ("TERPS") Obstruction Standards. Both the 20:1 and the 34:1 surfaces exist simultaneously for every published IAP, and are defined as "Obstacle Identification Surfaces," which do not establish obstacle clearance safety margins, but rather only define instrument approach visibility minimums. The FAA does not require either of these two surfaces to be free of penetration by obstacles, and thus "providing an additional margin of safety" as stated in the draft EA does not apply in the case of these two surfaces. Other TERPS surfaces (Obstacle Clearance Surfaces) are established which do ensure clearance from obstructions, and the FAA requires that these Obstacle Clearance Surfaces be clear of structures and terrain. The current IAPs to Runway 24 were designed by the FAA to accommodate all existing obstructions. Thus, shifting the runway 150 feet to the west would not enhance safety. Even if one were to assume that the draft EA is correct in the assertion that shifting the Runway 24 threshold would eliminate obstruction penetrations to the existing 34:1 Obstacle Identification Surface, the effect would not be a safety improvement, but would result only in a reduction in the required approach visibility minimums. In its response to the FAA's comments, ARB and MDOT drop the shifting of Runway 6/24 as a "need."

4. ARB and MDOT falsely conveyed the impression that ARB is located in a rural setting instead of in a densely populated area.

The draft EA intends to deceive readers as to the cosmopolitan location of the airport, utilizing Figure 2.1, for instance, which depicts unpaved Lohr and Textile Roads and vacant land and rock pits and gravel pits where developed communities of Pittsfield (Brian Hill, Lake Forest, Lake Forest Highlands, Lohr Lakes Village, St. James Woods, Silo Ridge, Stonebridge, and Waterways) and Lodi (Travis Pointe) Townships exist today, with more than 2,000 homes – making the area appear far more rural and not susceptible to the safety risks from added airport development that are actually posed.

V. THE EXTENSION OF THE RUNWAY WILL CAUSE SIGNIFICANT ENVIRONMENTAL IMPACTS ON THE SURROUNDING COMMUNITIES.

United States federal law states at 49 U.S.C. § 47101(a)(6) that it is "the policy of the United States - - that airport development under this subchapter provide for the protection and enhancement of natural resources and the quality of the environment of the United States." The Project will have a significant impact on the environment not only on the airport, but throughout the surrounding community. Since it is Pittsfield's duty and responsibility to protect the environment within its boundaries and protect its citizens from significant environmental impacts, it has serious concerns about the environmental impact the Project will have on the community.

A. The Data Used to Justify the Project Is Not Current.

Even when the draft EA first came out almost three years ago, Petitioners had issues about the timeliness of the data presented. The data that the Airport relied upon was almost three years old when it was used in the draft EA.

Moreover, it is the FAA's policy to use timely data instead of data that is stale, like the data used to justify the Project. In particular, ¶ 402a of FAA Order 1050.1E states that

> A draft EA may be assumed valid for a period of three years. If the approving official has not issued an EA/FONSI within three years of receipt of the final draft EA, a written reevaluation of the draft (see paragraph 410) must be prepared by the responsible FAA official to determine whether the consideration of alternatives, impacts, existing environment, and mitigation measures set forth in the EA remain applicable, accurate, and valid. If there have been changes in these factors that would be significant in the consideration of the proposal, a supplement to the EA or a new EA must be prepared in accordance with the procedures of this chapter.

FAA Order 1050.1E. Although it has not yet been three years since MDOT issued the draft EA, at the very least a written re-evaluation must be issued, particularly since the data used in the draft EA was stale when the draft EA was first issued.

B. The Project Does Not Take into Account the Noise Impact of the Project on the Surrounding Community.

It has long been "the policy of the United States - - that aviation facilities be constructed and operated to minimize current and projected noise impact on nearby communities." 49 U.S.C. § 47101(a)(2). Part of the FAA's mission is to ensure that the communities surrounding airports are not adversely impacted by noise from aircraft at airports. This mission is expressed in 49 U.S.C. § 47101(c), which states that "[i]t is in the public interest to recognize the effects of airport capacity expansion projects on aircraft noise. Efforts to increase capacity through any means can have an impact on surrounding communities. Noncompatible land uses around airports must be reduced and efforts to mitigate noise must be given a high priority." Thus, to the extent that noncompatible land uses around airports cannot be reduced, then the capacity of nearby airports should not be increased or else the FAA and the airport sponsor would be in violation of federal law. ARB and MDOT seem to be aware of the fact that increases in capacity at the airport will affect the noise levels in Pittsfield, because they studiously avoid the topic.

1. ARB and MDOT incorrectly assume that extending the runway will not increase the number of air operations, the fleet mix or other growth-inducing effects of the Project.

When considering an airport project for federal funding, the FAA is required to evaluate not merely the direct impacts of a project, but also its indirect impacts, including those "caused by the action and later in time but still reasonably foreseeable." 40 C.F.R. § 1508.8(b). Indirect impacts include a project's growth-inducing effects, such as changes in patterns of land use and population distribution associated with the project (40 C.F.R. § 1508.8(b)) as well as increased population, increased traffic, and increased demand for services. *City of Davis v. Coleman*, 521 F.2d 661, 675 (9th Cir. 1975). The "growth-inducing effects of [an] airport project appear to be its *raison d'etre*." *California v. U.S. D.O.T.*, 260 F.Supp.2d at 978, citing *City of Davis*, *supra*, 521 F.2d at 675. Even though the Project is virtually defined by its growth-inducing impacts, ARB and MDOT have ignored this requirement completely – not only in the draft EA, but in the public participation aspects of the Project as well. Although ARB and MDOT claim that the "percent of night and jet operations would remain constant between the existing condition and the future years," there is substantial evidence to indicate that the Project will cause a large increase in both types of operations. Exhibit 26, p.4-2.

As indicated above, there are no weight restrictions that must be lifted to allow ARB's "critical aircraft" to operate at the airport without weight restrictions. For example, the "load restrictions" referenced on page 2-12 of the draft EA refer not to category B-II aircraft, but to the fact that higher category aircraft (jets in the C-I and C-II categories) must currently operate at reduced weights in order to use the current 3,505 foot runway. Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel, all of which discourage these aircraft from conducting operations at ARB. A Cessna Citation II (Category B-II), for example, requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day, and can operate at unrestricted weight from the existing 3,505 foot runway. A Lear 35 (Category C-I), on the other hand, requires 5,000 feet for takeoff at maximum certificated gross weight on a standard day. While extending the runway to 4,300 feet would not facilitate unrestricted operations by the Lear 35, the required weight reduction would be less than is currently required. Therefore, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide no operational benefit to the Category B-II Citation jet, which the EA states is a "critical aircraft."

The primary reason why ARB and MDOT are so keen on extending the runway is to facilitate the loading of additional passengers and baggage on high performance jet aircraft outside of what ARB considers to be its "critical aircraft." Also, the ability to carry additional fuel may mean that, in certain cases, costly and time consuming intermediate fuel stops will become unnecessary. If the runway is lengthened to 4,300 feet, it is reasonably foreseeable that ARB will become much more attractive to operators of higher performance jet aircraft, such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II), who could then operate at ARB instead of driving to and from Willow Run Airport, a mere 12.3 mile car trip, where there are ample facilities for large aircraft.

2. The fact that night and jet operations will increase as a result of the Project has not been analyzed by either ARB or MDOT.

Contrary to ARB and MDOT's unsupported assertions in the draft EA (*see e.g.* Exhibit 26, p. 4-2; Appendix B-1, p. B-4), it is reasonably foreseeable that the fleet mix at ARB will change in favor of a higher percentage of jet operations as compared to the current level of light single and multi-engine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft account for a high percentage of ARB operations. B-II aircraft account for a low percentage of ARB operations. Because of the availability of a longer runway, it is therefore reasonably foreseeable that the number of night operations will increase as the number of arrivals of longer haul business jets often occur in the evening hours due to the longer time duration of their trips. Since one of the stated purposes of the Project is to increase interstate commerce, this is not merely an indirect, but also a direct effect, that the Project will have on the surrounding community. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

Thus, the evidence is clear that the Project will cause an increase in both jet and night operations. It is also reasonably foreseeable that these added high-performance jet aircraft operations and night operations will be accompanied by significant noise and air quality impacts. Nevertheless, ARB and MDOT have failed to acknowledge, let alone analyze, these reasonably foreseeable impacts caused by expansion of airport physical facilities and operational profile and, thus, the Project should not be approved for federal funding.

3. Increased jet aircraft and nighttime operations were not included in the noise modeling used by ARB and MDOT.

The sole presentation of the noise modeling performed by ARB and MDOT is presented in the draft EA. On its face it is insufficient to meet FAA standards. The FAA's Integrated Noise Model (INM) was used to model annual operations for the 2009 existing condition in the draft EA, *i.e.*, April 2008 through March 2009 and develop 65, 70 and 75 DNL noise contours for the Project. Exhibit 26, Appendix B-1, p.4, p. 4-3. The EA states that "[t]he existing 65 DNL contour does not extend beyond airport property." Exhibit 26, p. 4-3. However, during the time modeled, jet operations accounted for approximately 2 percent of total operations at ARB, and nighttime operations accounted for 4.2 percent of total operations. Exhibit 26, p. 4-2. The draft EA states: (1) "[t]he percent of night and jet operations would remain constant between the existing condition and the future years;" (2) "fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives would remain static"; and (3) "[t]he ARB 2014 proposed project alternative DNL 65 dBA noise contour does not extend beyond airport property." Exhibit 26, p. 4-2; Appendix B-1, p. B-4; p. B-6.

None of these assertions are based on facts or the reality of the situation that exists at ARB. As shown above, because of the increase in the length of the runway the Project will likely facilitate an increased number of night operations, and a change in fleet mix that will include higher performance jet aircraft. DNL calculations depend on, among other things, forecast numbers of operations, operational fleet mix and times of operation (day versus night). Exhibit 26, Appendix B-2, p. B-16. However, ARB and MDOT have failed to model or assess future increased night operations and fleet mix changes resulting from the Project.

The FAA requires the use of INM to produce, among other things: (1) noise contours at the DNL 75 dB, DNL 70 dB and DNL 65 dB levels; (2) analysis within the proposed alternative

DNL 65 dB contour to identify noise sensitive areas where noise will increase by DNL 1.5 dB ; and (3) analysis within the DNL 60-65 dB contours to identify noise sensitive areas where noise will increase by DNL 3dB, if DNL 1.5 dB increases as documented within the DNL 65 dB contour. FAA Order 1050.1E, Appendix A, p. A-62, & 14.4d. As the noise modeling failed to take into account the foreseeable increases in nighttime and jet aircraft operations at ARB, the questions of whether the future DNL 65 dB contour will be increased, and to what extent, and whether increased noise levels within the DNL 65 dB contour would necessitate designation of a DNL 60 dB contour remain unanswered.

4. Noise from aircraft, particularly high performance jets, remains a very real concern for communities that surround ARB.

The FAA last reviewed the technical bases for its noise policies in 1992. For example, 65 DNL as the "threshold of significant impact" under NEPA and the level below which land uses are deemed compatible has been used by the FAA without substantial change since *1978* (it was "re-affirmed" by FICAN in 1992). It is safe to say that the FAA's policy no longer reflects the best scientific evidence of the effects of aircraft noise exposure. This failure on the part of the FAA to update its policy undermines the trust that the public places in the FAA in their pursuit to understand noise exposure and its effects.

This is particularly true since substantial research done on the measurement and effect of aircraft noise on the communities surrounding airports has come from sources outside the United States. For example, the Hypertension & Exposure to Noise Near Airports (HYENA) study evaluated the effects of aircraft noise on 4,861 persons residing near 7 European airports between 2002 and 2006. The 2002 RANCH study from London studied the effect of aircraft and road traffic noise on 2,844 children's cognition and health. Both of these studies came out with rather startling results concerning the effect aircraft noise has on the quality of human life.

Finally, WHO Europe issued "Night Noise Guidelines," which were based on research done by the European Union. This type of study has largely been absent in the United States.

The emerging research suggests that current standards used by the FAA are outdated and underestimate the significant health risks posed by aircraft noise. The current understanding of the health effects of aircraft noise goes beyond mere annoyance and sleep disturbance, which the current DNL protocols were meant to address. The new research shows a strong correlation between aircraft noise and significant, serious health outcomes, such as hypertension and heart disease. Four studies from Europe have shown this connection:

1. Haralabidis AS, Dimakopoulou K, Velonaki V, Barbaglia G, Mussin M, Giampaolo M, Selander J, Pershagen G, Dudley ML, Babisch W, Swart W, Katsouyanni K, Järup L; for the HYENA Consortium. Can exposure to noise affect the 24 h blood pressure profile? Results from the HYENA study. *J Epidemiol Community Health*. 2010 Jun 27.

2. Haralabidis AS, Dimakopoulou K, Vigna-Taglianti F, Giampaolo M, Borgini A, Dudley ML, Pershagen G, Bluhm G, Houthuijs D, Babisch W, Velonakis M, Katsouyanni K, Jarup L; for the HYENA Consortium. Acute effects of night-time noise exposure on blood pressure in populations living near airports. *Eur Heart J*. 2008 Feb 12

3. Jarup L, Babisch W, Houthuijs D, Pershagen G, Katsouyanni K, Cadum E, Dudley M-L, Savigny P, Seiffert I, Swart W, Breugelmans O, Bluhm G, Selander J, Haralabidis A, Dimakopoulou K, Sourtzi P, Velonakis M, VignaTaglianti F, on behalf of the HYENA study team. Hypertension and Exposure to Noise near Airports - the HYENA study. *Environ Health Perspect* 2008; 116:329-33

4. Jarup L, Dudley ML, Babisch W, Houthuijs D, Swart W, Pershagen G, Bluhm G, Katsouyanni K, Velonakis M, Cadum E, Vigna-Taglianti F for the HYENA Consortium. Hypertension and exposure to noise near airports (HYENA) - Study design and noise exposure assessment. *Environ Health Perspect* 2005; 113:1473-8.

This is not to say that there has not been any research done in the United States on this issue. In March 2007, for example, Lisa Goines and Louis Hagler published their article entitled "Noise

Pollution: A Modern Plague" in the *Southern Medical Journal*. While it did not concentrate solely on aircraft noise, the article concluded that

> [n]oise produces direct and cumulative adverse effects that impair health and that degrade residential, social, working, and learning environments with corresponding real (economic) and intangible (well-being) losses. It interferes with sleep, concentration, communication, and recreation. The aim of enlightened governmental controls should be to protect citizens from the adverse effects of airborne pollution, including those produced by noise. People have the right to choose the nature of their acoustical environment; it should not be imposed by others.

ARB and MDOT are imposing the nature of their "acoustical environment" on Pittsfield and its citizens, rather than having the citizens choosing for themselves.

In addition several "findings" have been issued by governmental or quasi-governmental sources. The Federal Interagency Committee on Aviation Noise (FICAN) has issued two findings: *FICAN Recommendation for use of ANSI Standard to Predict Awakenings from Aircraft Noise* (2008) and *Findings of the FICAN Pilot Study on the Relationship between Aircraft Noise Reduction and Changes in Standardized Test Scores* (2007). Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER), a collaboration among the FAA, NASA and TransportCanada, issued in July 2010, its *Review of the Literature Related to Potential Health Effects of Aircraft Noise*, (prepared by Hales Swift). That review concluded that "[p]otentially serious health outcomes have been identified in studies involving transportation noise exposure in a population. These include heart disease and hypertension and the observed effects seem to be related especially to nighttime noise exposure although similar daytime exposure effects have also been identified." PARTNER 2010, p.62. PARTNER has also issued several other reports:

• Sonic Boom and Subsonic Aircraft Noise Outdoor Simulation Design Study. Victor W. Sparrow, Steven L. Garrett. A PARTNER Project 24 report. May 2010. Report No. PARTNER-COE-2010-002.

• Passive Sound Insulation: PARTNER Project 1.5 Report. Daniel H. Robinson, Robert J. Bernhard, Luc G. Mongeau. January 2008. Report No. PARTNER-COE-2008-003.

• Vibration and Rattle Mitigation: PARTNER Project 1.6 Report. Daniel H. Robinson, Robert J. Bernhard, Luc G. Mongeau. January 2008. Report No. PARTNER-COE-2008-004.

• Low Frequency Noise Study. Kathleen Hodgdon, Anthony Atchley, Robert Bernhard. April 2007. (Report No. PARTNER-COE-2007-001) PARTNER Project 1, Low Frequency Noise Study, final report.

• Land Use Management and Airport Controls: A further study of trends and indicators of incompatible land use. Kai Ming Li, Gary Eiff. September 2008. Report No. PARTNER-COE-2008-006

• En Route Traffic Optimization to Reduce Environmental Impact: PARTNER Project 5 Report. John-Paul Clarke, Marcus Lowther, Liling Ren, William Singhose, Senay Solak, Adan Vela, Lawrence Wong. July 2008. Report no. PARTNER-COE-2008-005

• Land Use Management and Airport Controls: Trends and indicators of incompatible land use. Kai Ming Li, Gary Eiff, John Laffitte, Dwayne McDaniel. December 2007. (Report No. PARTNER-COE-2008-001) PARTNER Project 6 final report.

Thus, there is no shortage of relevant, topical information for ARB, MDOT and the FAA to use in assessing the health risks and impacts of noise on the communities surrounding ARB. It is readily apparent that the current system does not fully account for the increased health risks communities surrounding airports are subject to due to the increased noise levels. FAA needs to re-evaluate its noise modeling and insist that health risks to the surrounding communities be assessed prior to ARB receiving federal funds for any expansion that will result in an increase in aviation operations.

C. ARB and MDOT Have Failed to Take Into Account the Effects the Project Will Have on Air Pollution in the Surrounding Community.

Section 7506 of the Federal Clean Air Act (42 U.S.C. § 7401 et seq.) mandates that "[n]o department, agency, or instrumentality of the Federal Government shall engage in, support in any way or provide financial assistance for, license or permit, or approve, any activity which does not conform to [a State Implementation Plan] after it has been approved or promulgated under [42 U.S.C. §7410]." The Environmental Protection Agency (EPA) has promulgated regulations implementing § 7506 (the "Conformity Provision") in 40 C.F.R. § 93.150 *et seq*. ("General Conformity Rule"). The General Conformity Rule requires, in part, that federal agencies first determine if a project is either exempt from conformity analysis or presumed to conform. If it is neither, the agency must conduct a conformity applicability analysis to determine if a full conformity determination is required. *See Air Quality Procedures for Civilian Airports and Air Force Bases*, p. 13.

The project area, *i.e.*, Washtenaw County, is in attainment for five of the seven criteria pollutants, and marginal nonattainment for Ozone. Exhibit 28. Washtenaw County is designated as in nonattainment for $PM_{2.5}$. *Id*. Therefore, one of the following applies:(1) the project is exempt from conformity; (2) the project is presumed to conform; or (3) the agency must conduct a conformity applicability analysis to determine if a conformity determination for $PM_{2.5}$ is required. Neither ARB nor MDOT has indicated that any of the required actions was performed.

The draft EA does not provide any guidance as to whether the Project is exempt or presumed to conform. At page C-4, the draft EA states unequivocally that "[f]or this analysis it will be assumed that the project is *neither* exempt nor presumed to conform." (Emphasis added). However, on the next page, the draft EA states that ". . . a conformity determination is not required and the proposed project *is presumed to conform* to the state implementation plan."

Exhibit 26, p.C-5, (emphasis added). Under either scenario, however, ARB and MDOT have failed to meet the "public disclosure" requirement under NEPA.

1. ARB and MDOT have failed to establish that the Project is exempt.

There are two options in determining that a project is exempt from conformity analysis: (1) if the project is included in the list of exempt actions listed in § 93.153(c)(2); or (2) if the project's total of direct and indirect emissions are below the emissions levels specified in § 95.153(b) of the Conformity Regulations ("*de minimis*"), § 93.153(c)(1).

The first option does not apply here because none of the actions to be undertaken as part of the Project are included as "exempt actions" § 93.153(c)(2). Exhibit 26, p. 2-1. Nor does the Project qualify as exempt because of *de minimis* emissions under 40 C.F.R. § 93.153(c)(1). The closest ARB and MDOT come to any type of air quality analysis can be found on pp. 4-17 and 4-18 of the draft EA. ARB and MDOT, instead of performing a site-relevant analysis, rely on an outdated study, 1996 MDOT Bureau of Aeronautics Air Quality Study of seven general aviation airports (which notably do not include ARB), to conclude that "typical GA airports generate a low level of pollutants." Exhibit 26, p. 4-17. From there, ARB and MDOT extrapolate that because ARB is comparable in size and activity to the seven airports studied, it can be assumed that emissions resulting from the Project will not exceed the conformity threshold levels, and, on that basis, concludes that a conformity analysis is not required.

This assumption, however, does not comply with federal law for at least two reasons. First, neither ARB nor MDOT has quantified $PM_{2.5}$ emissions from flight operations at ARB. Even the superannuated 1996 Study makes no mention of ARB. Second, because ARB and MDOT have failed to quantify the emissions, there can be no comparison with the *de minimis* thresholds established in 40 C.F.R. § 93.153(c)(1). While the original version of 40 C.F.R. §

93.153(c)(1) did not establish explicit thresholds for $PM_{2.5}$, as distinguished from PM_{10}, the newly implemented revised General Conformity Rule does establish that distinction, and now serves as the template for the air quality analysis required in the EA. Moreover, FAA Order 1050.1E, Appendix A, p. A3, § 2.16 includes both PM_{10} and $PM_{2.5}$ in "particulate matter."

2. ARB and MDOT have failed to establish that the project is "presumed to conform."

The second option, the presumption of conformity, does not apply here either. In order for a federal action to be "presumed to conform," the Project has to fall within a category of actions predetermined by the responsible federal agency to carry a presumption of conformity. *See* 40 C.F.R. § 93.154(f) – (h). In July, 2007, the FAA published its *Federal Presumed to Conform Actions Under General Conformity Final Notice*, 72 Fed.Reg. 41,565-580 (July 2007), in which the FAA listed fifteen Airport Project categories that the FAA presumes to conform to applicable SIPs. None of the actions to be undertaken by the Project fall within any of those presumed to conform categories. ARB and MDOT cannot unilaterally presume that the Project is in conformity and therefore the draft EA's statement is in error.

3. ARB and MDOT have failed to establish the Project's conformity status under the Clean Air Act.

Finally, the antiquated study of General Aviation airports in Michigan other than ARB is an inadequate substitute for the required analysis. 40 C.F.R. § 93.159 requires that analyses under the General Conformity Rule be based on, among other things: (1) "the latest planning assumptions" (§ 93.159(a)); and (2) "the latest and most accurate emissions estimation techniques available" (§ 93.159(b)). The 1996, 17-year old, study patently fails to fall within either, let alone both, of these parameters. In summary, the EA fails to establish the existence of any of the necessary components of the required finding of conformity for a project that can be supported by federal funds, and, thus, is inadequate under federal aviation statutes, NEPA and the Clean Air Act.

D. ARB and MDOT Have Failed to Take Into Account the Effect the Project Will Have on Water Resources in the Surrounding Communities.

Throughout this process ARB and MDOT have consistently understated the significance of water resources. The principal use of the grounds where the airport is located is for the collection and pumping of water for the City. However, water quality is something that must be taken much more seriously than ARB or MDOT has taken it. As FAA Order 1050.1E points out "[i]f there is the potential for contamination of an aquifer designated by the [EPA] as a sole or principal drinking water resource for the area, the responsible FAA official needs to consult with the EPA regional office, as required by section 1424(e) of the Safe Drinking Water Act, as amended." FAA Order 1050.1E, pp. A-74, 75, ¶ 17.1c. Likewise, "[w]hen the thresholds indicate that the potential exists for significant water quality impacts, additional analysis in consultation with State or Federal agencies responsible for protecting water quality will be necessary. *Id*., pp. A-75, A-76, ¶ 17.4a. Finally, in situations such as this, "[i]f the EA and early consultation [with the EPA] show that there is a potential for exceeding water quality standards [or] identify water quality problems that cannot be avoided or mitigated . . . an EIS may be required. *Id*., pp. A-75, ¶ 17.3.

The Airport is the location of a porous sand/gravel formation that yields a large amount of water for pumping. Historically, the land where the airport is located was originally acquired by the City of Ann Arbor for water rights in 1929. Until recently, 15% of Ann Arbor's water supply came from the three wells located on Airport property. Exhibit 29, Water Quality Report, 2008, City of Ann Arbor, p. 2. The paving that the Project will require increases not only the impervious area on top of the aquifer, but also increases the risk of contamination. This in turn reduces the infiltration of water that feeds the aquifer/City water supply. Adding 950 feet to the end of the runway adds another 71,250 square feet of impervious area over an aquifer that is vital to the City. However, ARB and MDOT have given this issue only passing mention: "[b]ased on coordination with the City of Ann Arbor, the proposed runway extension would not impact the water supply wells or the new water supply line (Bahl, 2009)." Exhibit 26, p. 4-20. Notably absent from their coordination efforts is the EPA or its Regional Office with respect to water resource issues.

ARB and MDOT's nonchalance with respect to a principal source of Ann Arbor's water supply raised serious issues with the Washtenaw County Water Resources Commissioner – another entity with whom ARB and MDOT should have been consulting from the very beginning. In response to the draft EA, the Washtenaw County Water Resources Commissioner pointed out:

> It is noted in the [draft EA] that: "The amount of impervious surface on site would increase slightly due to the extension of the runway and taxiway from the existing 7 percent of the 837 acres to 7.4 percent." This slight increase noted equates to an additional 3.348 acres or 145,839 square feet. This increase in impervious surface is considered by this office to be significant and not slight particularly knowing that the additional runoff from this area will discharge to the Wood Outlet Drain.

Exhibit 17, p.2. This, coupled with the fact that the City owns and operates four water wells on ARB's property, causes deep concern with the County.

This issue has become even more important since the draft EA was published back in 2010. In May, 2012, it was reported that the water table in the Ann Arbor area, has risen substantially. As pointed out in the Ann Arbor Chronicle, "[t]he only hard data that the city has collected on the water table is at the municipal airport, and there the water table measures between 2-7 feet below the surface now, compared to 15 feet below the surface 50 years ago." Exhibit 30.[17] This is not an insubstantial problem. With the water table at the airport now being 2-7 feet below the ground surface instead of 15 feet, when the drinking water wells were first dug, the groundwater is even more vulnerable to contamination because there is much less soil for any surface pollution to filter through or attach to soil particles before it reaches the water table. This dramatic change in the water table may also alter ground water data from the past. That is, the rise in the water table may have altered the direction of groundwater flow, or there may now be some barrier blocking the traditional pathway for the water to flow, which would cause Ann Arbor's principal drinking water supply to be contaminated.

The Washtenaw County Water Resources Commissioner raised additional significant concerns that have yet to be addressed by either ARB or MDOT.

> 3. It is indicated that the preferred alternative does not impact the stream that is existing on the site. [Draft EA, p.4-18]. Using GIS measurements it appears that the stream is less than 1,000 linear feet from the existing runway. The runway extension would bring this infrastructure within 50 linear feet or less of the stream. In addition to this the grading limits shown in Appendix D-7 clearly extend into and beyond the location of the stream. Based on this information *it is not understood how it has been concluded that there are no impacts to the stream*.
>
> 4. It is indicated that the preferred alternative does not impact the floodplain for the stream that is existing on the site. It is indicated that proposed grading for the expansion would not occur within the designated floodplain boundary. [Draft EA, p.4-24]. Based on the floodplain boundary shown on FEMA Community-Panel Number: 260623 0010 C these statements are incorrect. Not only do the grading limits indicated for the preferred alternative extend into the floodplain boundary but the runway extension itself will extend into this floodplain boundary. Based on this information it is *not understood how it has been concluded that there are no impacts to the floodplain*.
>
> ….

[17] By contrast, the draft EA relies on data at least 15 years old. Since there is more current data, that should be used instead of outdated data. *See* Exhibit 26, p.4-20.

> 6. It is noted in the report that: "Implementation of appropriate best management practices (BMPs) would continue to control the rate of stormwater runoff and maintain water quality standards." [Draft EA, p.4-18]. It is unknown by this office as to what the control rate of stormwater is currently being implemented or whether this rate meets county standards. *The additional volume created by this increase in imperviousness is not spoken to at all by the report. The type or locations of the appropriate BMPs indicated are not identified*.

Exhibit 17, pp.1-2 (emphasis added). Petitioners have the same concerns about how water resources will be managed by ARB and MDOT should this Project move forward. These issues have not been sufficiently addressed by either ARB or MDOT in the draft EA or at any of the public hearings.

VI. REDRESS

By this Petition, and for the reasons stated above, Pittsfield Charter Township and the Committee for Preserving Community Quality, Inc. respectfully request that the Secretary of Transportation take the following actions with respect to Ann Arbor Municipal Airport, which is located solely in Pittsfield Charter Township:

1. Halt any further FAA action regarding MDOT and ARB's proposal to extend the primary runway at Ann Arbor Municipal Airport pending the resolution of this petition.

2. Vacate the current Airport Layout Plan as being improvidently approved by MDOT and reinstate the prior Airport Layout Plan.

3. Inform MDOT that federal funds may not be used for the extension of the primary runway at Ann Arbor Municipal Airport due to the fact that MDOT and ARB have failed to state a legitimate purpose and need for the extension.

4. Inform MDOT and ARB that should the primary runway be extended without the agreement or acquiescence of Pittsfield, it will be in violation of its federal grant assurances.

5. If the Secretary of Transportation fails to take the actions described in ¶¶ 3 and 4 above, Pittsfield Charter Township requests that he order that an Environmental Impact

Statement be conducted that assesses the impact the extension of the runway will have on the surrounding communities and that addresses the significant environmental impacts detailed in this Petition.

6. If the Secretary of Transportation declines to order that an Environmental Impact Statement be conducted, Petitioners request that the Secretary of Transportation direct MDOT to make federal block grant funds available to Pittsfield to conduct its own Environmental Assessment and/or Environmental Impact Statement. In addition, Petitioners request that the Secretary of Transportation inform MDOT and ARB that federal funds will not be available for the implementation of the extension of the runway until such time as Pittsfield completes its Environmental Impact Statement.

7. If the Secretary of Transportation declines to take any of the actions described in the above paragraphs, Petitioners request that the Secretary direct MDOT to conduct a written re-evaluation of the Project and publish a new draft Environmental Assessment, which would then be subject to public participation in the form of substantive public hearings and comments.

8. Inform MDOT and ARB that in order to use federal funds for any future airport actions that will affect the surrounding community in general and Pittsfield in particular, they must consult and receive approval from Pittsfield prior to commencing any such action.

VII. CONCLUSION

Federal law requires the Secretary of Transportation to give this petition prompt consideration. Additionally, under the Administrative Procedure Act "agency action" is defined to include "the whole or part of an agency rule, order, license, sanction, relief, or the equivalent denial there of *or failure to act.*" Therefore, Petitioners are requesting a substantive response to this petition within one hundred eighty (180) calendar days.[18] In the absence of an affirmative response, Petitioners will be compelled to consider litigation in order to achieve the agency actions requested.

Dated: January 28, 2013

Respectfully submitted,

TABER LAW GROUP, P.C.

Steven M. Taber
TABER LAW GROUP, P.C.
P.O. Box 60036
Irvine, California 92602-0036
(949) 735-8217 (phone)
(714) 707-4282 (fax)
staber@taberlaw.com

Counsel for Petitioners Pittsfield Charter Township and Committee for Preserving Community Quality, Inc.

[18] Petitioners note that a response period of 180 days is reasonable under the APA. *See* 42 U.S.C. § 7604(a) requiring notice of 180 days prior to commencement of an action for unreasonable delay.

EXHIBIT LIST

No.	Title	Page
01	Airport Information for Ann Arbor Municipal Airport (KARB) as Reported on AirNav.com	5
02	Airport Master Record for Ann Arbor Municipal Airport (FAA Form 5010-1)	5
03	Bylaws of Ann Arbor Municipal Airport Advisory Committee	5
04	Resolution R-280-7-78 of the Ann Arbor City Council Approving Agreement between the City of Ann Arbor and Pittsfield Charter Township. July 6, 1978.	6, 9
05	Agreement Supplementing 1979 Policy Statement Relative to Airport Layout Plans, Aeronautical Facilities and Non-Aeronautical Facilities at the Ann Arbor Airport. October 1, 2009.	6,9
06	Resolution R-31-1-07 of the Ann Arbor City Council to Approve the URS Corporation Airport Layout Plan Update for the Ann Arbor Municipal Airport which Illustrates Existing and Proposed Facilities to meet the Future Demands of Airport Tenants and Users. January 22, 2007.	8,9
07	February 28, 2007, Request by the Ann Arbor City Council to MDOT to approve the Revised Airport Layout Plan.	8
08	March 24, 2009, Res #09-23 of Pittsfield Charter Township Opposing Proposed Expansion of the Ann Arbor Municipal Airport Runway.	10
09	May 12, 2009, Resolution # 2009-009 of Lodi Township Opposing Proposed Runway Expansion of the Ann Arbor Municipal Airport.	10
10	FAA Notice of Intent to Prepare an Environmental Assessment; Ann Arbor Municipal Airport, Ann Arbor, MI. 74 Fed.Reg. 28768 (June 17, 2009).	11
11	Meeting Minutes from the May 4, 2009, meeting of the Ann Arbor Municipal Airport Citizens Advisory Committee.	12
12	Meeting Minutes of the July 20, 2009, meeting of the Ann Arbor Municipal Airport Citizens Advisory Committee.	12
13	Meeting packet for the February 22, 2010, meeting of the Ann Arbor Municipal Airport Citizens Advisory Committee.	13
14	Notice of Availability of Draft Environmental Assessment; Ann Arbor Municipal Airport, Ann Arbor, MI. 75 Fed.Reg. 13334 (March 19, 2010).	14

No.	Title	Page
15	April 19, 2010, Comments on the Draft Environmental Assessment submitted by Pittsfield Charter Township.	15
16	April 19, 2010, Comments on the Draft Environmental Assessment submitted by Committee for Preserving Community Quality.	15
17	April 19, 2010, Comments on the Draft Environmental Assessment submitted by Janis A. Bobrin, Washtenaw County, Michigan Water Resources Commissioner.	15, 48 – 50
18	May 13, 2010, Comments on the Draft Environmental Assessment by the Federal Aviation Administration.	7, 15, 16, 26
19	November 15, 2010, Response of Michigan Department of Transportation to FAA's Comments on the Draft Environmental Assessment.	7, 16, 27, 29, 32
20	April 27, 2012, Ann Arbor Chronicle Article regarding Airport Request for Additional Funding.	17
21	FAA Grant Assurances Airport Sponsors (4/2012).	22
22	Map of Lakes and Ponds that Support Hazardous Wildlife in Vicinity of Ann Arbor Municipal Airport.	23
23	URS Study Excluded from Draft Environmental Assessment and Airport Layout Plan.	23
24	Images of Aircraft Emergency Landing: Stonebridge Golf Course – June, 2009.	23
25	National Safety Transportation Board Reports regarding fatal accidents in the vicinity of Ann Arbor Municipal Airport.	23
26	March, 2010, Draft Ann Arbor Municipal Airport Environmental Assessment.	6, 27 – 33, 37, 39, 40, 45, 48, 49
27	Supplement Report Airport User Survey, December, 2009.	32
28	Nonattainment Status for Each County by Year for Michigan.	44
29	2008 Drinking Water Quality Report, Ann Arbor Public Services.	48
30	The Ann Arbor Chronicle Article from April 27, 2012 indicating rise in water table at Ann Arbor Municipal Airport.	49
31	2007 and 2008 Airport Layout Plans for Ann Arbor Municipal Airport.	8, 9

Exhibit 1

AIRNAV.COM

Airports | Navaids | Airspace Fixes | Aviation Fuel | AIRBOSS | iPhone App

1692 users online LOGIN

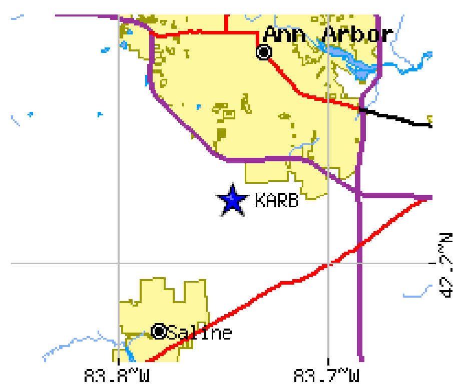
KARB Ann Arbor Municipal Airport
Ann Arbor, Michigan, USA

FAA INFORMATION EFFECTIVE 10 JANUARY 2013

Loc | Ops | Rwys | IFR | FBO | Links
Com | Nav | Svcs | Stats | Notes

Location

FAA Identifier: ARB
Lat/Long: 42-13-22.7410N / 083-44-44.1860W
42-13.379017N / 083-44.736433W
42.2229836 / -83.7456072
(estimated)
Elevation: 839 ft. / 256 m (estimated)
Variation: 05W (1985)
From city: 3 miles S of ANN ARBOR, MI
Time zone: UTC -5 (UTC -4 during Daylight Saving Time)
Zip code: 48108



Road maps at: MapQuest MapPoint Yahoo! Maps Google Rand McNally
Satellite photo at: TerraServer Virtual Earth

Airport Operations

Airport use: Open to the public
Activation date: 04/1940
Sectional chart: DETROIT
Control tower: yes
ARTCC: CLEVELAND CENTER
FSS: LANSING FLIGHT SERVICE STATION
NOTAMs facility: ARB (NOTAM-D service available)
Attendance: APR-OCT 0800-1800, NOV-MAR 0800-2000
TERMINAL OPEN 0700-DUSK.
Pattern altitude: 1839 ft. MSL
Wind indicator: lighted
Segmented circle: yes
Lights: WHEN ATCT CLSD ACTVT ODALS RY 24 - CTAF.
Beacon: white-green (lighted land airport)
Operates sunset to sunrise.

Aerial photo

WARNING: Photo may not be current or correct

Airport Communications

CTAF: 120.3
UNICOM: 123.0
ATIS: 134.55

WX ASOS:	PHONE 313-668-7173
ANN ARBOR GROUND:	121.6 [0800-2000]
ANN ARBOR TOWER:	120.3 [0800-2000]
DETROIT APPROACH:	118.95
DETROIT DEPARTURE:	118.95
CLEARANCE DELIVERY:	121.6
EMERG:	121.5
WX ASOS at YIP (10 nm E):	132.35 (734-485-9056)
WX ASOS at DTW (17 nm E):	PHONE 734-941-7848

Nearby radio navigation aids

VOR radial/distance	VOR name	Freq	Var
SVMr214/13.0	SALEM VORTAC	114.30	03W
CRLr312/16.6	CARLETON VORTAC	115.70	03W
DXOr278/16.8	DETROIT VOR/DME	113.40	06W
PSIr201/30.2	PONTIAC VORTAC	111.00	03W
JXNr099/31.7	JACKSON VOR/DME	109.60	05W

NDB name	Hdg/Dist	Freq	Var	ID
TECUMSEH	035/13.0	239	06W	TCU - -.-. ..-
ADRIAN	041/25.8	278	06W	ADG .- -.. --.
HOWELL	162/26.8	243	05W	OZW --- --.. .--
GROSSE ILE	293/27.4	419	07W	RYS .-. -.-- ...

Airport Services

Fuel available:	100LL JET-A
Parking:	hangars and tiedowns
Airframe service:	MAJOR
Powerplant service:	MAJOR
Bottled oxygen:	HIGH/LOW
Bulk oxygen:	HIGH/LOW

Runway Information

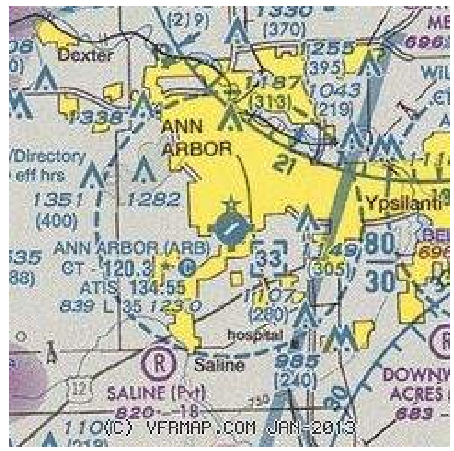
Runway 6/24

Dimensions:	3505 x 75 ft. / 1068 x 23 m	
Surface:	concrete/grooved, in fair condition	
Weight bearing capacity:	Single wheel: 45.0	
	Double wheel: 70.0	
Runway edge lights:	medium intensity	
	RUNWAY 6	**RUNWAY 24**
Latitude:	42-13.214628N	42-13.549472N
Longitude:	083-45.006382W	083-44.374113W
Elevation:	831.3 ft.	826.0 ft.
Gradient:	0.1%	0.1%
Traffic pattern:	left	left
Runway heading:	060 magnetic, 055 true	240 magnetic, 235 true
Markings:	nonprecision, in fair condition	nonprecision, in fair condition

Photo by Andrew Thompson.
Photo taken 27-Jun-2009

Do you have a better or more recent aerial photo of Ann Arbor Municipal Airport that you would like to share? If so, please **send us your photo**.

Sectional chart



Airport diagram

CAUTION: Diagram may not be current

Download PDF
of official airport diagram from the FAA

Airport distance calculator

Flying to Ann Arbor Municipal Airport? Find the distance to fly.

Visual slope indicator:	4-light PAPI on left (3.00 degrees glide path) RY 06, PAPI UNUSABLE 7 DEGS LEFT & RIGHT OF COURSE.	2-box VASI on left (3.00 degrees glide path)
Approach lights:		ODALS: omnidirectional approach lighting system
Runway end identifier lights:	yes	
Touchdown point:	yes, no lights	yes, no lights
Obstructions:	33 ft. trees, 924 ft. from runway, 370 ft. left of centerline, 21:1 slope to clear	59 ft. trees, 1500 ft. from runway, 22:1 slope to clear

Runway 12/30

Dimensions:	2750 x 110 ft. / 838 x 34 m	
Surface:	turf, in fair condition	
Runway edge markings:	12/30 MKD WITH YELLOW CONES.	
	RUNWAY 12	**RUNWAY 30**
Latitude:	42-13.495667N	42-13.254500N
Longitude:	083-45.050167W	083-44.534500W
Elevation:	839.0 ft.	822.0 ft.
Gradient:	0.6%	0.6%
Traffic pattern:	left	left
Runway heading:	127 magnetic, 122 true	307 magnetic, 302 true
Runway end identifier lights:	no	no
Obstructions:	42 ft. trees, 990 ft. from runway, 23:1 slope to clear	60 ft. trees, 768 ft. from runway, 115 ft. left of centerline, 12:1 slope to clear

Airport Ownership and Management from official FAA records

Ownership: Publicly-owned
Owner: ROGER W. FRASER
100 N, FIFTH AVE
ANN ARBOR, MI 48104
Phone 734-994-2650
Manager: MATTHEW KULHANEK
100 N, FIFTH AVE, P.O. BOX 8647
ANN ARBOR, MI 48107-8647
Phone 734-994-9124

Airport Operational Statistics

Aircraft based on the field:	165	Aircraft operations: avg 161/day *
Single engine airplanes:	137	64% local general aviation
Multi engine airplanes:	16	36% transient general aviation
Jet airplanes:	1	* for 12-month period ending 31 December 2011
Helicopters:	10	
Ultralights:	1	

Additional Remarks

From [ ] to KARB

CALCULATE DISTANCE

Sunrise and sunset

Times for 24-Jan-2013

	Local (UTC-5)	Zulu (UTC)
Morning civil twilight	07:26	12:26
Sunrise	07:57	12:57
Sunset	17:38	22:38
Evening civil twilight	18:08	23:08

Current date and time

Zulu (UTC)	24-Jan-2013 22:19:29
Local (UTC-5)	24-Jan-2013 17:19:29

METAR

KARB	734-668-7173 242153Z 32005KT 10SM CLR M09/M20 A3053 RMK AO2 SLP357 T10891200 $
KYIP 9nm E	242153Z AUTO 30005KT 10SM CLR M08/M18 A3055 RMK AO2 SLP357 T10831183 TSNO
KDTW 18nm E	242153Z 27004KT 10SM BKN220 M08/M19 A3056 RMK AO2 SLP359 T10781194

TAF

KYIP 9nm E	241726Z 2418/2518 34009KT P6SM FEW060 FM250100 VRB02KT P6SM BKN100 OVC220 FM250900 15005KT 5SM -SN BKN050 OVC100 FM251300 16005KT 3SM -SN BR BKN010 OVC020 FM251700 16005KT 1SM -SN BR OVC020
KDTW 18nm E	241726Z 2418/2524 33009KT P6SM FEW025 SCT100 FM250100 VRB02KT P6SM BKN100 OVC220 FM251000 15005KT 5SM -SN BKN050 OVC100 FM251300 16005KT 3SM -SN BR BKN010 OVC020 FM251700 16005KT 1SM -SN BR OVC020 FM252100 18006KT 5SM -SN BR OVC030

NOTAMs

Click for the latest **NOTAMs**

NOTAMs are issued by the DoD/FAA and will open in a separate window not controlled by AirNav.

- BIRDS ON & INVOF ARPT.
- WHEN ATCT CLSD CONFIRM SNOW REMOVAL OPNS & WINTER CONDS - CTAF.
- RY 24 RUNUP AREA, FIRST 200 FT OF TWY A, & TWY AI BTN TWY A & RY 24 HOL LINE NOT VSB FM TWR.
- NO SNOW REMOVAL FOR RY 12/30.
- 24 HR RESTROOMS LCTD IN Q-ROW NW HANGARS, COMBINATION 13455.

Instrument Procedures

NOTE: All procedures below are presented as PDF files. If you need a reader for these files, you should download the free Adobe Reader.

NOT FOR NAVIGATION. Please procure official charts for flight.
FAA instrument procedures published for use between 10 January 2013 at 0901Z and 7 March 2013 at 0900Z.

STARs - Standard Terminal Arrivals

CRUXX FOUR	2 pages: [1] [2] (253KB)
GOHMA TWO	download (143KB)
LLEEO TWO	download (319KB)
SPRTN THREE	download (155KB)

IAPs - Instrument Approach Procedures

RNAV (GPS) RWY 06	download (221KB)
RNAV (GPS) RWY 24	download (256KB)
VOR RWY 06	download (201KB)
VOR RWY 24	download (206KB)
NOTE: Special Alternate Minimums apply	download (26KB)

Departure Procedures

AKRON THREE	2 pages: [1] [2] (272KB)
ERRTH THREE	2 pages: [1] [2] (372KB)
FORT WAYNE FOUR	2 pages: [1] [2] (249KB)
MOONN THREE	2 pages: [1] [2] (362KB)
PALACE SIX ****NEW****	2 pages: [1] [2] (450KB)
RICHMOND FIVE	2 pages: [1] [2] (266KB)
ROSEWOOD THREE	2 pages: [1] [2] (259KB)
ST. CLAIR FIVE ****NEW****	download (306KB)

Other nearby airports with instrument procedures:

KYIP - Willow Run Airport (10 nm E)
3TE - Meyers-Diver's Airport (15 nm SW)
1D2 - Canton-Plymouth-Mettetal Airport (15 nm NE)
KDTW - Detroit Metropolitan Wayne County Airport (17 nm E)
Y47 - Oakland Southwest Airport (18 nm N)

FBO, Fuel Providers, and Aircraft Ground Support

Business Name	Contact	Services / Description	Fuel Prices	Comments
		Aviation fuel, Oxygen service, Aircraft parking	AVFUEL	

Ann Arbor Aviation Center Inc.	UNICOM 123.00 734-662-6806 734-662-0559 [web site] [email]	(ramp or tiedown), Flight training, Aircraft rental, Aerial tours / aerial sightseeing, Aircraft maintenance, ... More info and **photos** of Aviation Center	100LL Jet A FS $5.69 $4.89 GUARANTEED MEMBERS ONLY Discounts Login Join	21 read write
Solo Aviation	UNICOM 123.00 734-994-6651 734-994-6671 [web site] [email]	Excellence in Aviation. From beginning student pilots through ATP, Aircraft Sales, Full Service Maintenance facility and professional staff, Solo Aviation is conveniently located at the main terminal. More info and **photos** of Solo Aviation PART 141 PILOT SCHOOL	AVFUEL 100LL Jet A FS $5.75 $4.98 GUARANTEED MEMBERS ONLY Discounts Login Join	not yet rated 5 read write

FS=Full service

UPDATE PRICES

Where to Stay: Hotels, Motels, Resorts, B&Bs, Campgrounds

In this space we feature lodging establishments that are convenient to the Ann Arbor Municipal Airport. If your hotel/inn/B&B/resort is near the Ann Arbor Municipal Airport, provides convenient transportation, or is otherwise attractive to pilots, flight crews, and airport users, consider listing it here.

FEATURE A LODGING ESTABLISHMENT

AirNav users who flew into KARB have stayed at...

	Miles	Price ($)
COURTYARD BY MARRIOTT ANN ARBOR	1.3	159-169
SHERATON ANN ARBOR HOTEL	1.3	149-169
CLARION HOTEL AND CONFERENCE CENTER	4.7	75-120
RED ROOF INN ANN ARBOR - UNIVERSITY OF MICHIGAN SOUTH	1.2	70-71
HOLIDAY INN EXPRESS & SUITES ANN ARBOR	1.2	133-209
CANDLEWOOD SUITES DETROIT ANN ARBOR	1.5	103-139
SLEEP INN & SUITES	9.4	80-120

Hotels in other cities near Ann Arbor Municipal Airport

27 in Ann Arbor	2 in Chelsea
1 in Ypsilanti	3 in Plymouth
1 in Milan	27 in Romulus
4 in Belleville	4 in Dundee
9 in Canton	2 in Northville

Other hotels near Ann Arbor Municipal Airport

	Miles	Price ($)
EXTENDED STAY AMERICA DETROIT - ANN ARBOR	1.1	80-90
THE KENSINGTON COURT	1.2	148-168
COMFORT INN & SUITES ANN ARBOR	1.2	110-111
HAMPTON INN ANN ARBOR-SOUTH	1.2	144-145
RESIDENCE ANN ARBOR BY MARRIOTT	1.2	169-179
FAIRFIELD INN BY MARRIOTT ANN ARBOR	1.3	89-99
EXTENDED STAY DELUXE DETROIT - ANN ARBOR	1.3	83-98
HOLIDAY INN & SUITES ANN ARBOR UNIV MICHIGAN AREA	1.4	137-176
LAMP POST INN	3.0	54-73
A VICTORY INN & SUITES - ANN ARBOR	3.7	50-80
ANN ARBOR REGENT HOTEL & SUITES	3.9	114-144

DAYS INN OF ANN ARBOR	3.9	59-85
BELL TOWER HOTEL	3.9	199-304
COMFORT INN AND SUITES ANN ARBOR	3.9	80-90

Distances are approximate, and may vary depending on the actual route traveled and the location of the travel start on the airport.

Would you like to see your business listed on this page?

If your business provides an interesting product or service to pilots, flight crews, aircraft, or users of the Ann Arbor Municipal Airport, you should consider listing it here. To start the listing process, click on the button below

ADD YOUR BUSINESS OR SERVICE

Other Pages about Ann Arbor Municipal Airport

- www.ci.ann-arbor.mi.us/...
- www.umich.edu/...
- Page from the Michigan Airport Directory (PDF)

UPDATE, REMOVE OR ADD A LINK

Exhibit 2

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

AIRPORT MASTER RECORD

PRINT DATE: 01/24/2013
AFD EFF 01/10/2013
Form Approved OMB 2120-0015

> 1 ASSOC CITY: ANN ARBOR | 4 STATE: MI | LOC ID: ARB | FAA SITE NR: 09524.*A
> 2 AIRPORT NAME: ANN ARBOR MUNI | 5 COUNTY: WASHTENAW MI
3 CBD TO AIRPORT (NM): 03 S | 6 REGION/ADO: AGL/DET | 7 SECT AERO CHT: DETROIT

GENERAL

10 OWNERSHIP: PU
> 11 OWNER: ROGER W. FRASER
> 12 ADDRESS: 100 N, FIFTH AVE
ANN ARBOR, MI 48104
> 13 PHONE NR: 734-994-2650
> 14 MANAGER: MATTHEW KULHANEK
> 15 ADDRESS: 100 N, FIFTH AVE, P.O. BOX 8647
ANN ARBOR, MI 48107-8647
> 16 PHONE NR: 734-994-9124
> 17 ATTENDANCE SCHEDULE:

APR-OCT	ALL	0800-1800
NOV-MAR	ALL	0800-2000

18 AIRPORT USE: PUBLIC
19 ARPT LAT: 42-13-22.7410N ESTIMATED
20 ARPT LONG: 083-44-44.1860W
21 ARPT ELEV: 839.0 ESTIMATED
22 ACREAGE: 837
> 23 RIGHT TRAFFIC:
> 24 NON-COMM LANDING:
25 NPIAS/FED AGREEMENTS:NGY
> 26 FAR 139 INDEX:

SERVICES

> 70 FUEL: 100LL A
> 71 AIRFRAME RPRS: MAJOR
> 72 PWR PLANT RPRS: MAJOR
> 73 BOTTLE OXYGEN: HIGH/LOW
> 74 BULK OXYGEN: HIGH/LOW
75 TSNT STORAGE: HGR, TIE
76 OTHER SERVICES:
AVNCS, CHTR, INSTR, RNTL, TOW

FACILITIES

> 80 ARPT BCN: CG
> 81 ARPT LGT SKED: SEE RMK
> 82 UNICOM: 123.000
> 83 WIND INDICATOR: YES-L
84 SEGMENTED CIRCLE: YES
85 CONTROL TWR: YES
86 FSS: LANSING
87 FSS ON ARPT: NO
88 FSS PHONE NR:
89 TOLL FREE NR: 1-800-WX-BRIEF

BASED AIRCRAFT

90 SINGLE ENG:	137
91 MULTI ENG:	16
92 JET:	1
TOTAL:	154
93 HELICOPTERS:	10
94 GLIDERS:	0
95 MILITARY:	0
96 ULTRA-LIGHT:	1

OPERATIONS

100 AIR CARRIER:	0
102 AIR TAXI:	0
103 G A LOCAL:	37,511
104 G A ITNRNT:	21,174
105 MILITARY:	0
TOTAL:	58,685

OPERATIONS FOR 12 MONTHS ENDING 12/31/2011

RUNWAY DATA

> 30 RUNWAY IDENT:	06/24	12/30		
> 31 LENGTH:	3,505	2,750		
> 32 WIDTH:	75	110		
> 33 SURF TYPE-COND:	CONC-F	TURF-F		
> 34 SURF TREATMENT:	GRVD			
35 GROSS WT: SW	45.0			
36 (IN THSDS) DW	70.0			
37 DTW				
38 DDTW				
> 39 PCN:				
LIGHTING/APCH AIDS				
> 40 EDGE INTENSITY:	MED			
> 42 RWY MARK TYPE-COND:	NPI - F / NPI - F	- / -	- / -	- / -
> 43 VGSI:	P4L / V2L	/	/	/
44 THR CROSSING HGT:	20 / 20	/	/	/
45 VISUAL GLIDE ANGLE:	3.00 / 3.00	/	/	/
> 46 CNTRLN-TDZ:	N - N / N - N	N - N / N - N	- / -	- / -
> 47 RVR-RVV:	- N / - N	- N / - N	- / -	- / -
> 48 REIL:	Y /	N / N	/	/
> 49 APCH LIGHTS:	/ ODALS	/	/	/
OBSTRUCTION DATA				
50 FAR 77 CATEGORY:	A(NP) / A(NP)	A(V) / A(V)	/	/
> 51 DISPLACED THR:	/	/	/	/
> 52 CTLG OBSTN:	TREES / TREES	TREES / TREES	/	/
> 53 OBSTN MARKED/LGTD:	/	/	/	/
> 54 HGT ABOVE RWY END:	33 / 59	42 / 60	/	/
> 55 DIST FROM RWY END:	924 / 1,500	990 / 768	/	/
> 56 CNTRLN OFFSET:	370L / 0B	0B / 115L	/	/
57 OBSTN CLNC SLOPE:	21:1 / 22:1	23:1 / 12:1	/	/
58 CLOSE-IN OBSTN:	N / N	N / N	/	/
DECLARED DISTANCES				
> 60 TAKE OFF RUN AVBL (TORA):	/	/	/	/
> 61 TAKE OFF DIST AVBL (TODA):	/	/	/	/
> 62 ACLT STOP DIST AVBL (ASDA):	/	/	/	/
> 63 LNDG DIST AVBL (LDA):	/	/	/	/

(>) ARPT MGR PLEASE ADVISE FSS IN ITEM 86 WHEN CHANGES OCCUR TO ITEMS PRECEDED BY >

> 110 REMARKS:

A 017	TERMINAL OPEN 0700-DUSK.
A 042	RWY 12 12/30 MKD WITH YELLOW CONES.
A 043	RWY 06 RY 06, PAPI UNUSABLE 7 DEGS LEFT & RIGHT OF COURSE.
A 081	RWY APT WHEN ATCT CLSD ACTVT ODALS RY 24 - CTAF.
A 110	THIS AIRPORT HAS BEEN SURVEYED BY THE NATIONAL GEODETIC SURVEY.
A 110-1	BIRDS ON & INVOF ARPT.
A 110-2	WHEN ATCT CLSD CONFIRM SNOW REMOVAL OPNS & WINTER CONDS - CTAF.

111 INSPECTOR: (S) 112 LAST INSP: 07/11/2012 113 LAST INFO REQ:

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

AIRPORT MASTER RECORD

PRINT DATE: 01/24/2013
AFD EFF 01/10/2013
Form Approved OMB 2120-0015

> 1 ASSOC CITY: *****CONTINUED***** 4 STATE: MI LOC ID: ARB FAA SITE NR: 09524.*A
> 2 AIRPORT NAME: 5 COUNTY:
3 CBD TO AIRPORT (NM): 6 REGION/ADO: AGL/DET 7 SECT AERO CHT:

GENERAL

10 OWNERSHIP:
> 11 OWNER:
> 12 ADDRESS:
> 13 PHONE NR:
> 14 MANAGER:
> 15 ADDRESS:
> 16 PHONE NR:
> 17 ATTENDANCE SCHEDULE:

18 AIRPORT USE:
19 ARPT LAT:
20 ARPT LONG:
21 ARPT ELEV:
22 ACREAGE:
> 23 RIGHT TRAFFIC:
> 24 NON-COMM LANDING:
25 NPIAS/FED AGREEMENTS:
> 26 FAR 139 INDEX:

SERVICES

> 70 FUEL:
> 71 AIRFRAME RPRS:
> 72 PWR PLANT RPRS:
> 73 BOTTLE OXYGEN:
> 74 BULK OXYGEN:
75 TSNT STORAGE:
76 OTHER SERVICES:

FACILITIES

> 80 ARPT BCN:
> 81 ARPT LGT SKED:
> 82 UNICOM:
> 83 WIND INDICATOR:
84 SEGMENTED CIRCLE:
85 CONTROL TWR:
86 FSS:
87 FSS ON ARPT:
88 FSS PHONE NR:
89 TOLL FREE NR:

BASED AIRCRAFT

90 SINGLE ENG:
91 MULTI ENG:
92 JET:
TOTAL:
93 HELICOPTERS:
94 GLIDERS:
95 MILITARY:
96 ULTRA-LIGHT:

OPERATIONS

100 AIR CARRIER:
102 AIR TAXI:
103 G A LOCAL:
104 G A ITNRNT:
105 MILITARY:
TOTAL:

OPERATIONS FOR 12 MONTHS ENDING

RUNWAY DATA

> 30 RUNWAY IDENT:				
> 31 LENGTH:				
> 32 WIDTH:				
> 33 SURF TYPE-COND:				
> 34 SURF TREATMENT:				
35 GROSS WT: SW				
36 (IN THSDS) DW				
37 DTW				
38 DDTW				
> 39 PCN:				
LIGHTING/APCH AIDS				
> 40 EDGE INTENSITY:	- / -	- / -	- / -	- / -
> 42 RWY MARK TYPE-COND:	/	/	/	/
> 43 VGSI:	/	/	/	/
44 THR CROSSING HGT:	/	/	/	/
45 VISUAL GLIDE ANGLE:	- / -	- / -	- / -	- / -
> 46 CNTRLN-TDZ:	- / -	- / -	- / -	- / -
> 47 RVR-RVV:	/	/	/	/
> 48 REIL:	/	/	/	/
> 49 APCH LIGHTS:				
OBSTRUCTION DATA	/	/	/	/
50 FAR 77 CATEGORY:	/	/	/	/
> 51 DISPLACED THR:	/	/	/	/
> 52 CTLG OBSTN:	/	/	/	/
> 53 OBSTN MARKED/LGTD:	/	/	/	/
> 54 HGT ABOVE RWY END:	/	/	/	/
> 55 DIST FROM RWY END:	/	/	/	/
> 56 CNTRLN OFFSET:	/	/	/	/
57 OBSTN CLNC SLOPE:	/	/	/	/
58 CLOSE-IN OBSTN:				
DECLARED DISTANCES	/	/	/	/
> 60 TAKE OFF RUN AVBL (TORA):	/	/	/	/
> 61 TAKE OFF DIST AVBL (TODA):	/	/	/	/
> 62 ACLT STOP DIST AVBL (ASDA):	/	/	/	/
> 63 LNDG DIST AVBL (LDA):				

(>) ARPT MGR PLEASE ADVISE FSS IN ITEM 86 WHEN CHANGES OCCUR TO ITEMS PRECEDED BY >

> 110 REMARKS:

A 110-3 RY 24 RUNUP AREA, FIRST 200 FT OF TWY A, & TWY AI BTN TWY A & RY 24 HOL LINE NOT VSB FM TWR.
A 110-4 NO SNOW REMOVAL FOR RY 12/30.
A 110-5 24 HR RESTROOMS LCTD IN Q-ROW NW HANGARS, COMBINATION 13455.

111 INSPECTOR: (S) 112 LAST INSP: 07/11/2012 113 LAST INFO REQ:

Exhibit 3

BY LAWS OF THE
ANN ARBOR MUNICIPAL AIRPORT ADVISORY COMMITTEE

As adopted November 15, 1995
Revised and Approved at *the January* 25, *2006 Meeting*

WHEREAS, the Ann Arbor City Council has created the Airport Advisory Committee for the purpose of making recommendations to the Council regarding the construction and operation of the Airport, and

WHEREAS, the Committee size is established at seven (7) members, and

WHEREAS, the Committee finds it desirable to adopt By Laws so that it may more efficiently fulfill its obligations to the City and Council; and

WHEREAS, the Airport Advisory Committee is playing an increasingly important part in policy matters regarding the airport; and

WHEREAS, the need of diligence and continuity of effort has increased; and

WHEREAS, the members of the committee have expressed a desire to amend the By Laws which govern them;

THEREFORE, the Airport Advisory Committee has approved the following By Laws effective January 18, 1995, as amended April 17, 1996, May 15, 1996, July 17, 1996, June 18, 1997, April 15, 1998, November 18, 1998, June 20,2001, February 19, 2003 and January 25, 2006.

I

OFFICE

1. The principal office of the Committee shall be at the Ann Arbor Municipal Airport Administration Building.

2. The Committee may also have offices in such other places as the Committee may from time to time designate.

II

MEMBERS AND OFFICERS

1. The voting members of the Committee shall be seven (7) individuals duly designated by the Mayor and approved by City Council. Each new member shall serve for a term of three (3) years, and may serve no more than two (2) terms. A member whose term has expired may serve until a successor is appointed, or sixty days after the expiration of the term, whichever occurs first.

2. The Airport Manager shall be an ex-officio member without vote. Pittsfield and Lodi Townships may each name an ex-officio non-voting member to the committee.

3. Members are expected to attend all regularly scheduled and convened meetings of the Committee. Should a member miss two (2) meetings in succession or two (2) of four (4) meetings, the Chair may inquire of the absent member concerning their intention to continue serving on the Committee. Should a member miss three (3) meetings in succession or three (3) of five (5) meetings, the Chair may refer the name of the absent member to the Mayor of the City with the suggestion to dismiss the member and appoint another person to fill the unexpired term.

4. The officers of the Committee shall be a Chair, and Vice Chair. The Airport Manager shall serve as secretary.

5. The Committee at its November meeting shall choose the Chair and Vice Chair for one-year terms, effective at its next regularly scheduled meeting.

6. The Chair and Vice Chair shall hold office until their successors are chosen and qualify in their stead. If the office of Chair becomes vacant the Vice Chair shall succeed to that office for the unexpired term of that office. If the office of Vice Chair becomes vacant the Committee shall elect a successor from its membership at the next regular meeting, and such election shall be for the unexpired term of that office.

III

MEETINGS

1. Place. All meetings of the Committee shall be held at its offices at the Ann Arbor Municipal Airport Administration Building or at such other place as the Committee may from time to time designate.

2. Regular Meetings. Regular meetings of the Committee shall be held without notice on the third Wednesday of every other month (January, March, May, July, September, and November) at the offices of the Committee or such other time and place as may be designated in accordance with these By Laws.

3. Special Meetings. The Chair of the Committee may, when deemed by the Chair to be expedient, and shall, upon the request of at least one member of the Committee, call a special meeting of the Committee for the purpose of transacting any business designated in the call. The call for a special meeting may be issued to each member of the Committee no later than two (2) days prior to the date of such special meeting. At such special meeting, no business shall be considered other than as designated in the call, but if all of the voting members of the Committee are present at a special meeting any and all business may be transacted at such special meeting.

4. Quorum. At all meetings of the Committee, a majority of the appointed voting members of the Committee shall constitute a quorum for the purpose of transacting business. Ex-officio members of the Committee shall not be counted in determining a quorum.

5. Order of Business. At the regular meeting of the Committee the following shall be the order of business:

1. Roll Call
2. Approval of Agenda
3. Reading and approval of minutes of previous meeting
4. Audience participation
5. Reports of Airport Manager
6. Reports of Townships/FAA Tower Manager/Committees
7. Unfinished business
8. New Business
9. Items for Next Agenda
10. Notice of Next Scheduled Meeting
11. Adjournment

The order of business may be changed with the consent of a majority of members present.

6. Audience Participation. Audience participation in Committee meetings shall appear near the beginning of the agenda, for the purpose of addressing any item on the agenda. Speakers shall be limited to three minutes. However, the sole representative of a group may speak five minutes. Audience participation may also be permitted later, regarding items not on the agenda.

7. Rules of Parliamentary Procedure. The rules of parliamentary practice comprised in Roberts Rules of Order shall govern the Committee in all cases to which they are applicable, provided they are not in conflict with these By-Laws.

8 . Minutes of Proceedings. It shall be the responsibility of the secretary to prepare the minutes of the proceedings of each regular and special meeting of the Committee. At the option of the secretary, audio or video recordings may be utilized to assist in the production of written minutes.

IV

ANNUAL REPORT

The Committee shall present to the Ann Arbor City Council in the month of February of each year, a report on the activities of the Committee and the Airport for the past calendar year. The report may contain recommendations to the Council.

V

AMENDMENT TO THE BY LAWS

The By Laws of the Committee may be amended, added to, or repealed, or new By Laws may be adopted in lieu hereof by the affirmative vote of a majority of the Committee, provided that notice thereof shall be in the call of the meeting.

Exhibit 4

Council unanimously agreed with Councilmember Morris to amend Paragraph A of Section I (Annexation - General) of the policy agreement as follows:

A. All land areas in The Township lying west of U.S. 23 Expressway and north of the ~~centerline~~ SOUTH LINE of Ellsworth Road from U.S. 23 to the west line of ~~Platt~~ STATE Road, ~~thence southerly to the Railroad right-of-way adjacent to the City Landfill, thence westerly along the landfill line extended to Stone School Road, thence northerly along the east line of Stone School Road to the south line of Ellsworth Road, thence westerly to the west line of State Street~~, thence northerly to the south line of I-94,...

The question being the Resolution with the amended Policy Agreement.

On a voice vote, Chair declared the motion carried unanimously.

The Resolution as adopted reads as follows:

R-280-7-78

RESOLUTION TO APPROVE CITY OF ANN ARBOR AND PITTSFIELD TOWNSHIP AGREEMENT

WHEREAS, the City of Ann Arbor officials and Pittsfield Township officials have spent many months negotiating an agreement of understanding; and,

WHEREAS, both governments agree to the principle of cooperation and not confrontation; and,

WHEREAS, the agreement is deemed in the best interests of the citizens of both units of government;

NOW, THEREFORE, BE IT RESOLVED that the following agreement of understanding be approved.

CITY OF ANN ARBOR–CHARTER TOWNSHIP OF PITTSFIELD POSITION PAPER ON PROMULGATION OF POLICIES

Promulgation of Policies

The CITY OF ANN ARBOR "The City", and the CHARTER TOWNSHIP OF PITTSFIELD, "The Township", by their respective governing bodies, for the purpose of furthering their common welfare, do hereby promulgate certain policies, and declare their intentions to abide the same in their exercise of governmental authority so far as practical and not in conflict with law.

I–ANNEXATION–GENERAL

A. All land areas in The Township lying west of U.S. 23 Expressway and north of the south line of Ellsworth Road from U.S. 23 to the west line of State Road, thence

northerly to the south line of I-94, thence westerly to the western boundary of The Township, shall be designated as "The Territory" and shall be eventually annexed to the City in an orderly manner.

B. It shall be understood that this aforementioned line is the unofficial boundary line until such times it can be so officially designated.

C. Inasmuch as the Township and the City have an existing contract for sewer service for portions of the Township, the Township shall not make plans to provide municipal sewer and/or water service to any properties within said Territory, however the Township shall maintain all other legal authority and responsibility for Township lands and residents in the Territory until such time as they do become annexed to the City.

D. Notwithstanding previous policies, decisions and procedures, the City and Township hereby agree that individual properties in the designated area may be annexed to the City even where such annexation may create new islands. Neither the City nor the Township shall interpose in any judicial or other proceeding pertaining to the annexation of any portion of the said Territory an objection to such annexation by reason that the same would create an enclave of Township land within the City.

E. Neither the City nor the Township shall seek to require annexation to the City of any such enclave of Township land lying within the Territory, solely because of its constituting an enclave, whether now existing or hereafter created through the annexation of a portion of the Territory. Nevertheless, upon request to the City by the owner of a property within any said enclave for City water and/or sewer service to such property, the City may require such property to become annexed to the City as a condition of granting such service.

F. The Township agrees that rather than furthering litigation in the case of the Pittsfield Islands, it will agree to the Boundary Commission decision of 1973 (File No. 8322) if the individual review procedure as set forth in paragraph I-H is applied.

G. Through joint resolutions of the City and Township governing bodies any portion of the Territory within the designated area may be annexed to the City upon the petition therefor signed by the petitioners as provided by MCLA 117.9(8) in the case of such alternate method of annexation.

H. Upon annexation to the City of properties within said Territory the City "deferred charges" thereon, for benefits conferred by capital improvements made prior to the annexation shall be payable at the property owners option, either in full, or in not

less than six (6) equal annual installments, provided that the same shall be payable in up to twelve (12) equal annual installments in cases of a property being, and continuing to be, the homestead of an owner occupant who has special hardship problems or is otherwise adjudged in need of special consideration. Hardship and special considerations may be conferred upon the single owner occupant at time of annexation. A transition appeals committee shall be established for the purpose of determining such need. It shall be authorized to make recommendations to City Council for special consideration and shall be comprised of two (2) members appointed from the City and one (1) member appointed from the Township.

II–MUNICIPAL AIRPORT

A. The City agrees that the pending appeal of the decision of the Washtenaw Circuit Court in the suit of the Township vs. the City (Docket No. 77-12619) respecting the City's proceedings to annex Territories in and about the Municipal Airport and a portion of Eisenhower Boulevard shall be dismissed.

B. The Township agrees to cooperate with the City in the establishment of an Airport Land Use Plan which recognizes the compatibility of light industrial, warehousing, gravel mining and other uses on airport lands. The Township will review and comment on the plan before City adoption. It is further understood that any private construction on Airport lands will require approval under Township zoning and site plan requirements, as well as Township Building and Safety Department permit requirements. Plans for municipal construction on Airport lands must be submitted to the Township for review and comment.

C. The Township agrees to establish a land use plan for the environs of the Airport which recognizes only land uses which are compatible to airport operations from a safety and environmental point of view. The City will review and comment on the plan before adoption by the Township.

D. It is further agreed that gravel mining may take place only for use on City of Ann Arbor roads and public works projects and for use on Pittsfield Township roads, and public works projects. In addition, that a gravel processing plan, a restoration plan and a soil erosion plan be filed and reviewed by the Township.

E. Excepting as exempt by law, the Township shall assess for taxes the real and personal properties of and upon the airport lands.

F. The Township agrees to provide right-of-way for City sanitary sewage mains to the Airport to serve Airport properties uses only.

III–LANDFILL

A. The City desires to expand its Landfill operations to the west on property known as the Derck, Nielsen, and McCalla parcels.

B. The Township agrees to actively support and assist in acquisition negotiations such expansion on the conditions that:

1. A land use and restoration plan be developed for long range use of the landfill area.

2. That a reasonable strip of land immediately east of Stone School Road, as well as along Ellsworth Road, as well as along the northern edge of what is known as the Morgan properties is excluded for environmental purposes.

C. A Landfill Expansion Advisory Committee composed of four (4) persons appointed by the City and three (3) persons appointed by the Township shall be created to advise the City on environmental and operational plans.

D. The Township desires that it be given preferred customer consideration by the City in the use of the Landfill or offered an opportunity for proportionate investment equity if the Landfill is to be expanded in this location.

E. The Township shall not adopt any ordinance, rule or regulation which regulates or attempts to regulate the City's use of the landfill property so long as that property is used for disposal of refuse materials or for park purposes.

IV–SEWER/WATER SERVICEES

A. Upon acceptance and execution of this position paper, the City agrees to immediately approve the Township's request for sewer service limited to the Township Hall and the State Road frontage of a proposed commercial development at Ellsworth and State Roads in accordance with procedures established in Paragraph I-A of the Ann Arbor Pittsfield Sewer Service Agreement dated September 30, 1975. It is understood State Department of Natural Resources approval will be sought eagerly by the City.

B. The sewer service will be provided at 103% of City rates in accordance with the aforementioned agreement.

C. The City will agree to consider additional requests for service prior to the completion of the new "area wide treatment plant" on a case by case basis.

COMMUNICATIONS FROM THE MAYOR

Mayor Louis D. Belcher informed Councilmembers that he will be communicating with Mr. Robert Lillie, Pittsfield Township Supervisor, to advise him of the changes made tonight in the Pittsfield Township Agreement.

* *

Mayor Belcher alerted Council that there are several major Planning matters comming up for consideration, such as the eighty acres of land to be developed in the Briarwood area and a proposal for downtown housing.

* *

Mayor Belcher recommended the appointment of Hugh M. Wanty, 2061 Pauline Boulevard, to the Housing Board of Appeals to replace James J. O'Kane for an indefinite term.

Moved by Councilmember Trowbridge that Council concur in the recommendation of the Mayor.

On roll call the vote was as follows: Yeas, Councilmembers Latta, Greenberg, Morris, Senunas, Sheldon, Trowbridge, Cmejrek, Mayor Belcher, 8

Nays, 0

Councilmember Bell was absent from the Council Chamber at the time the vote was taken.

Chair declared the motion carried.

* *

Mayor Belcher recommended the appointment of Roberta Lea Shrope, 321 South Revena Boulevard, to the Planning Commission, effective July 1, 1978 for a three year term ending June 30, 1981.

Moved by Councilmember Cmejrek that Council concur in the recommendation of the Mayor.

On roll call the vote was as follows: Yeas, Councilmembers Senunas, Sheldon, Trowbridge, Cmejrek, Bell, Mayor Belcher, 6

Nays, Councilmembers Latta, Greenberg, Morris, 3

Chair declared the motion carried.

* *

Mayor Belcher laid the nomination on the table of Charles T. Wagner, 3425 Brentwood Court, to the Planning Commission to be confirmed at the next session of Council.

COMMUNICATIONS FROM COUNCIL COMMITTEES

None.

Exhibit 5

AGREEMENT SUPPLEMENTING 1979 POLICY STATEMENT RELATIVE TO AIRPORT LAYOUT PLANS, AERONAUTICAL FACILITIES AND NON-AERONAUTICAL FACILITIES AT THE ANN ARBOR AIRPORT

This agreement ("Agreement") is between the City of Ann Arbor ("Ann Arbor"), a Michigan Municipal Corporation and Pittsfield Charter Township ("Pittsfield"), a Michigan Municipal Corporation.

RECITALS:

Ann Arbor owns and operates the Ann Arbor Airport ("Airport"), which is located in Pittsfield Charter Township.

In 1979 Pittsfield and Ann Arbor entered into an agreement entitled "Policy Statement," a portion of which has addressed certain aspects of the operation of the Ann Arbor Airport.

This Agreement is not intended to replace the Policy Statement. However, in the event of any conflict with the Policy Statement, this agreement shall apply.

Under the Michigan Aeronautics Code, MCL 259.1 et seq., Ann Arbor has jurisdictional control for the management, governance and use of the Airport, including application of its police powers, rules, regulations and ordinances, and including the zoning and planning of aeronautical facilities on the Airport property.

The City of Ann Arbor has adopted its construction code, including the building code, electrical code and mechanical code components thereof, in accordance with the Stille-DeRossett-Hale Single State Construction Code Act (MCL 125.1501 et seq.) ("construction code"). The City and the Township do not agree as to the authority granted to the City by the Michigan Aeronautics Code to extend and enforce its construction code at the Airport relative to aeronautical facilities. However, without deciding the extent of the City's authority under the Michigan Aeronautics Code, the City and the Township agree that to the extent it may be necessary, this agreement is an agreement between two public agencies that constitutes an interlocal agreement for purposes of Sections 4 and 5 of the Urban Cooperation Act (MCL 124.504 and 124.505) and Subsection 8b(2) of the Stille-DeRossett-Hale Single State Construction Code Act (MCL 125.1508b(2)) by which the City and the Township agree that the City shall extend and enforce its construction code to all aeronautical facilities constructed on Airport property, including issuing permits, inspections and enforcement of violations.

The Airport is serviced in whole by Pittsfield sanitary sewer service and is serviced in part by Pittsfield water service.

Unless and until Ann Arbor or the Airport qualifies as an authorized public agency for the Airport under Section 9110 of Part 91, Soil Erosion and Sedimentation Control, of

the Natural Resources and Environmental Protection Act, MCL 324.9110, Pittsfield has jurisdiction over the Airport for soil erosion and sedimentation control.

Wherefore, the parties agree as follows:

1. "Aeronautical facilities" means Airport buildings, landing fields and other facilities that are used for and serve aeronautical or aeronautically related operations and purposes. Aeronautical facilities include both facilities constructed by Ann Arbor and facilities that are privately constructed.

2. "Non-aeronautical facilities" means facilities whose use is unrelated to aeronautical operations or purposes.

3. A modification of the Airport Layout Plan is a land use plan as used in Section II.B. of the Policy Statement.

4. If a modification of the Airport Layout Plan is proposed, Ann Arbor will give notice to Pittsfield's Building Official or such other person as Pittsfield designates in writing, of the intent to modify the Airport layout plan at least 30 days before authorizing a professional services agreement for the modification. At least 30 days before submitting a modification of the Airport Layout Plan for approval by the Michigan Aeronautics Commission or the Federal Aviation Administration, Ann Arbor will provide Pittsfield's Building Official with copies of the documents to be submitted to those bodies. After approval of a modified Airport Layout Plan by the Michigan Aeronautics Commission or the Federal Aviation Administration, Ann Arbor will provide Pittsfield's Building Official with a copy of the proposed modification at least 30 days before the Ann Arbor City Council meeting at which it is to be submitted for approval.

5. Annually Ann Arbor will provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with a copy of the five year Airport Improvement Plan for the Airport.

6. If Ann Arbor applies for grant funds for new or expanded facilities shown or listed on the Airport Layout Plan or Airport Improvement Plan it will notify Pittsfield's Building Official, or such other person as Pittsfield designates in writing, of the application.

7. Aeronautical facilities being constructed at the Ann Arbor Airport are not required to go through the Pittsfield site plan review and approval process. However, when civil construction drawings for a project have been completed, but prior to bid for construction of the facilities, Ann Arbor will submit copies of the civil construction drawings to Pittsfield's Building Official, or such other person as Pittsfield designates in writing, for review and comment. The plans submitted to Pittsfield shall consist of four (4) sets of full sized drawings and a description of

the type of project, the general scope and the time frame. All proposed utilities associated with civil construction drawings for a project shall meet all current Township Land Development Standards.

8. Typical administrative fees will not be charged for the review of the plans submitted pursuant to paragraph 7, but the City will be responsible for establishing an Airport Plan (AP) escrow account for costs, which Pittsfield agrees shall be limited to its actual costs for plan review and comment.

9. Pittsfield will provide a written evaluation of the plans specified in paragraph 7 based on the Pittsfield Zoning Ordinance and Land Development Standards to Ann Arbor's Fleet & Facilities Manager, or such other person as Ann Arbor designates in writing, within two (2) weeks of the submittal in order to permit Ann Arbor staff to consider its comments.

10. Ann Arbor will consider and endeavor to incorporate reasonable recommendations provided by Pittsfield.

11. Ann Arbor will obtain soil erosion and sedimentation control permits for the Airport from Pittsfield until such time as Ann Arbor or the Airport qualifies as an authorized public agency for the Airport under Section 9110 of Part 91, Soil Erosion and Sedimentation Control, of the Natural Resources and Environmental Protection Act, MCL 324.9110.

12. Ann Arbor will obtain Pittsfield utility permits as required by Pittsfield ordinance for connections to Pittsfield sanitary sewer or water lines.

13. Ann Arbor shall extend and enforce its construction code, including the building code, electrical code and mechanical code components thereof, to all aeronautical facilities constructed on Airport property and provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with copies of all construction permit documents including the application, the permit, inspection reports and any certificate of occupancy within thirty days of being issued or received.

14. Non-aeronautical facilities at the Airport will be required to comply with Pittsfield planning and zoning requirements and the Pittsfield construction code ordinance.

15. Nothing contained in this agreement shall be construed as limiting Pittsfield's authority to enforce the State Construction Code regarding any violations of that code for non-aeronautical facilities.

16. Nothing contained in this agreement shall exempt aeronautical facilities from being in compliance with the State Construction Code unless said facilities are under the jurisdiction of the Federal Aviation Administration.

17. Ann Arbor shall extend and enforce its fire prevention code to all aeronautical facilities located on Airport property and provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with copies of all fire inspection documents including fire alarm and detection systems and fire extinguishing system certification and test reports, and all required operational permits within thirty days of being issued or received.

18. This agreement shall be approved by the concurrent resolutions of the Ann Arbor City Council and Pittsfield Charter Township Board of Trustees.

19. This agreement shall take effect October 1, 2009 or after a copy has been filed with both the Washtenaw County Clerk and the Michigan Secretary of State, whichever is later.

20. This agreement shall have a term of 5 years beginning on October 1, 2009. It shall automatically renew for successive 5 year periods unless either party provides the other with written notice of non-renewal at least 60 days before the end of a term.

Dated: ________________________	Dated: ________________________
City of Ann Arbor	Pittsfield Charter Township
By______________________________	By______________________________
John Hieftje, Mayor	Mandy Grewal, Township Supervisor
By______________________________	By______________________________
Jacqueline Beaudry, City Clerk	Allen Israel, Township Clerk
Approved as to form:	Approved as to form:
________________________________	________________________________
Stephen K. Postema, City Attorney	R. Bruce Laidlaw, Township Attorney

Council unanimously agreed with Councilmember Morris to amend Paragraph A of Section I (Annexation - General) of the policy agreement as follows:

A. All land areas in The Township lying west of U.S. 23 Expressway and north of the ~~centerline~~ SOUTH LINE of Ellsworth Road from U.S. 23 to the west line of ~~Platt~~ STATE Road, ~~thence southerly to the Railroad right-of-way adjacent to the City Landfill; thence westerly along the landfill line extended to Stone School Road, thence northerly along the east line of Stone School Road to the south line of Ellsworth Road; thence westerly to the west line of State Street~~, thence northerly to the south line of I-94,...

The question being the Resolution with the amended Policy Agreement.

On a voice vote, Chair declared the motion carried unanimously.

The Resolution as adopted reads as follows:

R-280-7-78

RESOLUTION TO APPROVE CITY OF ANN ARBOR AND PITTSFIELD TOWNSHIP AGREEMENT

WHEREAS, the City of Ann Arbor officials and Pittsfield Township officials have spent many months negotiating an agreement of understanding; and,

WHEREAS, both governments agree to the principle of cooperation and not confrontation; and,

WHEREAS, the agreement is deemed in the best interests of the citizens of both units of government;

NOW, THEREFORE, BE IT RESOLVED that the following agreement of understanding be approved.

CITY OF ANN ARBOR–CHARTER TOWNSHIP OF PITTSFIELD POSITION PAPER ON PROMULGATION OF POLICIES

Promulgation of Policies

The CITY OF ANN ARBOR "The City", and the CHARTER TOWNSHIP OF PITTSFIELD, "The Township", by their respective governing bodies, for the purpose of furthering their common welfare, do hereby promulgate certain policies, and declare their intentions to abide the same in their exercise of governmental authority so far as practical and not in conflict with law.

I–ANNEXATION–GENERAL

A. All land areas in The Township lying west of U.S. 23 Expressway and north of the south line of Ellsworth Road from U.S. 23 to the west line of State Road, thence

northerly to the south line of I-94, thence westerly to the western boundary of The Township, shall be designated as "The Territory" and shall be eventually annexed to the City in an orderly manner.

B. It shall be understood that this aforementioned line is the unofficial boundary line until such times it can be so officially designated.

C. Inasmuch as the Township and the City have an existing contract for sewer service for portions of the Township, the Township shall not make plans to provide municipal sewer and/or water service to any properties within said Territory, however the Township shall maintain all other legal authority and responsibility for Township lands and residents in the Territory until such time as they do become annexed to the City.

D. Notwithstanding previous policies, decisions and procedures, the City and Township hereby agree that individual properties in the designated area may be annexed to the City even where such annexation may create new islands. Neither the City nor the Township shall interpose in any judicial or other proceeding pertaining to the annexation of any portion of the said Territory an objection to such annexation by reason that the same would create an enclave of Township land within the City.

E. Neither the City nor the Township shall seek to require annexation to the City of any such enclave of Township land lying within the Territory, solely because of its constituting an enclave, whether now existing or hereafter created through the annexation of a portion of the Territory. Nevertheless, upon request to the City by the owner of a property within any said enclave for City water and/or sewer service to such property, the City may require such property to become annexed to the City as a condition of granting such service.

F. The Township agrees that rather than furthering litigation in the case of the Pittsfield Islands, it will agree to the Boundary Commission decision of 1973 (File No. 8322) if the individual review procedure as set forth in paragraph I-H is applied.

G. Through joint resolutions of the City and Township governing bodies any portion of the Territory within the designated area may be annexed to the City upon the petition therefor signed by the petitioners as provided by MCLA 117.9(8) in the case of such alternate method of annexation.

H. Upon annexation to the City of properties within said Territory the City "deferred charges" thereon, for benefits conferred by capital improvements made prior to the annexation shall be payable at the property owners option, either in full, or in not

less than six (6) equal annual installments, provided that the same shall be payable in up to twelve (12) equal annual installments in cases of a property being, and continuing to be, the homestead of an owner occupant who has special hardship problems or is otherwise adjudged in need of special consideration. Hardship and special considerations may be conferred upon the single owner occupant at time of annexation. A transition appeals committee shall be established for the purpose of determining such need. It shall be authorized to make recommendations to City Council for special consideration and shall be comprised of two (2) members appointed from the City and one (1) member appointed from the Township.

II–MUNICIPAL AIRPORT

A. The City agrees that the pending appeal of the decision of the Washtenaw Circuit Court in the suit of the Township vs. the City (Docket No. 77-12619) respecting the City's proceedings to annex Territories in and about the Municipal Airport and a portion of Eisenhower Boulevard shall be dismissed.

B. The Township agrees to cooperate with the City in the establishment of an Airport Land Use Plan which recognizes the compatibility of light industrial, warehousing, gravel mining and other uses on airport lands. The Township will review and comment on the plan before City adoption. It is further understood that any private construction on Airport lands will require approval under Township zoning and site plan requirements, as well as Township Building and Safety Department permit requirements. Plans for municipal construction on Airport lands must be submitted to the Township for review and comment.

C. The Township agrees to establish a land use plan for the environs of the Airport which recognizes only land uses which are compatible to airport operations from a safety and environmental point of view. The City will review and comment on the plan before adoption by the Township.

D. It is further agreed that gravel mining may take place only for use on City of Ann Arbor roads and public works projects and for use on Pittsfield Township roads, and public works projects. In addition, that a gravel processing plan, a restoration plan and a soil erosion plan be filed and reviewed by the Township.

E. Excepting as exempt by law, the Township shall assess for taxes the real and personal properties of and upon the airport lands.

F. The Township agrees to provide right-of-way for City sanitary sewage mains to the Airport to serve Airport properties uses only.

III–LANDFILL

A. The City desires to expand its Landfill operations to the west on property known as the Derck, Nielsen, and McCalla parcels.

B. The Township agrees to actively support and assist in acquisition negotiations such expansion on the conditions that:

1. A land use and restoration plan be developed for long range use of the landfill area.

2. That a reasonable strip of land immediately east of Stone School Road, as well as along Ellsworth Road, as well as along the northern edge of what is known as the Morgan properties is excluded for environmental purposes.

C. A Landfill Expansion Advisory Committee composed of four (4) persons appointed by the City and three (3) persons appointed by the Township shall be created to advise the City on environmental and operational plans.

D. The Township desires that it be given preferred customer consideration by the City in the use of the Landfill or offered an opportunity for proportionate investment equity if the Landfill is to be expanded in this location.

E. The Township shall not adopt any ordinance, rule or regulation which regulates or attempts to regulate the City's use of the landfill property so long as that property is used for disposal of refuse materials or for park purposes.

IV–SEWER/WATER SERVICEES

A. Upon acceptance and execution of this position paper, the City agrees to immediately approve the Township's request for sewer service limited to the Township Hall and the State Road frontage of a proposed commercial development at Ellsworth and State Roads in accordance with procedures established in Paragraph I-A of the Ann Arbor Pittsfield Sewer Service Agreement dated September 30, 1975. It is understood State Department of Natural Resources approval will be sought eagerly by the City.

B. The sewer service will be provided at 103% of City rates in accordance with the aforementioned agreement.

C. The City will agree to consider additional requests for service prior to the completion of the new "area wide treatment plant" on a case by case basis.

COMMUNICATIONS FROM THE MAYOR

Mayor Louis D. Belcher informed Councilmembers that he will be communicating with Mr. Robert Lillie, Pittsfield Township Supervisor, to advise him of the changes made tonight in the Pittsfield Township Agreement.

* *

Mayor Belcher alerted Council that there are several major Planning matters comming up for consideration, such as the eighty acres of land to be developed in the Briarwood area and a proposal for downtown housing.

* *

Mayor Belcher recommended the appointment of Hugh M. Wanty, 2061 Pauline Boulevard, to the Housing Board of Appeals to replace James J. O'Kane for an indefinite term.

Moved by Councilmember Trowbridge that Council concur in the recommendation of the Mayor.

On roll call the vote was as follows: Yeas, Councilmembers Latta, Greenberg, Morris, Senunas, Sheldon, Trowbridge, Cmejrek, Mayor Belcher, 8

Nays, 0

Councilmember Bell was absent from the Council Chamber at the time the vote was taken.

Chair declared the motion carried.

* *

Mayor Belcher recommended the appointment of Roberta Lea Shrope, 321 South Revena Boulevard, to the Planning Commission, effective July 1, 1978 for a three year term ending June 30, 1981.

Moved by Councilmember Cmejrek that Council concur in the recommendation of the Mayor.

On roll call the vote was as follows: Yeas, Councilmembers Senunas, Sheldon, Trowbridge, Cmejrek, Bell, Mayor Belcher, 6

Nays, Councilmembers Latta, Greenberg, Morris, 3

Chair declared the motion carried.

* *

Mayor Belcher laid the nomination on the table of Charles T. Wagner, 3425 Brentwood Court, to the Planning Commission to be confirmed at the next session of Council.

COMMUNICATIONS FROM COUNCIL COMMITTEES

None.

Exhibit 6

Councilmember Johnson moved, seconded by Councilmember Teall, that the resolution be adopted.

On a voice vote, the Mayor declared the motion carried.

****

R-31-1-07 APPROVED

RESOLUTION TO APPROVE THE URS CORPORATION AIRPORT LAYOUT PLAN UPDATE FOR THE ANN ARBOR MUNICIPAL AIRPORT, WHICH ILLUSTRATES EXISTING AND PROPOSED FACILITIES TO MEET THE FUTURE DEMANDS OF AIRPORT TENANTS AND USERS

Whereas, An approved Airport Layout Plan (ALP) is required by the FAA and the Michigan Department of Transportation (MDOT)-Bureau of Aeronautics for the Ann Arbor Municipal Airport to participate in the federal and state airport improvement program;

Whereas, The airport's ALP is no longer current and does not depict all airport facilities as required by the FAA and MDOT-Bureau of Aeronautics;

Whereas, The MDOT-Bureau of Aeronautics and FAA, funded the ALP Update at a cost split of 90% Federal, 5% State, and 5% City and URS Corporation a Michigan Planning and Consulting firm was selected to develop the plan;

Whereas, The recommended ALP document depicts existing and future airport facilities and was completed using FAA and MDOT design and planning standards, which included the requirement for participation by users, tenants and the general public; and

Whereas, On July 19, 2006, the Airport Advisory Committee voted unanimously to recommend City Council approval of the ALP Update for the Ann Arbor Municipal Airport;

RESOLVED, That Council approve the ALP Update for the Ann Arbor Municipal Airport;

RESOLVED, That the Mayor and City's Airport Manager be hereby authorized and directed to execute said ALP Document after approval as to form by the City Attorney and approval as to substance by the City Administrator; and

RESOLVED, That the City Administrator be authorized to take the necessary administrative actions to implement this resolution.

Councilmember Higgins moved, seconded by Councilmember Teall, that the

- Staff to bring back a separate proposal regarding extending the runway within the next 60 days and that notification of the proposal be sent out to citizens in the surrounding area.

On a voice vote, the Mayor declared the motion carried.

****

R-32-1-07 APPROVED

RESOLUTION ACCEPTING UTILITY EASEMENT FROM PLYMOUTH GREEN CROSSINGS, L.L.C.

Whereas, Plymouth Green Crossings, L.L.C., a Michigan limited liability company, is the fee simple owner of property located in the City of Ann Arbor, Washtenaw County, Michigan as described in the Washtenaw County Records at Liber 4539, Page 688, recorded February 21, 2006;

Whereas, The First Amended and Restated Operating Agreement of Plymouth Green Crossings, L.L.C., dated August 30, 2006, authorizes the delivery of a perpetual easement to the City for public utilities; and

Whereas, Plymouth Green Crossings, L.L.C., has delivered an easement to the City for the construction and maintenance of municipally operated public services comprising the public utilities system to run with the land and burden the respective property perpetually, being more particularly described as follows:

Description of Variable Width Water Main:

Commencing at the center of Section 14, Town 2 S, Range 6 E, City of Ann Arbor, Washtenaw County, Michigan; thence S 00°05'25" W 667.92 feet along the N and S 1/4 line of said Section 14; thence N 89°54'35" W 40.00 feet to a point on the Westerly right-of-way line of Green Road; thence along the said right-of-way line in the following courses: Southerly 46.90 feet along the arc of a 490.00 foot radius circular curve to the left through a central angle of 05°29'00" having a chord which bears S 02°39'05" E 46.88 feet, S 05°23'35" E 353.86 feet, Southerly 271.22 feet along the arc of a 630.00 foot radius circular curve to the right through a central angle of 24°40'00" having a chord which bears S 06°56'25" W 269.13 feet and S 19°16'25" W 71.37 feet; thence N 90°00'00" W 213.38 feet to the POINT OF BEGINNING;

thence S 56°41'39" W 101.15 feet;
thence N 89°54'35" W 139.18 feet;
thence S 45°05'25" W 24.77 feet;
thence S 00°05'25" W 34.72 feet;

Exhibit 7

CITY OF ANN ARBOR, MICHIGAN

100 North Fifth Avenue, P.O. Box 8647
Ann Arbor, Michigan 48107-88647
Phone (734) 994-2841 • Fax (734) 997-1133
http://www.ci.ann-arbor.mi.us

Municipal Airport
Public Services Area

February 28, 2007

John Pierce, Transportation Planner
Michigan Department of Transportation
Bureau of Aeronautics
2700 East Airport Service Dr.
Lansing, MI 48906-2160

Subject: Ann Arbor Municipal Airport Layout Plan (revision)

Dear Mr. Pierce:

The Ann Arbor City Council, at their January 22, 2007 meeting, approved an action directing staff to revise the Airport Layout Plan (ALP) to reflect a 4,300 feet runway and return that Plan to Council for consideration within 60 days. Council has been informed that the process for revising the ALP is underway but cannot be completed within 60 days.

Please accept this letter as our request to revise the ALP to show the runway improvement. My understanding is that this process begins with resubmitted drawings and an airspace review by the FAA. The Airport's consultant, URS Corporation, has completed the revisions to the drawings showing the 800 feet runway improvement and will be submitting those to you under separate cover. If you have any questions or need additional information, please contact me at (734) 972-9112.

Sincerely,

Matthew J. Kulhanek

Matthew J. Kulhanek
Airport Manager

CITY OF ANN ARBOR, MICHIGAN

100 North Fifth Avenue, P.O. Box 8647
Ann Arbor, Michigan 48107-88647
Phone (734) 994-2841 • Fax (734) 997-1133
http://www.ci.ann-arbor.mi.us

Municipal Airport
Public Services Area

February 13, 2007

John Pierce, Transportation Planner
Michigan Department of Transportation
Bureau of Aeronautics
2700 East Airport Service Dr.
Lansing, MI 48906-2160

Subject: Ann Arbor Municipal Airport Layout Plan

Dear Mr. Pierce:

Enclosed please find one complete set of drawings and three signed cover sheets for the approved Airport Layout Plan of the Ann Arbor Municipal Airport. The documents were approved by the City Council at their meeting on January 22, 2007. If you have any questions or need additional information, please contact me at (734) 972-9112.

Sincerely,

Matthew J. Kulhanek
Airport Manager

Enc.

Exhibit 8

PITTSFIELD CHARTER TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RES #09-23
RESOLUTION OPPOSING PROPOSED EXPANSION OF THE ANN ARBOR MUNICIPAL AIRPORT RUNWAY

MARCH 24, 2009

Minutes of a Regular Meeting of the Township Board of Pittsfield Charter Township, Washtenaw County, Michigan, held at the Township Administration Building located at 6201 W. Michigan Avenue, in said Township, on the 24th day of March, at 6:30 p.m.

Members Present: Grewal, Israel, Scribner, Ferguson, Hunt, Krone, Yi.
Members Absent: None.

The following preamble and resolution were offered by Member Scribner and supported by Member Ferguson.

WHEREAS, the Ann Arbor airport is under the jurisdiction of the City of Ann Arbor and operated by an independent Authority and the land is located within Pittsfield Charter Township immediately adjacent to a residential area; and

WHEREAS, the existing width and length has not posed any substantial safety concerns in the past with only five incidents of landing mishaps out of a total of 600,000 landings in the past eight years; and

WHEREAS, the proposed changes and expansion would shift the runway dangerously close to a busy township roadway (Lohr Road) and closer to dense residential subdivisions; and

WHEREAS, such a runway expansion will significantly increase air traffic volumes and noise pollution experienced by residential subdivisions in the vicinity of the Ann Arbor airport, thereby resulting in a decline of residential home property values; and

WHEREAS, the City of Ann Arbor has not fully demonstrated the economic and safety justifications for undertaking the proposed runway expansion; and

WHEREAS, the City of Ann Arbor appears to have not taken into consideration the negative safety implications such a runway expansion may impose on the surrounding residential subdivisions by expanding a runway closer to residential subdivisions

NOW THEREFORE BE IT RESOLVED, the Pittsfield Charter Township Board of Trustees urges the City of Ann Arbor to reconsider the merits of expanding the Ann Arbor Airport runway in light of the negative implications such an expansion would impose on the residents of Pittsfield Charter Township.

AYES: Grewal, Israel, Scribner, Ferguson, Hunt, Krone, Yi.
NAYS: None.
ABSENT: None.
ABSTAIN: None.

RESOLUTION DECLARED ADOPTED.

Alan Israel

Alan Israel, Clerk
Pittsfield Charter Township

DATED: March 24, 2009.

CERTIFICATE

I, Alan Israel hereby certify that the foregoing is a true and complete copy of a resolution adopted by the Township Board of Pittsfield Charter Township, County of Washtenaw, State of Michigan, at a Regular Meeting held on March 24, 2009, and that said meeting was conducted and public notice of said meeting was given pursuant to and in full compliance with the Open Meetings Act, being Act 267, Public Acts of Michigan, 1976, and that the minutes of said meeting were kept and will be or have been made available as required by said Act.

Alan Israel, Clerk
Pittsfield Charter Township

DATED: March 24, 2009.

Exhibit 9

LODI TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RESOLUTION # 2009-009
A RESOLUTION OPPOSING PROPOSED RUNWAY EXPANSION OF THE ANN ARBOR MUNICIPAL AIRPORT

WHEREAS, the Ann Arbor airport is under the jurisdiction of the City of Ann Arbor and operated by an independent Authority and the land is located within Pittsfield Charter Township immediately adjacent to residential areas, including Lodi Township;

WHEREAS, the existing width and length of Runway 6-24 has not be posed any substantial safety concerns in the past with only five incidents of landing mishaps out of a total of 600,000 landings in the past eight years; and

WHEREAS, the proposed changes and expansion would shift the runway so that it ends a mere 700 yards from a busy roadway (Lohr Road) and closer to dense residential subdivisions; and

WHEREAS, such a runway will significantly accommodate larger and heavier aircraft, increase air traffic volumes, and increase noise pollution experienced by residential subdivisions in the vicinity of the Ann Arbor airport, thereby resulting in a decline in residential home property values; and

WHEREAS, the City of Ann Arbor has not fully demonstrated the economic and safety justifications for undertaking the proposed runway expansion; and

WHEREAS, the City of Ann Arbor appears to have not taken into consideration the negative safety implications such a runway expansion may impose on the surrounding residential subdivisions by expanding a runway closer to residential subdivisions;

NOW, THEREFORE BE IT RESOLVED, the Lodi Township Board of Trustees urge the City of Ann Arbor to reconsider the merits of expanding the Ann Arbor Airport runway in light of the negative implications such an expansion would impose on the residents of Lodi Township.

ROLL CALL VOTE:
Ayes: Masters, Staebler, Lindemann, Canham, Foley, and Godek.
Nays: Rentschler.
Absent: None.
Abstain: None.

RESOLUTION DECLARED ADOPTED

____
Elaine Masters, Clerk, Lodi Township
DATED: May 12, 2009

Exhibit 10

car owners relative to identification marks on railroad equipment. FRA, railroads, and the public refer to the stenciling to identify freight cars.

Annual Estimated Burden Hours: 18,750 hours.

Title: Rear-End Marking Devices.

OMB Control Number: 2130–0523.

Type of Request: Extension of a currently approved collection.

Affected Public: Railroads.

Abstract: The collection of information is set forth under 49 CFR Part 221 which requires railroads to furnish a detailed description of the type of marking device to be used for the trailing end of rear cars in order to ensure rear cars meet minimum standards for visibility and display. Railroads are required to furnish a certification that the device has been tested in accordance with current "Guidelines For Testing of Rear End Marking Devices." Additionally, railroads are required to furnish detailed test records which include the testing organizations, description of tests, number of samples tested, and the test results in order to demonstrate compliance with the performance standard.

Annual Estimated Burden Hours: 89 hours.

Title: Locomotive Certification (Noise Compliance Regulations).

OMB Control Number: 2130–0527.

Type of Request: Extension of a currently approved collection.

Affected Public: Railroads.

Abstract: Part 210 of title 49 of the United States Code of Federal Regulations (CFR) pertains to FRA's noise enforcement procedures which encompass rail yard noise source standards published by the Environmental Protection Agency (EPA). EPA has the authority to set these standards under the Noise Control Act of 1972. The information collected by FRA under Part 210 is necessary to ensure compliance with EPA noise standards for new locomotives.

Annual Estimated Burden Hours: 2,767 hours.

ADDRESSES: Send comments regarding these information collections to the Office of Information and Regulatory Affairs, Office of Management and Budget, 725 Seventeenth Street, NW., Washington, DC, 20503, *Attention:* FRA Desk Officer. Alternatively, comments may be sent via e-mail to the Office of Information and Regulatory Affairs (OIRA), Office of Management and Budget, at the following address: *oira_submissions@omb.eop.gov.*

Comments are invited on the following: Whether the proposed collections of information are necessary for the proper performance of the functions of the Department, including whether the information will have practical utility; the accuracy of the Department's estimates of the burden of the proposed information collections; ways to enhance the quality, utility, and clarity of the information to be collected; and ways to minimize the burden of the collections of information on respondents, including the use of automated collection techniques or other forms of information technology.

A comment to OMB is best assured of having its full effect if OMB receives it within 30 days of publication of this notice in the **Federal Register**.

Authority: 44 U.S.C. 3501–3520.

Issued in Washington, DC, on June 11, 2009.

Donna M. Alwine,

Acting Director, Office of Financial Management, Federal Railroad Administration.

[FR Doc. E9–14254 Filed 6–16–09; 8:45 am]

BILLING CODE 4910–06–P

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

FAA Notice of Intent to Prepare an Environmental Assessment; Ann Arbor Municipal Airport, Ann Arbor, MI

AGENCY: The Federal Aviation Administration, Department of Transportation.

ACTION: Notice of Intent to prepare an Environmental Assessment (EA) and conduct Citizen Advisory Meetings.

SUMMARY: The FAA has delegated selected responsibilities for compliance with the National Environmental Policy Act to the MDOT as part of the State Block Grant Program authorized under Title 49 U.S.C., Section 47128. This notice is to advise the public pursuant to the National Environmental Policy Act of 1969, as amended, (NEPA) 42 U.S.C. 4332(2)(c) that MDOT intends to prepare an EA for the proposed extension of runway 6/24 at the Ann Arbor Municipal Airport. While not required for an EA, the FAA and MDOT are issuing this Notice of Intent to facilitate public involvement. This EA will assess the potential environmental impacts resulting from the proposed extension of runway 6/24 from 3,500 feet to 4,300 feet. All reasonable alternatives will be considered including a no action alternative.

FOR FURTHER INFORMATION CONTACT: Ms. Molly Lamrouex, Environmental Specialist, Bureau of Aeronautics and Freight Services, MDOT, 2700 Port Lansing Road, Lansing, Michigan (517) 335–9866.

SUPPLEMENTARY INFORMATION: The EA will include analysis which will be used to evaluate the potential environmental impacts in the study area. During scoping, and upon publication of a draft EA and a final EA, MDOT will be coordinating with federal, state and local agencies, as well as the public, to obtain comments and suggestions regarding the EA for the proposed project. The EA will assess potential impacts and reasonable alternatives including a no action alternative pursuant to NEPA; FAA Order 1050.1E, Policies and Procedures for Considering Environmental Impacts; FAA Order 5050.4B, National Environmental Policy Act (NEPA) Implementing Instructions for Airport Actions; and the President's Council on Environmental Quality (CEQ) Regulations implementing the provisions of NEPA, and other appropriate Agency guidance.

Public Input Process: During development of the draft EA, a series of meetings to provide for public input will be held to identify potentially significant issues or impacts related to the proposed action that should be analyzed in the EA. For more information regarding the meetings for public input contact Molly Lamrouex, MDOT Bureau of Aeronautics and Freight Services, (517) 335–9866.

Issued in Romulus, Michigan, June 4, 2009.

Matthew J. Thys,

Manager, Detroit Airports District Office, Great Lakes Region.

[FR Doc. E9–14167 Filed 6–16–09; 8:45 am]

BILLING CODE 4910–13–P

DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

Petition for Exemption From the Vehicle Theft Prevention Standard; Nissan

AGENCY: National Highway Traffic Safety Administration (NHTSA) Department of Transportation (DOT).

ACTION: Grant of petition for exemption.

SUMMARY: This document grants in full the Nissan North America, Inc.'s (Nissan) petition for an exemption of the Murano vehicle line in accordance with 49 CFR Part 543, *Exemption from the Theft Prevention Standard.* This petition is granted because the agency has determined that the antitheft device to be placed on the line as standard equipment is likely to be as effective in

Exhibit 11

Ann Arbor Municipal Airport	50178.000	May 4, 2009	May 26, 2009
PROJECT	PROJECT NO.	MEETING DATE	ISSUE DATE

Ann Arbor Municipal Airport	Citizens Advisory Committee Meeting
MEETING LOCATION	MEETING PURPOSE
Amy Eckland	
ISSUED BY	SIGNATURE
PARTICIPANT	COMPANY
See attached list.	

DISCUSSION

The first Citizens Advisory Committee (CAC) meeting was held to discuss: 1) the purpose and mission of the CAC, 2) study history and purpose and need, 3) airport improvements, 4) the Environmental Assessment process, 5) study status and next steps, and 6) questions and answers.

Purpose and Mission of CAC

The CAC was established to provide a means to communicate with those interested in the activities occurring at the Ann Arbor Airport. The people that participate in the CAC are intended to represent a wide variety of potentially interested stakeholder groups. The CAC does not have formal decision-making powers and is acting only in an advisory role. The CAC will help guide the study process and will help communicate the results of the study back to their respective stakeholder groups.

If there are people that are interested in the CAC activities, they are encouraged to contact members of the CAC to express their concerns or questions. These individuals can also submit comments independently to the City and/or JJR. These individuals are encouraged to attend the public hearing in the fall and to provide comments during the public comment period.

Study History and Purpose and Need

In 2007, an Airport Layout Plan (ALP) was approved that depicted a bump out in State Road to provide adequate distance between the end of Runway 6/24 and State Road. In 2008, after discussing the State Road Corridor Study recommendations with local road commission and township officials, a revised ALP was approved that eliminated the bump out of State Road and resolved the distance conflict by proposing a shift of Runway 6/24. The new ALP includes a 150 foot shift of the primary runway, a 950 foot extension (a net increase of 800 feet), and an adjustment of the taxiway and holding bay. The 2008 ALP was approved by MDOT and FAA. It was then approved by City Council in September 2008.

The improvements at the Airport are being proposed to:

1. Provide the recommended runway length to accommodate the B-II category Critical Aircraft that are presently using the airport.
2. Minimize the FAA tower line of sight issues.

3. Address the need for a future 34:1 approach slope on Runway 24.
4. Minimize the occurrence of runway overrun incidents.

Airport Improvements

The proposed improvements at the airport include:

1. Shifting Runway 6/24 150 feet to the southwest.
2. Extending Runway 6/24 by 800 feet, from 3,500 feet to 4,300 feet in total overall length.
3. Moving the holding bay so it is parallel with Runway 6/24 instead of being perpendicular to the runway.
4. The parallel taxiway will be extended to meet the new Runway 6/24 end.

All existing runway and taxiway widths will be maintained. The offset between the runway and taxiway will also be maintained. Any changes to surface drainage will be retained within Airport property. Other alternatives were evaluated that included rotation of the runway, however, none showed merit.

There will be no changes to the fencing at the Airport.

Environmental Assessment Process

The preparation of an Environmental Assessment (EA) is governed by the National Environmental Policy Act (NEPA), 1969, under guidance from the FAA. An EA is intended to be a concise public document that analyzes the environmental impacts of a proposed action. An EA will document, 1) the need for the proposed improvements, 2) alternatives considered, 3) proposed improvements, 4) potential environmental impacts, 5) mitigation measures, and 6) agency coordination and public participation

Following preparation of the EA, the document is then distributed to the public and is available for review and comment during the public comment period. During the 30 day comment period, the document is distributed to resource and regulatory agencies for review and it is available to the public for review. Copies of the document will be made available at public locations: libraries, airport, local municipalities, etc. During those 30 days, comments will be accepted from those interested in the proposed project. At the end of the 30 days, a public hearing will be held.

The EA is a tool to determine whether to prepare an Environmental Impact Statement (EIS) or a Finding of No Significant Impact (FONSI). If the EA concludes that the proposed improvements will not have potential “significant” impacts, a FONSI is prepared. A FONSI is a public document that explains the federal agency’s (FAA) conclusion as to why a proposed action would not have a significant effect on the natural and human environment. The FONSI will also outline proposed measures to mitigate impacts as agreed to in the EA. The FONSI will be jointly signed by both MDOT and FAA.

If it is determined that the project would have significant impact, additional studies may be needed and/or an EIS may be prepared.

Study Status and Next Steps
The overall study will be completed by January 2010. Currently, the study team is still completing the environmental investigations. This will be followed by the preparation of a draft EA. Following a review of the EA by MDOT and the City, the EA will be distributed and the 30 day public comment period will begin. A public hearing will be held at the end of the comment period, which is anticipated to occur in late fall. Following the public hearing, the document will receive State and Federal clearance, and, if appropriate, a FONSI will be prepared. The final EA will be distributed by MDOT.
There will be two more CAC meetings. The second CAC meeting will likely be in July and the third meeting will in October.

Questions and Answers
Throughout the meeting, CAC members asked questions regarding the information presented. The questions are summarized below.

Q. Has the tower blind spot been there since it was built? If so, why is this now a safety concern?

A. Although not considered "unsafe", the blind spot has been a safety concern for several years. Now that there is a proposed project to reconfigure the runway, it is a logical time to incorporate any safety recommendations that will enhance the operational safety of the airport.

Q. How close can the planes be to the adjacent homes during takeoff and landing?

A. The existing traffic pattern altitude for aircraft in the vicinity of Ann Arbor Municipal Airport is 1,000' above ground level. However, during the approach and departure phases of flight, aircraft do descend below this altitude. Actual flight profiles of various models of departing aircraft, including heights above Lohr Road, will be determined and provided at the next CAC meeting.

Q. Why does the airport need to allow for a 34:1 approach slope?

A. The runway approach slope over State Street has been 20:1 for quite some time. Since the current critical aircraft has been determined to be a B-II category jet, FAA Part 77 regulations specify the flatter 34:1 slope as the appropriate approach surface. The proposed 34:1 approach slope will provide approaching aircraft with greater vertical clearance over obstructions, and as a result, a greater margin of safety when operating in low-visibility conditions.

Throughout the meeting, several questions were raised that required additional follow-up information. These are the questions and a response.

Q. What makes the number of overruns "unusually high"? Can the data for the seven reported overruns be provided?

A. The data is still being compiled and will be made available on the Airport website in the upcoming weeks.

Q. How high will planes be over Lohr Road and the adjacent homes?

A. This analysis is ongoing. Results will be provided when they are available.

Q. Why is the 34:1 approach on State Street needed, particularly if State Street will not be widened in the immediate future?

A. The runway approach slope over State Street has been 20:1 for quite some time. Since the current critical aircraft has been determined to be a B-II category jet, FAA Part 77 regulations specify the flatter 34:1 slope as the appropriate approach surface. The proposed 34:1 approach slope will provide approaching aircraft with greater vertical clearance over obstructions, and as a result, a greater margin of safety when operating in low-visibility conditions.

Q. Has the justification for the improvements been fully examined?

A. The justification has been fully examined. The impetus for the improvements is to provide the recommended runway length for the Critical Aircraft that are currently using the airport, as well as the appropriate clear approach surfaces to Runway 6/24. The airport has documented well over 500 annual operations by type B-II aircraft, making this the current Critical Aircraft category. As documented in the Michigan Aviation System Plan (MASP 2008), and supported by FAA Advisory Circular 150/5325-4B, a runway length of 4,300 feet is recommended for category B-II aircraft, based on safety considerations.

Q. It was requested that a copy of the Michigan Airport System Plan (MASP) be provided.

A. A copy of the MASP can be obtained at:

www.michigan.gov/documents/aero/Cover_thru_**MASP**_study_team_MI_airport_system_plan_**MASP**_256781_7.pdf

Q. It was requested that documentation be provided that demonstrated the 500 operations by B-II aircraft.

A. MDOT is finalizing the User Survey Report. Once the report is completed, it will be posted on the Airport's website.

Q. It was also requested that a copy of the FAA Advisory Circular regarding runway length be provided.

A. The FAA AC 150/5325-4B, Runway Length Requirements for Airport Design can be found at: www.**faa**.gov/airports_airtraffic/airports/resources/**advisory_circular**s/media/150-5325-4B/150_5325_4b.doc.

Q. Does the logic/process that justifies the runway extension imply that there will be a continual "creep" in the length of the runway?

A. The decision to extend a runway always rests with the Airport Sponsor (in this case, the City of Ann Arbor). So even if there is a future change in Critical Aircraft category, and enough operations to justify further extension of the runway, neither the State nor the FAA would actually mandate that the extension take place. Since a future runway extension (beyond the proposed 4,300') would result in the shifting (and possibly enlarging) of the Runway Safety Areas and Runway Protection Zones beyond the existing airport boundaries, it is extremely unlikely that the City of Ann Arbor would pursue additional extension of Runway 6/24.

If this report does not agree with your records or understanding of this meeting, or if there are any questions, please advise the writer immediately in writing; otherwise, we will assume the comments to be correct.

P:\50178\000\CAC\CAC #1\ARB CAC May 4 2009 Meeting Summary.docx

Exhibit 12

Ann Arbor Municipal Airport	50178.000	July 20, 2009	September 8, 2009
PROJECT	PROJECT NO.	MEETING DATE	ISSUE DATE
Ann Arbor Municipal Airport		Citizens Advisory Committee Meeting	
MEETING LOCATION		MEETING PURPOSE	
Amy Eckland			
ISSUED BY		SIGNATURE	
PARTICIPANT		COMPANY	
See attached list.			

DISCUSSION

This meeting summary provides an overview of the major topics and discussion items from the second Ann Arbor Municipal Airport Citizens Advisory Committee (CAC) meeting. This meeting summary is not intended to be a transcript of the meeting.

The second CAC meeting was held to discuss: 1) the environmental studies update (noise, historic resources, and botanical and wetland survey), 2) study justification and purpose and need, 3) study status and next steps, and 4) questions and answers.

Environmental Studies Update

Noise

The results of the noise analysis were presented by Mr. Dan Botto, URS. Mr. Botto provided a handout packet and three drawings illustrating noise contours (see attached). The noise analysis uses the Integrated Noise Model (INM), a methodology developed and approved by the Federal Aviation Administration (FAA). The INM is designed to estimate long-term average effects using average annual inputs, not the noise level of a single event.

The data used in the INM included aircraft operations, flight operations by aircraft type and time of day, runways and runway utilization, and flight tracks and flight track utilization. The data used in the model reflected 61,969 aircraft operations for 2009 and 69,717 aircraft operations for the future year 2014. It should be noted that the air taxi/commuter day/night split provided was incorrect. The actual and modeled day/night split for this category of flight operations is 100 percent of arrivals occur during the noise day period, while departures are 96 percent daytime and four percent nighttime. A list of aircraft operations was provided that was generated from Flight Explorer data and the MDOT User Survey.

The INM generated results for three scenarios: Base Year (2009), No Action (2014), and the proposed project (2014). Impacts are determined by comparing the future proposed project to the No Action. The analysis shows that noise impacts for the proposed project do not extend off of airport property; therefore, no impacts would occur to the adjacent properties. Refer to the attached handout and drawings for more detail.

Historic Resources

A review of historic resources was conducted by Commonwealth Cultural Resources Group (CCRG). CCRG completed a site file and literature search and a preliminary field survey. They looked at archaeological (below ground) and above-ground resources. The results of their review concluded there are no existing significant above-ground resources associated with the airport property. The analysis of the data for the below ground resources is pending. The results will be presented at the next CAC meeting.

Botanical and Wetland Survey

A botanical survey was completed by JJR in June of this year. During the site visit, an investigation was conducted for threatened or endangered species and general plant communities. The areas immediately surrounding the runway and the airport facilities are predominately either open field / lawn or agricultural fields. Currently over 160 acres of land owned by the airport are being farmed. Along the southern portion of the property, the area is forested, with some portions being a forested wetland. A drainage ditch passes through the airport. The vegetation along the ditch is mostly shrubs with some larger trees. We will be coordinating with the Washtenaw County Drain Commission to confirm county drain jurisdiction.

The wetland analysis is pending. MDEQ will be conducting a site visit and will make the final determination as to the presence of wetlands at the airport. The results will be presented at the next CAC meeting.

Study Justification / Purpose and Need

Mr. Mark Noel, MDOT, presented the results of the User Survey Report. He provided a handout (see attached). The Critical Aircraft as defined by FAA is the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport. Based on the results of the user survey, the critical aircraft for the airport is a B-II, small aircraft.

According to FAA Advisory Circular 150/5325-4B, the recommended runway length for categroy B-II Small Aircraft is 4,200 feet. MDOT recommends 4,300 feet, based on the recommendations of the Michigan Airport System Plan (MASP 2008). The recommended runway lengths will allow most B-II Small classification aircraft to operate at their optimum capabilities without weight restrictions.

It was noted that the Airport Advisory Committee's purpose for the project incorporates safety improvements: runway extension to minimize overruns and a runway shift to address State Road approach and FAA tower line of sight. This purpose differs from FAA and MDOT justification for runway extension, which is based on providing the recommended runway length for the current critical aircraft of the airport. A formal purpose and need statement for the project is being developed in accordance with National Environmental Policy Act (NEPA) guidelines.

Study Status and Next Steps

The study team is currently working to prepare a first draft of the Environmental Assessment. The next CAC meeting will be in the fall and will focus on an environmental studies update for the remaining resource categories.

Overrun Data

A summary of the overrun data was provided to the group. Each CAC member in attendance was provided a copy of a summary table followed by a report for each overrun, if the report was available. The overrun data was compiled based on reported incidents in the FAA databases and other unreported incidents. There have been five reported overruns, four unreported overruns, and two that are unknown (undetermined whether aircraft went off the end of the runway or off the side of the runway).

Member Update
Each CAC member was asked to provide an update on what they have been hearing from their constituency. The following is a summary of what the members expressed as concerns or comments from their constituency:

- The editorials and op eds are not stating the truth.
- There is a mix of supporters and non-supporters. The non-supporters are concerned because of the impact on their quality of life.
- Is it possible to raise the tower to eliminate the line of sight issues?
- There have been questions about the funding source for the project.
- Some are concerned about the project and its potential impacts, but there have been more comments on the Argo Dam at this time.
- There is an organized group very strongly opposed to the project.
- Safety is primary concern. Fear that planes will crash into nearby homes.
- Concerned about the use of tax dollars to pay for the project.
- Concern that Pittsfield Township provides safety response and that Pittsfield tax dollars are being used for that.

Other Items Discussed
Throughout the meeting, CAC members asked questions regarding the information presented. A summary of the items is provided below.

- Four sources were used for the User Survey Report: (1) Flight Aware data, data from the two FBOs: (2) Solo Aviation and (3) Ann Arbor Aviation Center, and (4) based aircraft records.
- The noise analysis is computer generated based on aircraft types. Field measurements for noise were not conducted.
- The noise analysis models flight paths for both existing and future conditions, compensating for the proposed change in runway length.
- There are no trees being cut in St. James Woods.
- A negative economic effect that might occur if the runway is not extended is aircraft that use the airport with weight restrictions may need to land and refuel, or be required to operate with reduced cargo or reduced passengers.
- MDOT has been involved with this project since early 2007, when the City of Ann Arbor started the process to modify the ALP.
- The Itinerant (visiting) Aircraft operational information was collected by the two FBOs located on the airport. Sources were the pilot sign-in registration logs (Airport Registers) from each FBO.

One item discussed was the date of the last user survey and the previous critical aircraft. The consultant team was not able to provide a definite answer at the meeting. Based on a file review by MDOT, the following information was obtained.

In June 2008 MDOT approved an ALP dated April 2008 that indicates a Beech King Air (approach category B-II) is the design group. The previous ALP, dated 1994, was approved by MDOT in 1995 and indicated the design aircraft was approach category B-II. Prior to 1994, the ALP's MDOT has on file do not definitively identify the critical aircraft, except the 1957 ALP. This ALP identifies effective lengths for aircraft of current conditions (3,500 feet) and future conditions (4,300 feet).

If this report does not agree with your records or understanding of this meeting, or if there are any questions, please advise the writer immediately in writing; otherwise, we will assume the comments to be correct.

P:\50178\000\CAC\ARB MeetingMinutes 7-20-09.docx

DISTRIBUTION

Ann Arbor Municipal Airport

Runway Extension EA

Aircraft Noise Analysis

July 20, 2009

FAA Policy and Guidance for NEPA Compliance

FAA Order 1050.1E

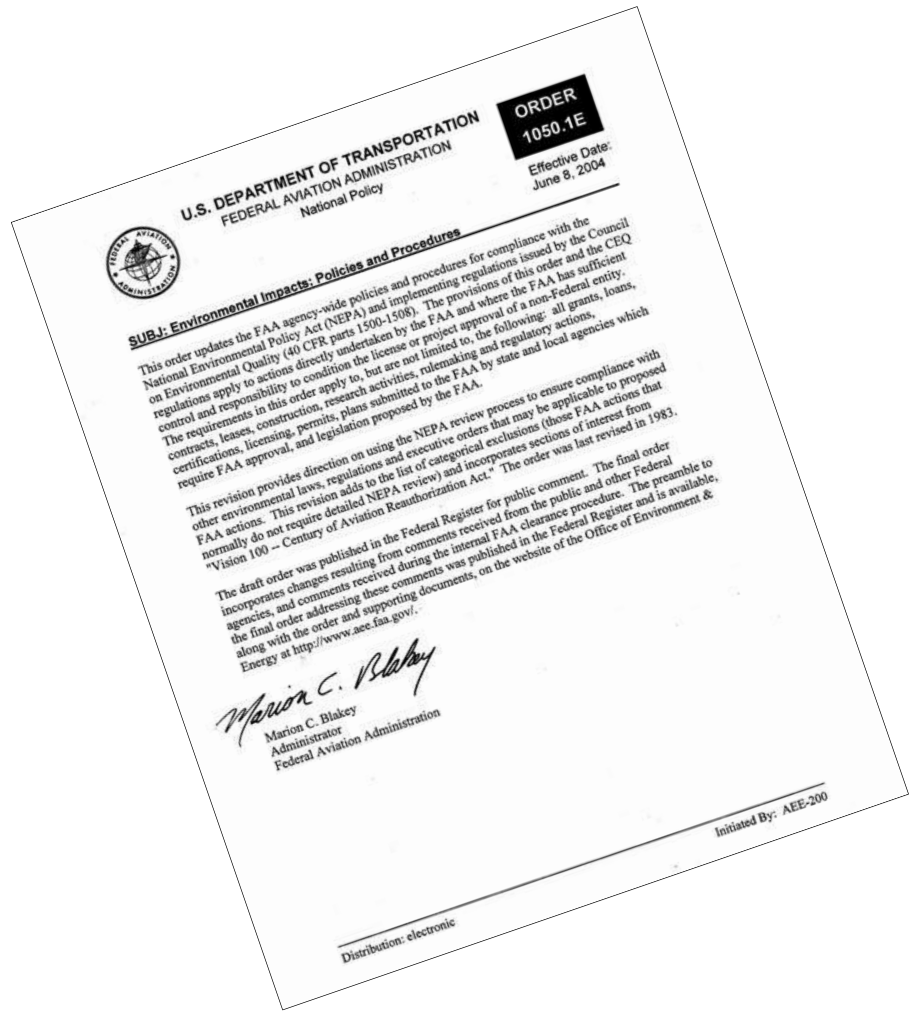
Environmental Impacts: Policies and Procedures

FAA Order 5050.4B

NEPA Implementing Instructions for Airport Actions

Title 14 CFR Part 150

Airport Noise Compatibility Planning



U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
National Policy

ORDER 1050.1E

Effective Date: June 8, 2004

SUBJ: Environmental Impacts: Policies and Procedures

This order updates the FAA agency-wide policies and procedures for compliance with the National Environmental Policy Act (NEPA) and implementing regulations issued by the Council on Environmental Quality (40 CFR parts 1500-1508). The provisions of this order and the CEQ regulations apply to actions directly undertaken by the FAA and where the FAA has sufficient control and responsibility to condition the license or project approval of a non-Federal entity. The requirements in this order apply to, but are not limited to, the following: all grants, loans, contracts, leases, construction, research activities, rulemaking and regulatory actions, certifications, licensing, permits, plans submitted to the FAA by state and local agencies which require FAA approval, and legislation proposed by the FAA.

This revision provides direction on using the NEPA review process to ensure compliance with other environmental laws, regulations and executive orders that may be applicable to proposed FAA actions. This revision adds to the list of categorical exclusions (those FAA actions that normally do not require detailed NEPA review) and incorporates sections of interest from "Vision 100 -- Century of Aviation Reauthorization Act." The order was last revised in 1983.

The draft order was published in the Federal Register for public comment. The final order incorporates changes resulting from comments received from the public and other Federal agencies, and comments received during the internal FAA clearance procedure. The preamble to the final order addressing these comments was published in the Federal Register and is available, along with the order and supporting documents, on the website of the Office of Environment & Energy at http://www.aee.faa.gov/.

Marion C. Blakey
Administrator
Federal Aviation Administration

Distribution: electronic

Initiated By: AEE-200

Assessment of Aircraft Related Noise

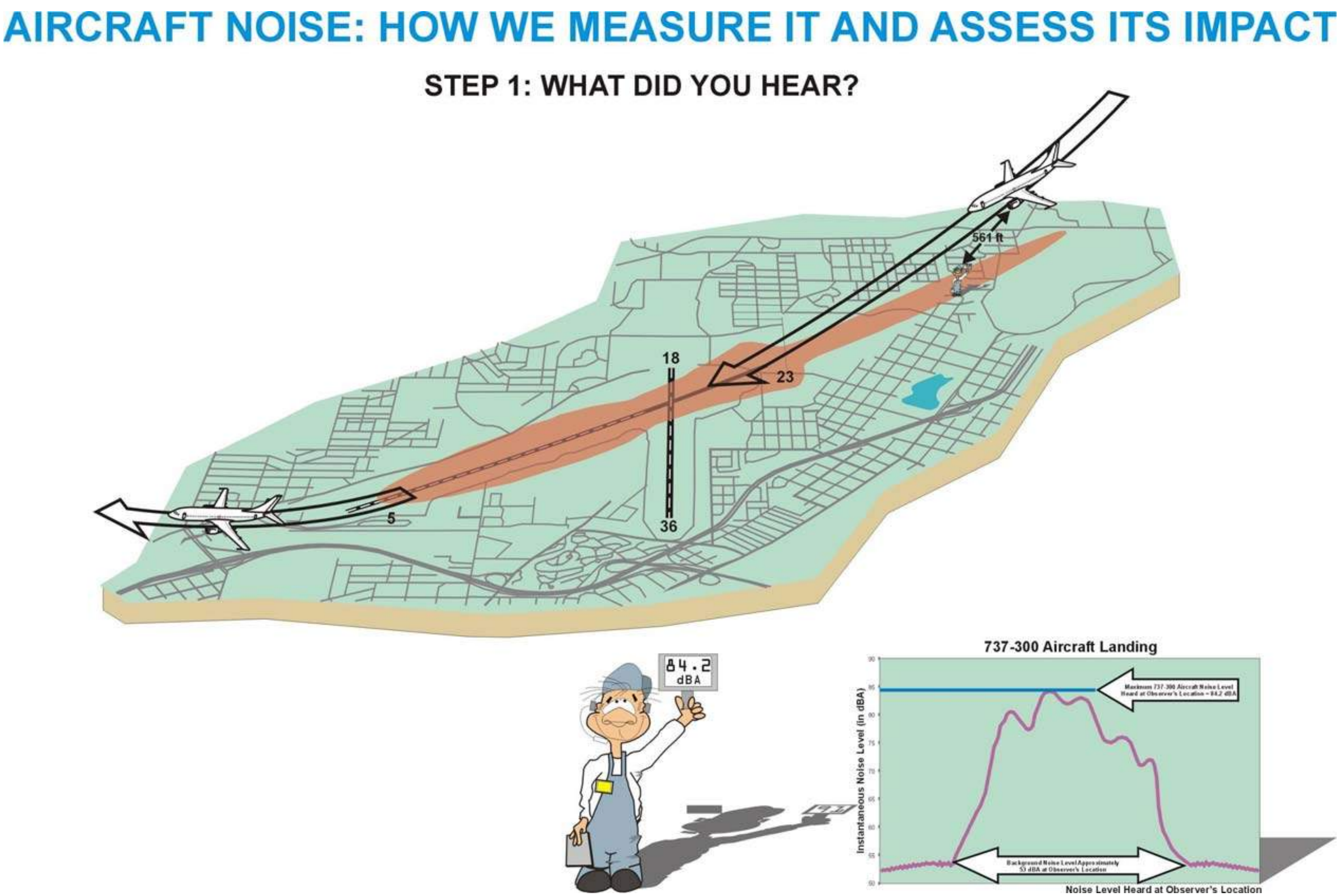
FAA Integrated Noise Model (INM) version 7.0a

- Has been distributed for use by the FAA since 1978
- Continual enhancements to stay consistent with evolving aircraft, technology, and best practices
- Required tool for FAR Part 150 Noise Compatibility Planning; Part 161 Approval of Airport Noise Restrictions; and FAA Order 1050 EA's and EIS's
- INM is an average value model designed to estimate long-term effects

Assessment of Aircraft Related Noise

- EA determines noise impacts on INM DNL contours
- Analysis will include:
  - Base year - 2009
  - Future year - 2014
    - With and without proposed project
  - Standard DNL Metric

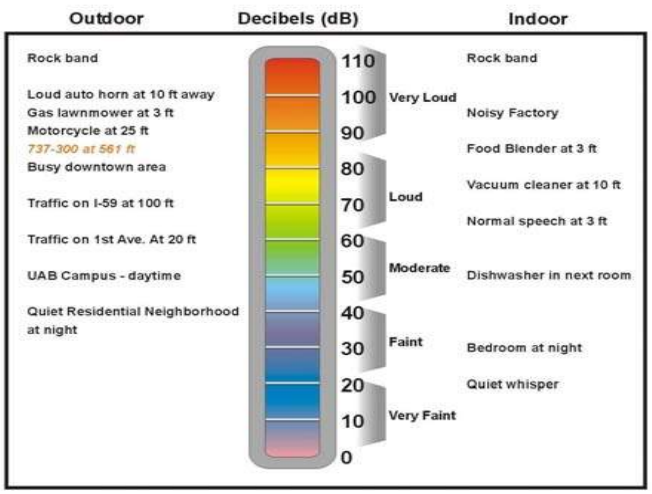
Aircraft Noise: How Do We Measure and Assess Impacts



Aircraft Noise: How Do We Measure and Assess Impacts

AIRCRAFT NOISE: HOW WE MEASURE IT AND ASSESS ITS IMPACT

STEP 2: HOW LOUD IS THAT?



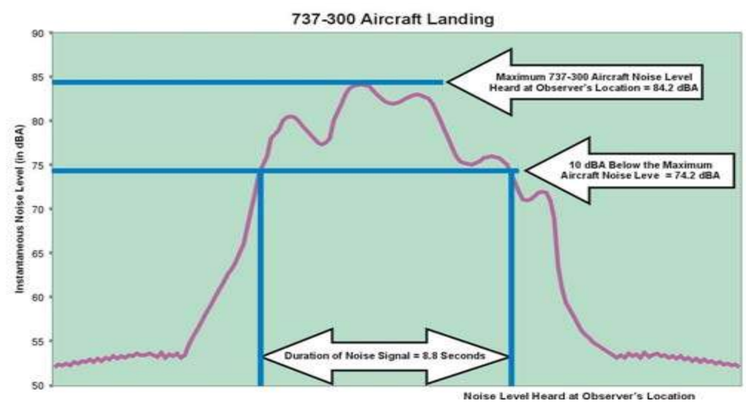
STEP 3: HOW LONG DID IT LAST?

The duration of an aircraft noise event is defined as the number of seconds between the first and last values of the instantaneous noise level which are a minimum of 10 dBA below the maximum aircraft noise level (Lmax).

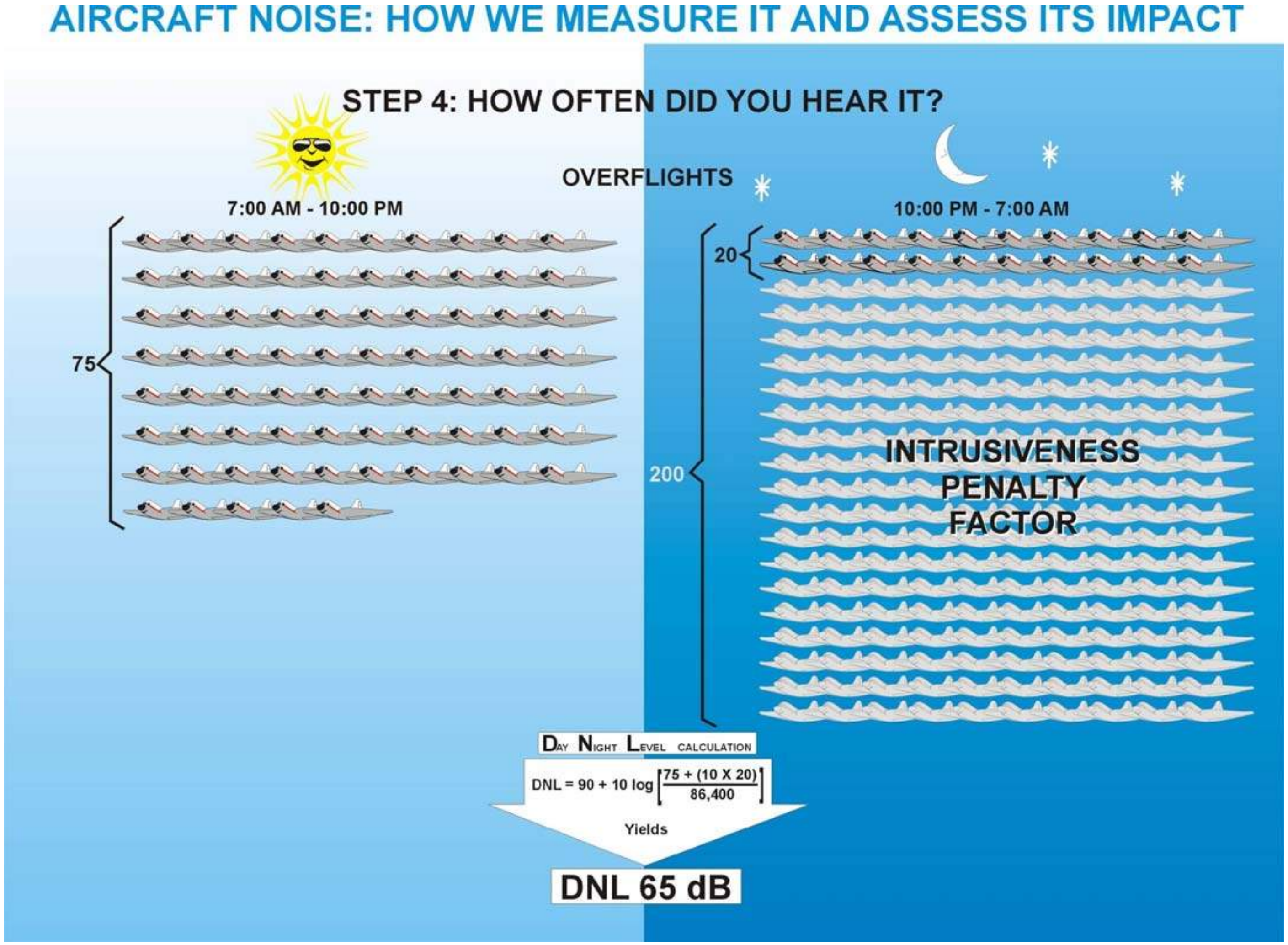
The Sound Exposure Level (SEL) describes with a single number the sound energy during an aircraft noise event. SEL takes into account both the duration and the magnitude of the aircraft noise event. The duration correction increases the magnitude in an attempt to account for the increased noisiness of sounds of long duration versus sounds of short duration. Because the duration of aircraft noise events are greater than one second, the numerical value of the SEL for an aircraft noise event is always greater than the numerical value of the maximum level, Lmax.

For Example:

Lmax = 84.2 dBA   Duration = 8.8 seconds   SEL = 90 dBA



Aircraft Noise: How Do We Measure and Assess Impacts



Noise Metric

- **Day-Night Average Sound Level (DNL)**:

DNL logarithmically averages aircraft sound levels at a location over a complete 24-hour period, with a 10-decibel adjustment added to those noise events occurring between 10:00 p.m. and 7:00 a.m. (local time) the following morning. Primary metric for airport noise impacts.

Noise Modeling Methodology

INM Input Data:

- Aircraft Operations
  - 2009 Base Year: FAA ATADS Data from April 08 through March 09
  - Forecast for Future Year 2014: FAA 2009 ARB TAF
- Flight Operations by Aircraft Type and Time of Day
  - From MDOT User's Survey and Flight Explorer® data
- Runways and Runway Utilization
  - From discussion with Air Traffic Control
- Flight Tracks and Flight Track Utilization
  - From discussion with Air Traffic Control and published flight procedures

Noise Modeling Methodology

INM Input Data:

- Aircraft Operations
  - 2009 Base Year: 61,969
  - Future Year 2014: 69,717
- Day / Night Split (Day 7:00 am to 9:59 pm, Night 10:00 pm to 6:59 am)
  - Air Taxi/Commuter: Arrivals 100% Day, Departures 96/4%
  - GA: Arrivals 95/5%, Departures 96/4%
- Flight Tracks:
  - Arrivals and departures are all straight in and straight out
  - Runways 06 and 12 have right turn patterns, Runways 24 and 30 have left turn patterns

Runway Utilization

Aircraft Type	Runway 06	Runway 24	Runway 12	Ruwnay 30
Jet	30 %	70 %		
Turbo prop	30 %	70 %		
Multi-engine Piston	30 %	70 %		
Single Engine Piston	27.5 %	67.5 %	2.5 %	2.5 %

Aircraft Operations – Air Taxi/Commuter

Table X-2
Fleet Mix and Annual Operations
Ann Arbor Municipal Airport
Runway Extension EA

Aircraft Category	INM Aircraft	Aircraft Name	Aircraft Type	Fleet Mix Percentage (%)		Annual			
						Itinerant		Local	
				Itinerant	Local	2009	2014	2009	2014
Air Taxi / Commuter	BEC58P	Beech 58 Baron	MEP	48.6	---	439	745	---	---
	CNA172	Cessna 172 Skyhawk	SEP	3.4	---	31	52	---	---
	CNA206	Cessna 206 Super Skywagon/Stationair	SEP	1.4	---	12	21	---	---
	CNA441	Cessna 441 Conquest II	TP	14.4	---	130	220	---	---
	CNA500	Cessna 500 / Citation II	Jet	1.4	---	12	21	---	---
	DC910	Douglas DC 9-10	Jet	0.7	---	6	10	---	---
	DHC6	de Havilland Dash 6	TP	8.2	---	74	126	---	---
	GASEPF	Composite - Single Engine Fixed Pitch Prop	SEP	0.7	---	6	10	---	---
	GASEPV	Composite - Single Engine Variable Pitch Prop	SEP	4.1	---	37	63	---	---
	LEAR35	Lear 35	Jet	2.7	---	25	42	---	---
	MU3001	Mitsubishi 300-10 Diamond	Jet	2.7	---	25	42	---	---
	PA28	Piper 28 Cherokee	SEP	7.5	---	68	115	---	---
	PA31	Piper 31 Navajo	MEP	4.1	---	37	63	---	---
		Total		**100**	---	**902**	**1,532**	---	---

Source: Flight Explorer®, 2009
Michigan DOT ARB User's Survey, 2009,
URS Corporation 2009.

Note: Numbers may not add due to rounding
SEP – Single Engine Piston
MEP – Multi Engine Piston
Jet – Turbofan/Turbo Jet
TP – Turbo Prop

Aircraft Operations

Table X-2 (cont)
Fleet Mix and Annual Operations
Ann Arbor Municipal Airport
Runway Extension EA

Aircraft Category	INM Aircraft	Aircraft Name	Aircraft Type	Fleet Mix Percentage (%)		Annual			
						Itinerant		Local	
				Itinerant	Local	2009	2014	2009	2014
General Aviation	B206L	Bell 206L LongRanger	Helo	13.5	---	3,039	3,255	---	---
	BEC58P	Beech 58 Baron	MEP	5.6	6.8	1,269	1,360	2,585	2,954
	CIT3	Cessna Citation III	Jet	0.01	---	2	2	---	---
	CNA172	Cessna 172 Skyhawk	SEP	32.6	42.0	7,326	7,848	16,219	18,536
	CNA206	Cessna 206 Super Skywagon/Stationair	SEP	3.8	4.5	863	925	1,732	1,980
	CNA441	Cessna 441 Conquest II	Tp	0.6	0.3	126	135	113	129
	CNA500	Cessna 500 / Citation II	Jet	0.05	---	12	12	---	---
	CNA510	Cessna 510 Mustang	Jet	0.01	---	2	2	---	---
	DHC6	de Havilland Dash 6	Tp	0.2	---	40	42	---	---
	GASEPF	Composite - Single Engine Fixed Pitch Prop	SEP	3.9	4.8	887	950	1,845	2,109
	GASEPV	Composite - Single Engine Variable Pitch Prop	SEP	10.3	11.9	2,315	2,480	4,613	5,272
	H500D	Hughes 500D	Helo	4.4	---	990	1,060	---	---
	IA1125	IAI Astra	Jet	0.01	---	2	2	---	---
	LEAR25	Lear 25	Jet	0.01	---	2	2	---	---
	LEAR35	Lear 35	Jet	0.01	---	3	4	---	---
	MU3001	Mitsubishi 300-10 Diamond	Jet	1.5	---	338	362	---	---
	PA28	Piper 28 Cherokee	SEP	23.1	29.7	5,180	5,550	11,472	13,111
	PA30	Piper 30 Twin Comanche	MEP	0.1	0.1	22	24	42	48
	PA31	Piper 31 Navajo	MEp	0.1	---	25	27	---	---
	R22	Robinson R22B	Helo	0.01	---	3	4	---	---
	SA365N	Aerospatiale (Eurocopter) SA-365N Dauphin	Helo	0.01	---	2	2	---	---
	Total			**100**	**100**	**22,446**	**24,047**	**38,621**	**44,138**
TOTAL				---	---	**23,348**	**25,579**	**38,621**	**44,138**

Source: Flight Explorer®, 2009
Michigan DOT ARB User's Survey, 2009,
URS Corporation 2009.

Note: Numbers may not add due to rounding
SEP – Single Engine Piston
MEP – Multi Engine Piston
Jet – Turbofan/Turbo Jet
TP – Turbo Prop

FAA INM Aircraft Substitutions
(INM Database contains 274 Aircraft and 260 substitutions)

SUB_ID	SUB_DESCR	ACFT_ID1
BEC200	Beech Super King Air 200	DHC6
BEC300	Beech Super King Air 300	DHC6
BEC30B	Beech Super King Air 300B	DHC6
BEC400	Beechcraft Beechjet 400	MU3001
BEC45	Beechcraft Model 45 Mentor (T34A & T34B)	GASEPV
BEC90	Beech King Air C90	CNA441
BEC9F	Beech F90 Super King Air	CNA441
BECM35	Beechcraft Model M35 Bonanza	GASEPV
CNA182	Cessna 182 Skylane	CNA206
CNA185	Cessna Skywagon	CNA206
CNA404	Cessna 404 Titan	BEC58P
CNA501	Cessna Citation I Single Pilot (SP)	CNA500
CNA525	Cessna Citation Jet	CNA500
CNA550	Cessna Model 550 Citation II	MU3001
CNA551	Cessna Citation II Single Pilot (SP)	MU3001
CNA560	Cessna 560 Citation V	MU3001
CNA650	Cessna 650 Citation VII	CIT3
FAL200	Falcon 200	LEAR35
FAL20A	Falcon 2000	CL600
IA1123	IAI 1123 Westwind	LEAR25
IA1124	IAI 1124 Westwind	IA1125
IARAVA	IAI Arava	DHC6
IL114	Ilyushin-114	CVR580
IL62	Ilyushin-62	707QN
IL76	Ilyushin-76	DC8QN
IL86	Ilyushin-86	DC8QN
IL96	Illyushin-96	747200
JST1TF	Jetstar 1 Turbofan	LEAR35
JST1TJ	Jetstar 1 Turbojet	LEAR25
JST2TF	Lockheed Jetstar 2	LEAR35
KC135E	Boeing KC135 Stratotanker (Re-engined)	707320
LA42	Lake LA-4-200 Buccaneer	GASEPV
LEAR23	Learjet 23	LEAR25
LEAR24	Learjet 24	LEAR25
LEAR31	Learjet 31	LEAR35
LEAR36	Learjet 36	LEAR35
LEAR45	Learjet 45	LEAR35
LEAR55	Learjet 55	LEAR35
LEAR60	Learjet 60	LEAR35

FAA INM Aircraft Substitutions
(INM Database contains 274 Aircraft and 260 substitutions)

SUB_ID	SUB_DESCR	ACFT_ID1
BEC200	Beech Super King Air 200	DHC6
BEC300	Beech Super King Air 300	DHC6
BEC30B	Beech Super King Air 300B	DHC6
BEC400	Beechcraft Beechjet 400	MU3001
BEC45	Beechcraft Model 45 Mentor (T34A & T34B)	GASEPV
BEC90	Beech King Air C90	CNA441
BEC9F	Beech F90 Super King Air	CNA441
BECM35	Beechcraft Model M35 Bonanza	GASEPV
CNA182	Cessna 182 Skylane	CNA206
CNA185	Cessna Skywagon	CNA206
CNA404	Cessna 404 Titan	BEC58P
CNA501	Cessna Citation I Single Pilot (SP)	CNA500
CNA525	Cessna Citation Jet	CNA500
CNA550	Cessna Model 550 Citation II	MU3001
CNA551	Cessna Citation II Single Pilot (SP)	MU3001
CNA560	Cessna 560 Citation V	MU3001
CNA650	Cessna 650 Citation VII	CIT3
FAL200	Falcon 200	LEAR35
FAL20A	Falcon 2000	CL600
IA1123	IAI 1123 Westwind	LEAR25
IA1124	IAI 1124 Westwind	IA1125
IARAVA	IAI Arava	DHC6
IL114	Ilyushin-114	CVR580
IL62	Ilyushin-62	707QN
IL76	Ilyushin-76	DC8QN
IL86	Ilyushin-86	DC8QN
IL96	Illyushin-96	747200
JST1TF	Jetstar 1 Turbofan	LEAR35
JST1TJ	Jetstar 1 Turbojet	LEAR25
JST2TF	Lockheed Jetstar 2	LEAR35
KC135E	Boeing KC135 Stratotanker (Re-engined)	707320
LA42	Lake LA-4-200 Buccaneer	GASEPV
LEAR23	Learjet 23	LEAR25
LEAR24	Learjet 24	LEAR25
LEAR31	Learjet 31	LEAR35
LEAR36	Learjet 36	LEAR35
LEAR45	Learjet 45	LEAR35
LEAR55	Learjet 55	LEAR35
LEAR60	Learjet 60	LEAR35

Assessment of Aircraft Related Noise Impacts in an Environmental Assessment

- Noise Exposure Contours at DNL 65, 70, and 75 dB
- No-Action and Proposed Project
- Average Annual Day: Daily average of annual operations
- **Impacts determined by**:

  Yearly Day/Night Average Sound Level (DNL)

Assessment of Aircraft Related Noise Impacts

- Impacts are determined by comparing future Proposed Project DNL contours to the No-action alternative DNL contour.
- Significant impact occurs at noise sensitive locations with an increase of 1.5 dB or greater within the DNL 65 Contour
- If significant impact exists, analysis within the DNL 60 for an increase of 3 dB or greater is required.

INM Output Data

- INM provides the following noise data for existing and future conditions for comparison purposes:
  - Noise contours (DNL 65, 70 and 75 dB)
  - Noise levels at identified noise sensitive sites (if necessary)
  - Noise levels in metrics other than DNL, such as L_{max}, L_{eq}, SEL, and Number of Events Above (if necessary)

M:\Projects\12941618\ArcGIS\2007 Existing Noise Contours.mxd

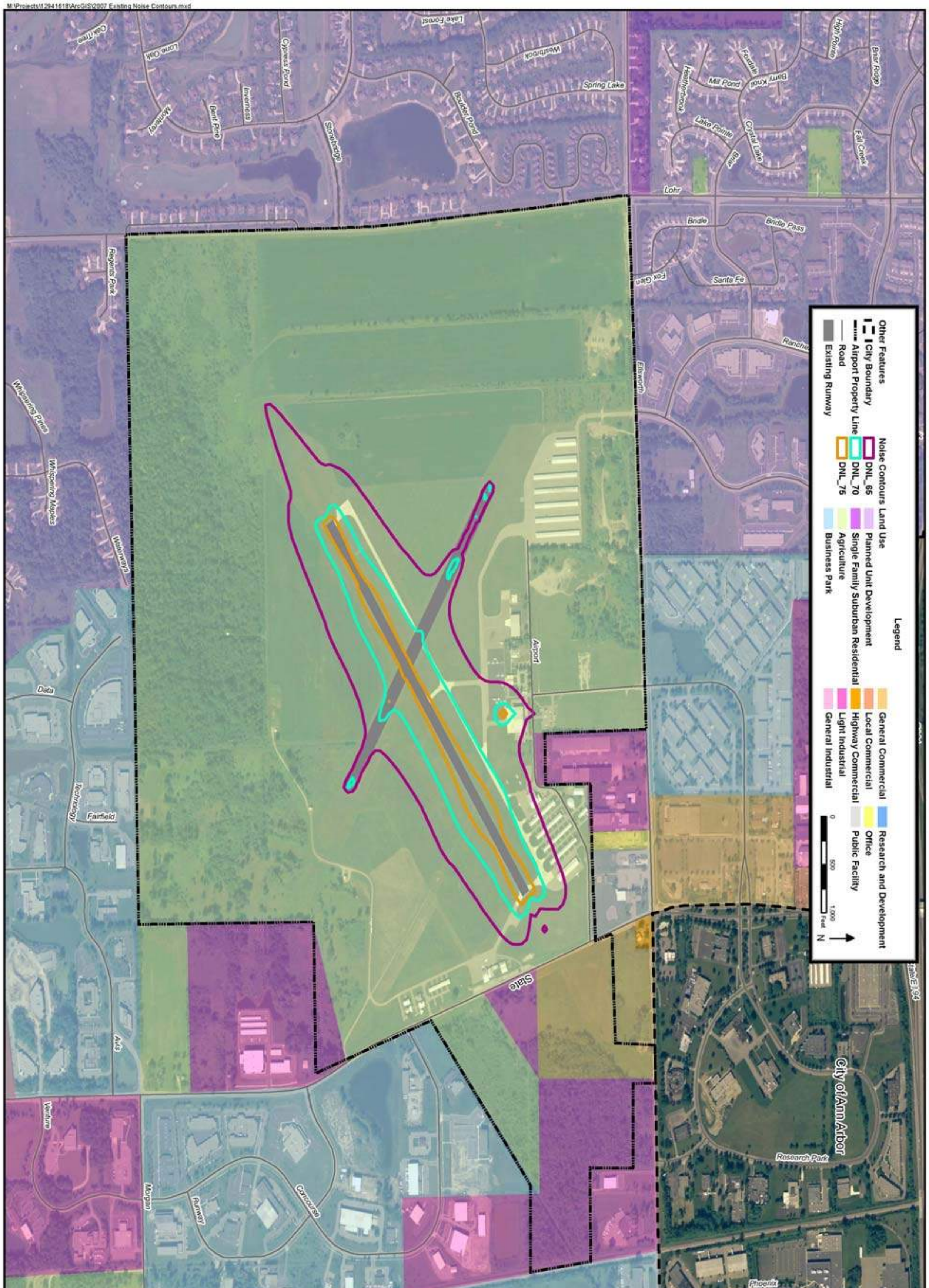


Figure N-1

Ann Arbor Municpal Airport

2007 Existing Noise Contour Map

URS

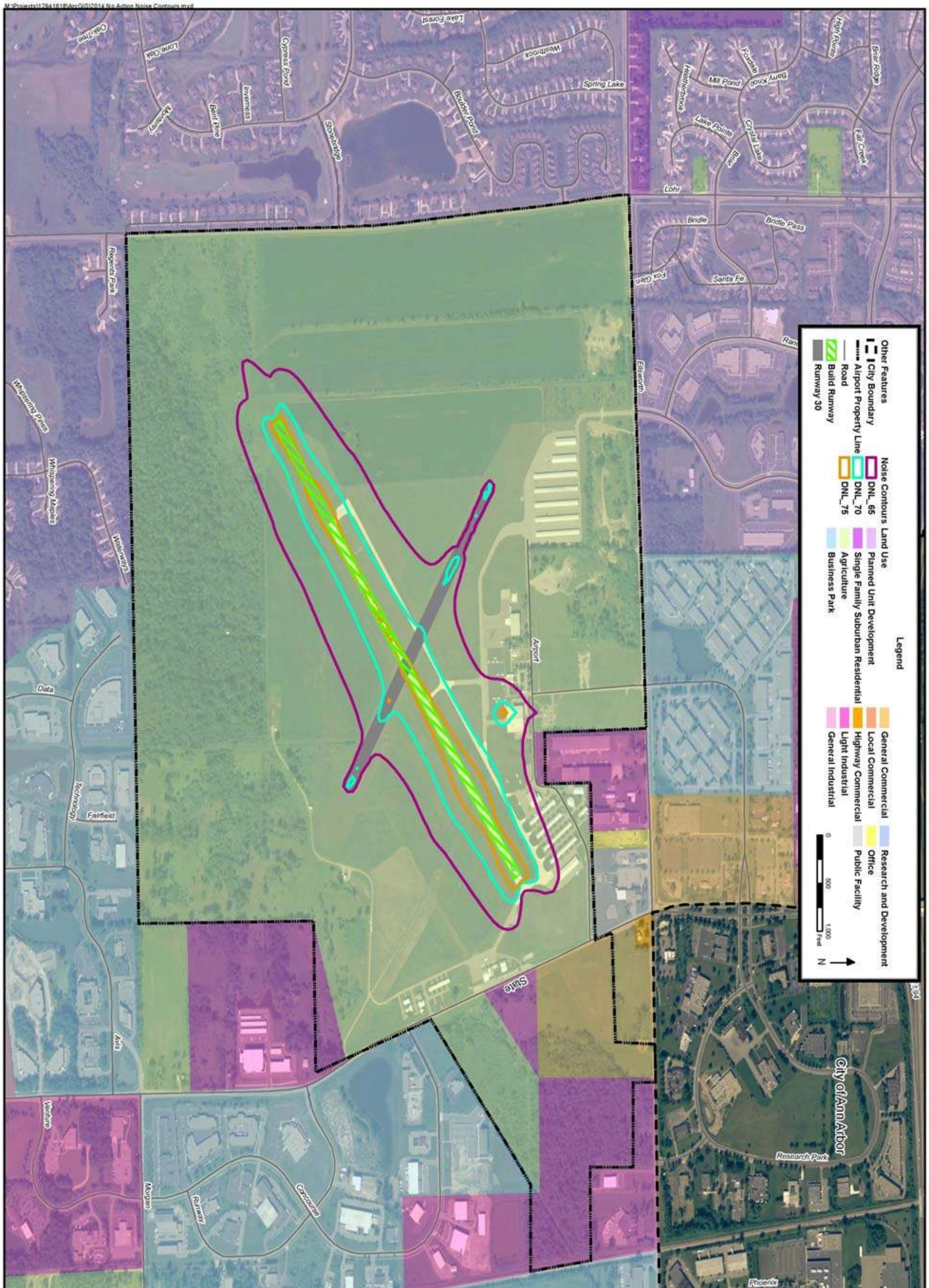
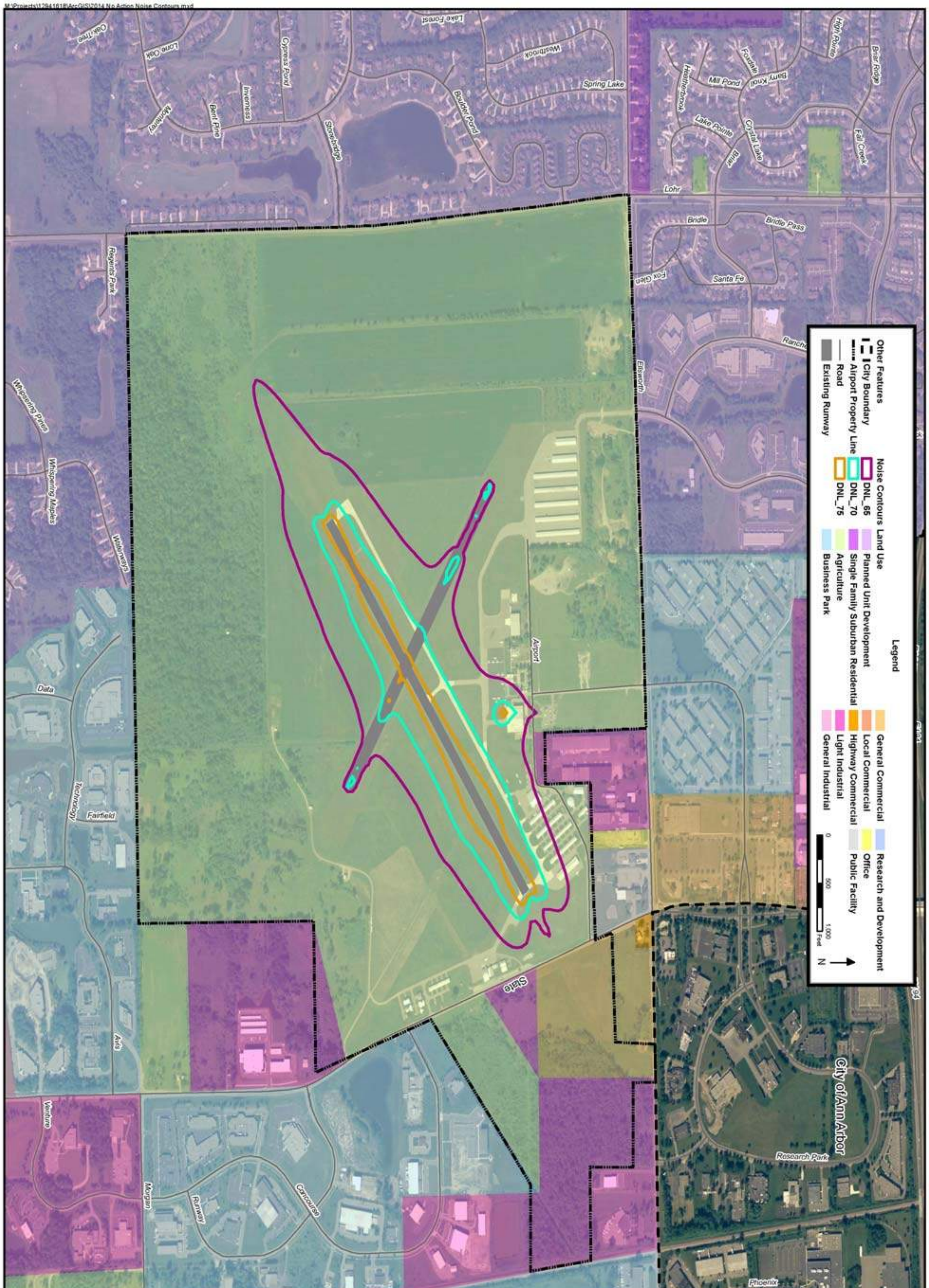


Figure N-3

Ann Arbor Municpal Airport

2014 Build Noise Contour Map

URS



Ann Arbor Municpal Airport

2014 No Action Noise Contour Map

Figure N-2

CRITICAL AIRCRAFT:

The Critical Aircraft is defined by FAA as the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport. In cases where the Critical Aircraft weighs less than 60,000 lbs, a classification is used rather than a specific aircraft model.

Based on analysis of the recent User Survey at Ann Arbor Municipal Airport, the current Critical Aircraft classification has been determined to be a **B-II, Small Aircraft**. Aircraft in this category have approach speeds between 91 and 120 knots, wingspans between 49 and 78 feet, and have a maximum certificated takeoff weight of 12,500 lbs. or less.

A representative aircraft of this classification is the Beechcraft King Air 200, a twin-engine turboprop aircraft that typically seats 10-12 passengers, including crew.

AIRCRAFT CLASSIFICATION (FAA):

Approach Category:

Category A:	Approach speed less than 91 knots.
Category B:	Approach speed 91 to 120 knots.
Category C:	Approach speed 121 to 140 knots.
Category D:	Approach speed 141 to 165 knots.
Category E:	Approach speed 166 knots +

Design Group:

Group I:	Wingspan less than 49 feet.
Group II:	Wingspan 49 to 78 feet.
Group III:	Wingspan 79 to 117 feet.
Group IV:	Wingspan 118 to 170 feet.
Group V:	Wingspan 171 to 213 feet.
Group VI:	Wingspan 214 feet +

Small Airplane: An airplane of 12,500 lbs. or less maximum certificated takeoff weight.

Large Airplane: An airplane of more than 12,500 lbs. maximum certificated takeoff weight.

RUNWAY LENGTH RECOMMENDATIONS FOR B-II, SMALL AIRCRAFT:

MDOT – Michigan Airport System Plan (MASP 2008): **4,300 feet**
(statewide standard)

FAA – Advisory Circular 150/5325-4B,
"Runway Length Requirements for Airport Design" **4,200 feet** *
(airport-specific standard, from Figure 2-2)

* Note: Runway length obtained graphically from Figure 2-2. The following data for Ann Arbor Municipal Airport was used in the determination:
Airport Elevation: 839 feet above mean sea level
Temperature: 83 degrees F mean daily maximum temp of hottest month of year (July)

As stated in FAA Advisory Circular 150/5325-4B, "The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions." The Critical Aircraft is considered the regular use aircraft.

The recommended lengths listed above will allow most B-II Small classification aircraft to operate at their optimum capabilities (without weight restrictions), most of the time. Interstate commerce into and out of a community can be negatively impacted if business aircraft are forced to operate with load restrictions (i.e. reduced passengers, fuel, cargo) due to a shorter than recommended length primary runway.

The recommended lengths are also a safety enhancement, that not only provide enough runway for takeoff by a fully-loaded Critical Aircraft, but also provide additional runway for the purpose of bringing the aircraft to a stop in an aborted-takeoff situation. In takeoff situations where pilots detect a problem with the aircraft while on the takeoff roll, if there is not enough runway remaining to bring the aircraft to a stop, pilots are forced to continue the takeoff and deal with the problem in the air. By having enough remaining runway to safely abort a takeoff and bring the aircraft to a stop, a pilot would be able to avoid a potentially hazardous situation of taking to the air with a mechanically-deficient aircraft.

Citizens Advisory Committee Meeting

July 20, 2009

Meeting Attendees

Matt Kulhanek	Ann Arbor Municipal Airport
Mark Perry	Airport Advisory Committee
Kristine Martin	5th Ward Resident
Ray Hunter	4th Ward Resident
Tony Derezinski	Ann Arbor City Council
Jad Donaldson	Pilot - Avfuel
David Schrader	FAA Safety Team
Shlomo Castell	Stonebridge Community Association
Jan Godek	Lodi Township Supervisor
Barb Fuller	Pittsfield Township Deputy Supervisor
Kristin Judge	Washtenaw County Commissioner, 7th District
Amy Eckland	JJR
Connie Dimond	JJR
Neal Billetdeaux	JJR
Molly Lamrouex	MDOT
Mark Noel	MDOT
Carol Aldrich	MDOT
Bill Malinowski	URS
Dan Botto	URS

Exhibit 13

Citizens Advisory Council – Meeting #3

Ann Arbor Municipal Airport Environmental Assessment

February 22, 2010
3:00 pm – 4:30 pm

1.	Introductions	3:00 - 3:10
2.	Environmental Studies Update a. Wetland Resources b. Surface/Groundwater Resources c. Cultural Resources	3:10 - 3:20
3.	Study Justification a. Purpose and Need Summary b. User Survey Supplemental Report	3:20 - 3:40
4.	Study Status & Next Steps a. Departure Profile Analysis b. Next steps	3:40 - 4:00
5.	Discussion a. CAC member report	4:00 - 4:30

Information Packet – Citizens Advisory Council Meeting #3

Ann Arbor Municipal Airport Environmental Assessment

Prepared By: JJR

February 22, 2010

The JJR consultant team has completed investigations to assess existing conditions on airport property and its immediate vicinity for the following categories: noise analysis; land use; socioeconomics; air quality; historic resources; contaminated sites; Section 4(f) resources; and the physical and ecological environment. Data from these investigations is used as a base to identify potential impacts from proposed improvements at the airport. Potential mitigation measures to minimize impacts are also being addressed. Data collection has involved fieldwork, literature searches, and coordination with appropriate resource agencies.

The specific categories of studies are listed below along with a brief description and status of the analysis being completed.

Noise – The noise analysis compares the existing noise levels with future levels under two scenarios, a No Build Alternative and a Build Alternative. The Build Alternative assumes the proposed improvements are implemented at the airport. The results of this analysis are compared with the surrounding land use to ensure compatibility.

> ***Status:*** Completed. The noise analysis, which indicates that the Build Alternative is not expected to have any significant aircraft noise impacts, was presented at CAC Meeting #2.

Land Use – Existing land use data was collected and compared with any anticipated changes as a result of the proposed improvements at the airport. These changes were compared to the existing land use plans and future land use plans of City of Ann Arbor and surrounding municipalities.

> ***Status:*** Complete. Existing and proposed land use adjacent to and in the immediate vicinity of ARB is compatible with normal airport operations.

Socioeconomics – This category includes potential impacts on community displacements (residential and commercial) community cohesion, community facilities, demographics, economy, and environmental justice. Environmental justice considers impacts to low-income and minority populations with the intention of avoiding disproportionate impacts to these populations.

> ***Status:*** Complete. There would be no displacements or impacts to community cohesion, facilities, demographics or economy. There would be no impacts to low-income or minority populations.

Air Quality –The study team completed an assessment of the project in accordance with the FAA Air Quality Procedures for Civilian Airports & Air Force Bases (1997). Based on this assessment and prior studies on general aviation airports, the project is not expected to result in violations of National Ambient Air Quality Standards (NAAQS)

> ***Status:*** Complete. It is anticipated that agency coordination will continue through the environmental clearance phase.

Historic Resources – The study team evaluated cultural resources, both above-ground and below-ground including a review of the state archaeological site files and the state above-ground resource files to determine if there are any previously recorded cultural resources in or near the airport property.

> ***Status:*** Complete with a determination of no affect from the State Historic Preservation Office.

Contamination/Hazardous Materials – The study team researched environmental records including State and Federal databases of sites containing hazardous or contaminated materials to determine whether listed sites exist within the project area. The results of the database search have been summarized in relation to the potential for encountering hazardous or contaminated materials within the limits of the proposed improvements.

> ***Status:*** Complete. The proposed improvements are not anticipated to have an impact on known properties listed by state and/or federal agencies as either contaminated or sites of environmental concern.

Section 4(f) Resources - Section 4(f) of the Department of Transportation Act (1966) specifies that publicly-owned land, such as a park, recreational area, or wildlife and waterfowl refuge, of national, state, or local significance, or any land from a historic site of national, state, or local significance, may not be used for transportation projects unless there is no other prudent and feasible alternative.

> ***Status:*** Complete; no Section 4(f) resources will be affected by the proposed Build Alternative.

Physical and Ecological Environment- This category encompasses many resources, including water resources, biotic communities, threatened and endangered species, wetland resources, floodplains, and farmland.

> **Water Resources** –Based on a review of existing databases and fieldwork, the study team evaluated potential impacts to surface water and subsurface groundwater, including issues related to siltation, runoff, dredge and/or fill activities in navigable waters, aquifer or well contamination, and impacts on sensitive ecological areas.
>
> > ***Status:*** Complete. It is estimated that impervious surface resulting from the Build Alternative would increase slightly from the existing 7 percent to 7.4 percent of the site. Surface and subsurface groundwater resources would not be affected by the proposed improvements.
>
> **Biotic Communities –** Biotic communities that may be impacted by the proposed airport expansion were identified and characterized based on: 1) existing available data, 2) coordination with the U.S. Fish and Wildlife Service (FWS), the Michigan Department of Natural Resources (MDNR), and Michigan Department of Environmental Quality (MDEQ), and 3) and fieldwork.
>
> > ***Status:*** Complete. No existing natural biotic communities would be impacted by the proposed Build Alternative.

Threatened and Endangered Species – The study team coordinated with the U.S. Fish and Wildlife Service and the Michigan Natural Features Inventory to determine if there are any known threatened or endangered species protected under Federal and/or State jurisdiction within the project area. One state endangered and one state special concern bird species has been observed in the vicinity of the project area.

> ***Status:*** Complete. ARB is coordinating with the Audubon Society to identify restricted mowing areas during breeding seasons for these species.

Wetlands – Wetlands were identified through a review of National Wetland Inventory maps, the county soil survey, USGS topographical maps and a field investigation. The Michigan Department of Environmental Quality (MDEQ) completed a field review of the property on July, 21, 2010 to delineate wetlands in the vicinity of proposed improvements.

> ***Status:*** Complete. The Build Alternative would have no wetland impact. The results of the MDEQ investigation will be presented at the February 22, 2010 CAC meeting.

Floodplains – The study team reviewed Federal Emergency Management Administration (FEMA) flood boundary maps for the existing stream on the property.

> ***Status:*** Completed. No grading or fill is proposed within the floodplain boundary.

Farmland –Impacts to prime and unique farmland, and farmland of state or local significance were determined through a review of county soil maps and coordination with the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), Michigan Department of Agriculture, and the MDNR. Form AD1006 was completed and submitted to the NRCS for determination of impacts to prime or important agricultural soils.

> ***Status:*** The completed Form AD1006 has been reviewed by the Washtenaw County NRCS with a determination of no impacts to prime and unique farmlands resulting from this project.

Light Emissions – Light emissions were evaluated based on the location and type of airfield lighting proposed and proximity to these land uses.

> ***Status:*** Completed. Impacts from light emissions are not considered significant. New lights would be directed upwards and LED units would be used where appropriate.

Draft Section 2. Purpose and Need

Section 2.
Purpose and Need

2.1 PROJECT LOCATION AND DESCRIPTION

Note: The following information contains a large number of aviation-related acronyms. A glossary with definitions is included in Section 10 of this document.

Ann Arbor Municipal Airport (ARB) is a public-use, general aviation airport located in Washtenaw County, Michigan. The airport is located in Pittsfield Township and consists of approximately 837 acres. ARB is generally bound by Ellsworth Road to the north, State Road to the east, and Lohr Road to the west (Figure 2-1).

ARB is in close proximity to state highways including US-23, M-14, US-12, and I-94. Direct access to the airport is from Ellsworth and State Roads. The closest public-use airport is Willow Run Airport in Ypsilanti, which is approximately 12 miles to the east (approximately a 20 minute drive by automobile). The southeastern region of Michigan has a high level of commerce, and high levels of commercial, corporate, and general aviation air traffic.

The City of Ann Arbor owns and operates ARB. The city is responsible for contracting with the Fixed Base Operators (FBO), which are Solo Aviation, Ann Arbor Aviation Center, and Bijan Air. ARB's operating budget is an enterprise fund comprised solely of revenue generated by airport operations.

The primary runway, Runway 6/24, is 3,505-feet long by 75-feet wide and is oriented in a northeast/southwest direction. ARB has 22 permanent aviation service buildings, including the administration building, the FBOs, maintenance facilities, conventional box hangars, a privately owned hangar, and the FAA Air Traffic Control Tower (ATCT). The airport also provides 150 T-hangar spaces in an additional 13 T-hangar structures.

The current FAA-approved Airport Layout Plan (ALP) was updated in 2008 (Figure 2-2), and it incorporates the future development proposed in the Airport Capital Improvement Plan for ARB.

The proposed improvements from the ALP that are documented in this EA include:

- Shift and extend existing Runway 6/24, resulting in a runway that would be 4,300-feet long by 75-feet wide.
- Shift and extend the parallel taxiway to coincide with the revised Runway 6/24.
- Provide a new taxiway connector to the extended Runway 6 end.
- Provide a new taxiway connector and holding bay to the shifted Runway 24 end.

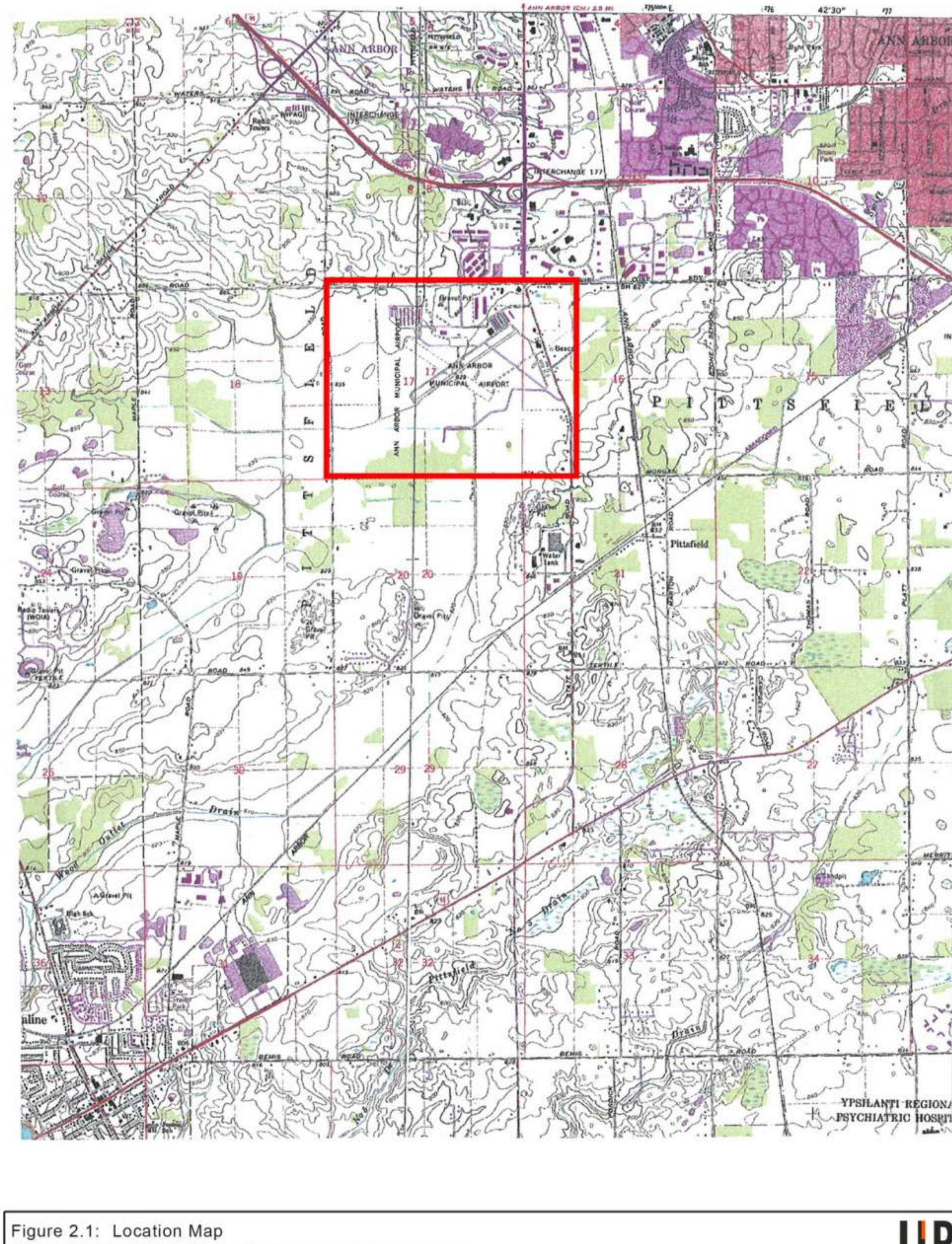


Figure 2.1: Location Map
Ann Arbor Municipal Airport Environmental Assessment

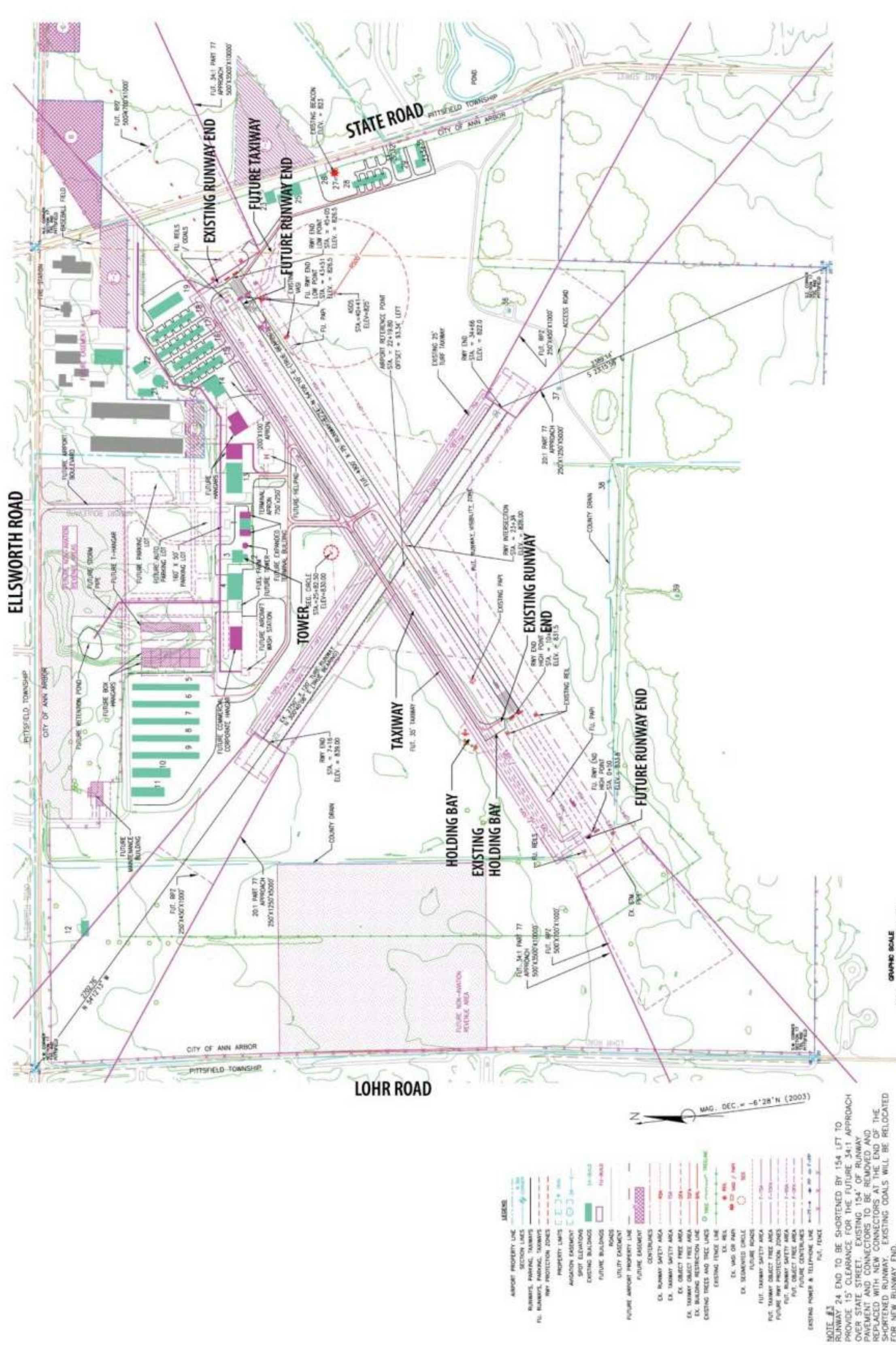


Figure 2.2: Airport Layout Plan
Ann Arbor Municipal Airport Environmental Assessment

2.2 PURPOSE AND NEED

The purpose of the proposed improvements at ARB is to provide facilities that more effectively and efficiently accommodate the *critical aircraft* that presently use the airport, as well as to enhance the operational safety of the airport.

The critical aircraft is defined by the FAA as the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport. In cases where the critical aircraft weigh less than 60,000 lbs, a classification of aircraft is used rather than a specific individual aircraft model.

A recent Airport User Survey has confirmed that the critical aircraft classification for ARB is "B-II Small Aircraft" (MDOT, 2009). Aircrafts in this category have runway approach speeds between 91 and 120 knots, wingspans between 49- and 79-feet, and maximum certificated takeoff weights of 12,500 lbs or less. A representative aircraft of this classification is the Beechcraft King Air 200, a twin-engine turboprop aircraft that typically seats 10-12 people, including the flight crew.

As stated in FAA Advisory Circular 150/5325-4B, "*The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions*." Airplanes that are classified within an airport's critical aircraft classification are considered by the FAA to be the regular use aircrafts of the primary runway.

Development of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small classification aircraft to operate at their optimum capabilities (without weight restrictions). Interstate commerce into and out of a community can be negatively impacted if business aircraft are forced to operate with load restrictions (i.e. reductions in passengers, cargo, and fuel associated with aircraft range) due to lack of suitable runway length.

An origin-destination analysis was conducted on Instrument Flight Rules (IFR) flight plan records associated with ARB as part of the user survey process. Although the data analyzed did not include records of all operations conducted at ARB, it did confirm that there are a significant number of operations between ARB and distant locations throughout the country.

Flight operations were verified between ARB and at least 31 other states (approximately 63 percent of the continental US). Also, approximately 67 percent of the IFR flight plan records examined were between ARB and out-of-state locations. These factors are strong indicators of corporate flight activity associated with interstate commerce, as opposed to local pleasure flying by general aviation pilots. The large number of states that were linked to ARB is also a strong indicator of use of the airport by many corporations, as opposed to a single or few corporate users. Some of the larger corporations that were confirmed by the user survey as being users of ARB are Synergy International, Wells Fargo, Polaris Industries, Bombardier Aerospace, Avis Industrial Corporation, Thumb Energy, NetJets, and AvFuel. NetJets provides on-demand air charter service and corporate aircraft fractional ownership opportunities to a large number of businesses located throughout the country. AvFuel Corporation, a nationwide supplier of aviation fuels and aviation support services, is headquartered in Ann Arbor and bases their Cessna 560 Excel Jet at ARB.

The City of Ann Arbor proposes to extend the existing 3,505-foot primary runway to 4,300-feet in total length in order to more effectively accommodate the critical aircraft that currently use the airport. The runway extension would enhance interstate commerce associated with business aviation, and the other proposed modifications would enhance the operational safety of ARB.

The objectives of the proposed project are to:

- Enhance interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions.
- Enhance operational safety by improving the FAA ATCT line-of-sight issues.
- Enhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road.
- Reduce the occurrence of runway overrun incidents by small category A-I aircraft (local objective).
- Relocate and potentially upgrade the Runway 24 Approach Light System.

2.2.1 Safety Enhancement

The proposed 150-foot shift of the Runway 24 threshold to the west would enhance the safety of ground operations by taxiing aircraft. Currently, a hangar structure blocks the line-of-sight from the FAA ATCT to a portion of the parallel taxiway at the east end of the runway, including most of the taxiway hold area for departing aircrafts. While this situation is not considered hazardous, the proposed shift would enhance operational safety, and possibly prevent a runway incursion, by expanding the view of the hold area and parallel taxiway to ATCT personnel.

The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles. This is particularly beneficial when aircraft are operating in low-visibility conditions. Provision of a clear 34:1 approach surface would also potentially allow visibility minimums to the Instrument Approach Procedure to Runway 24 to be lowered to 3/4 of a mile, as opposed to the current 1-mile visibility minimum. This would enhance the all-weather capability of the airport (and also interstate commerce) by allowing aircraft to continue to access the airport when weather conditions resulted in visibility dropping below the current 1-mile minimum.

Due to the proposed relocation of the Runway 24 threshold, it is also proposed that the existing runway approach light system be relocated accordingly. The airport currently uses an Omni-Directional Approach Lighting System (ODALS) to identify the approach end of Runway 24. The sequentially-flashing strobe lights assist pilots in identifying the runway threshold location and runway centerline alignment in low-visibility conditions. Since the FAA no longer installs ODALS, the current approach light system would potentially be upgraded and replaced with the newer Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF) as part of the relocation. The MALSF would serve the same function as the ODALS, and is structurally very similar.

2.2.2 Role of the Airport

ARB is a public-use facility that serves the local community by supporting economic development and public services. The following businesses and organizations are located at and operate from the airport and employ staff that supports the operations of the airport:

- Two fixed-wing FBOs;
- A helicopter FBO;
- Three national rental car agencies;
- Two flying clubs;
- Four flight schools and pilot training centers;
- FAA ATCT; and,
- Air taxi, aircraft sales, aviation insurance and aviation fueling businesses.

ARB serves the Ann Arbor medical and biomedical industries with professional air ambulance services, transporting patients, human organs, radio isotopes, and other biomedical products and services.

Community pilots and aircraft owners are members of nonprofit organizations providing "no charge" charitable gifts of flight time to citizens in need. Some of these organizations include Wings of Mercy, Angel Flight, and Dreams and Wings. Wings of Mercy has documented 292 fights into or out of ARB since 1992 including 51 flights in 2009.

ARB is included in the FAA's National Plan of Integrated Airport Systems (NPIAS) as a general aviation airport. Not all public-use airports are included in this nationwide airport system plan. Inclusion in the NPIAS signifies that the FAA considers this airport an important part of the nation's air transportation system, and it makes ARB eligible to receive federal grants as part of the FAA's Airport Improvement Program.

ARB is also included in MDOT's Michigan Airport System Plan (MASP) (MDOT, 2008). The MASP presents the results of an airport system planning process that has been aligned with the goals and objectives of MDOT's State Long Range Plan. The MASP supports programming decisions and is useful in evaluating programming actions related to airport system and airport facility deficiencies.

As part of the MASP development, each of Michigan's public-use airports were assigned to one of three tiers based on their contribution to the state system goals. Tier 1 airports respond to essential/critical airport system goals. These airports should be developed to their full and appropriate level. Tier 2 airports complement the essential/critical airport system and/or respond to local community needs. Focus at these airports should be on maintaining infrastructure with a lesser emphasis on facility expansion. Tier 3 airports duplicate services provided by other airports and/or respond to specific needs of individuals and small business.

The MASP identifies ARB as a Tier 1 airport, with a current MASP classification of B-II. Basic standard developmental items for B-II category airports, as outlined in Table 40 of the MASP, are a paved primary runway of 4,300-feet in length by 75-feet wide, a paved parallel taxiway, appropriate runway lighting and visual aids, a runway approach protection plan, basic pilot and aircraft services, all-weather access, year-round access, and landside access. Although it is not a requirement, MDOT encourages all of Michigan's Tier 1 airport sponsors to consider development of their airports to comply with the basic development standards outlined in the MASP.

ARB currently meets all MASP basic development standards for category B-II airports, with the exception of runway length. The current primary runway is only 3,505-feet in length by 75-feet wide. An extension of the primary runway to 4,300-feet in length would result in the airport meeting all state-recommended standards for B-II category airports.

2.2.3 Aircraft Operations and Runway Length Recommendations

The Airport Reference Code (ARC) is a coding system developed by the FAA to correlate airport design criteria with the operational and physical characteristics of the airplane types that regularly use a particular airport. The critical aircraft, or grouping of aircraft, are generally the largest, most demanding types that conduct at least 500 operations per year at the airport. The ARC for each particular airport is determined based on two characteristics of the critical aircraft: the approach speed to the runway and the wingspan of the aircraft.

The first component, designated by letter A through E, is the critical aircraft's Approach Category. This is determined by the approach speed to the runway:

- Category A: Approach speed less than 91 knots.
- Category B: Approach speed 91 knots or more, but less than 121 knots.
- Category C: Approach speed 121 knots or more, but less than 141 knots.
- Category D: Approach speed 141 knots or more, but less than 166 knots.
- Category E: Approach speed 166 knots or more.

The second component, designated by Roman numeral I through VI, is the critical aircraft's Design Group. This is determined by the wingspan of the aircraft:

- Group I: Wingspan less than 49-feet.
- Group II: Wingspan 49-feet or more, but less than 79-feet.
- Group III: Wingspan 79-feet or more, but less than 118-feet.
- Group IV: Wingspan 118-feet or more, but less than 171-feet.
- Group V: Wingspan 171-feet or more, but less than 214-feet.
- Group VI: Wingspan 214-feet or more, but less than 261-feet.

The FAA has also established categories for aircraft based on their certificated Maximum Takeoff Weights (MTOW), which are determined by each specific aircraft's manufacturer. *Small Aircraft* are those with MTOWs of 12,500 lbs. or less. *Large Aircraft* are those with MTOWs greater than 12,500 lbs.

As previously mentioned, the airport user survey confirmed that the current critical aircraft category (and ARC) for ARB is "**B-II Small Aircraft**". Based on the findings of the user survey analysis, the primary runway length recommendations by MDOT and FAA are as follows:

MDOT – *Source: Michigan Airport System Plan (MASP 2008)* **4,300-feet**
Table 40 (*statewide standard for all ARC B-II airports*)

FAA – *Source: FAA Advisory Circular 150/5325-4B,* **4,200-feet***
"Runway Length Requirements for Airport Design"
Figure 2-2 (*airport-specific standard for ARB*)

* *Note: The FAA runway length recommendation was obtained from Figure 2-2 in Advisory Circular 150/5325-4B. The following specifics for ARB were used in the determination:*
Airport Elevation: 839-feet above mean sea level
Temperature: 83 degrees F mean daily maximum temp, hottest month of year (July)

The FAA recommended runway length of 4,200-feet at ARB was obtained by calculation from FAA Advisory Circular 150/5325-4B, *"Runway Length Requirements for Airport Design"*, a publication that is used nationally by the agency. The resulting recommended runway lengths are airport-specific, and can vary by hundreds of-feet from site to site, depending on the specific airport elevations and mean daily maximum temperatures used in the calculations.

The MDOT recommendation of 4,300-feet is a statewide standard for all airports in the state with category B-II critical aircraft classifications. Since airport elevations and mean maximum temperatures do not vary significantly from airport to airport in Michigan, as opposed to many other states, MDOT uses a single runway length recommendation for all airports of the same critical aircraft classification.

The existing ARC shown on the current ALP for the airport is category B-II. This classification has been confirmed correct by the recent airport user survey. Even if the proposed extension to 4,300-feet is constructed, the ALP shows that the future ARC for the airport will remain category B-II.

2.2.4 Airport Operational Forecasts

Year 2007 was the onset year of planning activities associated with the potential extension of Runway 6/24, and the year in which the airport manager and FBOs were requested to collect based and itinerant aircraft operational data for the purpose of determining project justification. In order to maintain consistency, FlightAware operational records from target year 2007 were also examined during the user survey analytical process.

Actual total operations for year 2009 were recently published (January 2010) by the FAA for airports with ATCT. From the user survey operational data year 2007 through the most recent operational data year 2009, total annual operations at ARB have decreased approximately 21.8%

(from 72,853 actual in 2007 to 57,004 actual in 2009). Since the operational totals were obtained from actual ATCT records, rather than estimates, they are considered very accurate.

By applying the 21.8% decrease in total annual operations at ARB from 2007 to 2009 to the user survey results, a very accurate estimate can be obtained for the current level of operations by B-II category critical aircraft. The user survey report documents a total of 750 actual annual operations by B-II category critical aircraft from survey data year 2007. A 21.8% decrease in this number is 586 - still well above the FAA's substantial use threshold of 500. Therefore, even with the current decrease in annual operations due to the economic recession, there is still justification at the present time for the runway extension.

The FAA's Terminal Area Forecast (TAF) shows year 2009 to be a low-point in total annual operations at ARB. The TAF projects total annual operations to continually increase every single year, from year 2010 through year 2030. Since the estimated 586 annual operations by B-II category aircraft in year 2009 confirm present justification for the runway extension, the continual increase in operations that are forecasted by the TAF confirm that justification for the runway extension is substantiated through year 2030.

The following actual and forecasted Total Operations at ARB, from year 2000 through year 2030, are from the FAA data sources listed below. The Estimated Category B-II Operations for each year have been calculated based on the percentage of actual B-II operations to actual total operations in survey data year 2007.

Table 2-1
Actual and Forecasted Total Operations at ARB

Year	Total Operations	Estimated Category B-II Operations
2000	104,342 *	1,074
2001	102,321 *	1,053
2002	91,414 *	941
2003	77,051 *	793
2004	65,516 *	674
2005	67,940 *	699
2006	71,785 *	739
2007	72,853 *	750***
2008	64,910 *	668
2009	57,004 *	586
2010	56,986 **	586
2010	57,514 **	592
2012	58,073 **	598
2013	58,639 **	604
2014	59,212 **	610
2015	59,791 **	616
2016	60,376 **	622
2017	60,968 **	628
2018	61,567 **	634
2019	62,173 **	640
2020	62,786 **	646
2021	63,405 **	653
2022	64,032 **	659
2023	64,666 **	666
2024	65,307 **	672
2025	65,956 **	679
2026	66,613 **	686
2027	67,277 **	693
2028	67,948 **	700
2029	68,627 **	706
2030	69,314 **	714

* = Actual Total Operations from FAA ATCT records
** = Forecasted Total Operations from FAA TAF
*** = Actual (from User Survey)

Forecasts from the MDOT MASP also project increasing total operations at ARB from years 2010 through 2030. The MDOT forecasts, which are independent of the FAA forecasts, further substantiate the mid-term and long-term FAA projections of a rebound in activity at ARB to near survey year 2007 operational levels.

AvFuel Corporation, which bases a B-II Large category Citation 560 Excel jet at ARB, has confirmed in writing that their operations at ARB increased from 211 actual operations in 2007 to 223 actual operations in 2008. Their Chief Pilot has also submitted written documentation that forecasts their future operational levels potentially increasing to 350 to 450 operations per year at ARB.

The FAA TAF forecast, MDOT MASP forecast, and AvFuel's operational forecast all provide support to the fact that survey year 2007 operational data that was analyzed in the user survey process is a very pertinent representation of estimated future operational levels at ARB.

2.2.5 Surrounding Land Uses

ARB is bordered by Ellsworth Road to the north, Lohr Road to the west, and State Road to the east. The primary runway is situated in a northeast/southwest direction. Residential, business, industrial, recreational, agricultural, and forested areas are located adjacent to the airport, and efforts were made during the analysis of alternatives to minimize impacts to these resources. Residential properties are located along Lohr Road and business properties are located along State and Ellsworth Roads. A perennial stream crosses through the airport property and flows to the south connecting to a county drain (Wood Outlet). A portion of the stream near the southwest end of the runway is enclosed in a concrete culvert.

2.2.6 Other Considerations

Aircraft performance information and runway length requirements for each airplane are contained in the individual airplane flight operating manual. As quoted from FAA Advisory Circular 150/5325-4B, Paragraph 206, "*This information is provided to assist the airplane operator in determining the runway length necessary to operate safely. Performance information from those manuals was selectively grouped and used to develop the runway length curves in Figures 2-1 and 2-2. The major parameters utilized for the development of these curves were the takeoff and landing distances for Figure 2-1 and the takeoff, landing, and accelerate-stop distances for Figure 2-2*." As stated earlier in this section, Figure 2-2 of the Advisory Circular was used to determine the FAA-recommended runway length for ARB.

The *accelerate-stop distance* concept referred to above is an important operating consideration. In this concept, the pilot not only considers the amount of runway needed for takeoff, but also the amount of runway needed to abort the takeoff while on the takeoff roll and bring the aircraft to a stop. In situations where pilots detect a problem with the aircraft while on the takeoff roll, they are forced to continue the takeoff and contend with the problem in the air if there is not enough runway remaining to bring the aircraft to a stop. By having enough remaining runway to safely abort a takeoff and stop the aircraft while still on the ground, a pilot would be able to avoid a potentially hazardous situation of taking to the air with a mechanically-deficient aircraft.

A local objective is to reduce the occurrence of runway overrun incidents. While overrun incidents are not officially recognized by the FAA or MDOT as justification for extending runways, there is merit to this local objective. The 11 overrun incident reports that were analyzed showed that most runway overruns at ARB involved small single-engine category A-I aircraft. These types of incidents often involve student pilots or low-time, relatively inexperienced pilots. There is no evidence in the incident reports that any of the aircraft which overran the end of the existing 3,505-foot runway exceeded the limits of the 300-foot long turf Runway Safety Area. Therefore, in each of these cases, the proposed 4,300-foot long runway would have provided sufficient length for the small category A-I aircraft to safely come to a stop while still on the runway pavement, without running off the runway end.

The considerations mentioned above do not imply that the existing 3,505-foot runway is unsafe in any regard. Accelerate-stop distance requirements can be accommodated on the existing runway if pilots of critical category aircraft operate at reduced load capacities. In the cases of the previous runway overrun incidents, the turf Runway Safety Areas to the existing runway performed as designed and provided a clear area for the overrunning aircraft to come to a stop. There were no reports of personal injuries, although there were reports of aircraft damage in several of the incidents.

2.2.7 Summary

The proposed shift and extension of primary Runway 6/24 at ARB would provide a runway configuration that more effectively accommodates the critical aircraft that presently use the facility. The proposed project would satisfy the FAA design objective of providing sufficient runway length to allow airplanes that regularly use it to operate without weight restrictions. The proposed project would also result in ARB achieving full compliance with all MDOT basic developmental standards outlined in the MASP 2008 for category B-II airports.

In particular, the proposed project would provide the following benefits:

- Enhance business aviation and interstate commerce by providing sufficient runway length to allow the majority of category B-II Small critical aircraft that currently use ARB to operate without load restrictions (i.e. reduction in passengers, cargo, and fuel associated with aircraft range).
- Enhance the safety of ground operations, and lessen the chances of a runway incursion, by expanding the view of the parallel taxiway and aircraft hold area to ATCT personnel.
- Improve the all-weather capability of ARB and enhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24.
- Address the local objective of decreasing the number of runway overruns by small category A-I aircraft by providing approximately 800-feet of additional runway pavement.

Airport User Survey Supplemental Report

SUPPLEMENTAL REPORT
AIRPORT USER SURVEY

ANN ARBOR MUNICIPAL AIRPORT (ARB)
ANN ARBOR, MICHIGAN

December 2009

This Supplemental Report is associated with the original Airport User Survey Report for Ann Arbor Municipal Airport (ARB), dated July 2009. The information contained in this supplement provides additional details and updates to the information contained in the original report.

Additional analysis of the aircraft operational data has resulted in the generation of supplemental information, three new exhibits, and updates to the numbers of annual operations performed by category B-II critical aircraft. The following paragraphs explain in detail the information provided in the new exhibits, as well as the supplemental information and updates to the operational numbers listed in the original user survey report.

<u>EXHIBIT No. 1</u>: ***Annual Operations Analysis by Specific Aircraft Model***

This exhibit shows annual operations at ARB by specific aircraft model, rather than only by their FAA aircraft classification as shown in the original user survey report. The various aircraft models are listed in three separate tables, based upon groupings of their FAA classifications (B-II, C-I, and C-II).

Supplemental data associated with annual operations by the Beechcraft King Air C90 has been included in the B-II category table of this exhibit. Operations by this particular model of aircraft were not included in the original July 2009 Airport User Survey Report.

<u>EXHIBIT No. 2</u>: ***Origin / Destination Analysis by State***

Exhibit No. 2 shows the results of an origin and destination analysis of aircraft operations conducted at ARB, based on examination of the FlightAware database from survey year 2007. Although 274 of the operations had aircraft model and ownership information blocked from the database at the aircraft owner's request, the origin and destination cities of each flight were still included.

The first column of the table shown in this exhibit lists 31 states (and Washington DC) from which operations into ARB originated, or operations out of ARB were going to as a destination. The second column lists operations attributed to each state by the 274 total operations with blocked aircraft and ownership records. The third and fourth columns list operations attributed to each state by B-II Small and B-II Large category aircraft. The last column lists the total number of operations attributed to each state.

The numbers of operations associated with each state are from the FlightAware Instrument Flight Rule (IFR) flight plan database only, and do not include records of all itinerant operations between ARB and other states. Nonetheless, the numbers shown in this exhibit confirm that in 2007, flight operations were conducted between ARB and at least 31 other states (approximately 63% of the continental US). Also, approximately 67% of the IFR flight records for the category B-II critical aircraft were between ARB and out-of-state locations. These factors confirm that there is a significant amount of flight operations being conducted at ARB that are either going to, or coming from, distant locations in other states.

EXHIBIT No. 3: *Small 10-Seat Aircraft Analysis*

The table in this exhibit lists *Small* aircraft models (less than or equal to 12,500 lbs. maximum certificated takeoff weight) that have 10 or more passenger seats, and that conducted operations at ARB in survey year 2007. The numbers of annual operations listed in the table are from the FlightAware IFR flight plan database only, and do not include records of all operations by aircraft of this type. The FlightAware records show that there were 425 annual operations by Small 10-seat or higher aircraft.

Exhibit No. 3 also shows that there were 211 annual operations by *Large* category (greater than 12,500 lbs. maximum certificated takeoff weight) B-II aircraft from the Based Aircraft data source and another 85 annual operations by Large category B-II aircraft from the FlightAware data source. The number of annual operations performed by the Small 10-seat or higher aircraft and the Large category aircraft combined is shown as 721.

The operational numbers listed in Exhibit No. 3 do not include blocked FlightAware operations, Visual Flight Rule (VFR) operations, or operations logged by pilots on the Fixed Base Operator (FBO) airport registers. Although the information shown is only a partial representation of all applicable aircraft, the 721 annual operations that were substantiated significantly confirm that Figure 2-2 in FAA Advisory Circular 150/5325-4B is the appropriate chart to reference in the determination of the FAA-recommended runway length of 4,200 feet at ARB.

UPDATED BASED AIRCRAFT ANALYSIS:

The Based Aircraft Analysis of the original user survey report listed 200 estimated annual operations by AvFuel's B-II Large category aircraft (see page 3 of the original report). AvFuel's Chief Pilot has since confirmed in writing that the actual number of operations by their Cessna Citation XL 560 aircraft at ARB over the past three calendar years has been 224 operations in 2006, 211 operations in 2007, and 223 operations in 2008.

In order to maintain consistency with the other survey year 2007 operational records analyzed, Exhibit No. 1 of this Supplemental Report shows the 211 actual annual operations by this aircraft in the "Based Aircraft Data Source" column of the category B-II table, instead of the original estimate of 200.

UPDATED ITINERANT AIRCRAFT ANALYSIS: (FBO Data Sources)

Itinerant (visiting) aircraft operational data that was evaluated as part of the original user survey analysis was obtained from the pilot registration logs (airport registers) of two of the airport's FBOs - Solo Aviation and Ann Arbor Aviation Center. Data was examined for a six-month survey time frame, and cross-checked against FlightAware records in order to prevent counting the same aircraft twice. Any operations that were already included in the FlightAware records were not included in the operational totals that were generated from the FBO records.

The FBO records provided 40 additional operations by B-II and greater category aircraft (32 by category B-II aircraft, 6 by category C-I aircraft, and 2 by category C-II aircraft). Since this data was based on a six-month time frame instead of the full calendar year 2007, these 40 actual operations were prorated into an estimated equivalent annual rate of 80 operations. The additional 40 estimated operations were the only operations in the original user survey analysis that were obtained by prorating actual partial-year data into an estimated equivalent annual rate.

As part of the supplemental analysis, estimated operations that were originally generated as a result of prorating partial-year data were not considered in the determination of the annual operations at ARB. This eliminates the potential effect of seasonal variation in flight activity levels negatively influencing annual operational estimates. Only the 40 actual operations that were documented by the FBOs as having occurred within the six-month survey period were counted as valid operations, since they did in fact occur in 2007. No operations were attributed to the remaining six months.

Exhibit No. 1 of this supplemental report shows only the 40 actual documented operations (32 by category B-II aircraft, 6 by category C-I aircraft, and 2 by category C-II aircraft) in the column that is labeled "2 FBO Register Data Sources".

UPDATED FLIGHTAWARE DATABASE ANALYSIS:

The FlightAware database analysis that was performed for the original July 2009 Airport User Survey Report resulted in the determination of 265 actual annual operations by B-II Small aircraft, and another 85 actual annual operations by B-II Large aircraft (see page 6 of the original report). However, the resulting numbers did not include operations by the Beechcraft King Air C90 model.

The King Air C90 is a B-II Small category aircraft, with a wingspan of 50'3". Earlier versions of the King Air 90 models (A90 and B90) have wingspans of less than 49', and are therefore category B-I Small aircraft. Since the FlightAware records that were originally analyzed for ARB did not include information which identified the specific model of each King Air 90 operation, no operations by King Air 90s were included in the original user survey analysis and report.

Although the FlightAware records do not provide information regarding the specific model of each King Air 90 operation listed, they do provide the aircraft registration N-number of each aircraft. By entering the N-number into the computerized FAA aircraft registration database, the specific model of each King Air 90 operation was able to be determined. A total of 157 operations by the B-II Small category King Air C90 model have been identified, out of 220 operations by King Air 90 models of all types.

Exhibit No. 1 of this supplemental report shows the 157 King Air C90 operations included in the "Flight Aware Data Source" column of the category B-II table. By adding these operations to the 265 operations by B-II Small aircraft and 85 operations by B-II Large aircraft that were previously identified in the original user survey report, the updated total number of actual annual operations by B-II category aircraft obtained from the FlightAware data source is 507.

The FlightAware database also confirmed usage of the airport by many large corporations, in addition to AvFuel, which is the only one actually based at ARB. Some of the other corporate users of ARB include Synergy International, Wells Fargo, Polaris Industries, Bombardier Aerospace, Avis Industrial Corporation, Thumb Energy, and NetJets. NetJets provides on-demand air charter services and corporate aircraft fractional ownership opportunities to a large number of other corporations that are located throughout the country.

AIRCRAFT OPERATIONAL FORECASTS:

Year 2007 was the onset year of the current planning activities associated with the potential extension of Runway 6/24. At that time, the airport manager and FBOs were requested to collect based and itinerant aircraft operational data over the course of year 2007 for the purpose of determining project justification. This data was reviewed during the user survey analysis, which was conducted in early 2009.

FlightAware records for any given year are not published until that particular calendar year has ended, and all operations that took place during the course of that year counted. Since the user survey analysis was conducted in early 2009, the most current operational records available at the time from FlightAware were associated with calendar year 2008. Although year 2008 records were available, year 2007 records from FlightAware were used in the user survey analytical process. This was due to the importance of maintaining consistency of year of operational records in the analysis, and not combining operational data collected by the airport manager and FBOs over year 2007 with the more recent FlightAware records from year 2008. The FlightAware records, airport manager records, and FBO records from calendar year 2007 that were used in the user survey analysis were all only one-year old at the time, and still considered valid for use in determining project justification.

The FAA Terminal Area Forecast (TAF) does project a short-term approximate 22% decrease in total annual operations at ARB from user survey year 2007 through year 2009 (from 72,895 actual in 2007 to 56,956 estimated for 2009). However, beginning in year 2010, the TAF projects continuously increasing annual operations at ARB, from the year 2009 low-point through year 2030. Itinerant annual operations are even projected to surpass survey year 2007 levels prior to the end of the 2030 forecast period.

Even if the worst case short-term projected 22% decrease in total annual operations is applied to the user survey results, there is still significant justification for the runway extension. The user survey report documents a total of 750 actual annual operations by B-II category critical aircraft that justify the runway extension. A 22% decrease in this number is 585 - still well above the FAA's substantial use threshold of 500. And again, beginning in 2010, operations at ARB are projected by the FAA to begin increasing every single year from that point forward, through year 2030.

Forecasts from the MDOT Michigan Airport System Plan (MASP 2008) also project increasing itinerant and total operations at ARB from years 2010 through 2030. The MDOT forecasts further substantiate the mid-term and long-term FAA projections of a rebound in current operational activity at ARB to survey year 2007 levels.

AvFuel Corporation, which bases a B-II Large category Citation 560 Excel jet at ARB, has confirmed that their operations at ARB actually increased from 211 operations in 2007 to 223 operations in 2008. Their Chief Pilot estimates that their future operational levels could potentially increase to 350 to 450 operations per year at ARB.

The FAA TAF forecast, MDOT MASP forecast, and AvFuel's operational forecasts all provide support to the fact that survey year 2007 operational data is a very pertinent representation of estimated future operational levels at ARB.

SUMMARY:

The supplemental analysis that was conducted after publication of the July 2009 Airport User Survey Report has resulted in additional justification in support of extension of Runway 6/24 to 4,300' in length.

Further analysis of the FlightAware IFR flight plan database has confirmed 507 actual operations at ARB in survey year 2007 by B-II category aircraft. This number does not include operations in the FlightAware records with aircraft information blocked at the owner's request, or VFR operations that were conducted without flight plans. Judging by the high number of out-of-state origin and destination locations of operations listed in the blocked category (see Exhibit No. 2), it is very likely that many of the associated aircraft were of the B-II or greater categories. Therefore, actual operations at ARB by aircraft of these categories are likely considerably higher than the 507 substantiated operations obtained from the FlightAware database.

The 507 actual operations by B-II category aircraft that were obtained from the FlightAware database also do not include operations conducted by AvFuel's based Cessna Citation XL 560, or operations obtained from the two FBO airport registers. AvFuel has confirmed 211 actual operations at ARB in 2007 with their B-II category aircraft, and data provided by the FBOs has confirmed 32 actual operations in 2007 by B-II category aircraft.

In summary, the supplemental analysis of this user survey has confirmed a total of 750 actual annual operations at ARB by category B-II aircraft. FlightAware records also confirmed that operations by aircraft in this critical aircraft category were performed by many large corporations, some of which are listed on page 4 of this report.

CONCLUSION:

In the majority of airport user survey processes, determinations and recommendations are issued based on analysis of estimated annual operations obtained from various airport users. In conducting the user survey at ARB, the analysis focused on evaluation of actual annual operations performed at the airport. This is obviously a much more accurate method of calculating the total number of annual operations associated with the determination of the critical aircraft and Airport Reference Code. It also eliminates the possibility of an airport user inflating their estimated operational numbers, in the hopes of obtaining a longer runway that is not truly justified.

While the numbers listed in this report do not include every operation that occurred at ARB in survey year 2007 with B-II category aircraft, they do confirm substantial usage of the airport by aircraft of this critical aircraft category. The Origin/Destination Analysis has shown a significant number of operations between ARB and distant out-of-state locations, which is a very good indicator of corporate activity associated with interstate commerce, as opposed to pleasure flying by general aviation pilots. FlightAware records also confirmed usage of the airport by many large corporations.

The information contained in this Supplemental Report provides additional justification in support of the findings and recommendations of the original July 2009 Airport User Survey Report. The user survey analysis has shown that justification for the proposed extension of primary Runway 6/24 to 4,300-feet has been confirmed, and the proposed project has been determined to be eligible to receive state and federal funding.

Although justification for the proposed project has been substantiated according to current MDOT and FAA standards associated with runway length recommendations, neither agency requires that the runway be extended. It is ultimately – and entirely – the decision of the city of Ann Arbor whether or not to proceed with the development of the project.

Mark W. Noel

Mark W. Noel, P.E., Manager
Project Development Section
MDOT – Airports Division

ANN ARBOR MUNICIPAL AIRPORT USER SURVEY - SUPPLEMENTAL REPORT - DECEMBER 2009

EXHIBIT NO. 1

ANNUAL OPERATIONS ANALYSIS BY SPECIFIC AIRCRAFT MODEL

Aircraft Model	FAA Approach Category	FAA Design Group	FAA Weight Class	Seating	Maximum Takeoff Weight (lbs.)	Aircraft Engine Type	Flight-Aware Data Source	Based Aircraft Data Source	2 FBO Register Data Sources	Total Annual Operations by Model
Aero Commander 695	B	II	Small	<10	<12,500	Multi-Eng	4	0	0	4
Beechcraft King Air C90	B	II	Small	10+	<12,500	Multi-Eng	157	0	0	157
Beechcraft King Air 100	B	II	Small	10+	<12,500	Multi-Eng	39	0	2	41
Beechcraft King Air 200	B	II	Small	10+	<12,500	Multi-Eng	215	0	8	223
Cessna 441 Conquest II	B	II	Small	<10	<12,500	Multi-Eng	7	0	4	11
Beechcraft King Air 300	B	II	Large	10+	12,500+	Multi-Eng	11	0	8	19
Beechcraft King Air 350	B	II	Large	10+	12,500+	Multi-Eng	43	0	4	47
Cessna Citation II 550	B	II	Large	<10	12,500+	Jet	6	0	2	8
Cessna Citation XL 560	B	II	Large	<10	12,500+	Jet	25	211	2	238
Cessna Citation 680	B	II	Large	<10	12,500+	Jet	0	0	2	2
Total B-II Category Annual Operations							507	211	32	750

Aircraft Model	FAA Approach Category	FAA Design Group	FAA Weight Class	Seating	Maximum Takeoff Weight (lbs.)	Aircraft Engine Type	Flight-Aware Data Source	Based Aircraft Data Source	2 FBO Register Data Sources	Total Annual Operations by Model
Learjet 25	C	I	Large	<10	12,500+	Jet	0	0	2	2
Learjet 31	C	I	Large	<10	12,500+	Jet	0	0	2	2
Learjet 45	C	I	Large	<10	12,500+	Jet	0	0	2	2
Total C-I Category Annual Operations							0	0	6	6

Aircraft Model	FAA Approach Category	FAA Design Group	FAA Weight Class	Seating	Maximum Takeoff Weight (lbs.)	Aircraft Engine Type	Flight-Aware Data Source	Based Aircraft Data Source	2 FBO Register Data Sources	Total Annual Operations by Model
IAI Westwind 1125	C	II	Large	<10	12,500+	Jet	0	0	2	4
Total C-II Category Annual Operations							0	0	2	4

CRITICAL AIRCRAFT CATEGORY DETERMINATION: B-II (Based on 750 Total Annual Operations by Aircraft of this Category)

NOTE: The annual operations listed in the above tables are ACTUAL documented operations from calendar year 2007.
The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.
Operations recorded by the FBOs and listed above represent only a partial-year (six-month) time frame.

A total of 274 operations in the FlightAware database had aircraft model and ownership information blocked at the owner's request.
As a result, their operational numbers are NOT included in the information shown above.
Judging by the high number of out-of-state origin and destination locations of aircraft in the blocked category (see Exhibit No. 2),
it is very likely that many of the associated aircraft were of the B-II and greater categories.
Therefore, actual operations at ARB by aircraft of these categories are likely considerably higher than the numbers shown above.

EXHIBIT NO. 2 ORIGIN / DESTINATION ANALYSIS BY STATE

Origin / Destination Analysis of IFR Aircraft Operations Between ARB and Other States (Records from FlightAware 2007 Database)

	STATE	Aircraft Type & Category Blocked	B-II Small Category	B-II Large Category	Totals by State
1	Alabama	0	1	0	1
2	Arizona	1	0	0	1
3	Arkansas	2	1	0	3
4	Connecticut	5	2	0	7
5	Florida	29	3	3	35
6	Georgia	5	6	12	23
7	Illinois	25	64	5	94
8	Indiana	6	21	1	28
9	Iowa	1	20	3	24
10	Kansas	3	0	0	3
11	Kentucky	2	13	0	15
12	Maine	2	0	0	2
13	Maryland	1	3	7	11
14	Massachusetts	5	0	1	6
15	**Michigan**	**79**	**162**	**20**	**261**
16	Minnesota	2	3	2	7
17	Missouri	0	5	0	5
18	Nebraska	3	0	1	4
19	New Hampshire	1	2	0	3
20	New Jersey	9	2	4	15
21	New York	6	5	1	12
22	North Carolina	4	1	1	6
23	Ohio	16	38	13	67
24	Pennsylvania	14	23	4	41
25	South Carolina	0	4	0	4
26	South Dakota	4	18	0	22
27	Tennessee	2	5	0	7
28	Texas	30	0	0	30
29	Virginia	1	3	0	4
30	Washington DC	5	1	2	8
31	West Virginia	1	7	0	8
32	Wisconsin	10	9	4	23
	No Record	0	0	1	1
	Totals by Category	**274**	**422**	**85**	**781**

IFR Aircraft Operation Totals by Category:

Within Michigan	79	162	20	261
Outside of Michigan	195	260	64	519
No Record	0	0	1	1

NOTE: The numbers of operations listed above are ACTUAL documented operations from calendar year 2007. The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.

The numbers shown above are from the FlightAware IFR Flight Plan Database only, and do NOT include records of all itinerant operations between ARB and other states. Nonetheless, the numbers shown above confirm that in 2007, flight operations were conducted between ARB and at least 31 other states and Washington DC (approx 63% of the continental US). Approximately 67% of these IFR flight records were between ARB and out-of-state locations.

EXHIBIT NO. 3 SMALL 10-SEAT AIRCRAFT ANALYSIS

Small Airplanes Having 10 or More Passenger Seats (Records from FlightAware 2007 Database)							
Aircraft Model	FAA Approach Category	FAA Design Group	FAA Weight Class	Seating	Maximum Takeoff Weight	Aircraft Engine Type	Annual Operations
Cessna Caravan 208	A	II	Small	10+	<12,500	Single-Eng	11
Swearingen Merlin III	B	I	Small	10+	<12,500	Multi-Eng	3
Beechcraft King Air C90	B	II	Small	10+	<12,500	Multi-Eng	157
Beechcraft King Air 100	B	II	Small	10+	<12,500	Multi-Eng	39
Beechcraft King Air 200	B	II	Small	10+	<12,500	Multi-Eng	215

Total Small 10-Seat Aircraft Annual Operations **425**

Total B-II Large Category Aircraft Annual Operations

Based Aircraft Data Source (B-II Large): **211**
FlightAware Data Source (B-II Large): **85**

Grand Total Annual Operations at ARB Applicable to Figure 2-2 in FAA Advisory Circular 150/5325-4B: **721**

NOTE: The annual operations listed above are ACTUAL documented operations from canendar year 2007.
The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.

The numbers shown in the table above are from the FlightAware IFR Flight Plan Database only, and do NOT include records of all small aircraft operations at ARB with 10-seat or greater aircraft models. Nonetheless, the above analysis confirms that Figure 2-2 in FAA AC 150/5325-4B is the appropriate chart to reference in the determination of the FAA-recommended runway length for Ann Arbor Municipal Airport.

Exhibit 14

FOR FURTHER INFORMATION CONTACT: Copies of the applications are available for inspection in the Records Center, East Building, PHH–30, 1200 New Jersey Avenue, Southeast, Washington, DC or at *http://regulations.gov.*

This notice of receipt of applications for special permit is published in accordance with Part 107 of the Federal hazardous materials transportation law (49 U.S.C. 5117(b); 49 CFR 1.53(b)).

Issued in Washington, DC, on March 11, 2010.

Delmer F. Billings,

Director, Office of Hazardous Materials, Special Permits and Approvals.

NEW SPECIAL PERMITS

Application No.	Docket No.	Applicant	Regulation(s) affected	Nature of special permits thereof
14977–N	....	Air Products and Chemicals, Inc. Allentown, PA.	49 CFR 173.301(f)	To authorize the transportation in commerce of certain DOT Specification 3T cylinders containing Silane without pressure relief devices by motor vehicle and cargo vessel. (modes 1, 3).
14978–N	....	Air Products and Chemicals, Inc. Allentown, PA.	49 CFR 173.181	To authorize the transportation in commerce of pyrophoric liquids in inner metal containers (bubblers) with openings greater than 25mm (1 inch) which are engineered to specific electronics applications that require a larger opening. (modes 1, 3).
149979–N	....	M & N Aviation, Carolina Inc.	49 CFR 172.101 Column (9B).	To authorize the air transportation in commerce of certain explosives which are forbidden or exceed quantity limits for shipment by cargo-only aircraft. (mode 4).
14980–N	....	Fisk Tank Carrier, Inc. Columbus, WI.	49 CFR 173.315 (j)(4)	To authorize the one-way transportation in commerce of certain non-DOT specification storage tanks containing propane. (mode 1).
14981–N	....	Eclipse Aerospace, Inc. (EAI) Albuquerque, NM.	49 CFR 173.309(b)	To authorize the manufacture, marking, sale and use of non-DOT specification cylinders for use as fire extinguishers. (modes 1, 2, 3, 4, 5).

[FR Doc. 2010–5898 Filed 3–18–10; 8:45 am]

BILLING CODE 4909–60–M

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Notice of Availability of Draft Environmental Assessment; Ann Arbor Municipal Airport, Ann Arbor, MI

AGENCY: The Federal Aviation Administration is issuing this notice on behalf of the Michigan Department of Transportation (MDOT), Bureau of Aeronautics and Freight Services.

ACTION: Notice of Availability of a Draft Environmental Assessment (EA) for public review and comment.

SUMMARY: The FAA has delegated selected responsibilities for compliance with the National Environmental Protection Act to the MDOT as part of the State Block Grant Agreement authorized under Title 49 U.S.C., Section 47128. This notice is to advise the public pursuant to the National Environmental Policy Act of 1969, as amended, (NEPA) 42 U.S.C. 4332(2)(c) that MDOT has prepared a Draft EA for the proposed extension of runway 6/24 at the Ann Arbor Municipal Airport. While not required for an EA, the FAA is issuing this notice to facilitate public involvement. The Draft EA assesses the potential environmental impacts resulting from the proposed extension of runway 6/24 from 3,500 feet to 4,300 feet. This evaluation also includes the relocation or replacement of the Federally Owned Omni Directional Approach Lighting System. All reasonable alternatives were considered including the no action alternative.

DATES: Written comments on the Draft EA must be received by MDOT on or before 5:00 p.m. on April 12, 2010. Comments may be sent by electronic mail to Molly Lamrouex at *lamrouexm@michigan.gov* or written comments may be submitted to Molly Lamrouex, MDOT Bureau of Aeronautics and Freight Services, 2700 Port Lansing Road, Lansing, MI 48906. The Draft EA can be reviewed at the following locations:

(a) Ann Arbor City Library, 343 S. Fifth Ave., Ann Arbor, MI 48104
(b) Pittsfield Township Hall, 6201 W. Michigan Ave., Ann Arbor, MI 48108
(c) Ann Arbor Municipal Airport, 801 Airport Dr., Ann Arbor, MI 48103
(d) Ann Arbor City Hall, 100 N. Fifth Ave., Ann Arbor, MI 48104
(e) MDOT BAFS, 2700 Port Lansing Road, Lansing MI 48906

Copies of the Draft EA are available by contacting Molly Lamrouex, MDOT Bureau of Aeronautics and Freight Services, 2700 Port Lansing Road, Lansing, MI 48906 or by phone at 517–335–9866. The Draft EA is also available at *http://www.a2gov.org/government/publicservices/fleetandfacility/Airport/Pages/default.aspx* A public hearing to provide information on the draft EA and accept comments from the public will be held from 4 to 7 p.m. on Wednesday, March 31, 2010 at the Cobblestone Farm Barn, 2781 Packard Rd., Ann Arbor, MI 48108.

SUPPLEMENTARY INFORMATION: The EA includes analysis used to evaluate the potential environmental impacts in the study area. Upon publication of the Draft EA and a Final EA, MDOT will be coordinating with federal, state and local agencies, as well as the public, to obtain comments and suggestions regarding the EA for the proposed project. The Draft EA assesses impacts and reasonable alternatives including a no action alternative pursuant to NEPA; FAA Order 1050.1, Policies and Procedures for Considering Environmental Impacts; FAA Order 5050.4B, National Environmental Policy Act (NEPA) Implementing Instructions for Airport Actions; and the President's Council on Environmental Quality (CEQ) Regulations implementing the provisions of NEPA, and other appropriate Agency guidance.

Joe Hebert,

Acting Manager, Detroit Airports District Office, Great Lakes Region.

[FR Doc. 2010–5521 Filed 3–18–10; 8:45 am]

BILLING CODE 4910–13–P

DEPARTMENT OF TRANSPORTATION

Federal Transit Administration

Notice of Limitation on Claims Against Proposed Public Transportation Projects

AGENCY: Federal Transit Administration (FTA), DOT.

ACTION: Notice of Limitation on Claims.

SUMMARY: This notice announces final environmental actions taken by the Federal Transit Administration (FTA) for the following projects: (1) Jacksonville Transit Authority, Rapid Transit System Phase One, Jacksonville, FL; (2) Salem-Keizer Transit, Keizer Transit Center Project, Salem, OR; (3) Massachusetts Bay Transportation Authority, Installation of Elevators at Park Street Station Project, Boston, MA; (4) Erie Metropolitan Transit Authority, Expansion of the 14th Street Bus Facility, Erie, PA; and (5) Metropolitan Council, Central Corridor Light Rail Transit Project—Construction of Three Infill Stations, St. Paul, MN. The purpose of this notice is to announce publicly the environmental decisions by FTA on the subject projects and to activate the limitation on any claims that may challenge these final environmental actions.

DATES: By this notice, FTA is advising the public of final agency actions subject to Section 139(l) of Title 23, United States Code (U.S.C.). A claim seeking judicial review of the FTA actions announced herein for the listed public transportation projects will be barred unless the claim is filed on or before September 14, 2010.

FOR FURTHER INFORMATION CONTACT: Antoinette Quagliata, Environmental Protection Specialist, Office of Planning and Environment, 202–366–4265, or Christopher Van Wyk, Attorney-Advisor, Office of Chief Counsel, 202–366–1733. FTA is located at 1200 New Jersey Avenue, SE., Washington, DC 20590. Office hours are from 9 a.m. to 5:30 p.m., EST, Monday through Friday, except Federal holidays.

SUPPLEMENTARY INFORMATION: Notice is hereby given that FTA has taken final agency actions by issuing certain approvals for the public transportation projects listed below. The actions on these projects, as well as the laws under which such actions were taken, are described in the documentation issued in connection with each project to comply with the National Environmental Policy Act (NEPA) and in other documents in the FTA administrative record for the project. Interested parties may contact either the project sponsor or the relevant FTA Regional Office for more information on these projects. Contact information for FTA's Regional Offices may be found at *http://www.fta.dot.gov.*

This notice applies to all FTA decisions on the listed projects as of the issuance date of this notice and all laws under which such actions were taken, including, but not limited to, NEPA [42 U.S.C. 4321–4375], Section 4(f) of the Department of Transportation Act of 1966 [49 U.S.C. 303], Section 106 of the National Historic Preservation Act [16 U.S.C. 470f], and the Clean Air Act [42 U.S.C. 7401–7671q]. This notice does not, however, alter or extend the limitation period of 180 days for challenges of project decisions subject to previous notices published in the **Federal Register**. For example, this notice does not extend the limitation on claims announced in the **Federal Register** on September 2, 2009 (74 FR 169) for the original Record of Decision (ROD) issued for the Central Corridor Light Rail Transit Project.

The projects and actions that are the subject of this notice are:

1. *Project name and location:* Jacksonville Rapid Transit System Phase One—Downtown Transit Enhancements, Jacksonville, FL. *Project sponsor:* Jacksonville Transit Authority. *Project description:* The project will construct a Bus Rapid Transit system in Jacksonville, Florida. This project is a part of an overall strategy to bring high-capacity public transit to downtown Jacksonville. The 5.6 mile system will include: Restructured bus routes, 2.84 miles of dedicated bus lanes, 15 station-stop enhancements, a traffic signal priority system, and a real-time traveler information network. *Final agency actions:* Section 106 finding of no adverse effect; project-level air quality conformity determination; no use of Section 4(f) properties; and a Finding of No Significant Impact (FONSI) signed February 11, 2010. *Supporting documentation:* Supplemental Environmental Assessment dated November 2009 and Environmental Assessment dated September 2008.

2. *Project name and location:* Keizer Transit Center Project, Salem, OR. *Project sponsor:* Salem-Keizer Transit. *Project description:* The project will construct a transit hub for the medium-sized community of Salem, Oregon, located 40 miles south of Portland. The proposed Keizer Transit Center will accommodate transfers between bus routes, have a 70-space park-and-ride lot, a passenger plaza, a kiss-and-ride lot, a transit information kiosk, and bicycle storage units. *Final agency actions:* Section 106 finding of no adverse effect; project-level air quality conformity determination; no use of Section 4(f) properties; and a Finding of No Significant Impact (FONSI) signed February 4, 2010. *Supporting documentation:* Environmental Assessment dated December 2009.

3. *Project name and location:* Installation of Elevators at Park Street Station, Boston, MA. *Project sponsor:* Massachusetts Bay Transportation Authority. *Project description:* The project will modernize elevators at the Park Street Station of the Massachusetts Bay Transportation Authority. Park Street is an intersection point for both the Green and Red subway lines. The station has a unique historic heritage, originally built in 1897, as one of America's first street-level subway systems. The current travel path between the Green and Red Lines requires three elevator transfers and an approximate 0.10 mile walk. This path is unduly long and can pose a challenge for persons with limited mobility or low physical stamina. The purpose of the project is to provide a shorter elevator-accessible path between the Green Line westbound platform and Red Line center platform. *Final agency actions:* Section 106 finding of no adverse effect; project-level air quality conformity determination; Section 4(f) de minimis impact determination; and a Finding of No Significant Impact (FONSI) signed December 29, 2009. *Supporting documentation:* Environmental Assessment dated August 2009.

4. *Project name and location:* Expansion of the 14th Street Bus Facility, Erie, PA. *Project sponsor:* Erie Metropolitan Transit Authority. *Project description:* The project involves the expansion of a bus maintenance and storage facility in Erie, Pennsylvania. Located on the western coast of Pennsylvania, the city of Erie is 120 miles north of Pittsburg. The proposed 9-acre site will house bus maintenance, storage, fueling, and washing facilities. Site plans also include provisions for additional parking and administrative office space. In total, the project will centralize operations from nine under-utilized buildings into the new facility. *Final agency actions:* Section 106 finding of no adverse effect; project-level air quality conformity

Exhibit 15

CHEVALIER, ALLEN & LICHMAN LLP
Attorneys at Law
Aviation Law & Litigation • Environmental Law & Litigation • Commercial Litigation
www.calairlaw.com | www.aviationairportdevelopmentlaw.com

Gary M. Allen, Ph.D.
John Chevalier, Jr.*
Berne C. Hart
Barbara E. Lichman, Ph.D.
Jacqueline E. Serrao, LL.M.◊
Steven M. Taber○△
Anita C. Willis◊

*Retired
○Admitted in Illinois
△Admitted in Florida
◊Of Counsel

695 Town Center Drive, Suite 700
Costa Mesa, California 92626
Telephone (714) 384-6520
Facsimile (714) 384-6521
E-mail cal@calairlaw.com

April 19, 2010

By E-Mail
lamrouexm@michigan.gov

Molly Lamrouex
Airports Division
MDOT Bureau of Aeronautics and Freight Services
2700 Port Lansing Road
Lansing, Michigan 48906-2160

Re: Comments by The Charter Township of Pittsfield on the Environmental Assessment for Ann Arbor Municipal Airport

Dear Ms. Lamrouex:

The following comments are submitted on behalf of The Charter Township of Pittsfield on the February 2010 Environmental Assessment for Ann Arbor Municipal Airport ("EA").

I. THE PROJECT'S STATED PURPOSE AND NEED IS UNSUPPORTED BY THE EVIDENCE.

An EA must include a discussion of the purpose and need for the proposed action which must "specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action." [40 C.F.R. § 1502.13]. In addressing the Purpose and Need section of an EA, FAA Order 1050.1E provides that: "This discussion identifies the problem facing the proponent (that is, the need for an action), the purpose of the action (that is, the proposed solution to the problem), and the proposed timeframe for implementing the action." FAA Order 1050.1E, ¶ 405c. The EA accomplishes none of these goals.

A. The EA Supports Neither the Problem it Aims to Solve Nor its Purported Solution.

First, the EA defines the *purpose* of the Project[1] as "to provide facilities that more effectively and efficiently accommodate the *critical aircraft* that presently use the airport, as well as to enhance the operational safety of the airport." [EA, p. 2-4]. The EA defines "critical aircraft" as "the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport," *Id*., and states that a 2009 MDOT Airport User Survey "has confirmed that the critical aircraft classification for ARB is 'B-II Small Aircraft.'" *Id*.

To effectuate the stated purpose, the EA purports to support the construction of a runway extension from 3,505 feet to 4,300 feet. However, the extant evidence is clear that no "B-II Small Aircraft" require a 4,300 foot long runway. All B-II Small Aircraft are capable of operating on the existing 3,505 feet long runway without weight restriction. *See*, attached Williams Aviation Consultants Report [incorporated herein by reference]. In fact, the representative B-II Small Aircraft cited in the EA, the Beechcraft King Air 200, requires only 2,579 feet of runway to take-off fully loaded, and 2,845 feet to land. *See*, http://www.hawkerbeechcraft.com/beechcraft/ king_airb200gt/specifications.aspx. Thus, the statement that "[d]evelopment of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small Aircraft to operate at their optimum capabilities (without weight restrictions)" [p. 2-4], although true, is misleading. There is no need to extend Runway 6/24 to allow B-II aircraft to operate at ARB. They can operate on a 3,505 foot runway without weight restrictions. Therefore, the statement that interstate commerce would be negatively impacted by B-II Small weight restrictions does not state a valid need, and the purported purpose of "provid[ing] facilities that more effectively and efficiently accommodate the *critical aircraft* that presently use the airport" is an unnecessary solution to a nonexistent problem.

B. The EA Incorrectly Relies on ***Total*** Annual Operations to Support the Proposed Runway Extension.

The EA states, "[t]he critical aircraft, or grouping of aircraft are generally the largest, most demanding types that conduct at least 500 operations per year at the airport" [EA, p. 2-7], and concludes that the proper Airport Reference Code ("ARC") for ARB is "B-II Small", based on a total of "750 actual annual operations by B-II category critical aircraft from survey data year

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[1] The proposed improvements described at page 2-1 of the EA are referred to herein as the "Project."

2007." [EA, p. 2-9]. However, the EA's use of "annual operations" differs markedly from the FAA criteria for selecting runway lengths and widths set forth in FAA Order 5090.3C:

> 3-4. AIRPORT DIMENSIONAL STANDARDS
>
> Airport dimensional standards (such as runway length and width, separation standards, surface gradients, etc.) should be selected which are appropriate for the critical aircraft that will make substantial use of the airport in the planning period. Substantial use means either 500 or more annual ***itinerant*** operations, or scheduled commercial service. FAA Order 5090.3C, p. 21 (emphasis added).

(FAA Order 5090.3C does not state that critical aircraft must be the "largest.")

The FAA divides General Aviation operations into two categories, "local" and "itinerant." Itinerant operations are defined as "an operation performed by an aircraft, either IFR, SVFR, or VFR, that lands at an airport, arriving from outside the airport area, or departs an airport and leaves the airport area." [U.S. DOT JO 7210.695, p. 5]. Local operations are defined as "those operations performed by aircraft that remain in the local traffic pattern, execute simulated instrument approaches or low passes at the airport, and the operations to or from the airport and a designated practice area within a 20-mile radius of the tower." *Id*.

The EA, without reference to this distinction, relies on "annual operations" and "total annual operations" not "itinerant operations," *see,* EA, Table 2-1, p. 2-10. Separating itinerant and local operations at ARB would result in a dramatic reduction in the number of annual critical aircraft operations at the airport. For example, data from the website City-Data.com shows that there were 29,322 itinerant operations and 43,573 local operations at ARB in 2007, the year used by MDOT in the EA. *See*, http://www.city-data.com/airports/Ann-Arbor-Michigan.html. In that itinerant operations account for approximately 40% of the total operations at ARB, itinerant B-II operations for 2007 would be in the neighborhood of 300 operations per year [40% of 750 total operations], substantially below the FAA's threshold of 500 annual operations to constitute "substantial use." Moreover, the Airport User Survey shows only 293 annual B-II Small operations at ARB in 2007. [EA Appendix A-1, p. 7]. Thus, the FAA Order 5090.3C airport dimensional standards for B-II small aircraft do not apply.

C. Shifting Runway 6/24 150 Feet to the Southwest Will Not Achieve an Additional Margin of Safety.

The EA states as part of its purpose to "[e]nhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road." [EA, p. 2-5]. Operational safety in low visibility conditions will not be enhanced by providing a clear 34:1 approach surface to Runway 24. The EA is correct in stating that shifting the Runway 24 threshold 150 feet west would enhance safety by effectively removing the current obstruction to line-of-site vision (hangar) of the parallel taxiway for ATCT personnel. [EA, p. 2-5]. However, in the next paragraph the EA states, "The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles." [EA, p. 2-5]. This statement lacks support in either the Instrument Approach Procedure (IAP) design or Terminal Instrument Procedures ("TERPS") Obstruction Standards.

Both the 20:1 and the 34:1 surfaces exist simultaneously for every published IAP, and are defined as "Obstacle Identification Surfaces" which do not establish obstacle clearance safety margins, but rather only define instrument approach visibility minimums. The FAA does not require either of these two surfaces to be free of penetration by obstacles, and thus "providing an additional margin of safety," as stated in the EA, does not apply in the case of these two surfaces. Other TERPS surfaces (Obstacle Clearance Surfaces) are established which do ensure clearance from obstructions, and the FAA requires that these Obstacle Clearance Surfaces be clear of structures and terrain. The current IAPs to Runway 24 were designed by the FAA to accommodate all existing obstructions. Thus, shifting the runway 150' southwest would not enhance safety. Assuming that the EA is correct in the assertion that shifting the Runway 24 threshold would eliminate obstruction penetrations to the existing 34:1 Obstacle Identification Surface, the effect would not be a safety improvement, but would result only in a reduction in the required approach visibility minimums. [*See*, attached Williams Aviation Consultants Report]

II. THE EA DOES NOT CONSIDER ALL REASONABLE ALTERNATIVES.

The National Environmental Policy Act ("NEPA") [42 U.S.C. §§ 4321 *et seq.*] requires that federal agencies examine all reasonable alternatives in preparing environmental documents. [42 U.S.C. § 4332(c)(iii)]. An agency preparing an EA should develop a range of alternatives that could reasonably achieve the need that the proposed action is intended to address. The Council on Environmental Quality ("CEQ") Regulations ("NEPA Regulations"), which implement NEPA, require that Federal agencies "[u]se the NEPA process to identify and assess the reasonable alternatives to the proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment" 40 C.F.R. § 1500.2(e), and that "agencies shall . . . (a) Rigorously explore and objectively evaluate all reasonable alternatives . . ." 40 C.F.R. § 1502.14(a). The EA fails to explore all reasonable alternatives to the Preferred Alternative selected.

The EA [p. 2-5] lists five objectives of the proposed project:

- Enhance interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions.
- Enhance operational safety by improving the FAA ATCT line-of-sight issues.
- Enhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road.
- Reduce the occurrence of runway overrun incidents by small category A-I aircraft (local objective).
- Relocate and potentially upgrade the Runway 24 Approach Light System.

As shown in Section I above, enhancing interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions is not a valid need. Further, lengthening Runway 6/24 is not necessary to achieve the remaining four objectives. Those objectives could be met by simply shifting Runway 6/24 150 feet to the southwest, *i.e.*, removing 150 feet from the approach end of Runway 24 and adding 150 feet to the departure end of Runway 24. Runway length would remain 3,505 feet.

Section 2.2.1 of the EA states that a 150-foot shift of the Runway 24 threshold to the west would (1) enhance the safety of ground operations by taxiing aircraft; (2) enhance operational safety, and possibly prevent runway incursions, by expanding the view of the hold area and parallel taxiway to ATCT personnel; (3) allow for a clear 34:1 approach surface to the east end of the runway, providing an added margin of safety between approaching aircraft and ground-based obstacles, which is particularly beneficial when aircraft are operating in low-visibility conditions; and (4) include relocation and replacement of the existing runway approach light system with newer Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF). [EA, pp. 2-5, 2-6]. Shifting Runway 6/24 150 feet to the southwest without lengthening the runway would also accommodate future widening of State Road. Nevertheless, this reasonable alternative was not considered in the EA.

An Environmental Assessment "shall include brief discussions of . . . alternatives . . ." 40 C.F.R. § 1508.9(b).[2] Absent an analysis of an alternative based on a 150-foot southwesterly shift of the runway, without lengthening the runway, the EA is inadequate.

III. THE EA FAILS TO ADEQUATELY ANALYZE OR DISCLOSE THE PROJECT'S AIR QUALITY IMPACTS WHERE IT FAILS TO ADDRESS OR DETERMINE THE PROJECT'S CLEAN AIR ACT CONFORMITY.

Section 7506 of the Federal Clean Air Act [42 U.S.C. §§ 7401 *et seq*.] mandates that "[n]o department, agency, or instrumentality of the Federal Government shall engage in, support in any way or provide financial assistance for, license or permit, or approve, any activity which does not conform to [a State Implementation Plan] after it has been approved or promulgated under [42 U.S.C. § 7410]." The Environmental Protection Agency (EPA) has promulgated regulations implementing Section 7506 (the "Conformity Provision") in 40 C.F.R. §§ 93.150 *et seq*. ("General Conformity Rule"). The General Conformity Rule requires, in part, that Federal agencies first determine if a project is either exempt from conformity analysis or presumed to conform. If it is neither, the agency must conduct a conformity applicability analysis to determine if a full conformity determination is required. *See*, *Air Quality Procedures for Civilian Airports and Air Force Bases*, p. 13.

The project area, *i.e.*, Washtenaw County, is in attainment for five of the seven criteria pollutants [p. 4-17], and marginal nonattainment for Ozone [p. C-3].[3] The area is designated as in nonattainment for $PM_{2.5}$. [EA, p. C-4]. Therefore, one of the following must apply: (1) the Project is exempt from conformity; or (2) the Project is presumed to conform; or (3) the agency must conduct a conformity applicability analysis to determine if a conformity determination for $PM_{2.5}$ is required. The EA does not indicate that any of the required actions was performed.

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2 Courts have consistently held that the "existence of reasonable but unexamined alternatives renders an EIS inadequate." *See, e.g., Friends of Southeast's Future v. Morrison*, 153 F.3d 1059, 1065 (9th Cir. 1998).

3 The original six criteria pollutants are Ozone (O3), Particulate Matter (PM_{10}), Carbon Monoxide (CO), Nitrogen Oxides (NO2), Sulfur Dioxide (SO2) and Lead (Pb). FAA Order 1050.1E ("Environmental Impacts; Policies and Procedures"), p. A-3, ¶ 2.1b, includes both PM_{10} and $PM_{2.5}$ under the category Particulate Matter. On April 5, 2010 the EPA published Revisions to the General Conformity Regulations Final Rule [75 Fed. Reg. 17254-279 (2010)] which, among other things, added $PM_{2.5}$ to the list of criteria pollutants in 40 C.F.R. § 93.153(b).

As a threshold matter, the EA is internally inconsistent with regard to whether the Project is exempt or presumed to conform. At page C-4, the EA states unequivocally that "[f]or this analysis it will be assumed that the project is neither exempt nor presumed to conform." [Emphasis added.] However, at page C-5 the EA states ". . . a conformity determination is not required and the proposed project is presumed to conform to the state implementation plan." [Emphasis added.] Under either scenario, however, the EA is deficient and fails to meet the "public disclosure" requirement under the National Environmental Policy Act ("NEPA"), 42 U.S.C. §§ 4321 *et seq*.

A. The EA Fails to Establish That the Project Is Exempt.

A federal agency has two options to determine that a project is exempt from conformity analysis: (1) if the project is included in the list of exempt actions listed in § 93.153(c)(2); or (2) if the project's total of direct and indirect emissions are below the emissions levels specified in § 95.153(b) of the Conformity Regulations ("*de minimis*"). § 93.153(c)(1).

The first option does not apply here because runway and taxiway extension projects such as the one described in the EA [p. 2-1] are not included in the exempt actions listed in § 93.153(c)(2). Nor does the EA establish that the Project can be considered exempt as *de minimis* under 40 C.F.R. § 93.153(c)(1). The EA instead relies on a 1996 MDOT Bureau of Aeronautics Air Quality Study of seven general aviation airports (which notably do not include ARB) for the conclusion that "typical GA airports generate a low level of pollutants." [EA, p. 4-17]. From that nonspecific conclusion, the EA further generalizes to the assertion that, because ARB is comparable in size and activity to the seven airports studied, it can be assumed that emissions resulting from the Project will not exceed the conformity threshold levels and, on that basis, concludes that a conformity analysis is not required.

This assumption is fatally flawed, however, for at least two reasons: (1) the EA does not quantify $PM_{2.5}$ emissions from flight operations at ARB at all, relying exclusively on the 1996 Study; and (2) because there is no quantification, there is also no comparison with the explicit *de minimis* thresholds established in 40 C.F.R. § 93.153(c)(1). It is correct that the original version of 40 C.F.R. § 93.153(c)(1) did not establish explicit thresholds for $PM_{2.5}$, as distinguished from PM_{10}. However, the newly implemented revised General Conformity Rule does establish that distinction, and now serves as the template for the air quality analysis required in the EA. Moreover, FAA Order 1050.1E, Appendix A, p. A3, § 2.16 includes both PM_{10} and $PM_{2.5}$ in "particulate matter."

B. The EA Fails to Establish That the Project Is Presumed to Conform.

The second option, the presumption of conformity does not apply here either. In July, 2007, the FAA published a "Federal Presumed to Conform Actions Under General Conformity Final Notice" [72 Fed.Reg. 41,565-580 (July 2007)] in which the FAA listed fifteen Airport Project categories which the FAA presumes to conform to applicable SIPs. The runway and taxiway extension project described in the EA does not fall within any of those presumed to conform categories. Therefore, the FAA cannot rely on the Presumed to Conform Final Notice to presume that the Project is in conformity.

C. The EA Fails to Establish the Project's Conformity Status.

Finally, even if, for argument's sake, the study of airports other than ARB were adequate for air quality analysis of ARB in the EA (which it is not), the 1996 Study would be an inadequate substitute for the required analysis. 40 C.F.R. § 93.159 requires that analyses under the General Conformity Rule be based on, among other things: (1) "the latest planning assumptions," § 93.159(a); and (2) "the latest and most accurate emissions estimation techniques available," § 93.159(b). The 1996, 14-year old, Study patently fails to fall within either, let alone both, of these parameters.

In summary, the EA fails to establish the existence of any of the necessary components of the required finding of conformity for a Federal project, and, thus, is inadequate under both NEPA and the Clean Air Act.

IV. THE EA FAILS TO ACCOUNT FOR WELLS ON AIRPORT PROPERTY.

While Section 4.5.2 of the EA purports to address "Geology, Groundwater, and Soils" affected by the Project, it understates the significance of the fact that water resources are a principal use of the grounds where the airport is located.

"If there is the potential for contamination of an aquifer designated by the [EPA] as a sole or principal drinking water resource for the area, the responsible FAA official needs to consult with the EPA regional office, as required by section 1424(e) of the Safe Drinking Water Act, as amended." FAA Order 1050.1E, pp. A-74, 75, ¶ 17.1c. "When the thresholds indicate that the potential exists for significant water quality impacts, additional analysis in consultation with State or Federal agencies responsible for protecting water quality will be necessary. *Id.*, pp. A-75, A-76, ¶ 17.4a. "If the EA and early consultation [with the EPA] show that there is a potential for exceeding water quality standards [or] identify water quality problems that cannot be avoided or mitigated . . . an EIS may be required. *Id.*, pp. A-75, ¶ 17.3.

There are two issues raised by the Project that require further examination in the EA. First, there is the issue of contamination from the Airport. The Airport is the location of a porous sand/gravel formation that yields a large amount of water for pumping Historically, the land where the Airport is located was originally acquired by the City of Ann Arbor for water rights in 1929. Until recently, 15% of Ann Arbor's water supply came from the three wells located on Airport property. Water Quality Report, 2008, City of Ann Arbor, p. 2 (available at http://www.a2gov.org/government/publicservices/water_treatment/documents/ccr.pdf). Due to the importance of the water supply at ARB, the EA needs to have more than a few passing words ("Based on coordination with the City of Ann Arbor, the proposed runway extension would not impact the water supply wells or the new water supply line (Bahl, 2009)"). [EA, p. 4-20].

Second, paving the area for a runway, roads, *etc.* increases the impervious area on the aquifer. This in turn reduces the infiltration of water that feeds the aquifer/City water supply. Adding 950 feet to the end of the runway adds another 71,250 square feet of impervious area over an aquifer that it vital to the City of Ann Arbor. Further environmental review should provide detailed analyses of the impact of this increase in impervious surface, as well as the possibility of contamination, currently unexplored in the EA.

V. THE EA FAILS TO ANALYZE THE PRESENCE OF HAZARDOUS WILDLIFE NEAR THE AIRPORT AND FAILS TO PRESENT ANY MANDATORY MITIGATION MEASURES.

FAA Advisory Circular 150/5200-33B ["Hazardous Wildlife Attractants on or Near Airports"] contains standards for land uses that have the potential to attract hazardous wildlife on or near public-use airports. The standards are applicable to airport development projects, including airport construction, expansion and renovation. Airports that have received Federal grant-in-aid assistance must use these standards. [*See,* AC 150/5200-33B, p. ii]. The FAA recommends separation distances of 5,000 feet at airports that do not sell Jet-A fuel, and 10,000 feet at airports that sell Jet-A fuel for hazardous wildlife attractants. [AC 150/5200-33B, p.1]. ARB sells Jet-A fuel.

The FAA also "recommends a distance of 5 statute miles between the farthest edge of the airport's AOA [Air Operations Area] and the hazardous wildlife attractant if the attractant could cause hazardous wildlife movement into or across the approach or departure airspace." [AC 150/5200-33B, p. 1]. Finally, AC 150/5200-33B provides that "[a]irport operators should identify hazardous wildlife attractants and any associated wildlife hazards during any planning process for new airport development projects" [p. 17] and "[t]he FAA will not approve the placement of airport development projects pertaining to aircraft movement in the vicinity of hazardous wildlife attractants without appropriate mitigating measures." [pp. 17-18].

The FAA ranks geese as number three [3] in a list of the relative hazard to aircraft for 25 species groups. [AC 150/5200-33B, Table 1, p. iii]. However, the EA does not disclose that the area surrounding the airport is a prime habitat for large numbers of Canada Geese. EA Appendix F lists 38 species of birds that have either been observed, or for which there has been confirmed or probable breeding in Airport fields during 2006 through 2008. The list does not include Canada Geese. Canada Geese populate waterways on a golf course, in business parks and in neighboring wetlands located west and southwest of the Airport, well within the separation distances prescribed by the FAA.

The preferred alternative (Build Alternative 3) would extend Runway 6/24 950 feet to the southwest. The extension would allow aircraft landing on Runway 6 and departing on Runway 24 to overfly areas populated by Canada Geese at altitudes of less than 100 feet. The EA does not consider this hazardous condition. Even though they are not designated as "special concern", "threatened" or "endangered," the presence of Canada Geese in the Airport area poses a hazard to aircraft operational safety, and should be identified and analyzed in the EA, along with proper mitigation measures.

VI. <u>THE EA DOES NOT ACKNOWLEDGE OR ANALYZE THE PROJECT'S MANIFEST GROWTH-INDUCING IMPACTS</u>.

A Federal agency is required to evaluate not merely the direct impacts of a project, but also its indirect impacts, including those "caused by the action and later in time but still reasonably foreseeable." 40 C.F.R. § 1508.8(b). Indirect impacts include a project's growth-inducing effects, such as changes in patterns of land use and population distribution associated with the project [40 C.F.R., § 1508.8(b)] and increased population, increased traffic, and increased demand for services. *City of Davis v. Coleman*, 521 F.2d 661, 675 (9th Cir. 1975). "The growth-inducing effects of [a] project appear to be its raison d'etre." *Id*. The EA ignores this requirement, even though the Project is virtually defined by its growth-inducing impacts. Despite the fact that the EA assumes that the "percent of night and jet operations would remain constant between the existing condition and the future years" [EA, p. 4-2], there is substantial evidence to indicate that the Project will cause a large increase in both types of operations.

As indicated above, there are no weight restrictions that must be lifted to allow the EA's "critical aircraft" to operate at ARB without weight restrictions. The "load restrictions" referenced on page 2-12 refer not to category B-II aircraft, but to higher category aircraft (jets in the C-I and C-II categories) which must currently operate at reduced weights in order to use the 3,505-foot runway. (Required takeoff length is the primary restrictor.) Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel, all of which discourage these aircraft from conducting operations at ARB.

For example, a Cessna Citation II (Category B-II) requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day, and can operate at unrestricted weight from the existing 3,505 foot runway. A Lear 35 (Category C-I), on the other hand, requires 5,000 feet for takeoff at maximum certificated gross weight on a standard day. While extending the runway to 4,300 feet would not facilitate unrestricted operations by the Lear 35, the required weight reduction would be less than is currently required. Therefore, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide no operational benefit to the Category B-II Citation jet, which the EA states is a "critical aircraft."

The longer runway will facilitate the loading of additional passengers and baggage on high performance jet aircraft. Also, the ability to carry additional fuel may mean that, in certain cases, costly and time consuming intermediate fuel stops will become unnecessary. If the runway is lengthened to 4,300 feet, it is reasonably foreseeable that ARB will become much more attractive to operators of higher performance jet aircraft, such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II), who could then operate at ARB instead of driving to and from Willow Run Airport.

Contrary to the unsupported assertions in the EA [EA, p. 42; Appendix B-1, p. B-4], it is reasonably foreseeable that the fleet mix will change in favor of a higher percentage of jet operations, as compared to the current level of light single and multi-engine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft account for a high percentage of ARB operations. B-II aircraft account for a low percentage of ARB operations.

It is, therefore, reasonably foreseeable that the number of night operations will increase as the number of arrivals of longer haul business jets often occur in the evening hours due to the longer time duration of their trips. Since one of the stated purposes of the EA is to increase interstate commerce, this is not merely an indirect, but also a direct effect, the Project will have on the surrounding community. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

Thus, the evidence is clear that the Project will cause an increase in both jet *and* night operations. It is also reasonably foreseeable that these added high-performance jet aircraft operations and night operations will be accompanied by significant noise and air quality impacts. Nevertheless, the EA fails to acknowledge, let alone analyze, these reasonably foreseeable impacts caused by expansion of Airport physical facilities and operational profile and, thus, is inadequate.

VII. NOISE MODELING FOR THE PROJECT FAILED TO INCLUDE INCREASED JET AIRCRAFT AND NIGHTTIME OPERATIONS IN DEVELOPING NOISE CONTOURS.

The FAA's Integrated Noise Model ("INM") was used to model annual operations for the 2009 existing condition, *i.e.*, April 2008 through March 2009 [EA Appendix B-1, p. B-4] and develop 65, 70 and 75 DNL noise contours for the Project. [EA, p. 4-3]. The EA states that "[t]he existing 65 DNL contour does not extend beyond airport property." [EA, p. 4-3]. During the time modeled, jet operations accounted for approximately 2 percent of total operations at ARB, and nighttime operations accounted for 4.2 percent of total operations. [EA, p. 4-2]. The EA states: (1) "[t]he percent of night and jet operations would remain constant between the existing condition and the future years"; (2) "fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives would remain static" [EA, p. 4-2; Appendix B-1, p. B-4]; and "[t]he ARB 2014 proposed project alternative DNL 65 dBA noise contour does not extend beyond airport property." [EA, p. B-6].

However, as shown in Section VI above, the Project will likely facilitate an increased number of night operations, and a change in fleet mix, which will include higher performance jet aircraft. DNL calculations depend on, among other things, forecast numbers of operations, operational fleet mix and times of operation (day verses night). [EA, Appendix B-2, p. B-16]. However, the EA fails to model or assess future increased night operations and fleet mix changes resulting from the Project.

The FAA is required to use INM to produce, among other things: (1) noise contours at the DNL 75 dB, DNL 70 dB and DNL 65 dB levels; (2) analysis within the proposed alternative DNL 65 dB contour to identify noise sensitive areas where noise will increase by DNL 1.5 dB[4]; and (3) analysis within the ***DNL 60-65 dB contours*** to identify noise sensitive areas where noise will increase by DNL 3dB, ***if*** DNL 1.5 dB increases as documented within the DNL 65 dB contour. [FAA Order 1050.1E, Appendix A, p. A-62, ¶ 14.4d].

As the noise modeling failed to take into account the foreseeable increases in nighttime and jet aircraft operations at ARB, the questions of whether the future DNL 65 dB contour will be increased, and to what extent, and whether increased noise levels within the DNL 65 dB contour would necessitate designation of a DNL 60 dB contour remain unanswered.

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4 A significant noise impact would occur if analysis shows that the proposed action will cause noise sensitive areas to experience an increase in noise of DNL 1.5 dB or more at or above DNL 65 dB noise exposure when compared to the no action alternative for the same timeframe." [FAA Order 1050.1E, Appendix A, P. A-61, ¶ 14.3]

VIII. THE EA FAILS TO CONSIDER THE POLITICAL JURISDICTIONS AFFECTED BY THE PROJECT.

FAA Order 5050.4B, paragraph 706 provides a format for integrating the NEPA process with special purpose laws outside the scope of NEPA in preparing environmental assessments. Paragraph 706.e.(4) requires that an environmental assessment address "[p]olitical jurisdiction(s) the proposed action would affect." The EA fails to do that. The EA does not disclose that Pittsfield Township, the political jurisdiction in which the Project is located, and neighboring Lodi Township have both passed resolutions opposing the Project. The EA also fails to identify or analyze the effect that environmental impacts, which are certain to result from the Project (*e.g.*, noise, air quality, safety, economic impacts, *etc.*), will have on those political jurisdictions.

IX. CONCLUSION.

Given the Project's many potential significant environmental impacts that have not been identified or analyzed in the EA, a full Environmental Impact Statement (EIS) is required prior to approval and implementation of the Project. "No matter how thorough, an EA can never substitute for preparation of an EIS, if the proposed action could significantly affect the environment." *Anderson v. Evans*, 371 F.3d 475, 494 (9th Cir. 2004).

Sincerely,

CHEVALIER, ALLEN & LICHMAN, LLP

BC Hart

for Barbara E. Lichman, Ph.D.

Attachment (1)

Williams Aviation Consultants, Inc. was retained by the law firm of Chevalier, Allen & Lichman, LLP to review and comment on Chapters 1 and 2, and Appendices A and B of the DRAFT Ann Arbor Municipal Airport Environmental Assessment (DEA), February, 2010. The following are our comments on the DEA.

A. Accommodating the Critical Aircraft at Ann Arbor Municipal Airport (ARB)

As stated in paragraph 2.2.7, "*The proposed shift and extension of primary Runway 6/24 at ARB would provide a runway configuration that more effectively accommodates the critical aircraft that presently use the facility.* (Emphasis added)

In particular, the proposed project would provide the following benefits:

- *Enhance business aviation and interstate commerce by providing sufficient runway length to allow the majority of category B-II Small critical aircraft that currently use ARB to operate without load restrictions (i.e. reduction in passengers, cargo, and fuel associated with aircraft range).* (Emphasis added)

According to paragraph 2.2, Purpose and Need, "The purpose of the proposed improvements at ARB is to provide facilities that more effectively and efficiently *accommodate the critical aircraft* that presently use the airport, as well as to enhance the operational safety of the airport. (Emphasis added)

The critical aircraft is defined by the FAA as the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport. In cases where the critical aircraft weigh less than 60,000 lbs, a classification of aircraft is used rather than a specific individual aircraft model. A recent Airport User Survey has confirmed that the critical aircraft classification for ARB is "*B-II Small Aircraft.*" (Emphasis added)

Also stated under "Purpose and Need" "*Development of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small classification aircraft to operate at their optimum capabilities (without weight restrictions).* (Emphasis added)

WAC Comment: There are no aircraft in the B-II Small aircraft classification that require a runway length of 4,300 feet to conduct normal operations. All B-II Small Aircraft are capable of operating out of the current runway (3,505 feet long) without the need to reduce weight by off-loading passengers, baggage or fuel.

Regarding the establishment of the critical aircraft, ARB lacks the required number of 500 annual operations by B-II Small Aircraft, so they have added larger aircraft such as B-II Large, Category C-I and C-II operations to meet the 500 classification requirement. It is the Category C-I and C-II aircraft which would benefit by the runway extension to 4,300 feet, not

those aircraft that fall within the definition of Category B-II Small Aircraft. The current runway length of 3,500 feet is sufficient to handle all Category B-II Small Aircraft.

B. Lengthening Runway 6/24 to 4,300 Feet: The Impact on Aircraft Load Restrictions and Fleet Mix

The "load restrictions" referenced above in paragraph 2.2.7 refer to the fact that the higher category aircraft (primarily jets in the C-I and C-II categories) must currently operate at reduced weights in order to operate out of the current 3,500 foot runway (required takeoff length is the primary restrictor). Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel; all of which discourage these aircraft from conducting operations out of ARB.

For example: A Cessna Citation II (Category B-II) requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day and may therefore operate unrestricted as to weight from the current 3,500 foot runway. A Lear 35 (Category C-I) requires 5,000 feet for takeoff at maximum certificated gross weight on the same standard day.

The Category B-II Citation II can conduct unrestricted operations from the current 3,500 foot runway. Whereas extending the runway to 4,300 feet would not facilitate unrestricted operations by the Category C–I, Lear 35, the required weight reduction would be less than is currently required. In this way, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide no operational benefit to the Category B-II Small Citation jet, or any other Category B-II Small aircraft.

All Category B-II Small aircraft, i.e. the ARB critical design aircraft, are currently accommodated on the existing 3,500 foot runway. Contrary to what is stated in the DEA, lengthening the runway to 4,300 feet WOULD NOT "provide a runway configuration that more effectively accommodates the <u>critical aircraft</u> that presently use the facility."

If the runway is lengthened to 4,300 feet, other jets such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II) may be able to operate out of ARB with minor reductions in takeoff weight. This will impact the community as it could reasonably be expected that the longer runway will attract more of the larger, higher performance jet aircraft to the airport.

These added high performance jet aircraft operations will be accompanied by noise and air quality impacts. Many of these operations will take place at night, thereby negatively affecting the general quiet of the surrounding community.

C. **Shifting Runway 6/24 150 Feet to the West While Maintaining the Current Runway Length of 3,500 Feet: The Impact on Load Restrictions, Future Fleet Mix and Safety of Operations**

Load Restrictions

Maintaining the current runway length of 3,500 feet would mean that the Category C-1 and C-II aircraft would continue to suffer significant load restrictions. These load restrictions would thereby continue to serve as a deterrent to these aircraft operating out of ARB.

Future Fleet Mix

Maintaining the current runway length would serve to maintain the current fleet mix. Category B-II Small jet aircraft include lower powered models such as the smaller versions of the Cessna Citation (Category B-I/II) and the Mitsubishi Diamond jet (Category B-I). Higher powered jet aircraft such as the Lear 25 (Category C-I), Lear 35 (Category C-I), IAI Astra (Category C-I) and Cessna Citation III (Category C-II) may be generally discouraged from flying into Ann Arbor and would generally, with few exceptions choose to land at Detroit and drive the 40 miles to Ann Arbor.

Safety of Operations

2.2.1 Safety Enhancements:

In the first paragraph, the consultant is correct in stating that shifting the Runway 24 threshold 150 feet west would enhance safety by effectively removing the current obstruction to line-of-site vision (hangar) of the parallel taxiway for ATCT personnel.

However, in the next paragraph the consultant states, "The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles."

This statement betrays a lack of understanding by the consultant of Instrument Approach Procedure (IAP) design and TERPS Obstruction Standards. Regarding the 20:1 and the 34:1 surfaces; it is not either/or, but both/and. Both the 20:1 and the 34:1 surfaces exist simultaneously for every published IAP and are defined as "Obstacle Identification Surfaces" which do not establish obstacle clearance safety margins but rather only define instrument approach visibility minimums. The FAA does not require either of these two surfaces to be free of penetration by obstacles, and thus "providing an additional margin of safety" as stated by the consultant does not apply in the case of these two surfaces.

Other TERPS surfaces (Obstacle Clearance Surfaces) are established which do ensure clearance from obstructions and the FAA requires that these Obstacle Clearance Surfaces be clear of structures and terrain. The current IAPs to Runway 24 were designed by the

FAA to accommodate all existing obstructions. In this respect, shifting the runway 150' to the west would not enhance safety.

Summary: Assuming that the consultant is correct in their assertion that shifting the threshold would eliminate obstruction penetrations to the existing 34:1 Obstacle Identification Surface, the effect would not be a safety improvement but would only result in a reduction in the required approach visibility minimums.

D. Appendix B Noise Analysis Report
B-1 Noise Impact Analysis
B.1.3 Data
Flight Operations

The consultant states "INM-modeled annual operations for the 2009 existing condition, consisting of operations from April 2008 through March 2009, totaled 61,969 operations, which is approximately 169 daily operations. Jet operations accounted for approximately 2 percent of the total operations. Nighttime operations accounted for 4.2 percent of the total operations."

2014 future condition aircraft operations were obtained from the 2008 FAA TAF for ARB. Modeled annual operations for the 2014 condition totaled 69,717 operations, or approximately 191 daily operations. *It is assumed that the percent of night and jet operations will remain constant between the existing condition and the future years. In addition, it is also assumed that the fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives will remain static.* The existing and future fleet mix with annual operations is shown in Table B-2." (Emphasis added)

The consultant wrongly assumes that the percent of night and jet operations will remain constant, and that the fleet mix will remain static if Runway 6/24 is lengthened to 4,300 feet.

The longer runway will make ARB much more attractive to larger and higher performance jet aircraft as the added runway length will facilitate the loading of additional passengers and baggage on to these aircraft. Also, being able to carry additional fuel may mean that, in certain cases, costly and time consuming intermediate fuel stops will become unnecessary. As ARB becomes more attractive to higher performance jet aircraft, these larger aircraft may then consider operations to/from ARB in lieu of landing at Detroit and driving to Ann Arbor.

As more high performance jet aircraft begin operations at ARB, the fleet mix will change in favor of a higher percentage of jet operations as compared to the current level of light single and multiengine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft currently reflect a high percentage of ARB operations. B-II Small aircraft (the critical design aircraft) reflect a low percentage of ARB operations. Recall that Category B-II Large and Category C aircraft had to be added to the currently operating Category B-II Small aircraft design group in order to meet the 500 operation requirement for establishing the critical aircraft and thereby justify the runway extension.

The number of night operations also has the strong potential to increase as the number of arrivals of the larger, longer haul business jets often occur in the evening hours due to the longer time duration of their trips. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

Exhibit 16

CHEVALIER, ALLEN & LICHMAN LLP
Attorneys at Law
Aviation Law & Litigation • Environmental Law & Litigation • Commercial Litigation
www.calairlaw.com | www.aviationairportdevelopmentlaw.com

Gary M. Allen, Ph.D.
John Chevalier, Jr.*
Berne C. Hart
Barbara E. Lichman, Ph.D.
Jacqueline E. Serrao, LL.M.°
Steven M. Taber○△
Anita C. Willis°

*Retired
○Admitted in Illinois
△Admitted in Florida
°Of Counsel

695 Town Center Drive, Suite 700
Costa Mesa, California 92626
Telephone (714) 384-6520
Facsimile (714) 384-6521
E-mail cal@calairlaw.com

April 19, 2010

By E-Mail
lamrouexm@michigan.gov

Molly Lamrouex
Airports Division
MDOT Bureau of Aeronautics and Freight Services
2700 Port Lansing Road
Lansing, Michigan 48906-2160

Re: Comments on the Ann Arbor Municipal Airport Environmental Assessment

Dear Ms. Lamrouex:

Comments by the Committee for Preserving Community Quality on the Ann Arbor Municipal Airport Environmental Assessment are attached.

Sincerely,

CHEVALIER, ALLEN & LICHMAN, LLP

Steven M. Taber

Committee for Preserving Community Quality
5221 Crooked Stick Drive
Ann Arbor, MI 48108
734-944-9455

April 19, 2010

Molly Lamrouex
Airports Division
MDOT Bureau of Aeronautics and Freight Services
2700 Port Lansing Road
Lansing, Michigan 48906-2160

Re: Comments by The Committee for Preserving Community Quality on the Environmental Assessment for Ann Arbor Municipal Airport

Dear Ms. Lamrouex:

The Committee for Preserving Community Quality, a community group representing approximately 400 residents of Pittsfield and Lodi Townships and the cities of Ann Arbor and Saline, is filing these comments to strenuously object to the February 2010 Environmental Assessment for Ann Arbor Municipal Airport ("EA"). We feel, as the evidence below conclusively documents, that the EA is seriously flawed and that the proposed project is both dangerous and cannot be justified.

I. THE PROJECT'S STATED PURPOSE AND NEED IS UNSUPPORTED BY THE EVIDENCE.

An EA must include a discussion of the purpose and need for the proposed action which must "specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action." [40 C.F.R. § 1502.13]. In addressing the Purpose and Need section of an EA, FAA Order 1050.1E provides that: "This discussion identifies the problem facing the proponent (that is, the need for an action), the purpose of the action (that is, the proposed solution to the problem), and the proposed timeframe for implementing the action." FAA Order 1050.1E, ¶ 405c. The EA accomplishes none of these goals.

A. The EA Supports Neither the Problem it Aims to Solve Nor its Purported Solution.

First, the EA defines the *purpose* of the Project as "to provide facilities that more effectively and efficiently accommodate the *critical aircraft* that presently use the airport, as well as to enhance the operational safety of the airport." [EA, p. 2-4]. The EA defines "critical aircraft" as "the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport," *Id.*, and states that a 2009 MDOT Airport User Survey "has confirmed that the critical aircraft classification for ARB is 'B-II Small Aircraft.'" *Id.* To effectuate the stated purpose, the EA purports to support the construction of a runway extension from 3,505 feet to 4,300 feet. However, the extant evidence is clear that no "B-II Small Aircraft" require a 4,300 foot long runway. All B-II Small Aircraft are capable of operating on the existing 3,505 feet long runway without weight restriction. *See*, attached Williams Aviation Consultants Report [incorporated herein by reference]. In fact, the representative B-II Small Aircraft cited in the EA, the Beechcraft King Air 200, requires only 2,579 feet of runway to take-off fully loaded, and 2,845 feet to land. *See*, http://www.hawkerbeechcraft.com/beechcraft/ king_airb200gt/specifications.aspx. Thus, the statement that "[d]evelopment of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small Aircraft to operate at their optimum capabilities (without weight restrictions)" [p. 2-4], although true, is misleading. There is no need to extend Runway 6/24 to allow B-II aircraft to operate at ARB. They can operate on a 3,505 foot runway without weight restrictions. Therefore, the statement that interstate commerce would be negatively impacted by B-II Small weight restrictions does not state a valid need, and the purported purpose of "provid[ing] facilities that more effectively and efficiently accommodate the *critical aircraft* that presently use the airport" is an unnecessary solution to a nonexistent problem.

B. The EA Incorrectly Relies on *Total* Annual Operations to Support the Proposed Runway Extension.

The EA states, "[t]he critical aircraft, or grouping of aircraft are generally the largest, most demanding types that conduct at least 500 operations per year at the airport" [EA, p. 2-7], and concludes that the proper Airport Reference Code ("ARC") for ARB is "B-II Small", based on a total of "750 actual annual operations by B-II category critical aircraft from survey data year 2007." [EA, p. 2-9]. However, the EA's use of "annual operations" differs markedly from the FAA criteria for selecting runway lengths and widths set forth in FAA Order 5090.3C:

3-4. AIRPORT DIMENSIONAL STANDARDS

> Airport dimensional standards (such as runway length and width, separation standards, surface gradients, etc.) should be selected which are appropriate for the critical aircraft that will make substantial use of the airport in the planning period. Substantial

> use means either 500 or more annual ***itinerant*** operations, or scheduled commercial service. FAA Order 5090.3C, p. 21 (emphasis added).

(FAA Order 5090.3C does not state that critical aircraft must be the "largest.")

The FAA divides General Aviation operations into two categories, "local" and "itinerant." Itinerant operations are defined as "an operation performed by an aircraft, either IFR, SVFR, or VFR, that lands at an airport, arriving from outside the airport area, or departs an airport and leaves the airport area." [U.S. DOT JO 7210.695, p. 5]. Local operations are defined as "those operations performed by aircraft that remain in the local traffic pattern, execute simulated instrument approaches or low passes at the airport, and the operations to or from the airport and a designated practice area within a 20-mile radius of the tower." *Id.*

The EA, without reference to this distinction, relies on "annual operations" and "total annual operations" not "itinerant operations," *see* EA, Table 2-1, p. 2-10. Separating itinerant and local operations at ARB would result in a dramatic reduction in the number of annual critical aircraft operations at the airport. For example, data from the website City-Data.com shows that there were 29,322 itinerant operations and 43,573 local operations at ARB in 2007, the year used by MDOT in the EA. *See*, http://www.city-data.com/airports/Ann-Arbor-Michigan.html. In that itinerant operations account for approximately 40% of the total operations at ARB, itinerant B-II operations for 2007 would be in the neighborhood of 300 operations per year [40% of 750 total operations], substantially below the FAA's threshold of 500 annual operations to constitute "substantial use." Moreover, the Airport User Survey shows only 293 annual B-II Small operations at ARB in 2007. [EA Appendix A-1, p. 7]. Thus, the FAA Order 5090.3C airport dimensional standards for B-II small aircraft do not apply.

Even if, for argument's sake, we were to accept the critical aircraft data reported in the Airport User Survey [EA Appendix A-1, p.7], a detailed analysis shows that a weighted average of 78 percent of those B-II aircraft operations took place within a 450-mile radius of ARB, according to MDOT's own data analysis (Exhibit 1). These represent areas that are within the flight range of ARB's current based fleet, according to the User Survey data, from the current-length runway. Thus, by another means of calculus, itinerant operations beyond the range of need are fewer than 200 and Purpose and Need fails.

Further, MDOT's choice of 2007 as a year of certification for critical aircraft was based on an arbitrary and capricious decision. The year 2007 represents the greatest number of ARB operations in the 5-year period 2004-2009 and was selected, according to the MDOT analyst involved, because "our thoughts were that the current recession could possibly have affected the 2008 operational levels in such a way that 2008 year records would not be a true indicator of a post-recession return to normal operations at the airport. . .." (Noel, 2009). Even the FAA suggests ARB will not return to such high operating levels as 2007 for the next 20 years [FAA Terminal Area Forecast, EA, p. 2-10.] Thus, MDOT was showing bias and affording Ann Arbor a huge advantage in not even evaluating operational data from any other year. Objectively, since its standard is the independent Flight Aware data base, MDOT should analyze critical aircraft operational data for the five years 2004-2009 and base its decision on an average of those years' operational data.

C. Shifting Runway 6/24 150 Feet to the Southwest Will Not Achieve an Additional Margin of Safety.

The EA states as part of its purpose to "[e]nhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road." [EA, p. 2-5]. Operational safety in low visibility conditions will not be enhanced by providing a clear 34:1 approach surface to Runway 24. The EA is correct in stating that shifting the Runway 24 threshold 150 feet west would enhance safety by effectively removing the current obstruction to line-of-site vision (hangar) of the parallel taxiway for ATCT personnel. [EA, p. 2-5]. However, in the next paragraph the EA states, "The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles." [EA, p. 2-5]. This statement lacks support in either the Instrument Approach Procedure (IAP) design or Terminal Instrument Procedures ("TERPS") Obstruction Standards.

Both the 20:1 and the 34:1 surfaces exist simultaneously for every published IAP, and are defined as "Obstacle Identification Surfaces" which do not establish obstacle clearance safety margins, but rather only define instrument approach visibility minimums. The FAA does not require either of these two surfaces to be free of penetration by obstacles, and thus "providing an additional margin of safety" as stated in the EA does not apply in the case of these two surfaces. Other TERPS surfaces (Obstacle Clearance Surfaces) are established which do ensure clearance from obstructions, and the FAA requires that these Obstacle Clearance Surfaces be clear of structures and terrain. The current IAPs to Runway 24 were designed by the FAA to accommodate all existing obstructions. Thus, shifting the runway 150' west would not enhance safety. Assuming that the EA is correct in the assertion that shifting the Runway 24 threshold would eliminate obstruction penetrations to the existing 34:1 Obstacle Identification Surface, the effect would not be a safety improvement, but would result only in a reduction in the required approach visibility minimums. [*See*, attached Williams Aviation Report]

D. EA Falsely Intends to Convey Rural Setting in Densely Populated Area

The EA intends to deceive readers as to the cosmopolitan location of the airport, utilizing Figure 2.1 [Page 2-2], for instance, which depicts unpaved Lohr and Textile Roads and vacant land and rock pits and gravel pits where developed communities of Pittsfield (Brian Hill, Lake Forest, Lake Forest Highlands, Lohr Lakes Village, St. James Woods, Silo Ridge, Stonebridge, and Waterways) and Lodi (Travis Pointe) Townships exist today, with more than 2,000 homes – making the area appear far more rural and not susceptible to the safety risks from added airport development that are actually posed.

II. THE EA DOES NOT CONSIDER ALL REASONABLE ALTERNATIVES.

The National Environmental Policy Act ("NEPA") [42 U.S.C. §§ 4321 *et seq.*] requires that federal agencies examine all reasonable alternatives in preparing environmental documents. [42 U.S.C. § 4332(c)(iii)]. An agency preparing an EA should develop a range of alternatives that could reasonably achieve the need that the proposed action is intended to address. The Council on Environmental Quality ("CEQ") Regulations ("NEPA Regulations"), which implement NEPA, require that Federal agencies "[u]se the NEPA process to identify and assess the reasonable alternatives to the proposed actions that will avoid or minimize adverse effects of these actions upon the quality of the human environment" 40 C.F.R. § 1500.2(e), and that "agencies shall . . . (a) Rigorously explore and objectively evaluate all reasonable alternatives . . ." 40 C.F.R. § 1502.14(a). The EA fails to explore all reasonable alternatives to the Preferred Alternative selected.

The EA [p. 2-5] lists five objectives of the proposed project:

- Enhance interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions.
- Enhance operational safety by improving the FAA ATCT line-of-sight issues.
- Enhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road.
- Reduce the occurrence of runway overrun incidents by small category A-I aircraft (local objective).
- Relocate and potentially upgrade the Runway 24 Approach Light System.

As shown in Section I above, enhancing interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions is not a valid need. Further, lengthening Runway 6/24 is not necessary to achieve the remaining four objectives. Those objectives could be met by simply shifting Runway 6/24 150 feet to the southwest, *i.e.*, removing 150 feet from the approach end of Runway 24 and adding 150 feet to the departure end of Runway 24. Runway length would remain 3,505 feet. Section 2.2.1 of the EA states that a 150-foot shift of the Runway 24 threshold to the west would (1) enhance the safety of ground operations by taxiing aircraft; (2) enhance operational safety, and possibly prevent runway incursions, by expanding the view of the hold area and parallel taxiway to ATCT personnel; (3) allow for a clear 34:1 approach surface to the east end of the runway, providing an added margin of safety between approaching aircraft and ground-based obstacles, which is particularly beneficial when aircraft are operating in low-visibility conditions; and (5) include relocation and replacement of the existing runway approach light system with newer Medium

Intensity Approach Lighting System with Sequenced Flashers (MALSF). [EA, pp. 2-5, 2-6]. Shifting Runway 6/24 150 feet to the Southwest without lengthening the runway would also accommodate future widening of State Road. Nevertheless, this "reasonable alternative" was not considered in the EA.

An Environmental Assessment "shall include brief discussions of . . . alternatives . . ." 40 C.F.R. § 1508.9(b).[1] Absent an analysis of an alternative based on a 150-foot southwesterly shift of the runway, without lengthening the runway, the EA is inadequate.

III. THE EA FAILS TO ADEQUATELY ANALYZE OR DISCLOSE THE PROJECT'S AIR QUALITY IMPACTS WHERE IT FAILS TO ADDRESS OR DETERMINE THE PROJECT'S CLEAN AIR ACT CONFORMITY.

Section 7506 of the Federal Clean Air Act [42 U.S.C. §§ 7401 *et seq*.] mandates that "[n]o department, agency, or instrumentality of the Federal Government shall engage in, support in any way or provide financial assistance for, license or permit, or approve, any activity which does not conform to [a State Implementation Plan] after it has been approved or promulgated under [42 U.S.C. § 7410]." The Environmental Protection Agency (EPA) has promulgated regulations implementing Section 7506 (the "Conformity Provision") in 40 C.F.R. §§ 93.150 *et seq*. ("General Conformity Rule"). The General Conformity Rule requires, in part, that Federal agencies first determine if a project is either exempt from conformity analysis or presumed to conform. If it is neither, the agency must conduct a conformity applicability analysis to determine if a full conformity determination is required. *See*, *Air Quality Procedures for Civilian Airports and Air Force Bases*, p. 13.

The project area, *i.e*., Washtenaw County, is in attainment for five of the seven criteria pollutants [p. 4-17], and marginal nonattainment for Ozone [p. C-3].[2] The area is designated as in nonattainment for PM2.5. [EA, p. C-4]. Therefore, one of the following applies:(1) the project is exempt from conformity; (2) the project is presumed to conform; or (3) the agency must conduct a conformity applicability analysis to determine if a conformity determination for PM2.5 is required. The EA does not indicate that any of the required actions was performed

As a threshold matter, the EA is internally inconsistent with regard to whether the Project is exempt or presumed to conform. At page C-4, the EA states unequivocally that "[f]or this

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[1] Courts have consistently held that the "existence of reasonable but unexamined alternatives renders an EIS inadequate." *See, e.g.*, *Friends of Southeast's Future v. Morrison*, 153 F.3d 1059, 1065 (9th Cir. 1998).

[2] The original six criteria pollutants are Ozone (O3), Particulate Matter (PM10), Carbon Monoxide (CO), Nitrogen Oxides (NO2), Sulfur Dioxide (SO2) and Lead (Pb). FAA Order 1050.1E ("Environmental Impacts; Policies and Procedures"), p. A-3, ¶ 2.1b, includes both PM10 and PM2.5 under the category Particulate Matter. On April 5, 2010 the EPA published Revisions to the General Conformity Regulations Final Rule [75 Fed. Reg. 17254-279 (2010)] which, among other things, added PM2.5 to the list of criteria pollutants in 40 C.F.R. § 93.153(b).

analysis it will be assumed that the project is neither exempt nor presumed to conform." [Emphasis added.] However, at page C-5 the EA states ". . . a conformity determination is not required and the proposed project is presumed to conform to the state implementation plan." [Emphasis added.] Under either scenario, however, the EA is deficient and fails to meet the "public disclosure" requirement under the National Environmental Policy Act ("NEPA"), 42 U.S.C. §§ 4321 *et seq*.

A. The EA Fails to Establish That the Project Is Exempt.

A federal agency has two options to determine that a project is exempt from conformity analysis: (1) if the project is included in the list of exempt actions listed in § 93.153(c)(2); or (2) if the project's total of direct and indirect emissions are below the emissions levels specified in § 95.153(b) of the Conformity Regulations ("*de minimis*"), § 93.153(c)(1).

The first option does not apply here because runway and taxiway extension projects such as the one described in the EA [p. 2-1] are not included in the exempt actions listed in Section 93.153(c)(2). Nor does the EA establish that the Project can be considered exempt as *de minimis* under 40 C.F.R. § 93.153(c)(1). The EA instead relies on the 1996 MDOT Bureau of Aeronautics Air Quality Study of seven general aviation airports (which notably do not include ARB) for the conclusion that "typical GA airports generate a low level of pollutants." [EA, p. 4-17]. From that nonspecific conclusion, the EA further generalizes to the assertion that, because ARB is comparable in size and activity to the seven airports studied, it can be assumed that emissions resulting from the Project will not exceed the conformity threshold levels, and, on that basis, concludes that a conformity analysis is not required.

This assumption is fatally flawed, however, for at least two reasons: (1) the EA does not quantify PM2.5 emissions from flight operations at ARB at all, relying exclusively on the 1996 Study; and (2) because there is no quantification, there is also no comparison with the explicit *de minimis* thresholds established in 40 C.F.R. § 93.153(c)(1). It is correct that the original version of 40 C.F.R. § 93.153(c)(1) did not establish explicit thresholds for PM2.5, as distinguished from PM10. However, the newly implemented revised General Conformity Rule does establish that distinction, and now serves as the template for the air quality analysis required in the EA. Moreover, FAA Order 1050.1E, Appendix A, p. A3, § 2.16 includes both PM10 and PM2.5 in "particulate matter."

B. The EA Fails to Establish That the Project Is Presumed to Conform.

The second option, the presumption of conformity does not apply here either. In July, 2007, the FAA published a "Federal Presumed to Conform Actions Under General Conformity Final Notice" [72 Fed.Reg. 41,565-580 (July 2007)] in which the FAA listed fifteen Airport Project categories which the FAA presumes to conform to applicable SIPs. The runway and taxiway extension project described in the EA does not fall within any of those presumed to conform categories. Therefore, the FAA cannot rely on the Presumed to Conform Final Notice to presume that the Project is in conformity.

C. The EA Fails to Establish the Project's Conformity Status.

Finally, even if, for argument's sake, the study of airports other than ARB were adequate for air quality analysis of ARB in the EA, the 1996 Study would be an inadequate substitute for the required analysis. 40 C.F.R. § 93.159 requires that analyses under the General Conformity Rule be based on, among other things: (1) "the latest planning assumptions," 93.159(a); and (2) "the latest and most accurate emissions estimation techniques available," 93.159(b). The 1996, 14-year old, Study patently fails to fall within either, let alone both, of these parameters.

In summary, the EA fails to establish the existence of any of the necessary components of the required finding of conformity for a Federal project, and, thus, is inadequate under both NEPA and the Clean Air Act.

IV. THE EA FAILS TO ACCOUNT FOR WELLS ON AIRPORT PROPERTY.

While Section 4.5.2 of the EA purports to address "Geology, Groundwater, and Soils" affected by the Project, it understates the significance of the fact that water resources are a principal use of the grounds where the airport is located.

"If there is the potential for contamination of an aquifer designated by the [EPA] as a sole or principal drinking water resource for the area, the responsible FAA official needs to consult with the EPA regional office, as required by section 1424(e) of the Safe Drinking Water Act, as amended." FAA Order 1050.1E, pp. A-74, 75, ¶ 17.1c. "When the thresholds indicate that the potential exists for significant water quality impacts, additional analysis in consultation with State or Federal agencies responsible for protecting water quality will be necessary. *Id.*, pp. A-75, A-76, ¶ 17.4a. "If the EA and early consultation [with the EPA] show that there is a potential for exceeding water quality standards [or] identify water quality problems that cannot be avoided or mitigated . . . an EIS may be required. *Id.*, pp. A-75, ¶ 17.3.

There are two issues raised by the Project that require further examination in the EA. First, there is the issue of contamination from the Airport. The Airport is the location of a porous sand/gravel formation that yields a large amount of water for pumping Historically, the land where the airport is located was originally acquired by the City of Ann Arbor for water rights in 1929. Until recently, 15% of Ann Arbor's water supply came from the three wells located on Airport property. Water Quality Report, 2008, City of Ann Arbor, p. 2 (available at http://www.a2gov.org/government/publicservices/water_treatment/documents/ccr.pdf). Due to the importance of the water supply at ARB, the EA needs to have more than a few passing words ("Based on coordination with the City of Ann Arbor, the proposed runway extension would not impact the water supply wells or the new water supply line (Bahl, 2009)"). [EA, p. 4-20].

Second, paving the area for a runway, roads, *etc.* increases the impervious area on the aquifer. This in turn reduces the infiltration of water that feeds the aquifer/City water supply. Adding 950 feet to the end of the runway adds another 71,250 square feet of impervious area over an aquifer that is vital to the City of Ann Arbor. Further environmental review should provide detailed analyses of the impact of this increase in impervious surface, as well as the possibility of contamination, currently unexplored in the EA.

V. THE EA FAILS TO ANALYZE THE PRESENCE OF HAZARDOUS WILDLIFE NEAR THE AIRPORT AND FAILS TO PRESENT ANY MANDATORY MITIGATION MEASURES.

FAA Advisory Circular 150/5200-33B ["Hazardous Wildlife Attractants on or Near Airports"] contains standards for land uses that have the potential to attract hazardous wildlife on or near public-use airports. The standards are applicable to airport development projects, including airport construction, expansion and renovation. Airports that have received Federal grant-in-aid assistance must use these standards. [*See* AC 150/5200-33B, p. ii]. The FAA recommends separation distances of 5,000 feet at airports that do not sell Jet-A fuel, and 10,000 feet at airports that sell Jet-A fuel for hazardous wildlife attractants. [AC 150/5200-33B, p.1]. The Ann Arbor Municipal Airport sells both. The FAA also "recommends a distance of 5 statute miles between the farthest edge of the airport's AOA [Air Operations Area] and the hazardous wildlife attractant if the attractant could cause hazardous wildlife movement into or across the approach or departure airspace." [AC 150/5200-33B, p. 1]. Finally, AC 150/5200-33B provides that "[a]irport operators should identify hazardous wildlife attractants and any associated wildlife hazards during any planning process for new airport development projects" [p. 17] and "[t]he FAA will not approve the placement of airport development projects pertaining to aircraft movement in the vicinity of hazardous wildlife attractants without appropriate mitigating measures." pp. 17-18].

The FAA ranks geese as number three [3] in a list of the relative hazard to aircraft for 25 species groups. [AC 150/5200-33B, Table 1, p. iii]. However, the EA does not disclose that the area surrounding the airport is a prime habitat for large numbers of Canada Geese, which data clearly show it to be. More than a dozen Canada geese water habitats fall within the designated risk area (Exhibit 2), which are populated by numerous Canada geese much of the year (Exhibit 3 photographs), so much so that less than 1,000 feet from the Ann Arbor Municipal Airport itself, city officials must warn motorists of a Canada goose road crossing (Exhibit 4). And yet EA Appendix F lists 38 species of birds that have either been observed, or for which there has been confirmed or probable breeding in Airport fields during 2006 through 2008. And the list does not include Canada Geese. Canada Geese populate waterways on a golf course, in business parks and in neighboring wetlands located west and southwest of the airport, well within the separation distances prescribed by the FAA, as the exhibits document.

We raise the Canada geese issue because of growing safety concerns with respects to bird strikes in aviation. We know, for instance, that a 12-pound Canada goose struck by an aircraft traveling at 150 miles per hour has the kinetic energy impact of a 1,000 pound weight dropped from 10 feet. With more than 9,000 bird strike incidents in the U.S. last year (Associated Press, 2010), and seven reported in the history of the Ann Arbor Airport itself, it is a serious issue.

This type of risk contributed to the deaths of three passengers and two crew members in the crash of a Cessna Citation in Oklahoma City in 2008 because, according to the National Transportation Safety Board, a large bird hit the plane wing because the FAA had done an inadequate job of enforcement of wildlife hazard requirements (National Transportation Safety Board, 2009). With many large birds in the ARB area, in close proximity to many homes, at low altitudes of under 100 feet, citizens surrounding ARB do not want that type of disaster to be repeated here because of an ill-informed EA that ignores Canada geese.

It must be underscored that Canada geese were a subject of detailed communication between preparers of the EA and at least one member of the EA's Citizens Advisory Committee (CAC). CAC Committee Member Shlomo Castell, a commercial passenger airline pilot, requested that the EA's preparer, contractor JJR, collect papers from a national Birdstrike Prevention Forum in Chicago and, perhaps, seek the assistance of the panel's FAA liaison for a follow-up discussion with an FAA expert who presented important information at the conference for relevant Canada geese research. Mr. Castell's request was summarily rebuffed by JJR study coordinator Amy Eckland, writing, "The scope of this proposed project is to address the recommended runway length design parameters for the critical aircraft and to address line of sight issues from the tower. I will be meeting with CAC member and City of Ann Arbor Ornithologist, Dea Armstrong, to better understand the birds that are known to occur around the airport. Reviewing all of the information presented at the bird strike conference is an extensive inquiry that is beyond the scope of this project."

Mr. Castell followed up, explaining that in his view as a CAC member, bird strikes were environmental and a safety issue, and that as the only professional commercial passenger airline pilot on the panel he felt it important that such information be analyzed and that a "careful environmental study using FAA funds (via MDOT) would seriously consider the current work of the FAA's top bird strike expert." Mr. Castell went on to add: " . .In my flying career, I have encountered three bird strikes. The most severe one involved three geese on a final approach to Detroit in a Boeing 727. Their bones were later found in the wing's leading edge and flaps. Thankfully they were not ingested by the engines. Should something similar ever occur to a departing business jet, turbo-prop or light twin out of ARB, results will most likely be different."

But the subject was ignored by JJR, the EA and Ann Arbor.

Consequently, the preferred alternative (Build Alternative 3) would extend Runway 6/24 950 feet to the southwest. The extension would allow aircraft landing on Runway 6 and departing on Runway 24 to overfly areas populated by Canada Geese at altitudes of less than 100 feet. The EA does not consider this hazardous condition. Even though they are not designated as "special concern", "threatened" or "endangered," the presence of Canada Geese in the Airport area poses a hazard to aircraft operational safety, and should be identified and analyzed in the EA, along with proper mitigation measures.

VI. THE EA DOES NOT ACKNOWLEDGE OR ANALYZE THE PROJECT'S MANIFEST GROWTH-INDUCING IMPACTS.

A Federal agency is required to evaluate not merely the direct impacts of a project, but also its indirect impacts, including those "caused by the action and later in time but still reasonably foreseeable." 40 C.F.R. § 1508.8(b). Indirect impacts include a project's growth-inducing effects, such as changes in patterns of land use and population distribution associated with the project [40 C.F.R., § 1508.8(b)] and increased population, increased traffic, and increased demand for services. *City of Davis v. Coleman*, 521 F.2d 661, 675 (9th Cir. 1975). The "growth-inducing effects of [an] airport project appear to be its 'raison d'etre.'" *California v. U.S. D.O.T.*, 260 F.Supp.2d at 978, *citing City of Davis, supra*, 521 F.2d at 675. The EA ignores this requirement, even though the Project is virtually defined by its growth-inducing impacts. Despite the fact that the EA assumes that the "percent of night and jet operations would remain constant between the existing condition and the future years," [EA, p. 4-2] there is substantial evidence to indicate that the Project will cause a large increase in both types of operations.

As indicated above, there are no weight restrictions that must be lifted to allow the EA's "critical aircraft" to operate at ARB without weight restrictions. The "load restrictions" referenced on page 2-12 refer not to category B-II aircraft, but to the fact that higher category aircraft (jets in the C-I and C-II categories) must currently operate at reduced weights in order to use the current 3,505 foot runway. (Required takeoff length is the primary restrictor.) Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel, all of which discourage these aircraft from conducting operations at ARB.

For example, a Cessna Citation II (Category B-II) requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day, and can operate at unrestricted weight from the existing 3,505 foot runway. A Lear 35 (Category C-I), on the other hand, requires 5,000 feet for takeoff at maximum certificated gross weight on a standard day. While extending the runway to 4,300 feet would not facilitate unrestricted operations by the Lear 35, the required weight reduction would be less than is currently required. Therefore, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide no operational benefit to the Category B-II Citation jet, which the EA states is a "critical aircraft."

The longer runway will facilitate the loading of additional passengers and baggage on high performance jet aircraft. Also, the ability to carry additional fuel may mean that, in certain cases, costly and time consuming intermediate fuel stops will become unnecessary. If the runway is lengthened to 4,300 feet, it is reasonably foreseeable that ARB will become much more attractive to operators of higher performance jet aircraft, such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II), who could then operate at ARB instead of driving to and from Willow Run Airport.

Contrary to the unsupported assertions in the EA [EA, p. 42; Appendix B-1, p. B-4], it is reasonably foreseeable that the fleet mix will change in favor of a higher percentage of jet operations as compared to the current level of light single and multi-engine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft account for a high percentage of ARB operations. B-II aircraft account for a low percentage of ARB operations.

It is, therefore, reasonably foreseeable that the number of night operations will increase as the number of arrivals of longer haul business jets often occur in the evening hours due to the longer time duration of their trips. Since one of the stated purposes of the EA is to increase interstate commerce, this is not merely an indirect, but also a direct effect, the Project will have on the surrounding community. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

Thus, the evidence is clear that the Project will cause an increase in both jet *and* night operations. It is also reasonably foreseeable that these added high-performance jet aircraft operations and night operations will be accompanied by significant noise and air quality impacts. Nevertheless, the EA fails to acknowledge, let alone analyze, these reasonably foreseeable impacts caused by expansion of airport physical facilities and operational profile and, thus, is inadequate.

This is especially troublesome because these increased number of high-performance aircraft impact almost 10,000 citizens within Pittsfield Township and another 10,000 in surrounding communities and would cross over rooftops at projected altitudes of 93 feet when landing on an extended Runway 6 in densely populated neighborhoods.

VII. <u>POLITICAL JURISDICTIONS PROPOSED ACTION OR ALTERNATIVES WOULD IMPACT</u>

It is not surprising that Ann Arbor completely ignored the implications of its proposed actions or alternatives on the political jurisdictions affected, as described in Federal Aviation Administration Order 5050.4B in response to the National Environmental Policy Act, in its Environmental Assessment – and, in fact, omitted this section completely -- since the principal jurisdiction affected, Pittsfield Township, in which the airport is wholly located, has unanimously passed a Resolution to oppose the expansion and is strenuously fighting it. Neighboring Lodi Township has passed a similar Resolution opposing the expansion. That Ann Arbor continues its push to expand its airport in the face of such opposition represents an unconscionable, heavy-handed and perverse assertion of land rights despite the will of its neighbors, subjecting citizens of other communities to undue risks.

Worse, MDOT, which with its predecessor state agencies has been advocating the expansion of the Ann Arbor Airport's primary runway for almost four decades now, is charged under 49 USC 47128 with serving as the FAA's agent in Michigan but jeopardized its block grant status by taking an advocacy position, often abdicating its public agency obligation to represent all Michigan citizens and, instead, become a de facto sponsor of the Ann Arbor expansion. In so doing it subjects both the government of Pittsfield and the people of Pittsfield to untold potential future damage both in safety risks and in economic loss that could result in an effective taking of their property rights because of repeated low flying, heavy jet aircraft, forcing them to seek recovery in the event of a tragic accident or inverse condemnation class action proceedings, from Ann Arbor, a city already suffering from such financial difficulty that it could be unable to pay any significant damage awards. As such, Pittsfield victims would be left without effective remedy at law.

Thus, on behalf of the people of Pittsfield, Lodi, Ann Arbor, and Saline, the Committee for Preserving Community Quality seeks protection at the federal level to preserve the 14th Amendment rights of all area citizens, but notably Pittsfield citizens, and asks federal intervention to preserve their due process rights, since their local government is afforded no voice in the ultimate decision. Federal law, however, provides the Pittsfield government and citizens extraordinary petition rights direct to the U.S. Secretary of Transportation because their situation is so unusual and so serious (49 USC 47106 (C) (1) (iii)).

Pittsfield citizens would be subjected to a perfect storm of potential risks from low-flying aircraft in heavily populated neighborhoods that are also occupied by wildlife, including many Canada geese, during much of the year. This is confirmed by a study conducted by MDOT and Ann Arbor's own airport architects (URS Corporation) (Exhibit 5), which was excluded from the EA, and visualized on a projection of what the approach to an expanded Runway 6 would look like relative to the close proximity to area homes, which was corrected for accuracy (Exhibit 6).

An expanded Ann Arbor Municipal Airport would attract more jets of more types and bring multi-engine aircraft closer to heavily populated residential areas – within 600 yards at altitudes of 93 feet above rooftops of semi-luxury homes, or lower, on a regular, planned basis. Aircraft landing on Runway 6 would pass Lohr Road below 90 feet – the site of a new, planned non-motorized bike path, designated the Lohr-Textile Greenway Project, for which the Washtenaw County Parks and Recreation Commission has awarded Pittsfield a $ 300,000 Connecting Communities grant. Thus, low-flying, heavy jets would be landing just feet over people traversing a new non-motorized trail.

This is especially dangerous with heavier aircraft because, in the event of any common multi-engine aircraft mishaps -- such as an engine failure on takeoff, a bird strike on takeoff, climb out, or approach, or similar incident – with aircraft in very close proximity to homes, the risk could be grave – a perfect storm of environmental or human risk. Contrary to common belief, any twin-engine jet would lose 80 percent of its climb performance – and at low altitudes that could be tragic. In a light twin-engine aircraft, the consequences would be worse, because most will not continue to climb on one engine in takeoff configuration; neither can they turn back toward the airport at low altitude in takeoff configuration, which is why so many classically crash near airports.

This is no allusive fear. In June 2009, a small single-engine plane landing at the Ann Arbor Airport made an emergency landing 1,200 yards short of the field on a Stonebridge Golf Club fairway in Pittsfield after its engine died at low altitude on final approach. (Exhibit 7) The pilot said if there had been people on the fairway at the time, he would have "crashed into the trees," which would have probably been fatal for him and his grandson, whom he was instructing at the time (Wunderlich, 2008). And it is not insignificant that, between 1973 and 2001, nine people died from accidents flying in the Ann Arbor Airport traffic pattern within three miles of the airport (NTSB reports, 1973-2001). With the Ann Arbor runway moved 950 feet farther to the southwest and even closer to hundreds of homes, as proposed, and planes still lower on approach – and planes heavier, larger, carrying greater payloads, and more people – this poses a risk too grave to bring to a heavily populated community.

Such impacts and safety implications on political jurisdictions where airport decision-making bodies are absentees – and where local citizens and their governments have no say – must be investigated to protect the safety of all concerned. This was not done or addressed in the EA in any way.

VIII. NOISE MODELING FOR THE PROJECT FAILED TO INCLUDE INCREASED JET AIRCRAFT AND NIGHTTIME OPERATIONS IN DEVELOPING NOISE CONTOURS.

The FAA's Integrated Noise Model ("INM") was used to model annual operations for the 2009 existing condition, *i.e.*, April 2008 through March 2009 [EA Appendix B-1, p. B-4] and develop 65, 70 and 75 DNL noise contours for the Project. [EA, p. 4-3]. The EA states that "[t]he existing 65 DNL contour does not extend beyond airport property." [EA, p. 4-3]. During the time modeled, jet operations accounted for approximately 2 percent of total operations at ARB, and nighttime operations accounted for 4.2 percent of total operations. [EA, p. 4-2]. The EA states: (1) "[t]he percent of night and jet operations would remain constant between the existing condition and the future years"; (2) "fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives would remain static" [EA, p. 4-2; Appendix B-1, p. B-4]; and "[t]he ARB 2014 proposed project alternative DNL 65 dBA noise contour does not extend beyond airport property." [EA, p. B-6].

However, as shown in Section VI above, the Project will likely facilitate an increased number of night operations, and a change in fleet mix, which will include higher performance jet aircraft. DNL calculations depend on, among other things, forecast numbers of operations, operational fleet mix and times of operation (day verses night). [EA, Appendix B-2, p. B-16]. However, the EA fails to model or assess future increased night operations and fleet mix changes resulting from the Project.

The FAA is required to use INM to produce, among other things: (1) noise contours at the DNL 75 dB, DNL 70 dB and DNL 65 dB levels; (2) analysis within the proposed alternative DNL 65 dB contour to identify noise sensitive areas where noise will increase by DNL 1.5 dB;[3] and (3) analysis within the ***DNL 60-65 dB contours*** to identify noise sensitive areas where noise will increase by DNL 3dB, ***if*** DNL 1.5 dB increases as documented within the DNL 65 dB contour. [FAA Order 1050.1E, Appendix A, p. A-62, ¶ 14.4d].

As the noise modeling failed to take into account the foreseeable increases in nighttime

[3] A significant noise impact would occur if analysis shows that the proposed action will cause noise sensitive areas to experience an increase in noise of DNL 1.5 dB or more at or above DNL 65 dB noise exposure when compared to the no action alternative for the same timeframe." [FAA Order 1050.1E, Appendix A, P. A-61, ¶ 14.3]

and jet aircraft operations at ARB, the questions of whether the future DNL 65 dB contour will be increased, and to what extent, and whether increased noise levels within the DNL 65 dB contour would necessitate designation of a DNL 60 dB contour remain unanswered.

IX. PROCEDURAL JUSTICE.

For 40 months, the Ann Arbor Municipal Airport expansion proposal has been in the works. Most of that time, it has been clouded in injustice. A long line of Procedural Justice violations began with the birth of the expansion proposal by Ann Arbor on January 22, 2007. On that day, the Ann Arbor City Council unanimously approved Resolution R-31-1-07, formally adopting the airport's previous Airport Layout Plan (ALP) and ordering the city staff to return with a separate proposal to expand the airport's primary runway within 60 days and that "notification of the proposal be sent out to citizens in the surrounding area."

Not only did the Ann Arbor city staff not return to its City Council with an expansion proposal within 60 days, it did not share such a proposal with neighboring citizens such as Pittsfield as required by its Council's order. Instead, however, just 37 days after its initial City Council Resolution order, on February 28, 2007, the city of Ann Arbor secretly submitted to MDOT-AERO a proposal for an 800-foot extension of primary runway 06-24 at Ann Arbor Municipal Airport – essentially, the present proposal being considered by the FAA. No corresponding notice was given to Pittsfield.

Thus began a plan by an overzealous Ann Arbor City Administration and Airport Manager run amok, beyond the control and limits of even its own elected officials and their mandates, in what amounted to an illegal and systematic effort to evade and elude any type of public disclosure about its airport expansion plans, regardless of the legal and political consequences.

On September 12, 2007, the proposed ALP was amended at the request of MDOT to allow for the 150-foot southwesterly movement of the entire primary runway, to provide for the eventual widening of State Street-State Road, which MDOT concedes cannot be funded for decades. Still, Pittsfield had not been informed by the applicant or MDOT about the proposed expansion on land within its jurisdiction, even though the Airport Emergency Plan calls for Pittsfield to provide primary Fire and Rescue Protection at the airport.

On April 23, 2008, MDOT approved the revised Ann Arbor Airport ALP. The state review had taken 420 days.

On June 4, 2008, the FAA's review of the Ann Arbor Airport ALP was begun by Cheri Walter, an Airspace Program Manager of the FAA. On the day she began her review, Ann Arbor Airport Manager Matt Kulhanek wrote her the following:

> Cheri: Wow! I can't tell you how much I appreciate your timely response to our review. I was happy to just hear that you were moving it to the top of the pile. For you to be that responsive to our local concerns reflects someone with a good heart who truly wants to serve their customers. I can honestly say that I have never received such a high

> level of service from the FAA. I would be honored to share that with your supervisor if you want to provide me with the contact information. Again, thank you so much. I hope that at some point in the near future, this action assists us in providing a longer and safer runway for the aviation community. Have a great day! (Kulhanek, 2008.)

Ms. Walter responded early the next morning with a note of thanks and the e-mail address of her supervisor, John Weizenbach, to whom Mr. Kulhanek wrote on the following day:

> Mr. Weizenbach, I wanted to send you a short email to inform you of the excellent customer service I recently received from a member of your staff, Cheri Walter. Ms. Walter was assigned the airway facilities review for the Ann Arbor (MI) Layout Plan update. Unfortunately, the ALP update had taken an extended period of time through MDOT staff. This delay was causing timing and political issues on our proposed runway extension project. I was able to explain this to Ms. Walter whose response was remarkable. She located our plan and completed the review in a very timely manner. This quick turnaround from the FAA will greatly aid the success of our proposed project. Ms. Walter was pleasant, accommodating and very open to our local concerns. As a customer of the FAA, I could not have asked for better service. You should be very proud to have someone like Ms. Walter on your staff and representing the FAA in such a positive way. Have a great day. (Kulhanek, 2008.)

Not surprisingly, the FAA approved the Ann Arbor ALP on June 23, 2008 – just 19 days after the review was begun, less than 1/20th the time the state review took, and after the e-mail exchange of praise between the Ann Arbor Airport manager and the FAA reviewer. And, still, Pittsfield had not been officially notified about the expansion proposal.

On August 22, 2008, Ann Arbor first officially provided Pittsfield plans and notification of the proposed ARB expansion and detailed proposed changes in the ALP. These documents were required to be provided more than 18 months earlier under both the January 2007 Ann Arbor City Council Resolution mentioned hereinabove and under a separate 1979 Policy Statement referenced by the Ann Arbor official authoring the letter. It is noteworthy, that this first notification from Ann Arbor to Pittsfield is dated 59 days after the FAA approved the revised Ann Arbor Airport ALP. Under 49 USC 46110, routine federal court appeals are barred after 60 days. Thus, Pittsfield was effectively barred from legally objecting to the Ann Arbor ALP before even being notified by Ann Arbor about its revised ALP.

Pittsfield responded to Ann Arbor's August notice, objecting to the proposed expansion, citing the (1) increased noise that would be generated, (2) larger aircraft that would be attracted, and (3) and greater use by heavier aircraft that could result. Pittsfield subsequently unanimously Resolved (March 24, 2009) to oppose any expansion of the Ann Arbor Municipal Airport. Lodi Township subsequently passed a similar Resolution.

The Ann Arbor City Council approved the revised Ann Arbor ALP on September 22, 2008, without considering Pittsfield's objections, or those of Lodi Township.

Subsequently, in Spring 2009, a Citizens Advisory Committee (CAC) was appointed to advise the preparers of the Environmental Assessment submitted by Ann Arbor. The CAC was initially comprised of:

- The Ann Arbor Airport manager.
- The chairman of Ann Arbor's Airport Advisory Committee.
- An Ann Arbor 4th Ward resident, who is also a member of the Airport Advisory Committee.
- An Ann Arbor 3rd Ward resident, who is also a flight instructor at the airport.
- Another pilot based at the airport, who is also chief pilot of Avfuel, which operates the Cessna Citation 560 Excel based at the airport, which stands to be the single greatest beneficiary from the runway extension.
- Another airport flight instructor, who is also a member of the airport-based FAA Safety Team.
- A citizen member from Ann Arbor's 5th Ward.
- A representative from Ann Arbor's 2nd Ward, who is also a member of the Ann Arbor City Council.
- A representative of the Washtenaw Audubon Society, which conducted a previous study that found no Canada geese among 38 other species on the airport.
- Lodi Township Supervisor Jan Godek.
- Pittsfield Township Deputy Supervisor Barbara Fuller.

It was only after extensive political pressure that two additional outside members were added to the CAC:

- Shlomo Castell, a commercial passenger airline pilot from the Stonebridge Community Association in Pittsfield Township, and
- Kristin Judge, Washtenaw County Commissioner from District 7, which includes Pittsfield.

Even so, for an airport located in Pittsfield Township that most dramatically impacts Pittsfield and Lodi Townships and Ward 4 of Ann Arbor, the CAC was dominated by Ann Arbor and airport members who stood to benefit from the expansion and the CAC was under-represented by those immediately outside the airport perimeter whose safety could be placed at greater risk by any expansion. The Environmental Assessment never addressed nor studied the safety implications of any such expansion.

Throughout the process, the only opportunity for any public discussion -- with elected public officials present -- about the proposed expansion plan was before the Ann Arbor City Council, where speakers must call-in to register in advance. Only the first ten callers on the day of Council meetings are permitted to speak. Speakers are limited to three minutes. Such a process typically has a stifling effect on open and candid discussions for subjects as complex as an airport ALP and runway expansion proposal.

To satisfy the federal "Public Hearing" requirement, MDOT and Ann Arbor devised an equally stifling process. On March 31, 2010, a three-hour "open house" was held during the dinner hour period between 4-7 pm, during which individuals could assemble and provide public comments in response to the Environmental Assessment. Local media announcements of the event (AnnArbor.com) encouraged citizens to send Environmental Assessment comment letters directly to the Airport Manager, rather than MDOT, until Respondents intervened and requested that MDOT correct the process to restore a semblance of fairness. At the session itself, there was no dias of public officials impaneled. There were no open, public statements with the media present. All testimony was given in private rooms to court reporters, to be forwarded to MDOT for later evaluation and, presumably, incorporation into some finalized Environmental Assessment.

That citizens, not public officials, needed to police the process was the ultimate insult to ensure any semblance of fairness and equity. By this public hearing process being so restricted, members of the public were effectively deprived of their due process rights under the 14th Amendment of the U.S. Constitution to ever have an opportunity to speak in an open and fair forum in a reasonable amount of time in opposition to the airport expansion before a public body. That is because, if the expansion proposal goes forward, the Ann Arbor City Council generally restricts all outside speakers to three minutes, which is hardly an adequate time to offer an organized and coherent argument against such a complex proposition as an airport expansion, whereas – at the same time – city officials and their surrogates are afforded unlimited time to speak to the City Council to advocate in favor of the runway expansion, in clear violation to due process protections. Thus, by closing off the fairness and balance intended by this only federally-mandated forum, related to EA comments, stifled the only open public commentary and dissent regarding the airport, in violation of the law.

IX. CONCLUSION.

Given the Project's many potential significant environmental impacts that have not been identified or fully analyzed in the EA, the substantial potential risks to human and environmental life living in the vicinity of the airport that have not been properly studied and are placed at risk by the proposed expansion, it should be rejected. At minimum, a full Environmental Impact Statement (EIS) is required prior to approval and implementation of the Project. "No matter how thorough, an EA can never substitute for preparation of an EIS, if the proposed action could significantly affect the environment." *Anderson v. Evans*, 371 F.3d 475, 494 (9th Cir. 2004).

Sincerely,

Andrew R. McGill, Ph.D.

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Williams Aviation Consultants

Williams Aviation Consultants, Inc. was retained by the law firm of Chevalier, Allen & Lichman, LLP to review and comment on Chapters 1 and 2, and Appendices A and B of the DRAFT Ann Arbor Municipal Airport Environmental Assessment (DEA), February, 2010. The following are our comments on the DEA.

A. Accommodating the Critical Aircraft at Ann Arbor Municipal Airport (ARB)

As stated in paragraph 2.2.7, "*The proposed shift and extension of primary Runway 6/24 at ARB would provide a runway configuration that more effectively accommodates the critical aircraft that presently use the facility.* (Emphasis added)

In particular, the proposed project would provide the following benefits:

- *Enhance business aviation and interstate commerce by providing sufficient runway length to allow the majority of category B-II Small critical aircraft that currently use ARB to operate without load restrictions (i.e. reduction in passengers, cargo, and fuel associated with aircraft range).* (Emphasis added)

According to paragraph 2.2, Purpose and Need, "The purpose of the proposed improvements at ARB is to provide facilities that more effectively and efficiently *accommodate the critical aircraft* that presently use the airport, as well as to enhance the operational safety of the airport. (Emphasis added)

The critical aircraft is defined by the FAA as the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport. In cases where the critical aircraft weigh less than 60,000 lbs, a classification of aircraft is used rather than a specific individual aircraft model. A recent Airport User Survey has confirmed that the critical aircraft classification for ARB is "*B-II Small Aircraft*." (Emphasis added)

Also stated under "Purpose and Need" "*Development of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small classification aircraft to operate at their optimum capabilities (without weight restrictions).* (Emphasis added)

WAC Comment: There are no aircraft in the B-II Small aircraft classification that require a runway length of 4,300 feet to conduct normal operations. All B-II Small Aircraft are capable of operating out of the current runway (3,505 feet long) without the need to reduce weight by off-loading passengers, baggage or fuel.

Regarding the establishment of the critical aircraft, ARB lacks the required number of 500 annual operations by B-II Small Aircraft, so they have added larger aircraft such as B-II Large, Category C-I and C-II operations to meet the 500 classification requirement. It is the Category C-I and C-II aircraft which would benefit by the runway extension to 4,300 feet, not

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those aircraft that fall within the definition of Category B-II Small Aircraft. The current runway length of 3,500 feet is sufficient to handle all Category B-II Small Aircraft.

B. Lengthening Runway 6/24 to 4,300 Feet: The Impact on Aircraft Load Restrictions and Fleet Mix

The "load restrictions" referenced above in paragraph 2.2.7 refer to the fact that the higher category aircraft (primarily jets in the C-I and C-II categories) must currently operate at reduced weights in order to operate out of the current 3,500 foot runway (required takeoff length is the primary restrictor). Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel; all of which discourage these aircraft from conducting operations out of ARB.

For example: A Cessna Citation II (Category B-II) requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day and may therefore operate unrestricted as to weight from the current 3,500 foot runway. A Lear 35 (Category C-I) requires 5,000 feet for takeoff at maximum certificated gross weight on the same standard day.

The Category B-II Citation II can conduct unrestricted operations from the current 3,500 foot runway. Whereas extending the runway to 4,300 feet would not facilitate unrestricted operations by the Category C–I, Lear 35, the required weight reduction would be less than is currently required. In this way, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide no operational benefit to the Category B-II Small Citation jet, or any other Category B-II Small aircraft.

All Category B-II Small aircraft, i.e. the ARB critical design aircraft, are currently accommodated on the existing 3,500 foot runway. Contrary to what is stated in the DEA, lengthening the runway to 4,300 feet WOULD NOT "provide a runway configuration that more effectively accommodates the critical aircraft that presently use the facility."

If the runway is lengthened to 4,300 feet, other jets such as the Lear 25 (Category C-I), Cessna Citation III (Category C-II) and Cessna Citation Sovereign (Category C-II) may be able to operate out of ARB with minor reductions in takeoff weight. This will impact the community as it could reasonably be expected that the longer runway will attract more of the larger, higher performance jet aircraft to the airport.

These added high performance jet aircraft operations will be accompanied by noise and air quality impacts. Many of these operations will take place at night, thereby negatively affecting the general quiet of the surrounding community.

C. Shifting Runway 6/24 150 Feet to the West While Maintaining the Current Runway Length of 3,500 Feet: The Impact on Load Restrictions, Future Fleet Mix and Safety of Operations

Load Restrictions

Maintaining the current runway length of 3,500 feet would mean that the Category C-1 and C-II aircraft would continue to suffer significant load restrictions. These load restrictions would thereby continue to serve as a deterrent to these aircraft operating out of ARB.

Future Fleet Mix

Maintaining the current runway length would serve to maintain the current fleet mix. Category B-II Small jet aircraft include lower powered models such as the smaller versions of the Cessna Citation (Category B-I/II) and the Mitsubishi Diamond jet (Category B-I). Higher powered jet aircraft such as the Lear 25 (Category C-I), Lear 35 (Category C-I), IAI Astra (Category C-I) and Cessna Citation III (Category C-II) may be generally discouraged from flying into Ann Arbor and would generally, with few exceptions choose to land at Detroit and drive the 40 miles to Ann Arbor.

Safety of Operations

2.2.1 Safety Enhancements:

In the first paragraph, the consultant is correct in stating that shifting the Runway 24 threshold 150 feet west would enhance safety by effectively removing the current obstruction to line-of-site vision (hangar) of the parallel taxiway for ATCT personnel.

However, in the next paragraph the consultant states, "The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles."

This statement betrays a lack of understanding by the consultant of Instrument Approach Procedure (IAP) design and TERPS Obstruction Standards. Regarding the 20:1 and the 34:1 surfaces; it is not either/or, but both/and. Both the 20:1 and the 34:1 surfaces exist simultaneously for every published IAP and are defined as "Obstacle Identification Surfaces" which do not establish obstacle clearance safety margins but rather only define instrument approach visibility minimums. The FAA does not require either of these two surfaces to be free of penetration by obstacles, and thus "providing an additional margin of safety" as stated by the consultant does not apply in the case of these two surfaces.

Other TERPS surfaces (Obstacle Clearance Surfaces) are established which do ensure clearance from obstructions and the FAA requires that these Obstacle Clearance Surfaces be clear of structures and terrain. The current IAPs to Runway 24 were designed by the

FAA to accommodate all existing obstructions. In this respect, shifting the runway 150' to the west would not enhance safety.

Summary: Assuming that the consultant is correct in their assertion that shifting the threshold would eliminate obstruction penetrations to the existing 34:1 Obstacle Identification Surface, the effect would not be a safety improvement but would only result in a reduction in the required approach visibility minimums.

D. Appendix B Noise Analysis Report
B-1 Noise Impact Analysis
B.1.3 Data
Flight Operations

The consultant states "INM-modeled annual operations for the 2009 existing condition, consisting of operations from April 2008 through March 2009, totaled 61,969 operations, which is approximately 169 daily operations. Jet operations accounted for approximately 2 percent of the total operations. Nighttime operations accounted for 4.2 percent of the total operations."

2014 future condition aircraft operations were obtained from the 2008 FAA TAF for ARB. Modeled annual operations for the 2014 condition totaled 69,717 operations, or approximately 191 daily operations. *It is assumed that the percent of night and jet operations will remain constant between the existing condition and the future years. In addition, it is also assumed that the fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives will remain static.* The existing and future fleet mix with annual operations is shown in Table B-2." (Emphasis added)

The consultant wrongly assumes that the percent of night and jet operations will remain constant, and that the fleet mix will remain static if Runway 6/24 is lengthened to 4,300 feet.

The longer runway will make ARB much more attractive to larger and higher performance jet aircraft as the added runway length will facilitate the loading of additional passengers and baggage on to these aircraft. Also, being able to carry additional fuel may mean that, in certain cases, costly and time consuming intermediate fuel stops will become unnecessary. As ARB becomes more attractive to higher performance jet aircraft, these larger aircraft may then consider operations to/from ARB in lieu of landing at Detroit and driving to Ann Arbor.

As more high performance jet aircraft begin operations at ARB, the fleet mix will change in favor of a higher percentage of jet operations as compared to the current level of light single and multiengine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft currently reflect a high percentage of ARB operations. B-II Small aircraft (the critical design aircraft) reflect a low percentage of ARB operations. Recall that Category B-II Large and Category C aircraft had to be added to the currently operating Category B-II Small aircraft design group in order to meet the 500 operation requirement for establishing the critical aircraft and thereby justify the runway extension.

The number of night operations also has the strong potential to increase as the number of arrivals of the larger, longer haul business jets often occur in the evening hours due to the longer time duration of their trips. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

EXHIBIT 1

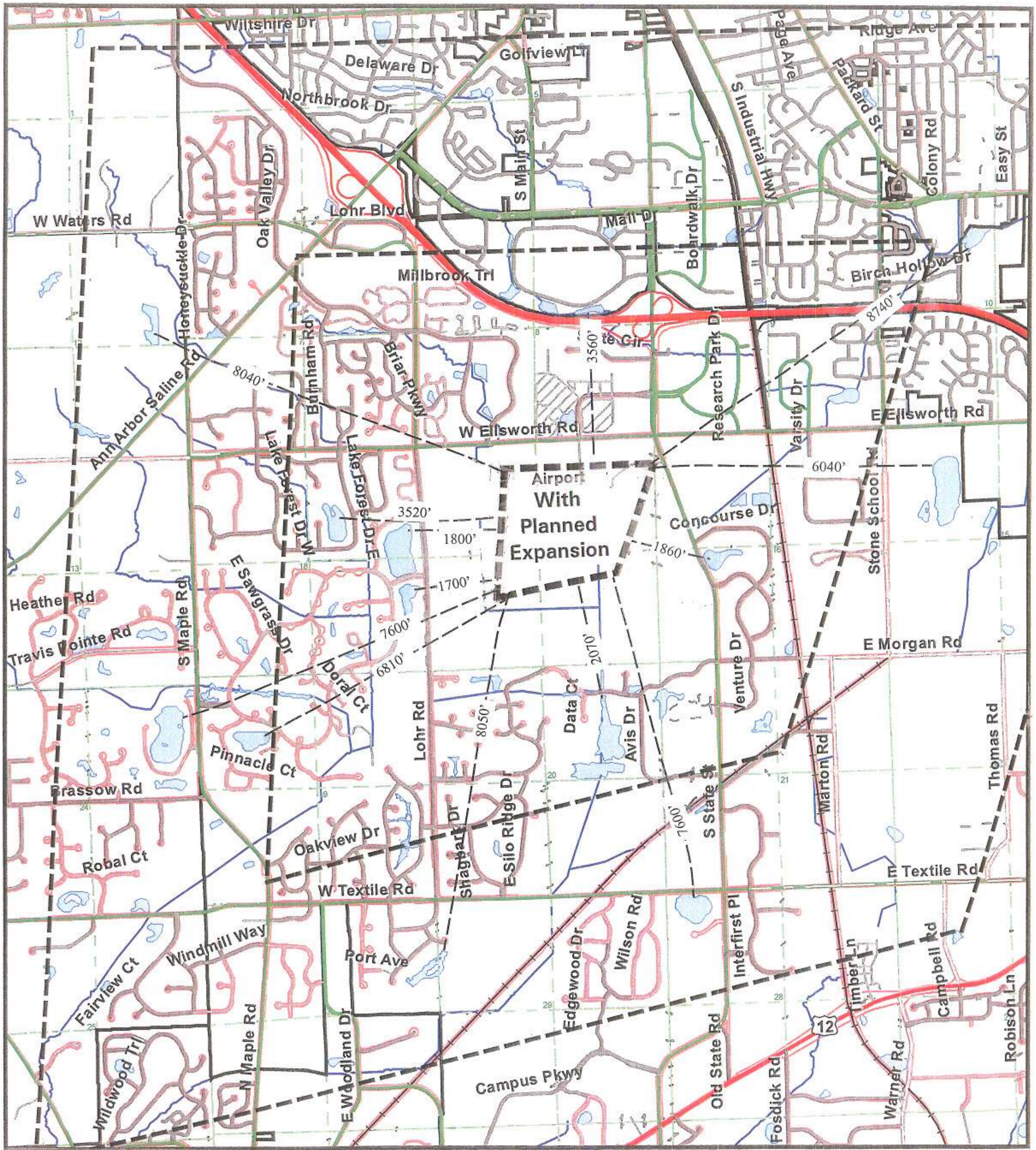
Table 1

Analysis of MDOT-AERO Origin-Destination Data

Analysis of MDOT-AERO Origin / Destination Analysis of IFR Operations

State	**B-II Large**	**B-II Small**
Illinois	5	64
Indiana	1	21
Michigan	20	162
Ohio	13	38
Wisconsin	4	9
Great Lakes Region Total	**43**	**294**
D.C.	2	1
Kentucky	0	13
Maryland	7	3
Pennsylvania	4	23
W. Virginia	0	7
Added Flights Within 450-Mile Radius of ARB	**13**	**47**
Total Flights Within 450-Mile Radius of ARB	**56**	**341**
% B-II Operations Within 450-Mile Radius of ARB	66%	81%

EXHIBIT 2



April 2010

GIS Map Print

Location Map

0 2,400 4,800

Feet

N

1 inch = 3,000 feet

WASHTENAW COUNTY MICHIGAN 1826

Geographic Information System

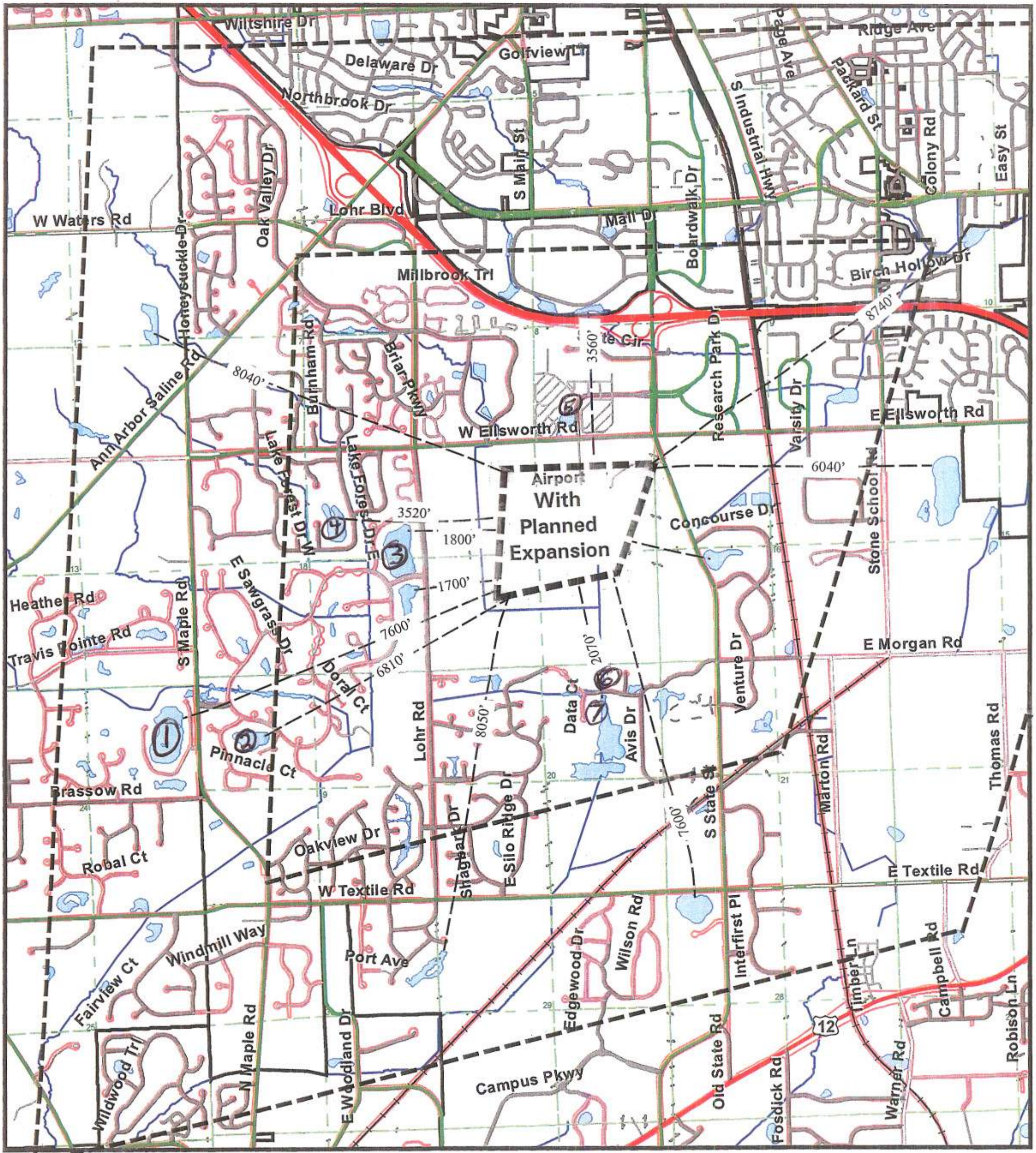
The information contained in this cadastral map is used to locate, identify and inventory parcels of land in Washtenaw County for appraisal and taxing purposes only and is not to be construed as a "survey description". The information is provided with the understanding that the conclusions drawn from such information are solely the responsibility of the user. Any assumption of legal status of this data is hereby disclaimed.

NOTE: PARCELS MAY NOT BE TO SCALE

Date Printed: 04/01/2010

Committee for Preserving Community Quality

EXHIBIT 3



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Date Printed: 04/01/2010

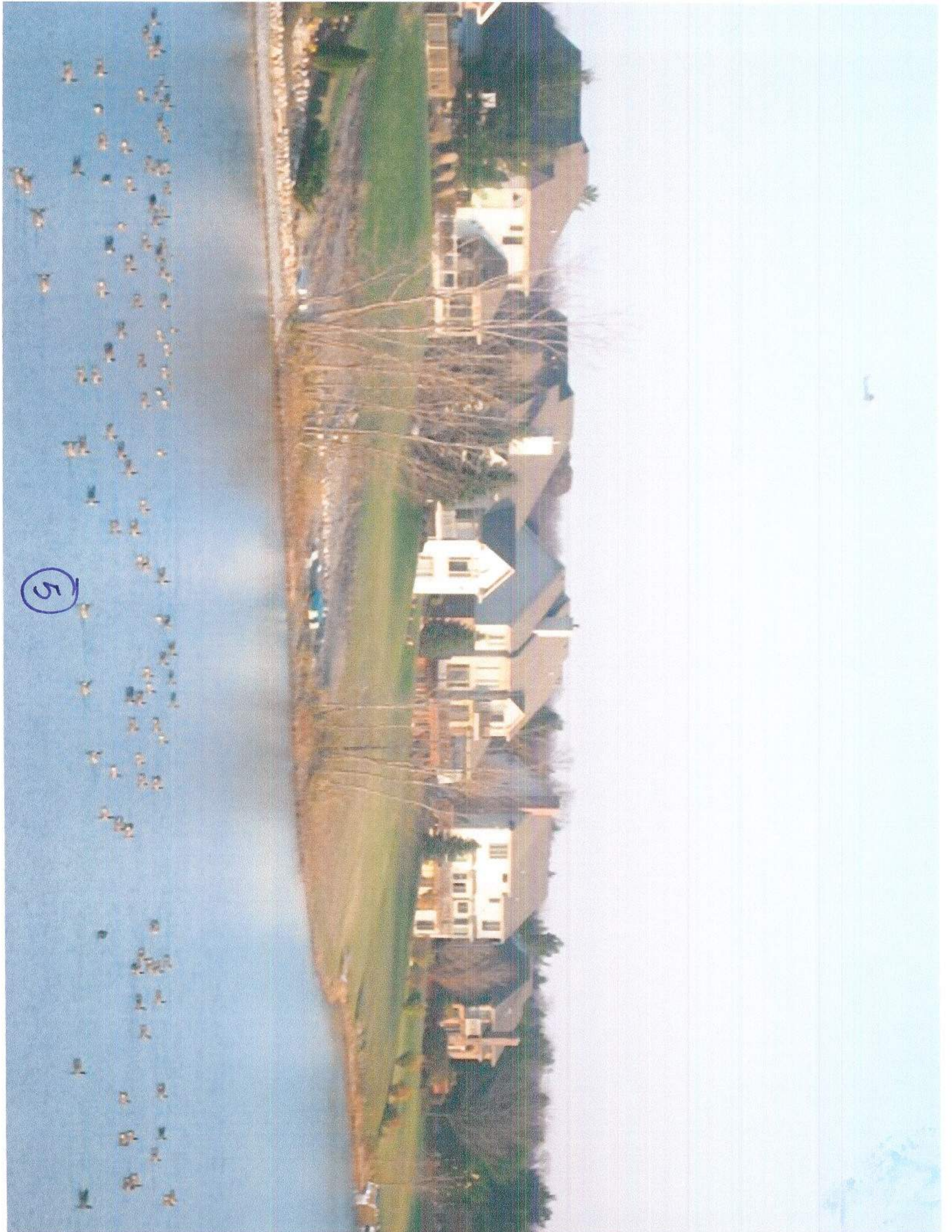
StopA2RunwayExtension.com

April 2010

1

2

4

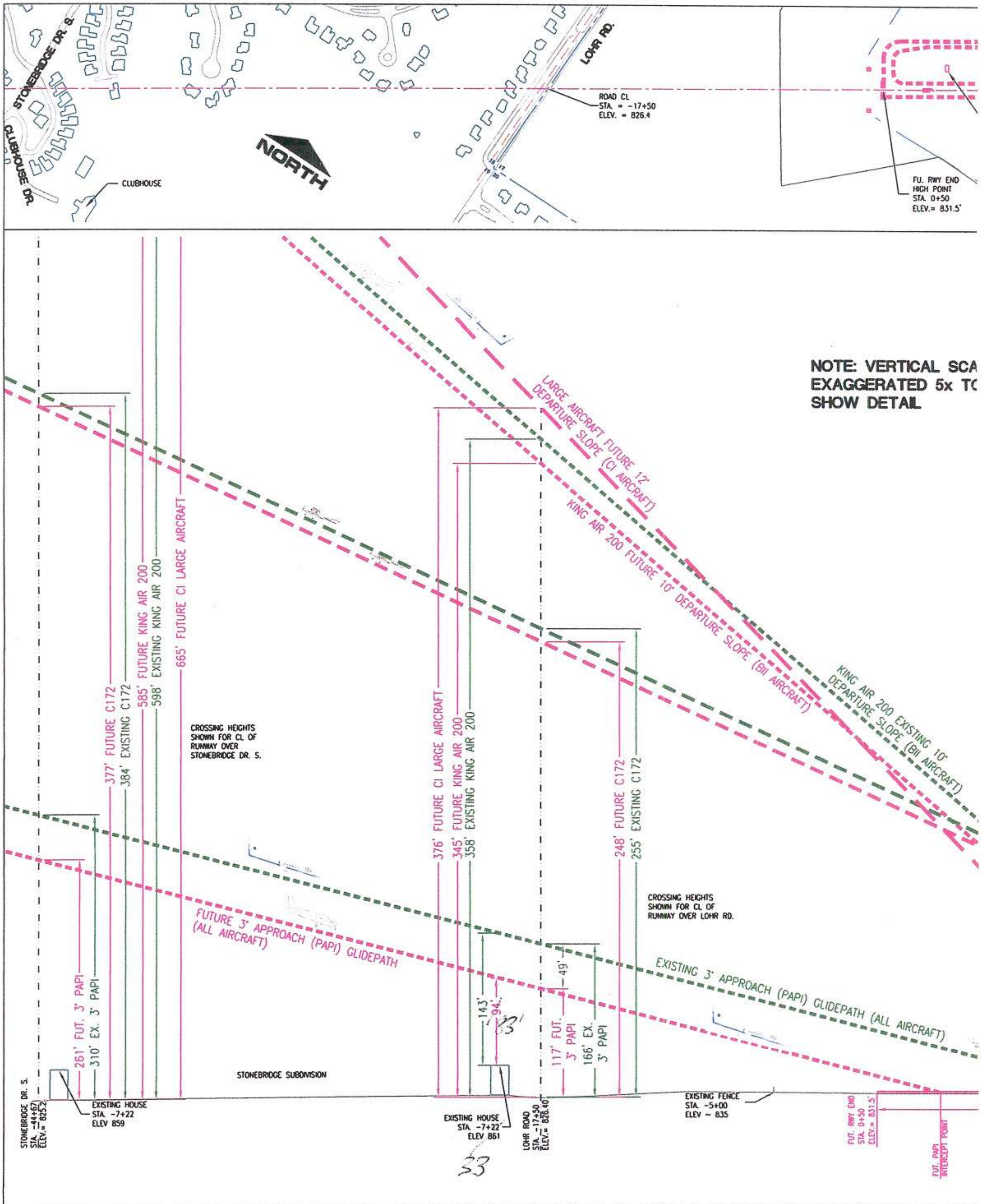



6

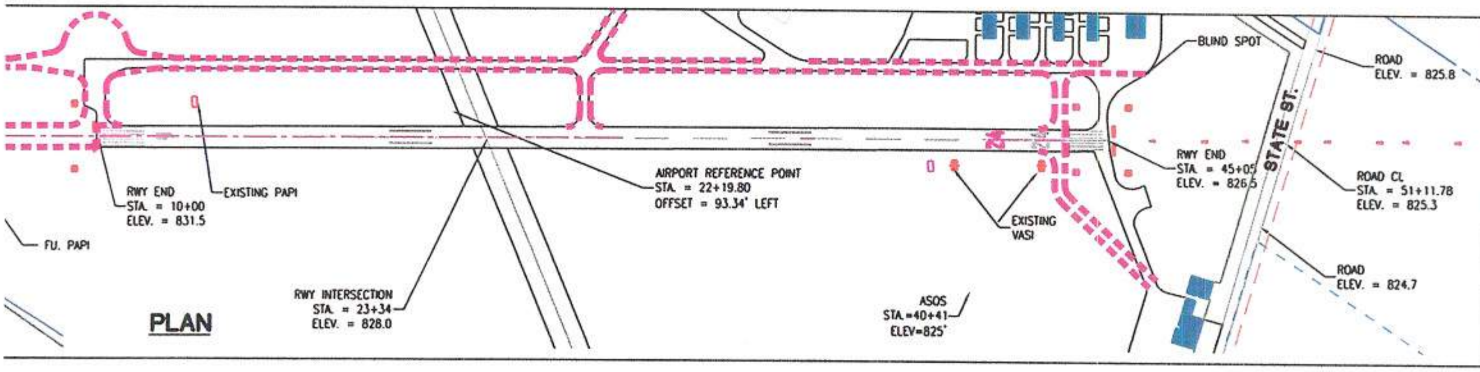
EXHIBIT 4


STOP
WARNING
GOOSE
CROSSING

EXHIBIT 5



APPROACH AND DEPARTURE



APPROACHES

APPROACH SLOPE FOR ALL AIRCRAFT WOULD BE AT 3° ALONG THE PRECISION APPROACH PATH INDICATOR (PAPI).

APPROACH CLEARANCE (LOHR RD.)
166' EXISTING
117' PROPOSED EXTENSION

TYPICAL CLIMB PERFORMANCE BY AIRCRAFT TYPE

AIRCRAFT TYPE	TYPICAL CLIMB ANGLE	TYPICAL CLIMB RATES
SINGLE ENGINE PISTON	4°–7°	500–1,000 FT/MIN
TWIN ENGINE PISTON	7°–9°	1,00–1,500 FT/MIN
TWIN ENGINE TURBOPROP	10°–11°	2,000–2,500 FT/MIN
JET	12°–16°	3,000–4,000 FT/MIN

DEPARTURES

DEPARTURE SLOPES ARE SHOWN FOR 3 AIRCRAFT TYPES FOR THE 839' AIRPORT ELEVATION AT 83°F. CROSSING HEIGHTS SHOWN FOR CL OF RUNWAY OVER LOHR RD.

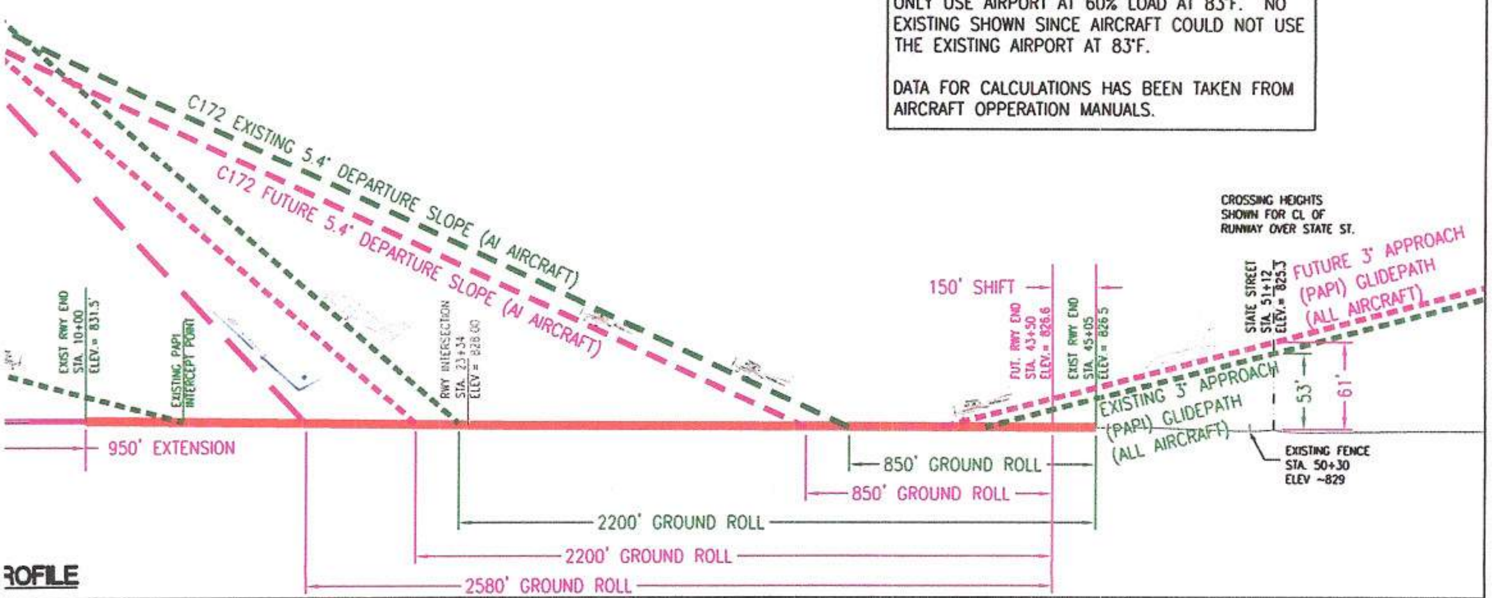
CESSNA 172 – AI SMALL AIRCRAFT
MAX. GROSS LOAD: 2,300 LBS
CLIMB RATE: 700 FT. PER MINUTE
CLIMB AIRSPEED: 73 KNOTS
CLIMB ANGLE: 5.4°
GROUND ROLL: 850 FT.
DEPARTURE CLEARANCE (LOHR RD.)
255' EXISTING
248' PROPOSED EXTENSION

KING AIR 200 – BII SMALL AIRCRAFT
MAX. GROSS LOAD: 12,5000 LBS
CLIMB RATE: 2,400 FT. PER MINUTE
CLIMB AIRSPEED: 125 KNOTS
CLIMB ANGLE: 10°
GROUND ROLL: 2200 FT.
DEPARTURE CLEARANCE (LOHR RD.)
358' EXISTING
345' PROPOSED EXTENSION

HAWKER 700A – CI LARGE AIRCRAFT
MAX. GROSS LOAD: 24,800 LBS*
CLIMB RATE: 3,000 FT. PER MINUTE
CLIMB AIRSPEED: 135 KNOTS
CLIMB ANGLE: 12°
GROUND ROLL: 2850 FT.
DEPARTURE CLEARANCE (LOHR RD.)
376' PROPOSED EXTENSION

* FOR FUTURE RUNWAY LENGTH AIRCRAFT COULD ONLY USE AIRPORT AT 60% LOAD AT 83°F. NO EXISTING SHOWN SINCE AIRCRAFT COULD NOT USE THE EXISTING AIRPORT AT 83°F.

DATA FOR CALCULATIONS HAS BEEN TAKEN FROM AIRCRAFT OPPERATION MANUALS.



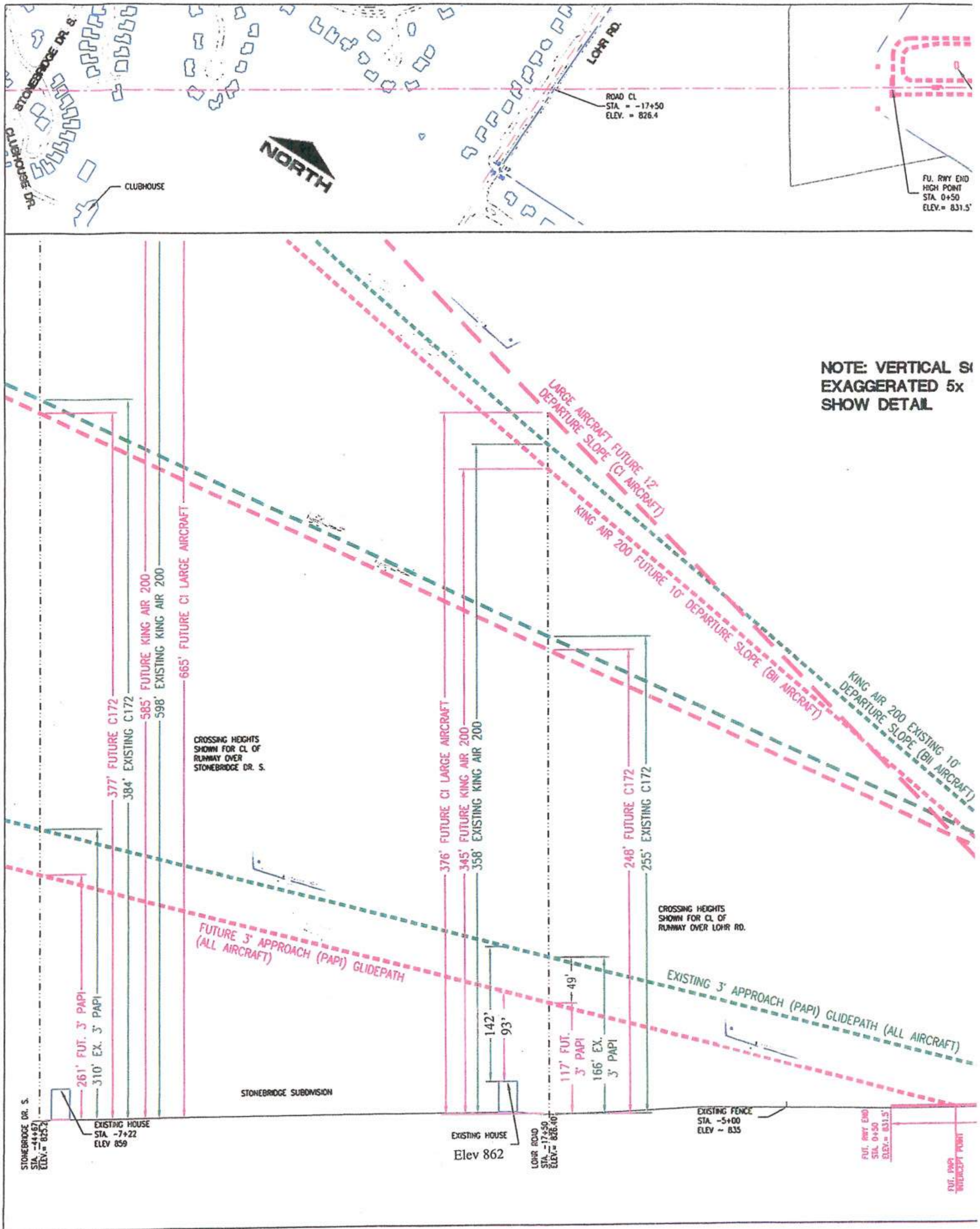
CLEARANCES

URS GRAND RAPIDS, MI. 3950 SPARKS DR. S.E. 616 574-8500

PROJECT NO. 12940723

ANN ARBOR MUNICIPAL AIRPORT

EXHIBIT 6



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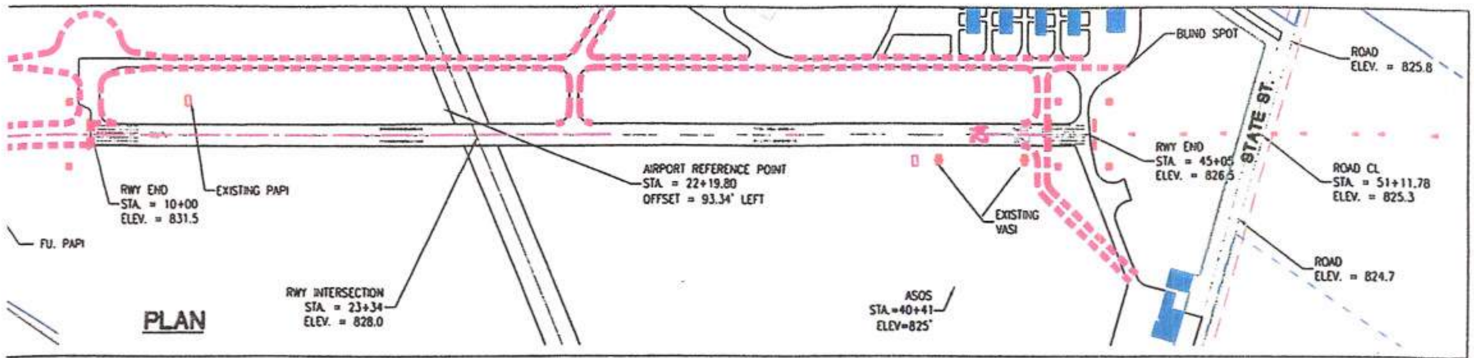

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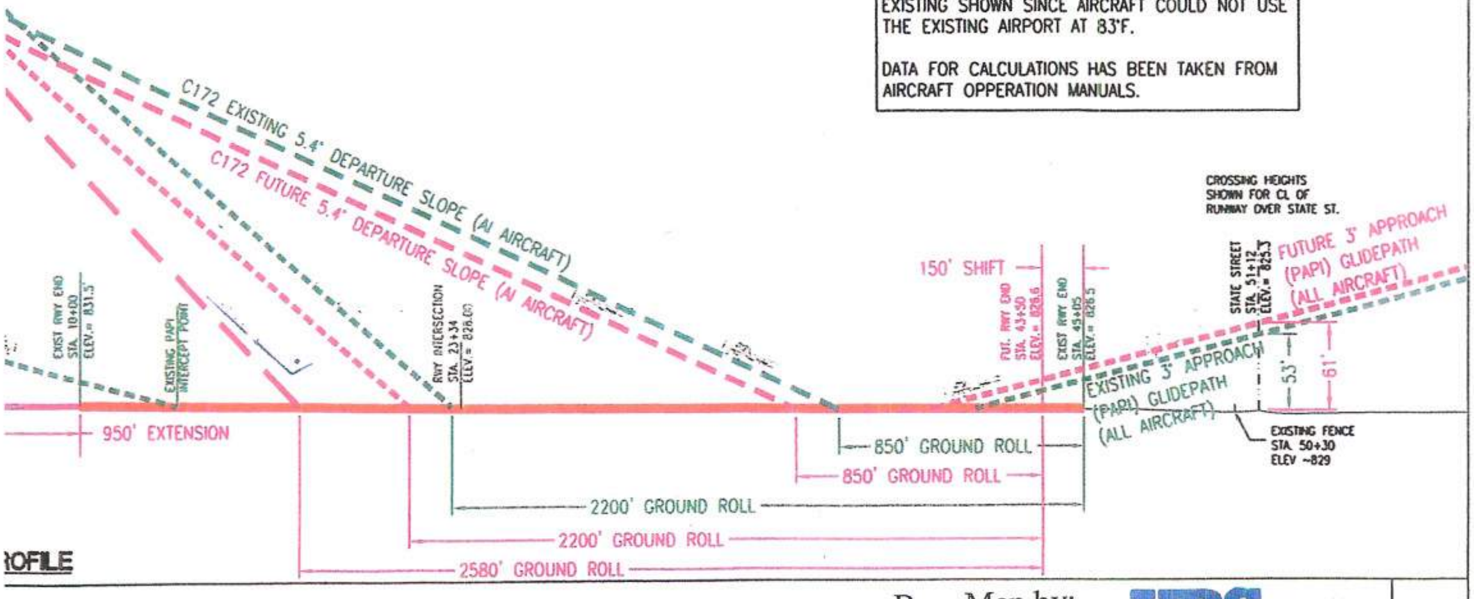


CLEARANCES

Base Map by: URS GRAND RAPIDS, MI.

ANN ARBOR MUNICIPAL AIRPORT

Committee for Preserving Community Quality April 2010

EXHIBIT 7

Exhibit 7

Aircraft Emergency Landing: Stonebridge Golf Course – June 2009

Exhibit 17

JANIS A. BOBRIN

WATER RESOURCES COMMISSIONER
705 North Zeeb Road
P.O. Box 8645
Ann Arbor, MI 48107-8645

email: drains@ewashtenaw.org
http://drain.ewashtenaw.org

DENNIS M. WOJCIK, P.E.
Chief Deputy Water Resources Commissioner

DANIEL R. MYERS, P.E.
Director of Public Works

Telephone 734.222.6860
Fax 734.222.6803

April 19, 2010

Ms. Molly Lamrouex
Airports Division
MDOT Bureau of Aeronautics and Freight Services
2700 Port Lansing Road
Lansing, Michigan 48906

Re: Ann Arbor Municipal Airport, Environmental Assessment

Dear Ms. Lamrouex:

This office has completed a review of the subject document received by this office on April 07, 2010. This review only took under consideration the sections that were in regard to water resources.

As a result of this review the following comments are offered:

1. The Wood Outlet Drain, a designated county drain, extends approximately 1,000 linear feet further to the north than is shown in Figure 4.8.
2. It is indicated that build alternative 3 is the preferred alternative. This alternative extends the runway 950 linear feet to the west.
3. It is indicated that the preferred alternative does not impact the stream that is existing on the site. Using GIS measurements it appears that the stream is less than 1,000 linear feet from the existing runway. The runway extension would bring this infrastructure within 50 linear feet or less of the stream. In addition to this the grading limits shown in Appendix D-7 clearly extend into and beyond the location of the stream. Based on this information it is not understood how it has been concluded that there are no impacts to the stream.
4. It is indicated that the preferred alternative does not impact the floodplain for the stream that is existing on the site. It is indicated that proposed grading for the expansion would not occur within the designated floodplain boundary. Based on the floodplain boundary shown on FEMA Community-Panel Number: 260623 0010 C these statements are incorrect. Not only do the grading limits indicated for the preferred alternative extend into the floodplain boundary but the runway extension itself will extend into this floodplain

boundary. Based on this information it is not understood how it has been concluded that there are no impacts to the floodplain.

5. It is noted in the report that: "The amount of impervious surface on site would increase slightly due to the extension of the runway and taxiway from the existing 7 percent of the 837 acres to 7.4 percent." This slight increase noted equates to an additional 3.348 acres or 145,839 square feet. This increase in impervious surface is considered by this office to be significant and not slight particularly knowing that the additional runoff from this area will discharge to the Wood Outlet Drain.
6. It is noted in the report that: "Implementation of appropriate best management practices (BMPs) would continue to control the rate of stormwater runoff and maintain water quality standards." It is unknown by this office as to what the control rate of stormwater is currently being implemented or whether this rate meets county standards.   The additional volume created by this increase in imperviousness is not spoken to at all by the report. The type or locations of the appropriate BMPs indicated are not identified.

If you would like to discuss these issues please contact me.

Sincerely,

Dennis M. Wojcik, P.E.
Chief Deputy Water Resources Commissioner

CC: M. Kulhanek, City of Ann Arbor
N. Billetdeaux, JJR

Exhibit 18

U.S. Department of Transportation
Federal Aviation Administration

Detroit Airports District Office
Metro Airport Center
11677 S. Wayne Road, Ste. 107
Romulus, MI 48174

May 13, 2010

Michigan Department of Transportation
Bureau of Aeronautics and Freight Services
c/o Ms. Molly Lamrouex
2700 Port Lansing Road
Lansing, MI 48906

Subject: Draft Environmental Assessment for Ann Arbor Municipal Airport
Federal Aviation Administration Review Comments

Dear Ms. Lamrouex:

We have completed a review of the draft Environmental Assessment (EA) submitted to the Federal Aviation Administration (FAA) Detroit Airports District Office (ADO). Based on our review the FAA offers the following.

Air Traffic offers the following comments:

No comments.

Tech Ops offers the following comments:

Cover sheet. If the document is to be accepted as a federal document the coversheet will need to reflect this.

Section 2.1. Second bullet states "Shift and extend the parallel taxiway to coincide with the revised Runway 6/24". We recommend *revised* be changed to *extended*.

Section 2.2. This section does not appear to clearly state the need for the proposed action. Are the bulleted "objectives of the proposed project" actually proposed actions? The last bullet states "Relocate and potentially upgrade the Runway 24 Approach Light System". When will it be known if the approach light system will be replaced or upgraded? What is this dependent on? The remainder of the document deals with the impact of the runway extension, but does not address impacts related to the relocation of the existing light system or an upgrade to a new system. Also, action associated with Runway End Identifier Lights (REIL) is mentioned later in Section 4.17 and should be listed here as a proposed action. Are there any other NAVAIDs moving or being established?

Section 2.2.1. This section states that the Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF) would serve the same function as the Omni-Directional Approach Lighting System (ODALS) and is structurally very similar. How would the footprint of the MALSF structures compare to the ODALS? What environmental impacts would installation of a MALSF create?

Section 3.1.2. We suggest adding a qualifier in the second paragraph to state the following: "...would be greater than those expected with the *proposed* expansion of ARB in its current location."

Section 4.4. The Consequences of the Preferred Alternative section states: "Comparisons of existing conditions at various airports with future build out conditions indicate that the net change in air emission is still below standards." Do these *conditions* include runway extension projects similar to the proposed action at ARB?

This section additionally states: "Consequently, the air model results for the Preferred Alternative would be identical to those for the No Build Condition." This statement implies that no air emissions would result from the proposed action. Is this accurate?

Section 4.5.1. Would the existing Storm Water Pollution Prevention Program cover the additional impervious surface area?

Section 4.5.2. We would recommend rewording the first sentence of the Consequences of the Preferred Alternative section to the following (if true and appropriate): *Surface and subsurface geological conditions would not be impacted by the Preferred Alternative.*

Flight Procedures offers the following comments:

No comments were provided by Flight Procedures Office (FPO).

However, it should be noted that the FPO must be notified by formal letter to request the development of future approach procedures for the relocated runway end coordinates. Information needed includes identification of when construction will start, finish, when the equipment will be relocated, etc. This information is critical for developing/amending approach procedures. The FPO must know the project phasing in order to have procedures ready when construction is complete. (Equipment relocation, threshold displacements, etc). Changes in runway pavement length will result in survey data. Please note that survey data must meet the specifications outlined in Advisory Circulars 150/5300-16, 17, and 18. Third party surveys must be coordinated with the FPO. The proponent must submit Proposed Equipment Relocation Data along with information related to any equipment that will be relocated or added to AVN-210 and ATA-110. 7. Publication of new/amended Approach Procedures could take from 18 months to 2 years after runway data is submitted to AVN-210 and ATA-110. NOTE: Development of Approach Procedures will not begin until an official letter of request for development of procedures is received by FPO and the proposed runway data and equipment data provided to AVN-210 and ATA-110. Proponent must update the airport FAA Form 5010-1 to reflect new runway data and updated runway changes.

Airports Division offers the following comments:

The report is not clear if there is a federal action being requested.

Based on the information contained within the draft EA it appears that at least two federal actions are being requested. These actions include the relocation or replacement of the current approach lighting system as well as the development for future approach procedures for the new runway end locations. The FAA recommends that these actions be clearly identified throughout the document. The first page of the document states that this draft EA will become a State of Michigan document when signed by the State Official and does not include similar language for the Federal Aviation Administration although there is a signature line included for a federal official. Please refer to FAA Order 5050.4B section 707(f).

Section 1 page 1-1. The draft EA states that the projects under consideration are those shown on the FAA approved Airport Layout Plan (ALP). This statement should be clarified as to the role of Michigan Department of Transportation (MDOT) in conditionally approving the ALP set on behalf of the FAA under the authority of the State Block Grant Program. When referencing the ALP throughout the document, additional emphasis should be made to the June 23, 2008 ALP approval letter that clearly states that the approval is conditional. Several conditions were placed on the approval letter including the requirements that the projects contained within the ALP set must comply with the National Environmental Policy Act (NEPA). The FAA recommends inclusion of the conditional ALP approval letter in the draft EA for disclosure purposes.

We also suggest the executive summary clearly outline who will be responsible for actions associated with the proposed project (i.e. local sponsor, local unit of government, State of Michigan, Federal Government). For the FAA to co-sign the document, the requested Federal Actions must be clearly identified within the executive summary and throughout the document where appropriate.

Section 2 page 2-1. References to the ALP set need to clarify that MDOT has only conditionally approved the ALP.

Section 2.2 page 2-4. The classification of a B-II Small Aircraft has been determined with a reference to MDOT 2009. Is the B-II "Small Aircraft" a designation that is contained within MDOT planning guidance? The FAA is not familiar with the classification of "small" when identifying the critical design aircraft for an airport. Please clarify how this distinction was derived.

Section 2.2 page 2-4. The paragraph discussing Origin-Destination Analysis should be expanded (or references made where information can be reviewed) to provide clarification to the general statements that are made. Specifically, is there a list of destinations that can be provided that will substantiate the need for a runway extension? A listing of destinations may aid the reader in putting the proposed project into perspective and may further substantiate the need for a runway extension. The report states that a significant number of operations occur between ARB and distant locations without quantifying the number and types of operations that are being referenced. The FAA recommends this be clarified in the report or referenced to the appropriate appendices.

Section 2.2 page 2-5. Are the bulleted items for the objectives of the proposed project presented in order of relative importance?

The statement that the project will enhance interstate commerce does not appear to be substantiated by supporting documentation here or elsewhere in the document. How has this been verified? What are the enhancements? Is this a need for the project? The FAA recommends referring to FAA Orders and Advisory Circulars that address runway length, operational capacity of the aircraft utilizing ARB, and any deficiencies that currently exist at ARB that are a function of the current runway length. Without a detailed discussion and explanation of what the interstate commerce enhancement is and how this has been quantified as a current need, the FAA does not recognize this as a need for the project based on the information provided.

If enhancing interstate commerce is a stated need for the project then the report should be expanded to include a full range of alternatives that can address this need including alternative modes of transportation as an example.

The last bulleted objective in this section is for the relocation and potential upgrade of the Runway 24 approach lighting system. The report does not appear to document why this is a need for the project or if the approach lighting system is currently required or needed in the future.

What benefit does the current approach lighting system provide the airport? There does not appear to be a credit for a reduction in minimums at the airport as a result of having the ODALS. Has a Benefit Cost Analysis (BCA) been completed or requested of the FAA substantiating the need for relocating or replacing the ODALS? Depending on the results of the BCA and associated justification for relocating the existing or installing a replacement light lane at ARB, the potential exists that the Federal Action may be limited to abandoning the existing ODALS and no relocation or replacement would occur with federal funds.

Section 2.2.1 page 2-5. The first paragraph implies that runway incursions have been occurring at ARB as a result of issues with the current line of sight between the ATCT and a portion of the taxiway system and taxiway hold area. The report further indicates that the proposed project will possibly prevent incursions from occurring. Are there any documented runway incursions resulting from the current line of sight issue that can be included in the report to substantiate this claim? The FAA supports safety enhancement projects and would consider this a measure to improve the line of sight from the ATCT to parallel taxiway and the hold area if it can be demonstrated that the existing condition contributes to runway incursions. While a goal of the FAA is to reduce the number of runway incursions at airports nationwide, the FAA can not definitively conclude that this proposed safety enhancement at ARB will potentially *prevent* runway incursions but rather if the line of sight issue is improved this may *reduce the possibility* of runway incursions.

This section includes discussion of the potential to achieve a clear 34:1 approach and reduce minimums at the airport. The ADO previously requested clarification on this issue in an e-mail dated March 4, 2010 (attached for reference). Based on the e-mail exchange, the FAA understands there is no anticipation of a reducing of minimums at this airport for the foreseeable planning future.

Since minimums will not be reduced as a result of the project, the FAA is unclear on the need for a 34:1 approach or how it enhances safety of the approach procedures currently published for the airport based on the existing 20:1 approaches. The document should better explain how providing a 34:1 approach enhances safety for the existing and future users at the airport or how this also may impact interstate commerce. Has the current 20:1 clear approach resulted in missed approaches that have been documented? If so how often does this condition occur?

Is providing clear 34:1 approaches a project need or a benefit that may result from the relocation of the runway? Earlier in the report it was identified as a stated objective, however, the discussion in the report does not appear to substantiate the need for this when combined with the e-mail exchange of March 4, 2010 and conditionally approved ALP dated June 23, 2008.

While the future 34:1 approaches are identified on the conditionally approved ALP, it should be noted that this would result in an expansion of the approach surface from the existing 500'x2,000'x5,000' to 500'x3,500'x10,000'. The EA needs to fully disclose the increase in the approach surface if a 34:1 approach is achieved and document any environmental impacts that result from the larger approach surface.

Section 2.2.2 page 2-6. It is not clear to the FAA why there is a summary of Wings of Mercy operations since 1992 including 51 flights reported in 2009. This data appears to be in addition to what was collected as part of the user survey report that relied predominately on information from calendar year 2007. What is the relevance of including the 2009 data or specifically identifying the Wings of Mercy flight operations? Are there a range of aircraft types that fly for Wings of Mercy? Does the proposed runway extension impact their operational capacity?

Section 2.2.2 page 2-7. Discussion on the Michigan State System Plan (MASP) identifies the airport reference code (ARC) as B-II. Does the MASP differentiate between B-II small and B-II large? In absence of a clearly defined category of B-II "small aircraft", the FAA would suggest simply referring to the airport with a B-II ARC.

Section 2.2.3 pages 2-7 and 2-8. This section most clearly identifies why a runway extension is being proposed in accordance with FAA advisory circulars and State standards outlined in the 2008 MASP. This section, in combination with section 2.2.4 that documents substantial use (i.e. over 500 annual operations) by the B-II critical design family of aircraft appears to substantiate the justification for the runway extension based on the 2007 operational data.

Section 2.2.4 page 2-9. Detailed operational information is presented for calendar year 2007. Subsequent years are generalized based on trend analysis and overall decrease in operations as reported in the FAA Terminal Area Forecast (TAF). There does not appear to be an evaluation to account for the 21.8% decrease in operations between 2007 and 2009. Would it be prudent to verify if the operational decrease impacted one user group more than other user groups? Are the numbers of local and itinerant operations decreasing at the same rate or is one segment impacted to a greater extent? This evaluation may be accomplished through additional user survey data collection or potentially from the ATCT located at ARB for subsequent years since 2007. Additionally, the FAA recommends that the year of the TAF being utilized for this report be identified.

Section 2.2.4 page 2-11. Specific information for AvFuel Corporation is presented to validate assumptions for the continued classification of the airport as B-II. It should be noted that AvFuel bases a Citation 560 Excel jet at ARB and is designated in the report as a B-II "*Large*" aircraft. The discussion further indicates that the Chief Pilot submitted written documentation regarding potential future operational levels at ARB. The written documentation does not appear to be included within the report or appendices. However, according to the text in the report, the Chief Pilot anticipates future operational levels increasing to 350-450 annual operations. This level of use, in combination with a limited number of additional similar B-II aircraft would appear to classify the airport as a B-II "*Large*" designation. The FAA reiterates the hesitation on identification of either a "small" or "large" within an airport reference code and recommends that any qualifier to the size of the B-II critical design aircraft be removed from the report. The number of operations forecasted to occur by AvFuel Corporation would further support the elimination of the qualifier as "small" to the ARC.

Section 2.2.6 page 2-12. The local objective of reducing runway overrun incidents appears to conclude that if the added runway length were present, all the incidents would have been avoided. Based on information presented, the FAA does not necessarily come to the same conclusion. There are many factors that go into any overrun incident and if additional runway length were present this may have only prolonged the overrun incident. The A-I category of aircraft involved with overrun incidents do not appear to have needed any length beyond the existing runway length to operate at full capacity and in a safe manner.

The paragraph that references Accelerated Stop Distance Available (ASDA) requirements appear to include fleet mixes other than A-I and implies that aircraft can accommodate their operational requirements with a reduced load capacity. The ADO is not aware of any A-I aircraft operating at ARB that would need to operate at a reduced load capacity to adequately satisfy their calculations for safely operating at ARB.

It is not clear when the 11 overrun incidents occurred, their cause, or conclusions that support that runway length was a factor in the overrun incidents. Can additional information be provided to support this position? If additional information is not available the FAA recommends removing this section from the document.

The FAA recognizes that this section of the report was included as a local objective and it is clearly and appropriately stated that the FAA does not recognize this as a need for extending the runway at ARB.

Section 2.2.7 page 2-12. The first bullet point indicates that additional runway length will allow for the majority of B-II "small" aircraft to operate without load restrictions. Has it been documented that the current B-II "small" users operate with load restrictions? If so, how often does this occur and what are the quantifiable impacts to their operations?

The third bullet implies that operational safety will be improved with a clear 34:1 approach. Currently the airport has LPV approaches with minimums of 300' and 1 mile. The ADO questions if a flatter approach is warranted in absence of reducing minimums as indicated in the March 4, 2010 e-mail correspondence. The discussion on the 34:1 approach should be re-evaluated and its need clearly identified. Currently the report does not seem to substantiate a need for a 34:1 approach if minimums are not anticipated to be lowered.

Section 3 page 3-1. The report indicates that alternatives were developed to meet the goals of ARB. These goals are to improve safety and efficiency and serve current users. These goals do not appear to be consistent with those previously outlined in the bullet points of section 2.2 (purpose and need). This section should refer to the stated needs and evaluate the alternatives ability to meet those needs.

Section 3.1.3 pages 3-3 and 3-4. There is discussion on extending the runway to the east and a listing of items impacted by pursuing this alternative. There is, however, no conclusion or statement that this option either should be, or was, eliminated. It can be inferred later in the report by the absence of this alternative that it was eliminated but the conclusion as to why it has been eliminated has not been stated.

When addressing the FAA's comments (included within this letter) associated with the stated needs for the project earlier in the report, the responses to these comments may influence the conclusions on why some of the alternatives carried forward have been eliminated. Specifically, if needs stated in section 2.2 are not further substantiated, or it is concluded that one or more of the needs do not exist, additional alternatives may need to be carried forward if they adequately address the needs for the project. The FAA will re-evaluate the conclusions of the alternatives section once the FAA's comments on the purpose and need section are addressed.

Section 3.3 page 3-8. Based on the information presented in the draft EA, the FAA has not reached the same conclusion that alternatives 1 and 2 do not meet the stated needs for the project. An apparent evaluation parameter for alternative 2 included in section 3.3.3 discusses the tower line of sight. This evaluation matrix does not appear to be consistent with those goals stated in Section 3 on page 3-1. The previous comment on the apparent disconnect between the different sections of the report also applies to the specific alternative evaluation. The FAA recommends that the decision matrix for which alternatives were eliminated be clarified in the EA.

Table 3-1 page 3-8. The table appears to incorrectly dismiss alternative 1 because it does not meet purpose and need. .The discussion in 3.3.2 does not support that conclusion. Additionally, there is reference to a future expansion of State Road. This appears to be the first reference to this issue. Is this a need for the State Road expansion project? In what time frame is the State Road expansion project expected to occur? Should there be expanded discussion on other regional planning projects in this EA so the public can better understand the different parameters that ARB is confined to or bound by?

Additional alternatives that may be considered for evaluation to address the need statements could include a combination of items such as: alternative modes of transportation to address enhancing interstate commerce, removal or relocation of obstructions that limit the ATCT line of sight issues, and raising or constructing a new ATCT to address the line of sight issues. Have any previous discussion on additional alternatives been eliminated prior to, or as part of the planning and environmental assessment process for ARB?

Section 3.4 page 3-9. This section contains a brief summary of environmental resources that will not be impacted by build alternative 3. Would it be advantageous to also summarize environmental impacts associated with the other build alternatives? There is a general statement regarding noise impact analysis in this section that identifies that the 65 DNL contour is not within 1,000 feet of any residential structure. What is the purpose for this statement? The FAA is not aware of an environmental impact decision matrix associated with the distance between residential structures and the 65 DNL contour.

Section 4.3.5 page 4-17. The conclusion for the implementation of the preferred alternative states that a positive result of improvements is the ability of business owners to achieve improved fleet efficiency for critical aircraft by maximizing their passenger and/or cargo loads. How has this statement been substantiated? What records exist that current users at ARB are not operating at maximum passenger and/or cargo loads? What has been the economic impact of the reduction of loads if they are occurring?

Section 4.9 pages 4-22 and 4-23. State endangered and special concern species were identified at ARB. The sponsor appears to be proposing a mitigation effort to limit grading for the project to avoid breeding seasons for the specific species. Has this proposed mitigation plan been found to be acceptable by the resource agencies? There is reference to an Audubon Society agreement regarding mowing boundaries. Who is the agreement between? Has this agreement been reviewed by the environmental assessment preparation team? Are there limitations or restrictions for use of airport land as a result of this agreement? Has the Audubon Society been included or have they provided input to this draft EA?

Section 4-15 pages 4-24 and 4-25. The FAA recommends that the score from the USDA form AD 1006 be disclosed in this section and explain what the score means. The consequences identify that some prime and unique farmland of local importance are impacted by this project. The amount of prime and unique farmland should be quantified. Are there any mitigation requirements for this change in use?

Section 4-16 page 4-25. The report identified a decrease in facility energy usage with the installation of LED taxiway lights. Is this net decrease in energy usage compared to baseline or existing conditions?

Section 4.17 page 4-25. There is no discussion on potential relocation of the ODALS or replacement with upgraded equipment. Would there be impacts with either scenario (relocation or replacement)? It should also be noted that the potential exists for the current ODALS to be abandoned if a relocation or upgrade is not justified with a BCA.

Section 4.20 page 4-26. The evaluation regarding construction impacts in the draft EA do not appear to address staging areas during project implementation. The FAA recommends the report verify that staging areas will not impact environmental resources; and as necessary, outline any required mitigation measures for staging area impacts.

Section 4.21 page 4-26. Should the reference to ASTM Standard E1527-94 be updated to E1527-05? The EA should also state if the review was done in accordance with FAA Order 1050.19B, *"Environmental Due Diligence Audits"*.

Section 5 page 5-1. The FAA suggests that this section be titled *Mitigation* rather than *Environmental Consequences – Other Considerations*. We also question if it is prudent to discuss noise, social impacts and community disruption, wetland impacts, and threatened and endangered species in this section since there appear to be no mitigation requirements associated with any of these categories. The FAA suggests either listing all environmental categories reviewed that do not require mitigation or not list any of the categories that do not have required mitigation. Is it a true statement that there are no mitigation measures for threatened and endangered species? Section 4.9 appears to indicate there are seasonal limitations on when grading will occur.

Would it be better to outline required permits for the project in this section, best management practices, construction requirements, etc. rather than having a discussion on what mitigation measures are not required?

Section 6.2.1 pages 6-1 and 6-2. This section includes a summary of when Citizen's Advisory Committee (CAC) meetings were held and the overall agenda for each meeting. The EA does not document either in the text or in an appendix what issues may have been raised and how they were addressed in the CAC meetings. The FAA suggests additional information from the CAC meetings be included in the EA.

Section 6.2.2, page 6-2. The last sentence of this section should indicate that comments received will be reviewed, summarized, and addressed.

Section 7 page 7-3. This section identifies a request that the state and federal agencies approve a Finding of No Significant Impact. This is the first location in the document that specifically requests a federal action. As discussed previously, the FAA requests that earlier in the document the specific actions being requested of each agency be outlined. Based on the review of this document the FAA anticipates that the FAA will be requested to evaluate, and as appropriate, abandon/relocate/replace the existing approach lighting system and develop new flight procedures for the new runway end locations.

Next steps.

The draft EA appears to be intended to be a jointly executed document by both MDOT and the FAA. Since there are several updates/clarifications requested by the FAA contained in this letter and the sponsor's responses may be substantial, it would be prudent to afford the public an additional opportunity to review and comment on the changes that are anticipated to be made for the final draft publication. Most specifically, the document will need to clearly outline the requested local, state and federal actions. Since this was not clearly presented in the initial draft EA, the FAA may consider these changes and clarifications as a material change to the document that should result in solicitation of additional public comment. This may be accomplished by an additional public information meeting or public hearing.

Once the FAA receives confirmation that the above comments have been addressed in the form of an updated draft EA, the FAA requests that we be allotted sufficient time to review, comment, and potentially concur with the updates prior to making the document available to the public for further comment.

If you desire further clarification of these comments, please contact me at (734) 229-2916.

Sincerely,

Brad N. Davidson, P.E.
Community Planner/Environmental Protection Specialist
Detroit Airports District Office

Encl: E-mail correspondence dated March 4, 2010 between the ADO and MDOT

Exhibit 19

JENNIFER M. GRANHOLM
GOVERNOR

STATE OF MICHIGAN
DEPARTMENT OF TRANSPORTATION
LANSING

KIRK T. STEUDLE
DIRECTOR

November 15, 2010

Mr. Ernest P. Gubry
Environmental Protection Specialist
Detroit Airports District Office
Metro Airport Center
11677 S. Wayne Road, Ste. 107
Romulus, MI 48174

Re: Ann Arbor Municipal Airport (ARB), Environmental Assessment (EA)
Response to Federal Aviation Administration (FAA) Comments

Dear Mr. Gubry:

The Michigan Department of Transportation (MDOT) Bureau of Aeronautics and Freight Services received comments from your office regarding the draft ARB EA dated May 13, 2010. This letter serves as a response to those comments. Please refer to FAA comments shown below in bold text, followed by MDOT responses.

1) **Cover sheet. If the document is to be accepted as a federal document the coversheet will need to reflect this.**

   Response: We were unaware of FAA's current preferred format for cover sheets. Please provide FAA guidance documentation/templates for EA cover sheets. An example of an acceptable cover sheet format would be helpful. We will revise the cover sheet to meet FAA requirements.

2) **Section 2.1. Second bullet states "Shift and extend the parallel taxiway to coincide with the revised Runway 6/24". We recommend revised be changed to extended.**

   Response: Comment acknowledged. This change will be noted in the amended EA.

3) **Section 2.2. This section does not appear to clearly state the need for the proposed action. Are the bulleted "objectives of the proposed project" actually proposed actions? The last bullet states "Relocate and potentially upgrade the Runway 24 Approach Light System". When will it be known if the approach light system will be replaced or upgraded? What is this dependent on? The remainder of the document deals with the impact of the runway extension, but does not address impacts related to the relocation of the existing light system or an upgrade to a new system. Also, action associated with Runway End Identifier Lights (REIL) is**

mentioned later in Section 4.17 and should be listed here as a proposed action. Are there any other NAVAIDs moving or being established?

Response: The bulleted items are considered objectives of the proposed project. The last bullet: "Relocate and potentially upgrade the Runway 24 Approach Light System", was included because the Omni-Directional Approach Lighting System (ODALS) will need to be relocated if the runway is shifted to the southwest, and these lights are very old. Since the ODALS are owned by the FAA, it is the responsibility of the FAA to determine whether the existing lights will be relocated, replaced with the more current MALSF, or abandoned altogether.

There is local preference by the pilots to maintain the ODALS. Since replacing/relocating the ODALS for the shifted runway end does not result in any adverse impacts, the EA conservatively included their relocation. A decision by the FAA that there is no benefit in maintaining them does not result in significant changes to the affected environment described in the EA.

The area of potential effect evaluated in the EA includes the area where the light system would be upgraded and/or relocated. Therefore potential impacts from an upgraded/relocated lighting system have been addressed.

The preferred alternative for a revised Runway 6/24 will result in the relocation and reestablishment of all other associated runway lighting. These lighting systems include Medium Intensity Runway Lights (MIRL), Runway End Identifier Lights (REIL), and Visual Approach Slope Indicator lights (VASI), as well as the Medium Intensity Taxiway Lights (MITL) on the parallel taxiway. These systems are owned and operated by the sponsor and are inherently part of the runway project. They were not called out in the project Purpose and Need, just as the need for new runway paint marking was not called out. Relocation/upgrade of the ODALS was called out specifically in the project justification because this action results in the need for FAA signature on this document. There are no other FAA-owned navigational aids (NAVAIDS) associated with the proposed project.

4) **Section 2.2.1. This section states that the Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF) would serve the same function as the Omni-Directional Approach Lighting System (ODALS) and is structurally very similar. How would the footprint of the MALSF structures compare to the ODALS? What environmental impacts would installation of a MALSF create?**

Response: The footprint of the MALSF would be 100' shorter than the footprint of the existing ODALS.

The MALSF consists of seven light structures, all of which are located on the extended runway centerline. The structures are located with a 200' spacing between each, for a total overall length of 1,400'.

The ODALS consist of five light structures located on the extended runway centerline, with a 300' spacing between each structure, for a total overall length of 1,500'. Two additional ground-level light fixtures are located at the runway threshold, one on each side.

Additional details regarding MALSF and ODALS approach light systems are included in FAA Advisory Circular 150/5340-30D. Installation of the MALSF will not result in any adverse environmental impacts, as identified in Section 4.17.

5) **Section 3.1.2. We suggest adding a qualifier in the second paragraph to state the following: "…would be greater than those expected with the proposed expansion of ARB in its current location."**

Response: Comment acknowledged. This change will be noted in the amended EA.

6) **Section 4.4. The Consequences of the Preferred Alternative section states: "Comparisons of existing conditions at various airports with future build out conditions indicate that the net change in air emission is still below standards." Do these conditions include runway extension projects similar to the proposed action at ARB?**

Response: The conditions referenced in this section are based on the comparison of operational emission rates of seven case study airports across the state. The case studies, which included airports similar to ARB, did evaluate the operational emission rates of the airports in their proposed ultimate build out conditions.

Project construction emission rates are estimated to be less than eight tons per year of NOx, well below the Environmental Protection Agencies de minimis threshold of 100 tons/year (rates derived from US Court of Appeals Case, City of Olmstead Falls v. FAA, 2002). Therefore, the emissions do not constitute a change in conditions for the proposed ARB runway extension project.

7) **This section additionally states: "Consequently, the air model results for the Preferred Alternative would be identical to those for the No Build Condition." This statement implies that no air emissions would result from the proposed action. Is this accurate?**

Response: As stated in this section of the draft EA, the Air Quality Study conducted by Landrum and Brown concluded that proposed projects at general aviation airports are not expected to cause or contribute to any new violations of the National Ambient Air Quality Standards (NAAQS). Also, the results of the air model analysis showed that net aircraft emissions are not expected to increase as a result of the proposed project. Therefore, aircraft emissions should be the same - with or without the project.

Additionally, a model was run to determine automotive-related emissions associated with the proposed project. Since there would be no revisions to the existing roadway system as a result of the project, the model showed that there would be no increase in air emissions attributed to automobiles.

8) **Section 4.5.1. Would the existing Storm Water Pollution Prevention Program cover the additional impervious surface area?**

Response: Yes

9) **Section 4.5.2. We would recommend rewording the first sentence of the Consequences of the Preferred Alternative section to the following (if true and appropriate): Surface and subsurface geological conditions would not be impacted by the Preferred Alternative.**

Response: Comment acknowledged. This change will be noted in the amended EA.

Flight Procedures offers the following comments:

10) **No comments were provided by Flight Procedures Office (FPO).**

11) **However, it should be noted that the FPO must be notified by formal letter to request the development of future approach procedures for the relocated runway end coordinates. Information needed includes identification of when construction will start, finish, when the equipment will be relocated, etc. This information is critical for developing/amending approach procedures. The FPO must know the project phasing in order to have procedures ready when construction is complete. (Equipment relocation, threshold displacements, etc). Changes in runway pavement length will result in survey data. Please note that survey data must meet the specifications outlined in Advisory Circulars 150/5300-16, 17, and 18. Third party surveys must be coordinated with the FPO. The proponent must submit Proposed Equipment Relocation Data along with information related to any equipment that will be relocated or added to AVN-210 and ATA-110. 7. Publication of new/amended Approach Procedures could take from 18 months to 2 years after runway data is submitted to AVN-210 and ATA-110. NOTE: Development of Approach Procedures will not begin until an official letter of request for development of procedures is received by FPO and the proposed runway data and equipment data provided to AVN-210 and ATA-110. Proponent must update the airport FAA Form 5010-1 to reflect new runway data and updated runway changes.**

Response: Comments acknowledged

Airports Division offers the following comments:

12) **The report is not clear if there is a federal action being requested.**

Response: The format of the draft EA is the same format used for other EA's co-signed by MDOT and FAA under the block grant agreement. The FAA was involved with this project since it began and understands the proposed actions. That said, we acknowledge the document does not explicitly state the 'proposed federal action'. We suggest that previous FAA/MDOT actions have included this information in the Finding of No Significant Impact (FONSI) document and that we use the same approach with this project.

13) **Based on the information contained within the draft EA it appears that at least two federal actions are being requested. These actions include the relocation or replacement of the current approach lighting system as well as the development for future approach procedures for the new runway end locations. The FAA recommends that these actions be clearly identified throughout the document. The first page of the document states that this draft EA will become a State of Michigan document when signed by the State Official and does not include similar language for the Federal Aviation Administration although there is a signature line included for a federal official. Please refer to FAA Order 5050.4B section 707(f).**

Response: As stated above, the requested federal action is relocation or abandonment of the federally owned NAVAIDs (ODALS). MDOT has never included development of a new approach as a stated action in an EA. To date, FAA Flight Procedures Office has always completed separate environmental clearance for new approaches. We request clarification from FAA that this is necessary and suggest that development of a new approach is inherent as part of the proposed runway shift/extension (e.g. like paint marking) and should not have to be called out as a separate proposed action.

14) **Section 1 page 1-1. The draft EA states that the projects under consideration are those shown on the FAA approved Airport Layout Plan (ALP). This statement should be clarified as to the role of Michigan Department of Transportation (MDOT) in conditionally approving the ALP set on behalf of the FAA under the authority of the State Block Grant Program. When referencing the ALP throughout the document, additional emphasis should be made to the June 23, 2008 ALP approval letter that clearly states that the approval is conditional. Several conditions were placed on the approval letter including the requirements that the projects contained within the ALP set must comply with the National Environmental Policy Act (NEPA). The FAA recommends inclusion of the conditional ALP approval letter in the draft EA for disclosure purposes.**

Response: The standard language that is used in the ALP approval letters for all FAA-NPIAS airports is that they are "conditionally approved", subject to environmental clearances, justification for development of specific projects, etc.

This language was originally developed by the FAA back when that agency was responsible for signing the ALP approval letters. When MDOT became a block grant state and took over the responsibility of signing the ALP approval letters on behalf of the

FAA, we kept the same boilerplate language that the FAA had been using, and referred to all approvals as "conditional approvals".

Although the standard language in the approval letter for the April 2008 ALP for Ann Arbor Municipal Airport states that it has been "conditionally approved" by MDOT, it is in fact a fully-approved ALP, the same as any other airport with an approved ALP. The ALP was reviewed by many branches of the FAA through the customary FAA-Airspace Review process, and all FAA comments or concerns were addressed prior to MDOT signing the standard format approval letter on behalf of the FAA.

Paragraph No. 1 of the ALP approval letter specifically states that the FAA has concurred with the proposed development on the ALP for planning purposes based on current safety, utility, and efficiency standards, with the condition that justification of need is required prior to seeking FAA financial participation in the actual development of the projects.

Since the ALP has in fact been thoroughly reviewed and approved by both the FAA and MDOT, we do not agree that when referencing the current approved ALP in the EA, there is a need to specify that it is "only conditionally approved by MDOT". Stating such would be misleading, as it infers that the ALP does not have FAA approval, and only a limited approval by MDOT.

ALP approval letters have never been a part of any of our past EAs, and there are no established procedures which require or recommend the inclusion of such. If the FAA would like to discuss a change in policy regarding inclusion of ALP approval letters in all future EAs, we are open to further discussion.

15) **We also suggest the executive summary clearly outline who will be responsible for actions associated with the proposed project (i.e. local sponsor, local unit of government, State of Michigan, Federal Government). For the FAA to co-sign the document, the requested Federal Actions must be clearly identified within the executive summary and throughout the document where appropriate.**

Response: The format of the draft EA is the same format used for other EA's co-signed by MDOT and FAA under the block grant agreement. The FAA was involved with this project since it began and understands the proposed actions. That being said, we acknowledge the document does not explicitly state the 'proposed federal action'. We suggest that previous FAA/MDOT actions have included this information in the FONSI document and that we use the same approach with this project.

16) **Section 2 page 2-1. References to the ALP set need to clarify that MDOT has only conditionally approved the ALP.**

Response: See response to comment 14.

17) **Section 2.2 page 2-4. The classification of a B-II Small Aircraft has been determined with a reference to MDOT 2009. Is the B-II "Small Aircraft" a designation that is contained within MDOT planning guidance? The FAA is not familiar with the classification of "small" when identifying the critical design aircraft for an airport. Please clarify how this distinction was derived.**

Response: In the User Survey Report, reference is made to FAA Advisory Circular 150/5325-4B "*Runway Length Requirements for Airport Design*". In this AC, the FAA has published guidance and runway length curves for family groupings of airplanes with similar performance characteristics and operating weights.

Chapter 2 of the AC provides FAA runway length recommendations and runway length curves for "Small Airplanes with Maximum Certificated Takeoff Weight of 12,500 Pounds or Less". Chapter 3 provides FAA guidance and runway length curves for "Airplanes with Maximum Certificated Takeoff Weight of More Than 12,500 Pounds Up To and Including 60,000 Pounds" (Large Airplanes).

In order to determine which chapter of the FAA AC was applicable to ARB, the weight classification of the critical aircraft family had to first be identified. The user survey analysis confirmed that the family grouping of airplanes that were included in the B-II critical aircraft category were of the "small" aircraft weight classification. Therefore, the runway length curves from Chapter 2 of the AC were referenced in the User Survey Report in the discussion regarding runway length recommendations. Use of the runway length curves from Chapter 3 would have resulted in longer runway length recommendations.

The critical aircraft weight category analysis was conducted solely for the purpose of referencing FAA AC 150/5325-4B. MDOT planning guidance regarding runway length recommendations does not distinguish between weight categories. The critical aircraft category as listed on the current approved ALP is "B-II". No reference is made to the small or large weight category.

18) **Section 2.2 page 2-4. The paragraph discussing Origin-Destination Analysis should be expanded (or references made where information can be reviewed) to provide clarification to the general statements that are made. Specifically, is there a list of destinations that can be provided that will substantiate the need for a runway extension? A listing of destinations may aid the reader in putting the proposed project into perspective and may further substantiate the need for a runway extension. The report states that a significant number of operations occur between ARB and distant locations without quantifying the number and types of operations that are being referenced. The FAA recommends this be clarified in the report or referenced to the appropriate appendices.**

Response: Additional Origin-Destination information, including a list of 32 states and numbers of operations between ARB and each state, is included in Exhibit No. 2 of the Supplemental Report to the Airport User Survey. The Supplemental Report is included in Appendix A-2 of the draft EA, which was reviewed by your office. We will add a note to the amended EA referencing Appendix A-2 for additional information.

19) Section 2.2 page 2-5. Are the bulleted items for the objectives of the proposed project presented in order of relative importance?

Response: No, it is simply a list of objectives for the proposed project.

20) The statement that the project will enhance interstate commerce does not appear to be substantiated by supporting documentation here or elsewhere in the document. How has this been verified? What are the enhancements? Is this a need for the project? The FAA recommends referring to FAA Orders and Advisory Circulars that address runway length, operational capacity of the aircraft utilizing ARB, and any deficiencies that currently exist at ARB that are a function of the current runway length. Without a detailed discussion and explanation of what the interstate commerce enhancement is and how this has been quantified as a current need, the FAA does not recognize this as a need for the project based on the information provided.

Response: The need for the project is not based on the enhancement of interstate commerce. Therefore, there is no documentation provided in the EA to substantiate that position. The need for the project is based on the objective of providing a primary runway of suitable length to safely accommodate critical category aircraft without operational weight restrictions.

Section 2.2 (Purpose and Need) and Appendix A (User Survey Reports) of the EA explain in detail the purpose, need, and justification for the project. FAA Advisory Circular 150/5325-4B "*Runway Length Requirements for Airport Design*" and the Michigan Airport System Plan (MASP) airport development standards were referenced in determining project justification and proposed runway length.

Enhancement of interstate commerce is a benefit of providing a runway long enough to avoid weight restrictions on critical aircraft. If business aircraft have to fly with restricted loads of passengers and/or cargo, there are obviously negative financial impacts to the operators. Such cases may result in an operator having to use two separate aircraft when one operated at its full capacity would have been sufficient to accomplish the objective. Also, if business aircraft have to fly with restricted fuel loads, the operators potentially would have to make interim fuel stops prior to reaching their destinations. Additional fuel stops result in time delays and additional operational expenses.

The final EA will clarify that the enhancement of interstate commerce is not a project objective or need, but rather a benefit of the proposed project.

21) If enhancing interstate commerce is a stated need for the project then the report should be expanded to include a full range of alternatives that can address this need including alternative modes of transportation as an example.

Response: As stated above, the enhancement of interstate commerce is not a stated need for the project, but rather an obvious benefit of the project. The airport serves aircraft that are being used for interstate commerce. Provision of a runway of sufficient length to allow critical category aircraft to operate without weight restrictions is a stated objective of the project.

22) **The last bulleted objective in this section is for the relocation and potential upgrade of the Runway 24 approach lighting system. The report does not appear to document why this is a need for the project or if the approach lighting system is currently required or needed in the future.**

Response: See response to comment 3.

23) **What benefit does the current approach lighting system provide the airport? There does not appear to be a credit for a reduction in minimums at the airport as a result of having the ODALS. Has a Benefit Cost Analysis (BCA) been completed or requested of the FAA substantiating the need for relocating or replacing the ODALS? Depending on the results of the BCA and associated justification for relocating the existing or installing a replacement light lane at ARB, the potential exists that the Federal Action may be limited to abandoning the existing ODALS and no relocation or replacement would occur with federal funds.**

Response: A BCA has not been completed at this time. Please see response to comment 3.

24) **Section 2.2.1 page 2-5. The first paragraph implies that runway incursions have been occurring at ARB as a result of issues with the current line of sight between the ATCT and a portion of the taxiway system and taxiway hold area. The report further indicates that the proposed project will possibly prevent incursions from occurring. Are there any documented runway incursions resulting from the current line of sight issue that can be included in the report to substantiate this claim? The FAA supports safety enhancement projects and would consider this a measure to improve the line of sight from the ATCT to parallel taxiway and the hold area if it can be demonstrated that the existing condition contributes to runway incursions. While a goal of the FAA is to reduce the number of runway incursions at airports nationwide, the FAA can not definitively conclude that this proposed safety enhancement at ARB will potentially prevent runway incursions but rather if the line of sight issue is improved this may reduce the possibility of runway incursions.**

Response: The first paragraph does not imply that runway incursions have been occurring at ARB as a result of ATCT line-of-sight issues. It merely states that the proposed threshold shift would "enhance operational safety" and "possibly prevent a runway incursion by expanding the view of the hold area and parallel taxiway to ATCT personnel". Certainly if the threshold shift "may reduce the possibility of runway incursions" as stated in your comment, then it would also "possibly prevent a runway incursion" from taking place.

The main point is that ATCT personnel do not have a clear view of the taxiway end and hold line area. The obstructed view restricts their ability to clearly see taxiing or holding aircraft and their N-numbers, and increases the possibility of runway incursion due to either pilot or controller error. While we are not aware of any incursions that have occurred as a result of this condition, we believe it is appropriate to address the condition while the runway extension is being considered.

Mr. Charles Smith, ATCT Manager at ARB, has expressed his concern over the non-visibility area and potential for runway incursion. He has stated in written correspondence to our office "I believe that the potential for an event is very real".

We are unclear why the FAA questions the justification of this safety enhancement measure when it obviously improves the existing condition and it is supported by ATCT management and staff. Does the FAA need records of adverse events that have actually occurred before they agree that there is justification to address a less than optimal situation?

MDOT would rather be proactive in enhancing the safety of this situation prior to a potentially catastrophic runway incursion taking place, rather than waiting for one to take place just for the record, and be reactive to it afterwards. We repeat neither the extension nor the shift result in measurable adverse impacts to the environment or surrounding communities.

25) **This section includes discussion of the potential to achieve a clear 34:1 approach and reduce minimums at the airport. The ADO previously requested clarification on this issue in an e-mail dated March 4, 2010 (attached for reference). Based on the e-mail exchange, the FAA understands there is no anticipation of a reducing of minimums at this airport for the foreseeable planning future.**

Response: Comment acknowledged. Additional clarification regarding the 34:1 approach surface will be provided in the amended EA.

26) **Since minimums will not be reduced as a result of the project, the FAA is unclear on the need for a 34:1 approach or how it enhances safety of the approach procedures currently published for the airport based on the existing 20:1 approaches. The document should better explain how providing a 34:1 approach enhances safety for the existing and future users at the airport or how this also may impact interstate commerce. Has the current 20:1 clear approach resulted in missed approaches that have been documented? If so how often does this condition occur?**

Response: There is currently not a "need" for the 34:1 approach. However, shifting the runway threshold to eliminate the ATCT line-of-sight concerns does result in the provision of a clear 34:1 surface to the relocated threshold.

As stated in the EA, with obstacles in the approach area remaining below the flatter 34:1 surface (as opposed to the existing steeper 20:1 surface), an additional margin of safety is provided between approaching aircraft and ground-based obstacles. This is particularly beneficial in low-visibility conditions, such as when aircraft are operating at night or in fog, rain, or snow.

If an aircraft is making an approach to a runway in conditions with poor visibility of the airport environment (either IFR or night VFR), and the pilot unwittingly drops below the intended glide path, there is the potential for the aircraft to strike an unseen obstacle in the approach area. Since a clear 34:1 approach surface provides a greater vertical distance between the aircraft and the obstacles than the clear 20:1 surface provides, the aircraft is less likely to collide with the unseen obstacles. It is obvious that an additional margin of safety is provided by a clear 34:1 approach surface, even though it is not required and it is not the reason for the proposed threshold relocation.

The EA stated that interstate commerce would be enhanced if the all-weather capability of the airport was improved by lowering visibility minimums of the Instrument Approach Procedure from the current 1-mile minimum to ¾-mile minimum. This would allow the airport to remain open for flight activity when the visibility dropped below 1-mile, thereby allowing for the continuation of business and interstate commerce. The EA did not say that the threshold shift, or providing for a 34:1 approach surface, would enhance interstate commerce.

Since we agreed to remove reference to the potential of a future ¾-mile visibility minimum Instrument Approach Procedure from the draft EA document (as stated in our response to the ADO e-mail dated March 4, 2010), we will also remove reference to the fact that interstate commerce would be enhanced by a ¾-mile approach procedure. Statements of clarification will be added to the amended EA.

Missed approaches are the result of pilots not being able to visually detect the airport environment well enough to complete the final phase of landing visually, upon reaching the published Minimum Descent Altitude of the Instrument Approach Procedure. They are unrelated to a clear 20:1 approach surface versus a clear 34:1 approach surface. Therefore, the current 20:1 approach surface has not resulted in missed approaches, documented or otherwise.

27) **Is providing clear 34:1 approaches a project need or a benefit that may result from the relocation of the runway? Earlier in the report it was identified as a stated objective, however, the discussion in the report does not appear to substantiate the need for this when combined with the e-mail exchange of March 4, 2010 and conditionally approved ALP dated June 23, 2008.**

Response: As previously stated, a clear 34:1 approach is not a project need, but it is a benefit that results from the relocation of the Runway 24 threshold. The threshold is not proposed to be relocated in order to provide for a clear 34:1 approach surface, but rather to enhance safety by eliminating the ATCT line-of-sight and non-visibility concerns.

28) While the future 34:1 approaches are identified on the conditionally approved ALP, it should be noted that this would result in an expansion of the approach surface from the existing 500'x2,000'x5,000' to 500'x3,500'x10,000'. The EA needs to fully disclose the increase in the approach surface if a 34:1 approach is achieved and document any environmental impacts that result from the larger approach surface.

Response: The achievement of a clear 34:1 approach surface is a byproduct of the proposed shift of the Runway 24 threshold for ATCT visibility purposes. The proposed project does not require a clear 34:1 approach surface, nor does it require any other 34:1 approach surface standards, including the application of the expanded approach surface dimensions. Therefore, discussion regarding environmental impacts that are associated with a larger approach surface are not included in the EA.

29) Section 2.2.2 page 2-6. It is not clear to the FAA why there is a summary of Wings of Mercy operations since 1992 including 51 flights reported in 2009. This data appears to be in addition to what was collected as part of the user survey report that relied predominately on information from calendar year 2007. What is the relevance of including the 2009 data or specifically identifying the Wings of Mercy flight operations? Are there a range of aircraft types that fly for Wings of Mercy? Does the proposed runway extension impact their operational capacity?

Response: This information was requested by FAA staff and it is intended to describe the nature of operations at the airport.

30) Section 2.2.2 page 2-7. Discussion on the Michigan State System Plan (MASP) identifies the airport reference code (ARC) as B-II. Does the MASP differentiate between B-II small and B-II large? In absence of a clearly defined category of B-II "small aircraft", the FAA would suggest simply referring to the airport with a B-II ARC.

Response: The MASP does not differentiate between B-II small and B-II large. Tables 40 and 41 of the MASP show that for the B-II airport classification as a whole, a primary runway length of 4,300' is an airport development standard throughout the state of Michigan. The ARC as listed on the current ALP is B-II, with no reference to either the small or large category. As stated earlier in this document, the reason that the small and large weight classifications were defined during the identification of the critical aircraft category was solely for the purpose of referencing the runway length recommendations contained within FAA AC 150/5325-4B.

31) Section 2.2.3 pages 2-7 and 2-8. This section most clearly identifies why a runway extension is being proposed in accordance with FAA advisory circulars and State standards outlined in the 2008 MASP. This section, in combination with section 2.2.4 that documents substantial use (i.e. over 500 annual operations) by the B-II

critical design family of aircraft appears to substantiate the justification for the runway extension based on the 2007 operational data.

Response: Comment acknowledged. Justification for the project is also substantiated by analysis of year 2009 operational data – the most current available. The updated analysis will be included in the amended EA.

32) **Section 2.2.4 page 2-9. Detailed operational information is presented for calendar year 2007. Subsequent years are generalized based on trend analysis and overall decrease in operations as reported in the FAA Terminal Area Forecast (TAF). There does not appear to be an evaluation to account for the 21.8% decrease in operations between 2007 and 2009. Would it be prudent to verify if the operational decrease impacted one user group more than other user groups? Are the numbers of local and itinerant operations decreasing at the same rate or is one segment impacted to a greater extent? This evaluation may be accomplished through additional user survey data collection or potentially from the ATCT located at ARB for subsequent years since 2007. Additionally, the FAA recommends that the year of the TAF being utilized for this report be identified.**

Response: Additional user survey data for calendar year 2009 has been collected and analyzed. This is the most up-to-date operational data available. Full details are included in the *Year 2009 Operational Data Analysis*. This report will be included in the amended EA.

The FAA TAF forecasted a 21.8% decrease in operations at ARB from years 2007 through 2009. Analysis of the actual year 2009 operational data later confirmed that even with the forecasted decrease in operations, there were still over 500 annual itinerant operations conducted by category B-II aircraft at ARB in 2009. Therefore, the current critical aircraft category has been substantiated as B-II.

The FAA TAF report that was referred to in the EA was obtained from the FAA database on July 2, 2009. During the most recent update of the user survey (Year 2009 Operational Data Analysis), an updated TAF was obtained from the FAA database on August 26, 2010 (forecasts issued December 2009). This most current version of the TAF projects itinerant operations at ARB to reverse the recent downward trend, and continually increase from years 2010 through 2030. A copy of this TAF will be included in the amended EA.

33) **Section 2.2.4 page 2-11. Specific information for AvFuel Corporation is presented to validate assumptions for the continued classification of the airport as B-II. It should be noted that AvFuel bases a Citation 560 Excel jet at ARB and is designated in the report as a B-II "Large" aircraft. The discussion further indicates that the Chief Pilot submitted written documentation regarding potential future operational levels at ARB. The written documentation does not appear to be included within the report or appendices. However, according to the text in the report, the Chief Pilot anticipates future operational levels increasing to 350-450 annual operations.**

This level of use, in combination with a limited number of additional similar B-II aircraft would appear to classify the airport as a B-II "Large" designation. The FAA reiterates the hesitation on identification of either a "small" or "large" within an airport reference code and recommends that any qualifier to the size of the B-II critical design aircraft be removed from the report. The number of operations forecasted to occur by AvFuel Corporation would further support the elimination of the qualifier as "small" to the ARC.

Response: It is noted in both the December 2009 Supplemental Report and the September 2010 update to the airport user survey (Year 2009 Operational Data Analysis) that AvFuel Corporation bases a B-II large category Citation 560 Excel jet at ARB. The December 2009 report was included in Appendix A-2 of the draft EA that was reviewed by your office.

Letters from AvFuel's Chief Pilot, which provide operational information for their Citation 560 Excel jet, are included in the September 2010 update to the airport user survey. This update will be included in the amended EA.

As mentioned in earlier responses, the user survey analysis distinguished between small and large category aircraft in order to determine the appropriate runway length guidance from FAA AC 150/5325-4B. The Airport Reference Code as shown on the ALP is B-II, with no reference to the small or large category.

34) **Section 2.2.6 page 2-12. The local objective of reducing runway overrun incidents appears to conclude that if the added runway length were present, all the incidents would have been avoided. Based on information presented, the FAA does not necessarily come to the same conclusion. There are many factors that go into any overrun incident and if additional runway length were present this may have only prolonged the overrun incident. The A-I category of aircraft involved with overrun incidents do not appear to have needed any length beyond the existing runway length to operate at full capacity and in a safe manner.**

Response: The vast majority, if not all, of the A-I category of aircraft that utilize ARB (including those involved with overrun incidents) do not need additional runway length to operate at full capacity and in a safe manner. Justification for the proposed runway extension was based solely on operational levels and needs by the more demanding category B-II aircraft.

Reduction of runway overrun incidents is clearly stated in the EA as a local objective, and it is not recognized by the FAA or MDOT as providing justification for the proposed runway extension. However, there is merit to the local objective, as the runway extension would in fact provide additional pavement for landing rollout for the small category A-I aircraft, and thereby reduce the potential for this category of aircraft to roll off the runway end into the turf Runway Safety Area.

35) **The paragraph that references Accelerated Stop Distance Available (ASDA) requirements appear to include fleet mixes other than A-I and implies that aircraft can accommodate their operational requirements with a reduced load capacity. The ADO is not aware of any A-I aircraft operating at ARB that would need to operate at a reduced load capacity to adequately satisfy their calculations for safely operating at ARB.**

Response: We are also unaware of any A-I category aircraft operating at ARB that would need to operate at reduced load capacity to adequately satisfy their calculations for safely operating at ARB. And yes, the larger category aircraft, including the B-II category critical aircraft, can safely accommodate accelerate-stop distance requirements at ARB with a reduced load capacity.

However, as stated in FAA AC 150/5325-4B, *"The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions"*. As clearly stated in the EA, the main objective of the proposed project is to provide a primary runway of sufficient length to allow the B-II critical aircraft family to operate without weight restrictions.

The point of your comment is unclear.

36) **It is not clear when the 11 overrun incidents occurred, their cause, or conclusions that support that runway length was a factor in the overrun incidents. Can additional information be provided to support this position? If additional information is not available the FAA recommends removing this section from the document.**

Response: Lack of suitable runway length was not a causal factor in the overrun incidents. Pilot error and mechanical problems with aircraft brakes were the factors indicated in the incident reports that resulted in the aircraft overrunning the runway end.

As previously stated, the justification for the extension of Runway 6/24 is based solely on the operational levels and requirements of category B-II critical aircraft. The local objective of reducing runway overruns is not recognized by existing MDOT or FAA standards as providing justification for the runway extension, and therefore it was mentioned in the "Other Considerations" section of the EA. Since this local objective does not technically generate justification for the runway extension from the state or federal perspective, there was no related in-depth information provided in the EA to substantiate the local perspective.

37) **The FAA recognizes that this section of the report was included as a local objective and it is clearly and appropriately stated that the FAA does not recognize this as a need for extending the runway at ARB.**

Response: Comment acknowledged.

38) **Section 2.2.7 page 2-12. The first bullet point indicates that additional runway length will allow for the majority of B-II "small" aircraft to operate without load restrictions. Has it been documented that the current B-II "small" users operate with load restrictions? If so, how often does this occur and what are the quantifiable impacts to their operations?**

Response: According to FAA AC 150/5325-4B, *"Runway Length Requirements for Airport Design"*, when the maximum certificated takeoff weight (MTOW) of critical category airplanes is 60,000 lbs. or less, the recommended runway length is determined according to a *family grouping of airplanes* having similar performance characteristics and operating weights. When the MTOW of critical category airplanes exceeds 60,000 lbs., the recommended runway length is determined according to *individual airplanes*.

Since the user survey confirmed that the current critical aircraft category at ARB is B-II small aircraft (12,500 lbs. or less), Figure 2-2 of the AC and Table 40 of the MASP were referenced in the determination of the recommended runway length of 4,300'. The runway length curves shown in Figure 2-2 of the AC were developed by the FAA for a family grouping of airplanes with similar performance characteristics and operating weights. As noted in the AC, the FAA considered takeoff, landing, and accelerate-stop distance requirements of the family grouping in the development of the runway length curves.

It has not been documented that all current B-II small aircraft operate with load restrictions at ARB, since we do not have information specific to the performance characteristics and corporate operating policies of every B-II category aircraft. However, as a means of confirming the accuracy and relevancy of the runway length curves developed for the family grouping of aircraft depicted in Figure 2-2 of the AC, an analysis was conducted using the individual airplane flight manual from the State of Michigan's Beechcraft King Air 200.

This airplane model is a very common B-II small category corporate aircraft, many of which currently operate at ARB. It is also a representative airplane of the family grouping of aircraft included in Figure 2-2. Analysis of the flight manual confirmed that this aircraft would indeed have to operate with load restrictions at ARB on an 83 degree F design day on the existing 3,505' runway. The analysis also confirmed that this same airplane could operate without load restrictions in the same conditions on the proposed 4,300' runway.

As stated on the title page of the FAA AC, "For airport projects receiving federal funding, the use of this AC is mandatory". The runway length curves contained within were developed based on the FAA objective of providing a runway of sufficient length to allow the critical aircraft family to operate without weight restrictions. The proposed project would achieve the FAA objective and benefit the family grouping as a whole by allowing for the majority, if not all, of B-II small category aircraft to operate without load restrictions.

The determination of quantifiable impacts of load restrictions is beyond the scope of the user survey process, and such highly detailed information is typically not used in the determination of justification for runway extensions. The benefits or requirements to perform such a study are also not discussed anywhere in the FAA AC regarding runway length requirements.

39) **The third bullet implies that operational safety will be improved with a clear 34:1 approach. Currently the airport has LPV approaches with minimums of 300' and 1 mile. The ADO questions if a flatter approach is warranted in absence of reducing minimums as indicated in the March 4, 2010 e-mail correspondence. The discussion on the 34:1 approach should be re-evaluated and its need clearly identified. Currently the report does not seem to substantiate a need for a 34:1 approach if minimums are not anticipated to be lowered.**

Response: As previously stated, there is not a "need" for a 34:1 approach. Rather, shifting the runway 24 threshold to eliminate the ATCT line-of-sight concerns results in the provision of a clear 34:1 surface to the relocated threshold. Additional clarification regarding the 34:1 approach surface will be provided in the amended EA.

40) **Section 3 page 3-1. The report indicates that alternatives were developed to meet the goals of ARB. These goals are to improve safety and efficiency and serve current users. These goals do not appear to be consistent with those previously outlined in the bullet points of section 2.2 (purpose and need). This section should refer to the stated needs and evaluate the alternatives ability to meet those needs.**

Response: The introductory paragraph to section 3 was intended to summarize project purpose and need as a means of introducing the alternatives considered. While the objectives previously stated in the project Purpose and Need of section 2 are not stated verbatim here, we believe "improve safety and efficiency, and serve current users" is sufficient summary.

41) **Section 3.1.3 pages 3-3 and 3-4. There is discussion on extending the runway to the east and a listing of items impacted by pursuing this alternative. There is, however, no conclusion or statement that this option either should be, or was, eliminated. It can be inferred later in the report by the absence of this alternative that it was eliminated but the conclusion as to why it has been eliminated has not been stated.**

Response: The last sentence in section 3.1.3 should have stated that this alternative was dismissed and why. Specifically, it should have stated "this alternative was dismissed because it is not compatible with local plans and due to the extent of safety, transportation and wetland impacts from relocating State Road". This sentence will be added to the amended EA.

42) **When addressing the FAA's comments (included within this letter) associated with the stated needs for the project earlier in the report, the responses to these comments may influence the conclusions on why some of the alternatives carried**

forward have been eliminated. Specifically, if needs stated in section 2.2 are not further substantiated, or it is concluded that one or more of the needs do not exist, additional alternatives may need to be carried forward if they adequately address the needs for the project. The FAA will re-evaluate the conclusions of the alternatives section once the FAA's comments on the purpose and need section are addressed.

Response: Comment acknowledged.

43) Section 3.3 page 3-8. Based on the information presented in the draft EA, the FAA has not reached the same conclusion that alternatives 1 and 2 do not meet the stated needs for the project. An apparent evaluation parameter for alternative 2 included in section 3.3.3 discusses the tower line of sight. This evaluation matrix does not appear to be consistent with those goals stated in Section 3 on page 3-1. The previous comment on the apparent disconnect between the different sections of the report also applies to the specific alternative evaluation. The FAA recommends that the decision matrix for which alternatives were eliminated be clarified in the EA.

Response: See responses to comments 24 and 40. This comment appears related to the need for addressing the ATCT line-of-sight issue and the need for the shift of the Runway 24 threshold.

44) Table 3-1 page 3-8. The table appears to incorrectly dismiss alternative 1 because it does not meet purpose and need. The discussion in 3.3.2 does not support that conclusion. Additionally, there is reference to a future expansion of State Road. This appears to be the first reference to this issue. Is this a need for the State Road expansion project? In what time frame is the State Road expansion project expected to occur? Should there be expanded discussion on other regional planning projects in this EA so the public can better understand the different parameters that ARB is confined to or bound by?

Response: Alternative 1 was considered because it moves the approach south of the Stonebridge neighborhood. It would result in measurable adverse environmental impacts including wetland fill, stream impacts and tree clearing. The rational for dismissal of this alternative indicated in 3.3.2 is valid. We agree that it would meet the project purpose and need and a revised Table 3-1 will be included in the amended EA.

Any future widening of State Road, as recommended in the 2006 State Road Corridor Study, would be completely independent of the proposed airport project. We do not know when, or even if, the Washtenaw County Road Commission proposes to widen State Road. As previously stated, the justification for the proposed shift of the Runway 24 threshold is to resolve ATCT line-of-sight issues. The provision of additional room to widen State Road would be a secondary benefit of the shift, but it is not a driving reason for the shift.

Exhibit 20

the ann arbor chronicle
it's like being there

City Council Acts on Zoning, Airport, Streets

Also: Residents raise concerns over flooding, DTE "smart meters"

BY DAVE ASKINS APRIL 21, 2012 at 6 pm

Ann Arbor city council meeting (April 16, 2012): The most significant item on the council's agenda was the introduction of the city's proposed fiscal year 2013 budget by city administrator Steve Powers.

But Powers led off the presentation by explaining that Monday evening would not be a time for detailed discussion and questions about the budget. For details of that presentation, see Chronicle coverage: "Ann Arbor Council Gets Draft 2013 Budget."

WEMU's Andrew Cluley had questions about the budget for Ann Arbor city administrator Steve Powers after the April 16 council meeting. Image links to Cluley's report. (Photos by the writer.)

The budget presentation occurred Monday night because of a city charter requirement. It was Powers' first such presentation – as he was hired by the council last year, and started the job in September. The city council will have until May 21, its second meeting in May, to modify and adopt the budget.

In terms of the sheer number of agenda items, the topic of zoning and land use was a main focus of the meeting. The council unanimously rejected a proposed conditional rezoning of 1320 S. University to a higher density than its current D2 (downtown interface) designation. But winning unanimous approval was a site plan for a Tim Hortons on South State Street, near Ellsworth. The council also gave initial approval to AAA Michigan for a rezoning request involving a parcel on South Main, which the auto club would like to have designated as P (parking). A half dozen different rezoning requests for parcels that had recently been annexed into the city also received initial approval.

Prompting considerable discussion among councilmembers were four resolutions concerning an environmental study on a possible extension of a runway at the Ann Arbor municipal airport. The resolutions all passed, but the main grant funding went through on just a 7-4 vote. The city was being asked for an additional $1,125 in matching funds to wrap up the final stages of an environmental assessment being done by the Michigan Dept. of Transportation, which was already mostly completed two years ago.

Also related to transportation, the council authorized over $6 million in contracts related to street resurfacing projects. That included a second set of local streets (after having approved funding for the first set at its previous meeting) as well as the section of East Stadium Boulevard between Packard and Washtenaw. In connection with those infrastructure projects, the council also authorized contracts for materials testing.

In other action related to infrastructure, the council approved a $93,438 item for construction of unisex bathrooms in city hall – but not without questions about the scope of the overall municipal center renovation work.

On personnel-related items, the council gave final approval to legislation that incorporates provisions of the collectively bargained labor contracts with police command officers and firefighters into the city's set of ordinances on retirement and health care.

As a result of other council action on Monday night, Ann Arbor police officers will be able to arrest and charge "super drunk" drivers who have more than 0.17 blood alcohol content – because the council modified the city's ordinances to conform with recent changes in state law.

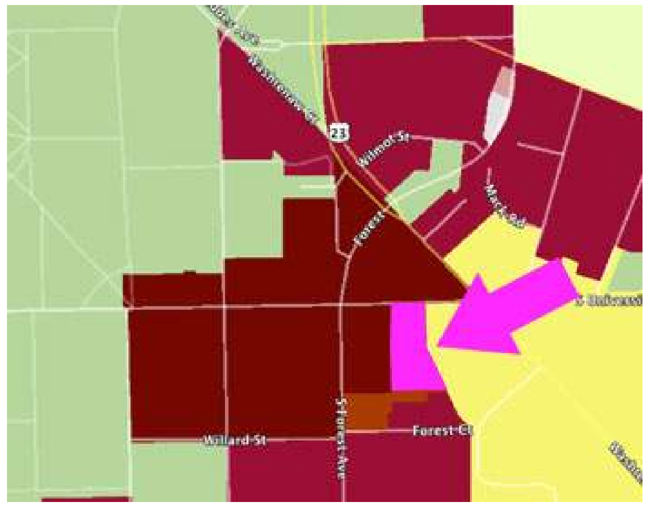
In other business, the council also authorized a contract with a new auditor, The Rehmann Group, set a hearing on a tax abatement for Sakti3, and imposed a temporary ban on digital billboards.

Highlights of public commentary included concerns about new DTE "smart meters" and localized flooding incidents in the city. The flooding was attributed by residents to the city's layering of new asphalt onto an adjacent street, and to the city's sanitary sewer disconnection program.

1320 S. University Rezoning

The council was asked to consider a request to conditionally rezone 1320 S. University – from D2 (downtown interface) to D1 (downtown core).

The request included setting conditions on the D1 designation, such as restrictions on height and floor area that are less than what's allowed in "unconditioned" D1. For example, the by-right height limit in D1 is 180 feet, but one condition the owner of the property – Philip Sotiroff – wanted to place on the property was a 145-foot height limit.



The magenta parcel and arrow indicate the 1320 S. University parcel proposed for conditional rezoning to a higher density use that's found in the dark brown (D1) areas to the west and north. The light brown area to the south and west is D2 (downtown interface). Light green is PL (public land). Yellow is R2B and dark purple is R4C – both residential zoning. (Image links to higher resolution image.)

That 145-foot limit, however, is more than twice the limit of the parcel's current D2 zoning, which allows buildings only as tall as 60 feet. Currently at the site – on the south side of South University, between Forest and Washtenaw avenues – is the three-story Park Plaza apartment building.

The site is adjacent to a D1 parcel to the east, where the Landmark apartment building is being constructed, at 601 S. Forest. But the 1320 S. University property also abuts lower-density residential zoning. Single-family homes are located to the south of the site, and a fraternity is located to the west.

The South University area was an intensely debated part of the A2D2 downtown rezoning initiative, which the city council finally ratified on Nov. 16, 2009 after more than two years of planning work. As part of that process, the city planning commission had initially recommended a zoning map that assigned D1 zoning to the 1320 S. University parcel. The city council subsequently drew the lines differently, which resulted in a D2 designation for the parcel, and sent the map back to the planning commission. The planning commission then revised some parts of its map, including the designation for 1320 S. University.

More recently, at its Feb. 7, 2012 meeting, planning commissioners voted unanimously not to recommend that 1320 S. University be rezoned from D2 to D1.

Council on S. University Rezoning: Public Hearing

Marc Gerstein introduced himself as a resident of Forest Court, and since 1982 the owner of a house that abuts the south boundary of a parking lot at the rear of 1320 S. University. He noted that any change in the zoning will affect him directly. He urged the council to follow the staff report and the unanimous recommendation of the city planning commission and to reject the request for conditional rezoning from D2 to D1.

He noted that the planning staff report finds that D2 was warranted for the parcel and was carefully considered by the city planning commission and the council. The staff had found there was no error in that decision. He noted there'd been no changes in the neighborhood since passage of A2D2 two years ago. To rezone the parcel now would strip away any buffer between the small residential houses and the 1320 S. University parcel. He concluded by asking the council to deny the petition for rezoning.

Council on S. University Rezoning: Council Deliberations

Tony Derezinski (Ward 2), who is the city council's representative to the city planning commission, described the location of the parcel proposed to be rezoned. Two high-rise buildings stand to the west at South University and South Forest – University Towers on the northwest corner and the currently under-construction Landmark Building (formerly called the 601 S. Forest). To the east stands a fraternity house. Derezinski noted the A2D2 zoning ordinances had been adopted after considerable debate. The planning commission had unanimously agreed with the recommendation of the staff that the parcel not be rezoned, he said.

Christopher Taylor (Ward 3) also concurred that the prior community conversation had been rigorous and extensive and warrants the council's respect.

Jane Lumm (Ward 2) added that she felt having a buffer in the form of D2 zoning makes a great deal of sense.

Outcome: The council unanimously rejected the proposed conditional rezoning of 1320 S. University.

The city council's vote was just its initial consideration of the request – a "first reading." A rezoning request, like any ordinance change, requires initial approval, followed by a public hearing and a final vote at a subsequent meeting. Often, councilmembers will advance an ordinance change to a second reading, if they have not settled on a position and are interested in hearing the sentiments that might be expressed at a public hearing. So the fact that the council rejected the proposal on first reading can be taken as a measure of the council's especially strong opposition to changing the zoning that was agreed on as part of the A2D2 process.

Tim Hortons Site Plan

On the April 16 agenda was a site plan for a new Tim Hortons restaurant at 3965 S. State St. The site plan had received a unanimous recommendation for approval by the Ann Arbor planning commission at its March 6, 2012 meeting. The site is located on the east side of the street, near the intersection of State and Ellsworth.

The plan calls for demolishing a vacant building on the 2.23-acre site where previous restaurants, including Enzo's and Gallagher's, were located. In its place, a one-story 1,953-square-foot restaurant with drive-thru facilities would be built on a 1.18-acre site divided from the current parcel. The building would face West Ellsworth and use an existing shared drive on South State, as well as a relocated drive onto West Ellsworth. An outdoor seating area is proposed on the east side of the building.

The property is zoned C3 (fringe commercial), which allows for construction of a drive-thru restaurant. The planning commission's recommendation of approval was contingent on two issues: (1) submission of a tree health evaluation form, and (2) approval of the parcel's land division, prior to the city issuing permits for construction of the new building.

Much of the discussion among planning commissioners at their meeting had focused on the proposed roundabout at State and Ellsworth. A spokesman for Tim Hortons said they'd found out about the roundabout plans late in the process, but were working to integrate their own plans to accommodate it. He indicated that if the company gets approval from the city, they hope to open in August. Construction for the roundabout is expected to begin in the spring of 2013, with completion in the fall of that year.

During council deliberations on April 16, Tony Derezinski (Ward 2), the city council's representative to the planning commission, made some brief remarks. He described it as a property that's been vacant for a couple of years. It would be a great improvement, he said. The planning commission went through ingress and egress issues. Derezinski said he felt it adds value and would be a good place to get coffee in the morning.

Sabra Briere (Ward 1) noted that the State Street corridor is currently undergoing a study. She wondered how this particular project fits into the ongoing discussions that the corridor study group has had. City planning manager Wendy Rampson told Briere that it doesn't really fit into ongoing discussions on the corridor, but it does remove a relatively blighted building on the site. The corridor study has not gotten as far as making land use recommendations yet, Rampson said.

Responding to a question from mayor John Hieftje, Rampson said that the plan is to begin construction in May. Tim Hortons is moving in a timely way, she said. A land division needs to be completed before they can start, she said. And the Tim Hortons team is coordinating with the Washtenaw County team that is planning the roundabout at Ellsworth and State. She figured in a couple of months, construction might start.

Outcome: The council voted unanimously to approve the Tim Hortons site plan.

AAA Request for Parking Zoning

Before the council for its consideration was initial approval to a proposal from AAA Michigan to rezone half of a parcel located at 1200 S. Main to P (parking). To take effect, the initial approval from the city council would need to be followed by a second and final approval following a public hearing at a subsequent meeting.

The rezoning to P (parking) is part of a two-parcel site plan proposal – for which the city planning commission provided a positive recommendation at its March 6, 2012 meeting. At that meeting, the commission took two votes on the 1200 S. Main parcel – the site plan and the rezoning proposal. And on both votes, the planning commission split 6-3. For the other, adjacent parcel at 1100 S. Main, the city planning commission voted unanimously to recommend the site plan for approval.

In front of the city council on April 16, however, was just the resolution to rezone a portion of the 1200 S. Main parcel to P (parking).

The two parcels, at 1100 and 1200 S. Main, are across from Michigan Stadium. An AAA branch built in the 1950s is located there. The owner wants to build a new branch on a different part of the site, tear down the existing building, and reconfigure parking spaces.

The two parcels are part of a 1.5-acre site containing four parcels owned by the auto club and all zoned O (office). Located on the 1200 S. Main parcel is the current one-story branch building with walk-out basement and 36 parking spaces, with exits onto South Main, Berkley and Potter.

The 1100 S. Main site is a surface parking lot, which has 72 spaces and exits onto both Potter and Keech. The owner is requesting to build a one-story, 5,443-square-foot new branch building on the northeast corner of that site, with parking for 21 spaces. A second phase of the project would include an eventual 2,230-square-foot addition to the south side of that building. There are six landmark trees on the site, and the plan would require removal of two that are located along South Main, near Keech. Other trees would be added elsewhere on the site.

After the new structure is completed, the old building at 1200 S. Main would be torn down and a 14-space parking lot would be put on that parcel. And to do that, the proposal asks that the northern 123 feet of that parcel – about half of the parcel – be rezoned from O (office) to P (parking), so that parking could become the principal use for that site. A site plan for that parcel is also required. The rezoning to P (parking) is what the city council considered on April 16.

The owner's overall plan called for a total of 35 spaces – a reduction from the current parking on the site, which was approved in the mid-1970s but no longer conforms with existing zoning. The 35 spaces would be four more spaces than the 31 maximum number permitted under the O (office) zoning, based on the new building's square footage in both phases. That's why the owner requested that a portion of the overall site be rezoned for parking – in the P (parking) district, there is no maximum.

AAA Request for Parking Zoning: Council Deliberations

City planning manager Wendy Rampson was asked to the podium to summarize the proposal, which she did. The current configuration has the AAA office sitting on the parcel to the south, with surface parking on the parcel to the north. She said the configuration was approved in the 1970s based on an interpretation that parking would be allowed on the northern parcel, based on the ownership by AAA of both parcels. The city does things differently now – if there's no other use on a parcel besides parking, then the city requires that it be zoned P (parking).

Rampson described what AAA wants to do as a "flip flop" – build a new branch office on the northern parcel and put parking on the south parcel. It's that south parcel that AAA wants rezoned. She noted that the city planning commission vote was 6-3 on rezoning. Staff also had some concerns about approving parking as a principle use, because that's something the city is trying to get away from. The plan has a lot of benefits with respect to stormwater detention, she said, and reduces the amount of impervious surface across the two sites, as well as the total amount of parking.

Tony Derezinski (Ward 2) said the site plan really did sell the proposal. The building that AAA is putting up is an improvement over the one that's currently there. The old building has a lot of mileage on it, he said. With its location across from the University of Michigan football stadium, the building would be noticed by a large number of visitors to Ann Arbor, he said.

Rampson added that it's a two-phase project. In the new building, AAA anticipates adding more services, so that's the rationale for wanting to have parking available on both parcels.

Carsten Hohnke (Ward 5) said he felt like the project is a step in a better direction, but not what the city would want if the project were starting from scratch. He wondered what AAA's plans would be if the council turned down the request to rezone. Rampson said she didn't know. Before AAA brought forward their proposal, however, they'd gone over ways to solve the parking issue without rezoning. One possibility would be to retrofit the existing building. They also considered different configurations that would reduce the amount of parking. But ultimately AAA did not want to pursue those, she said.

Mike Anglin (Ward 5) asked if there'd been given any consideration to moving the building further away from the sidewalk, and he wondered if AAA could be forced to comply with a greater setback requirement. Rampson reminded Anglin that the recent area, height and placement revisions had reduced the amount of setback required – which in this case allowed the building to be moved further way from the residential area to the west and closer to Main Street. Rampson also explained that the curbcuts to Main Street would be removed.

Stephen Kunselman (Ward 3) wanted to know what assurance the council would have that the old building will be torn down. Rampson explained that once it's zoned P (parking), the building couldn't be used for anything. And AAA is not intending to keep the building in place – the space is needed for parking.

Outcome: The council gave unanimous initial approval to the AAA Michigan rezoning request for 1200 S. Main.

Annexation Rezonings

The council was asked to consider initial approvals of six separate rezoning requests associated with annexation into the city of Ann Arbor from Scio Township. The zoning change in all cases is from the township to a residential category.

Five of the properties were annexed into the city on Oct. 3, 2011 – in connection with the expansion of a well-prohibition zone due to 1,4 dioxane groundwater contamination caused by the Pall Corp.'s Wagner Road facility, formerly owned by Gelman Sciences. Those five properties are: 305 Pinewood St.; 3225 Dexter Rd.; 427 Barber Ave.; 545 Allison Dr.; and 3249 Dexter Rd.

Annexation into the city allows the properties to connect to city of Ann Arbor water services. Pall has paid all petition filing fees as well as the connection and improvement charges for water and sanitary sewer service that are related to the annexations. The zoning for which the city council gave initial approval is for R1C (residential). [Google map of well prohibition zones and property locations] [.jpg of map with well prohibition zones and property locations]

A sixth parcel for which the council gave initial rezoning approval – also due to annexation, but not related to the well-prohibition zone – is located at 1575 Alexandra Blvd. The parcel was given initial approval to be rezoned from the township to R1A (residential) zoning.

As ordinance changes, all rezoning requests require an initial approval from the city council, followed by a public hearing and a final approval at a subsequent meeting.

Sabra Briere (Ward 1) offered the only council comment on any of the annexation-related rezoning requests, noting that they all went from township zoning to single-family residential.

Outcome: The council unanimously approved all the annexation-related rezoning requests. The requests need to come back for a second and final approval by the council, after a public hearing.

Ann Arbor Airport Study

On April 16 the council considered four different resolutions in connection with Ann Arbor's municipal airport, three of them connected to the completion of an environmental assessment of a proposed 800-foot lengthening of the airport runway.

The city council had initially authorized funding for the assessment project at its Feb. 2, 2009 meeting. The assessment began on May 4, 2009. The process appeared to culminate in a public hearing in April 2010. [See Chronicle coverage: "Ann Arbor Airport Study Gets Public Hearing."] In the interim, city councilmembers have removed the runway extension from the city's capital improvements plan (CIP) each year they've been asked to give the CIP its annual approval.

However, when the Federal Aviation Administration responded to the draft report, that prompted communication between the city of Ann Arbor and the FAA. And that back-and-forth has resulted in FAA requests for more work, which is meant to wrap up the environmental assessment (EA). From the staff memo accompanying one of the resolutions:

The FAA's response was received nearly a year later (September, 2011). The remaining work on the EA includes modifications based on the FAA comments, coding public and agency comments and responses for the final EA document, preparation of the Errata and FONSI for submission to MDOT-Aero. There is about 2-3 months of work remaining to complete the EA.

One of the resolutions authorizes $800 for an additional map to be prepared by URS Corp., one of two consultants that the Michigan Dept. of Transportation is using for the project. The amount is covered by MDOT's project contingency budget. This item is not specifically related to the environmental assessment.

A separate resolution authorized $12,000 of additional consulting work, also with URS. A third resolution authorized an additional $26,552 worth of consulting work from SmithGroupJJR. The additional work by URS and SmithGroupJJR is being covered by a $45,000 grant program, which consists of $42,750 in federal funds, $1,125 in state funds and $1,125 in airport matching funds (the city's portion.) Authorization of the grant program was the fourth airport-related item on the agenda.

Ann Arbor Airport Study: Public Comment

During public comment, **James Vincze** introduced himself as a member and vice chair of the airport advisory committee. He urged the council to complete the airport runway extension study. It's important to get the process completed, he said. Significant time and resources have already been spent and the public has been involved. Matt Kulhanek is a good airport manager, he said. Voting to complete the study doesn't mean the council favors runway extension, he said. Rather, it means the council wants to get the facts out and have a complete study and analysis.

Ann Arbor Airport Study: Council Deliberations

Airport manager Matt Kulhanek was asked to the podium to answer questions. Jane Lumm (Ward 2) began by asking why the city is continuing to spend money to study the runway extension, when the council had consciously removed the extension from the city's capital improvements plan. She had a hard time reconciling that, even though the amounts of money weren't actually all that large.

Kulhanek pointed out that the first airport-related item on the agenda – the $800 for the map preparation – was not related to the environmental assessment.

So mayor John Hieftje then asked the council to vote on that item. And that vote was unanimous in favor.

Kulhanek noted that the council's direction had been to get the facts on the proposed runway extension and that direction had come on two occasions, with votes to fund the environmental assessment. He said the council's subsequent action to remove the runway extension from the capital improvements plan was based on a concern that by including it in the capital projects budget, it reflected a de facto support of actually doing the project. But at no time has the staff received direction to pull back from completing the environmental assessment. Kulhanek indicated that another grant agreement would be coming to the council later, after the one they were considering that evening.

Jane Lumm (Ward 2) talks to Kathe Wunderlich (back to camera)

Mike Anglin (Ward 5) asked for clarification of the unexpected review by the FAA technical committee to which the staff memo had referred. Kulhanek explained that when the document was first entered into the system, the city was not expecting further FAA review. But two weeks ago, he said, the city received notification from FFA technical operations, a branch within the FAA, indicating that branch would need to sign off on it. The reason that technical operations would need to review it was due to two sets of navigational aids that would be relocated if the runway project moves forward. The document had already been given an 11-month review by the district office of the before the council meeting. Wunderlich has worked as part of a citizens group opposing the runway extension.

FAA, and the conclusion had initially been that the technical operations division didn't need to review it. At that point, the city had the understanding the FAA was finished. That changed in the last two weeks, when city staff found out that FAA technical operations would need to review it.

Stephen Kunselman (Ward 3) asked if the resolution that night was specifically for the relocation of navigational aids. No, replied Kulhanek. A resolution to approve another grant for that would come some time in the future. The grant before the council that night was to finish up the documentation of the environmental assessment and get it in a final format to submit to the FAA for review. What would come back to the council later is a reimbursement agreement for the work the FAA will have done to review the documentation.

Sabra Briere (Ward 1) briefed Stephen Kunselman (Ward 3) before the start of the meeting. They both voted against the grant funding for the environmental assessment of the airport runway extension.

Kunselman said he was confused why there'd be the need for another reimbursement agreement. Kulhanek reviewed the purpose of that night's grant agreement.

Sabra Briere (Ward 1) was up next to question Kulhanek and she apologized for putting him on the spot. His reply indicated he'd anticipated lots of questions: "That's okay, I didn't think I was going to get a pass tonight!"

In 2009, Briere said, the council had approved two grants and in 2010 the council had approved an additional grant. At the time, she said, she thought that the EA document was in draft form and almost complete. Kulhanek indicated that was not the case. The grant funding in 2009 had kicked off the project, he said. When the 2009 grants were approved, the city had also approved contracts with the two engineering firms.

Briere summarized what the council was considering as funding additional work by the engineering firms to get the EA document into shape to be submitted to the FAA. Kulhanek indicated that was basically right. The work the two firms would do would in essence finalize the document for everything except the FAA technical operations review. That review will have a specific scope – just the impact on the navigational aids.

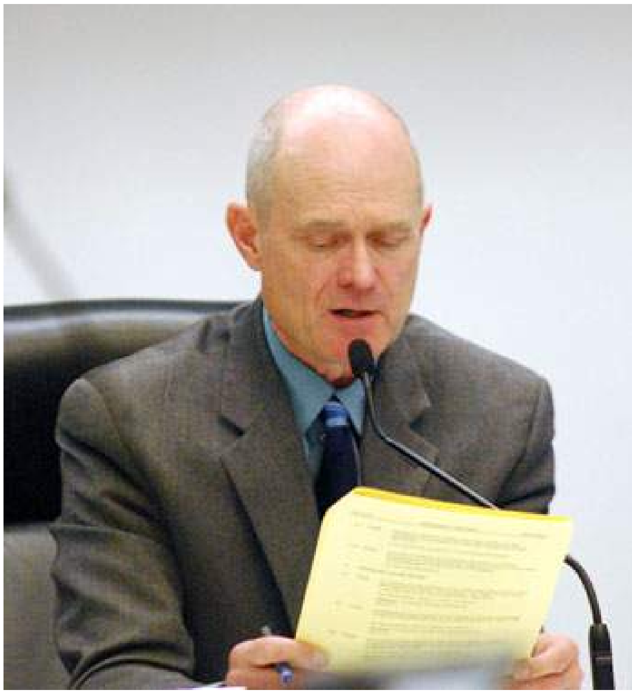
Responding to a question from Briere, Kulhanek explained that the EA would cover more than just a discussion of navigational aids. It would include economic impacts, physical impacts, noise impacts, and wetlands impacts. There's a whole variety of things that are included. It's a broad document that includes public comment, as well as input from various agencies like the county road commission, county water resources commissioner and the like.

Briere said she had trouble understanding why an environmental assessment would take four years.

Hieftje asked if Kulhanek saw a benefit to the city and users of the airport, if the council does not want to go ahead with the runway extension, once the process is completed. Kulhanek told the mayor that he felt the biggest benefit would be to finishing what they've started back in 2009. The council would be able to make a decision based on an actual study of what the impacts are – not what our gut feels or our heart feels. A decision could be based on actual data and feedback from the public and various agencies and everyone involved. Kulhanek said there's already been a lot of time and money invested in getting to this point in the project, and he thought it's important to follow through to have solid information. If the council chooses not to go forward on the runway project, it can make that choice.

Hieftje started adding up the money in the request. He asked Kulhanek how much more money would need to be spent – local as well as other money – to complete the project. Kulhanek said the first three grant agreements totaled $309,000.

The city's share of that had been $7,725. From a local perspective, he said, that's a minor cost. The



Mayor John Hieftje opposed the grant funding for completion of the environmental assessment for an extension of the Ann Arbor municipal airport.

grant agreement before the council that night was for $45,000 with a local share of $1,125. The next and last grant agreement will be around $30,000. The total for the EA would be around $385,000 with a local share of less than $10,000, Kulhanek said.

Kulhanek estimated that it would take the consultants another two months to do the additional work. He thought that three to six months from now, the last grant agreement would be back in front of the council for approval. Assuming three to four months for review, Kulhanek estimate that it would be early 2013 before the process was complete.

Hieftje asked again if there was some benefit to the environmental study, beyond knowing the impact of the runway extension. Kulhanek said it's good information. Knowing the noise levels is useful. Knowing about bird species is also useful, he said. There are some mowing restrictions to protect their habitats.

Kunselman contended that everything Kulhanek had just mentioned as beneficial had already been done, so what the council was being asked to do was approve more money for consultants to wrap things up. He said the city continues to throw money at a project at the end. He said he'd vote no on everything. It's taxpayer dollars, whether it's local or federal. He said his constituents don't want the runway extension and he'd vote no on that, too. The consultants can wrap it up without additional money, he said. He said he was done throwing money at this kind of thing.

Lumm said she'd been struggling with this. She allowed that it was a very small city share. Ultimately though, what the council would be doing is spending money on something that won't move forward. She reiterated the fact that the council had removed the project from the CIP, which she translated into a decision that the council wouldn't move forward. Kulhanek ventured that the council might be "wowed" by the EA and perhaps be open to the possibility of extending the runway.

Outcome: The main resolution, on the $45,000 grant, was approved on a 7-4 vote. Voting for a grant contract with the Michigan Dept. of Transportation were Sandi Smith (Ward 1), Tony Derezinski (Ward 2), Christopher Taylor (Ward 3), Margie Teall (Ward 4), Marcia Higgins (Ward 4), Carsten Hohnke (Ward 5) and Mike Anglin (Ward 5). Opposing it were Sabra Briere (Ward 1), Jane Lumm (Ward 2), Stephen Kunselman (Ward 3) and mayor John Hieftje. Both contracts with the consultants were opposed by Lumm and Kunselman. Hieftje joined them in opposing the contract with SmithGroupJJR.

Street Repair

The council was asked to consider two major contracts involving street resurfacing and reconstruction. One was a second large contract for street resurfacing work this season – $4,054,599 with Barrett Paving Materials Inc. At its previous meeting on April 2, 2012, the council had authorized a $3.6 million contract with Barrett for an initial set of streets to be resurfaced. The project includes a $405,000 contingency.

The second set of streets includes portions of the following: South Seventh Street, Mt. Pleasant Avenue, Park Drive, Mt. Vernon Avenue, Manhattan Drive, Meadowbrook Avenue, Martha Avenue, Palomar Drive, Catalina Avenue, Eton Court, South Forest Avenue, Vinewood Blvd., Dorset Road, Berkshire Road, Woodside Road, Londonderry Road, Tremmel Avenue, Page Court, Pine Valley Court, Esch Avenue, and Esch Court.

Also at the April 16 meeting, in connection with the regular street resurfacing program, the council considered a $143,455 contract with a different company, CTI and Associates Inc. (CTI), for construction materials testing services. The materials to be tested include oils, aggregates, asphalt, and concrete. Funds for the street resurfacing projects are drawn from the city's street repair tax, which voters agreed to renew in November 2011 for another five years, through 2016.

Another road construction project on the agenda was a contract with Dan's Excavating Inc. for $2,314,951 for replacement of two old water mains and resurfacing of the East Stadium Boulevard from Washtenaw Avenue to Packard Street. The total project is estimated to cost $3,600,000. Of that amount, $1,400,000 will come from the water fund capital budget and $2,200,000 will come from millage approved capital budget.

The East Stadium project will maintain the existing five lanes of vehicular traffic, and new bike lanes will be added on both sides of the street.

Also on the agenda was a materials testing contract for the East Stadium Boulevard project – $50,185 with Inspection Services Company Inc.

The only substantive discussion on the four items was on the materials testing. Mike Anglin (Ward 5) asked why the materials testing was being done. City project engineer Igor Kotlyar explained that such testing is always done for such projects. It's a standard testing procedure, he said. Some of it involves making sure the proper materials are delivered to the site. But it also involves making sure that the materials are properly deployed as the project work is done.

For example, when a water main is backfilled with sand, it's tested to make sure that the sand is compacted to the proper density. Gravel that's put into the road bed is also tested for property compaction, Kotlyar explained. Homayoon Pirooz, head of project management for the city, responded to a question from Anglin by explaining that the city itself is not certified to perform that kind of testing, and does not have the certified equipment to do that. He indicated that it's essentially a specialty.

Outcome: The council unanimously approved the four resolutions involved with street resurfacing and reconstruction work.

Fire, Police Retirement/Health Changes

On the April 16 agenda was a resolution for final approval of changes to the employee retirement system to accommodate recent changes to the collective bargaining agreement with the city's police command officers union and firefighters union. Also before the council was final approval to revisions of the retirement health care benefits to reflect changes to those collectively bargained agreements.

Changes to the retirement system include: (1) increasing the pension contribution of command officer members to 6% from 5%; (2) implementing a pick-up feature as permitted by the Internal Revenue Code for the pension contributions of firefighters and command officers, converting their 6% pre-tax contribution to a 6% post-tax contribution; (3) increasing the vesting and final average compensation requirements for firefighters hired after July 1, 2012; and (4) implementing a federal provision that allows eligible retired public safety officers to pay qualified health insurance premiums directly from their pensions.

The change to the retiree health care system stipulates that new hires after July 1, 2012 will be eligible for an access-only health care plan at the time of their retirement, instead of a city-paid retiree health care plan.

Fire, Police Retirement/Health Changes: Public Hearings

On the retirement changes for police command officers and fire personnel, **Thomas Partridge** questioned whether the public had been fully informed on the substance of the change. He felt that representatives of the police department and the union representatives involved in the contract negotiations should have been present to explain their side of the issue.

Edward Vielmetti flipped through the pages of the ordinance revision in the three-ring binder that holds the council agenda, and counted out the number of pages that had been red-lined as he flipped through them. When he got to 16, he did not continue counting, but noted that more than 16 pages of the ordinance have been amended. He stated that he had no idea how councilmembers could evaluate whether this is a good idea or a bad idea. He said that he himself (if he were a member of council) wouldn't know what to do with a proposal like that. He hoped the city was making a wise choice.

On the retiree health care benefits, Partridge complained that Gov. Rick Snyder and former city administrator Roger Fraser [who now works for the state as an assistant state treasurer] are attempting to erode benefits to public employees, including those in high-risk jobs.

Fire, Police Retirement/Health Changes: Council Deliberations

On the retirement changes, Sabra Briere (Ward 1) said she believed the primary changes reflect the bargained-for benefits from recent union settlements. The city is taking advantage of IRS rules, she said.

On the retiree health care changes, Jane Lumm (Ward 2) said that the changes to the ordinance were consistent with the changes to the access-only health plan that had been adopted by the command officers and firefighters.

Outcome: The council unanimously approved the ordinance changes affecting retirement and health care benefits for police command officers and firefighters.

0.17 BAC as Separate Offense

The council considered final approval to a change in the city's traffic ordinance to adopt a provision of the Michigan Vehicle Code – which establishes driving with a blood alcohol content (BAC) of more than 0.17 as a separate offense from operating under the influence. The council had given its initial approval to the ordinance change on April 2.

The Michigan legislature had previously changed the MVC, which Ann Arbor has adopted, to include the separate charge for the very high BAC of 0.17. However, the legislature did not at that time change the Home Rule Cities Act to allow cities to impose the greater penalty of 180 days in jail and/or $700 fine that comes with the BAC 0.17 charge. But in February 2012, the legislature amended the Home Rule Cities Act to allow for that penalty. Ann Arbor is making the change to its local ordinance in order to be able to charge drivers with the 0.17 offense.

Records from January 2010 through February 2012 provided to The Chronicle by CLEMIS (Courts and Law Enforcement Management Information System) show three instances of 0.17 offenses – which could not at the time be charged as a separate offense. The CLEMIS records for the same time period also show three reports for the moderately higher BAC level of .08, which could already be charged separately from operating under the influence. [.jpg of bar graph of OWI offenses]

As a change to the city's ordinances, the change required a second vote and a public hearing (which is separate from the general public commentary held at the start of the meeting.)

0.17 BAC: Public Hearing

Edward Vielmetti led off the hearing by asking where a copy of the proposed changes to the ordinance might be found. Mayor John Hieftje told him it was available online or in a large three-ring binder near the podium – which **Thomas Partridge** had been perusing. Vielmetti then reviewed the ordinance change, while Partridge held forth.

Partridge began by complaining about Hieftje's standard boilerplate recitation of the rules for public hearings, which include a provision that speakers confine their remarks to the topic of the public hearing. Partridge construes the rule as a way of inappropriately limiting free speech.

On the substance of the ordinance change, Partridge said it would have been better to attach a resolution that would stop people who are high on alcohol and drugs from driving or causing disruptive behavior in the city of Ann Arbor. He called for a parallel amendment to go forward, that would encourage and require all retailers and bars serving alcohol and supermarkets selling alcohol, to note the names and identity of people who purchase alcohol. He also called for bars to refuse service to patrons who have visited other bars before arriving, who are clearly under the influence of alcohol, and who intend to drive.

Based on his review – while Partridge was speaking – of the ordinance changes, Vielmetti said it appeared to him that the ordinance changes would increase the penalties for driving "super drunk." He pointed out that there are a number of students in Ann Arbor who don't just drive relatively drunk, but who also walk relatively drunk. And they may be so drunk that they pose a danger to others while driving, but also to themselves due to alcohol poisoning.

From reading the student press, Vielmetti said it's his understanding that there's a concern about prosecution for those who help their classmates who are trying to obtain treatment for alcohol poisoning – because they might be slapped with a "minor in possession" citation themselves. He cautioned the council not to overly hastily increase the penalties for drunken behavior, without also addressing the needs of those who need to receive treatment. It would be unfortunate to put yourself in a situation where you thought you were making an improvement, and then create some unintended consequences, he said – people driving themselves home, because they weren't ready to help their friends walk themselves home.

0.17 BAC: Council Deliberations

Sabra Briere (Ward 1) alluded to Vielmetti's comments during the public hearing, by saying she liked the idea of finding a solution for adolescents who are at risk of underage drinking violations. She felt the decision was straightforward. People who have 0.17 BAC should pay a heavier penalty, she said.

Stephen Kunselman (Ward 3) asked if the state law on 0.17 BAC was already in effect for people on University of Michigan property. Assistant city attorney Abigail Elias responded to the question by saying that for the "super drunk" provisions, which are for driving or operating a vehicle, the change to the ordinance simply brings it into conformity with the state law. If anyone were driving where the city did not have jurisdiction, she said, state law would apply.

Kunselman followed up by asking if UM's department of public safety already has the authority to enforce the 0.17 BAC provisions on the Ann Arbor city streets. Elias told Kunselman that Ann Arbor police officers would enforce the law on city streets. She said she did not know if UM DPS officers were enforcing state law on city streets. That's a question she could not answer, she said. Mayor John Hieftje said his understanding was that UM DPS officers have the ability to enforce laws on Ann Arbor city streets, but it's unusual for them to do so. He stated that he'd be happy to see UM DPS join in helping out on the "party patrol" that the Ann Arbor police department uses to police student neighborhoods on evenings when parties are frequently held.

Outcome: The council unanimously approved the 0.17 BAC ordinance change.

Selection of Auditor

The council was asked to consider a five-year contract for independent auditing work with The Rehmann Group – based on its $344,500 bid. The contract allows for two one-year extensions.

Margie Teall (Ward 4) chairs the council's audit committee.

Abraham & Gaffney, the firm that the city has used for the last few years, also bid on the work. The Abraham & Gaffney bid came in at $387,500. Two other firms also bid for the city of Ann Arbor auditing work: Andrews, Hooper, Pavlik PLLC ($340,500); and Doeren Mayhew ($361,300).

Andrews, Hooper, Pavlik's was the low bid, but the selection was not made purely on price. The amount of the bid counted for 30 points out of a possible 100. The other two categories were "expertise and experience" (40 points) and "auditing approach" (30 points). Rehmann and Abraham & Gaffney both scored the maximum 70 on the categories other than price. The memo accompanying the resolution indicates that the choice was also based on "a desire to periodically change service providers." [.pdf of scoring metric and comments]

For Rehmann, then, the fact that it was *not* the incumbent firm was an advantage for the city auditing contract award. Last year, when it competed for the Ann Arbor Transportation Authority's auditing contract, Rehmann had found its incumbent status to be a *disadvantage*. Because of the auditor rotation policy the AATA board had adopted on June 16, 2011, Rehmann was not eligible for selection when the AATA board opted to award the contract to Plante & Moran on Sept. 15, 2011.

Selection of Auditor: Council Deliberations

Margie Teall (Ward 4) introduced the resolution as chair of the audit committee, indicating that she was pleased that the audit committee had been asked to be a part of the selection and evaluation process. The audit committee had been pleased with the representative from Rehmann who had interviewed with the committee.

Jane Lumm (Ward 2) said she supported the selection of Rehmann, saying that it was considered best practice to rotate auditors and that Rehmann is well respected. She asked about the notation in the evaluation of proposals that indicated Rehmann projected using 200 hours less than Abraham & Gaffney. She asked if the city is comfortable with that.

Sandi Smith (Ward 1), who also serves on the audit committee, noted that the auditor's contract is a multi-year contract. The firm will need fewer hours as they get more familiar with the city's auditing project over time.

Outcome: The council unanimously approved the selection of The Rehmann Group as the city's auditor.

Hearing on Sakti3 Tax Abatement

On the agenda was a resolution to set a public hearing for May 7 regarding a tax abatement for

Sakti3 – an Ann Arbor-based battery technology spinoff from the University of Michigan. Sakti3 is led by UM professor Ann Marie Sastry.

According to the staff memo accompanying the resolution, Sakti3 is requesting an abatement on $151,433 of real property improvements and $1,374,861 of new personal property. If approved, it would reduce Sakti3 Inc.'s annual tax bill by $23,200 for each of three years in the recommended abatement period. The new building improvements and personal property investments would generate about $29,500 in property taxes for each year during the abatement period.

Previously, the council voted on March 21, 2011 to set a public hearing on the establishment of the industrial development district under which Sakti3 is applying for an abatement. And on April 4, 2011, the city council voted to establish the district.

Outcome: Without comment, the council unanimously approved setting a May 7 public hearing on a tax abatement for Sakti3.

Digital Billboards

The council was asked to consider a 180-day moratorium on two items: (1) city staff consideration of applications to erect digital billboards; and (2) the erection of digital billboards.

Coming under the temporary moratoria are "billboards commonly referred to as 'electronic message centers,' 'electronic message boards,' 'changeable electronic variable message signs,' or any billboard containing LEDs, LCDs, plasma displays, or any similar technology to project an illuminated image that can be caused to move or change, or to appear to move or change, by a method other than physically removing and replacing the sign or its components, including by digital or electronic input."

The resolution acknowledged that such signs are already prohibited by the city's sign ordinance. From that ordinance, the list of prohibited signs include those that "…incorporate in any manner or are illuminated by any flashing or moving lights other than for conveyance of noncommercial information which requires periodic change."

The resolution was added late to the agenda, after printed copies of the agenda were made for the council chamber audience. Based on the time stamp on the online agenda, the item appears to have been added at 6:48 p.m. – for the council meeting scheduled to start at 7 p.m. The item was sponsored by mayor John Hieftje.

Sabra Briere (Ward 1) said she was confident there are some places for digital billboards in our lives, but she did not want to see them on crowded downtown Ann Arbor streets. Imposing a temporary moratorium on whether to allow them in the city limits made sense to her, she said.

Mike Anglin (Ward 5) said that many of the billboards in the city had 30-35 year leases on them, and it becomes complex to get them removed. He said that Adams Outdoor Advertising had been asking to "do trades" for many years. As issues for the public, Anglin identified distractibility while driving and "virtual vision pollution." He gave the corner of Madison and Main, late at night, as an example. It looks like you're coming into an entertainment area, he said, like vaudeville or something. He called for a community discussion about whether to have digital billboards. Do they bring value? he asked. He didn't want to make the decision piecemeal.

Outcome: The council unanimously approved the temporary 180-day moratorium on digital billboards.

Personal Computer Replacement

The council had on its agenda a $450,000 purchase order with Sehi Computer Products to cover the replacement of personal computers over the next two years.

The project budget includes the purchase of a minimum of 305 desktops and 195 laptops. Funding for replacement of the city's computers comes from the information technology services unit.

Sabra Briere (Ward 1) asked for an explanation of the city's replacement policy. Paul Fulton, the city's IT service delivery manager, described how the replacement cycle for desktop machines and special-purpose laptops is five years. The replacement cycle for general purpose laptops is three years. About four years ago, he said, the city did a general refresh, and those machines are now coming due for replacement – a total of about 500 machines.

Outcome: The $450,000 purchase order with Sehi Computer Products was unanimously approved.

Biosolids Contract

The council considered a contract with BioTech Agronomics Inc. to spread biosolids from the wastewater treatment plant on agricultural fields – during April to December. The rest of the year, the material gets landfilled. The contract pays about $0.0321 per gallon, which works out to approximately $514,000 per year.

Paul Fulton (right, foreground) is typically on hand before the council meetings start, to handle any computer issues councilmembers might have. On April 16, he was called to the podium during the meeting to explain the computer replacement cycle.

Stephen Kunselman (Ward 3) wanted to know where the material was going. Ed Sajewski, contract/project services manager for the wastewater treatment plant, explained that it would be spread on farm fields in the outlying area. He described the nutritive benefit – carbon, nitrogen, phosphorus – of applying the material to fields, as opposed to just landfilling it. Kunselman wondered if there were testing procedures to make sure no heavy metals were in the material. Yes, replied Sajewski, the city has a lab to do that testing, and it's required to be done through the permit the city has with the U.S. Environmental Protection Agency.

Outcome: The council unanimously approved the $514,000 contract for spreading of biosolids.

Mowing Contracts

The city council considered three contracts for mowing different city-owned properties – traffic islands, areas of the wastewater treatment plant, and neighborhood athletic fields: (1) Green-Vision Lawn & Landscaping ($105,336 for 3 years); (2) A2 Outdoors Creations ($43,275 for 3 years); and (3) KBK Landscaping for mowing and trimming services at neighborhood athletic fields and five city locations in the amount of $17,190/year ($51,570 for 3 years).

Sabra Briere (Ward 1) said that people who drive into the city would have a right to complain if the city didn't maintain the traffic islands. Logistically, she described it as a challenge to get the mower out to the locations and to then mow just five square yards.

Stephen Kunselman (Ward 3) asked about the four parks that are a part of the contract – which parks? Matt Warba, acting field operations manager, told Kunselman the four are: Miller Nature Area, Forsythe, Kempf House and 875 S. Maple. Warba confirmed what Briere had said about the logistical challenge of mowing the areas covered in the contracts. He said there are 184 traffic islands. The city's strength is mowing large areas of grass, not the small intricate areas like traffic islands or the areas around Kempf House, a museum located on South Division.

Outcome: The council voted unanimously to approve the mowing contracts.

City Hall Restrooms

Pulled out of the consent agenda by Jane Lumm (Ward 2) for separate consideration was a $93,438 contract with LC Construction LLC. The project involves the construction of five unisex restrooms, on floors 2-6, in the old elevator tower of city hall.

Lumm was dissatisfied with the answer she'd received from staff before the meeting to a question about why the bathrooms had not been constructed as part of the overall municipal center renovation project.

She characterized the response she'd received as essentially, "We ran out of money." She wanted all the costs for such projects captured in one place.

Otherwise, it's hard to understand which costs are related to city hall renovation and which are not, she said.

Outcome: The council unanimously approved the restroom construction contract.

Before the council meeting, Jane Lumm (Ward 2) talked with city administrator Steve Powers (left).

Placid Way Park Improvements

Pulled out of the consent agenda by Sabra Briere (Ward 1) for separate consideration was a $79,980 contract with Michigan Recreational Construction Inc. for improvements to Placid Way Park. The contract – which involves installing new play equipment as well as park furniture and landscaping – had been recommended for approval by the city's park advisory commission at their March 20, 2012 meeting. The 1.32-acre neighborhood park is located on the city's north side near the larger Dhu Varren Woods Nature Area and Foxfire South Park.

In her brief remarks, Briere described Placid Way as an unusual park that runs between neighborhoods. It's heavily-used by a neighborhood that has many children, she said. And it's a pathway from one neighborhood to another. She was happy see the upgrades happening. Mike Anglin (Ward 5) who serves as one of two city council ex officio non-voting appointees to the park advisory commission, noted the discussion that PAC had had on the park.

Outcome: The council unanimously approved the Placid Way Park renovation contract.

Technical Amendment to Retirement System

Before the council for its final consideration were some amendments to the city ordinance that governs the retirement system. The first change explicitly describes the process that's already used to establish the interest rate in crediting participant contribution accounts. The second change corrects a language error introduced with an ordinance revision made last year, which misstates the methodology for calculating a participant's early retirement benefit. The staff memo accompanying the council resolution indicates that the rates have been calculated correctly, despite the language error.

During the public hearing on the amendments, **Edward Vielmetti** introduced himself as a graduate of the University of Michigan's economics department. He said he didn't know very much about retirement planning. But he said he did know that projections for future returns are notoriously unreliable. In the past, retirement plans that made naive assumptions about future returns have had catastrophic surprises attached to them. He said he could speak to that from some of his own investments over the last 20 years.

Even portfolios that appear to be diversified usually are not, Vielmetti said. He urged the council to do something other than the simplest straight-line projection of future interest rates to project the range of possible outcomes – because a very good year or very bad year early in the cycle can make an enormous difference. Retirement planning is a serious business, he said, and he hoped the city is not taking an oversimplified approach.

Deliberations by the council included brief remarks from Jane Lumm (Ward 2), who characterized the amendments as technical changes that had been requested by the city attorney's office. It's not a change to the actual retirement plan, but rather a cleanup of some language, she said.

Outcome: The council unanimously approved the technical changes to the retirement ordinance.

Communications and Comment

Every city council agenda contains multiple slots for city councilmembers and the city administrator to give updates or make announcements about issues that are coming before the city council. And every meeting typically includes public commentary on subjects not necessarily on the agenda.

Comm/Comm: Greenbelt

Carsten Hohnke (Ward 5) gave an update on the most recent greenbelt advisory commission – as the city council appointee to that body. He briefed his council colleagues on the mid-year financial report the group had received at its last meeting – there's about $6 million left in the millage fund for greenbelt acquisitions, and $4.5 million that's designated for park acquisitions. [For a more detailed look at the April 5, 2012 GAC meeting, see Chronicle coverage: "Greenbelt Commission Briefed on Food Hub," which includes details of the mid-year financial report.] Hohnke also highlighted a deal that the Southeast Michigan Land Conservancy had closed on 100 acres along Prospect Road, a large portion of which is open to the public. The deal was done in partnership with the Ann Arbor greenbelt program. [For coverage, see "Superior Greenway Deal Adds 100 Acres."]

Comm/Comm: Parks Millage

Christopher Taylor (Ward 3) – in his capacity as one of two city council ex officio non-voting appointees to the city park advisory commission – reminded his colleagues of the remaining public outreach activity the city is doing on the parks maintenance and capital improvements millage renewal. [For coverage of the millage proposal, which the city council will likely put on the November 2012 ballot, see "Park Commission Briefed on Millage Renewal."] A public meeting on the renewal of the tax will be held on April 23 from 6:30-7:30 p.m. at Leslie Science and Nature Center. And the final meeting will be April 26 at the Ann Arbor District Library Traverwood branch, Taylor said.

Comm/Comm: UM Wall Street Parking

Sabra Briere (Ward 1) reported that earlier in the day, Jim Kosteva –University of Michigan director of community relations – had informed members of the Ann Arbor city council that UM's board of regents would be voting on April 19 on a proposal to build a 700-space parking structure, to be located between Wall Street and Maiden Lane. [As expected, UM regents approved the project.]

By way of background, the university announced on Feb. 10, 2012 that it was withdrawing from a partnership with the city to build additional parking at the same site where the city hopes to build a transit station – just south of Fuller Road and north of East Medical Center Drive. The Fuller Road site, as a location for additional university parking, had been an alternative to constructing additional parking on Wall Street – which the UM was on course to build up until 2009. The news Briere was reporting, then, reflects the UM's decision to revert to a previous course.

Since before she was first elected [in 2007], Briere said, other members of the city council, the mayor, and other residents had tried to convince regents that while additional parking might be necessary, it should be considered for a satellite location, not a residential street. She said some folks look at the barren parking lot that forms the block between Maiden Lane and Wall Street and say, "Well, who'd want to live there, anyway? Go ahead, shove in a parking structure."

Briere said she'd rather have seen a much more serious effort on the part of UM to improve mass transit. She wanted to encourage the university to develop more aggressive carpooling and alternative transportation options for staff. She wanted to see the number of people reduced who feel that they need to be able to get into their car without walking or waiting. She wanted better consideration of the infrastructure and the environmental impact that the parking structure would have on the community.

For those who think that no one will care and that it's all a wasteland, she asked them to remember, "It's the university that created that wasteland, and the university that wants to make it increasingly inhospitable to the residents who live [there]." She asked the regents of the University of Michigan to remember that good neighbors work together. They could just as easily build parking structures on the north campus or the athletic campus, creating options for those who want to park there, and reducing the number of employees who choose to park and not ride [a play on the term for lots designed for people to arrive, park, then take public transportation to their final destination – called park-and-ride lots.]

Comm/Comm: Agenda Item Titles

Sabra Briere (Ward 1) noted that the length of the titles to agenda items had begun to creep longer and they were not getting clearer as a result. She asked that the 20-word rule on agenda item titles be followed.

By way of illustration, the following title appeared on that night's agenda (137 words):

> An Ordinance to Amend Sections 1:552.1, 1:561, 1:562, 1:565, 1:566, 1.567, 1:568, 1:572 and 1:592 of Chapter 18, Employees Retirement System, Title I of the Code of the City of Ann Arbor to Implement a "Pick-Up" Provision Allowed by Internal Revenue Code 414(h) for Members represented by the IAFF, Local 693 and the Command Officers Association, and Increase the Contribution Level for Members Represented by the Command Officers Association, and to Implement a HELPS provision for Eligible Retired Public Safety Officers, and to Implement an Other Qualified Adult Pop-Up Provision for Members represented by the Ann Arbor Police Officers Association, the Command Officers Association and AFSCME, and to Implement Other Collectively Bargained Changes for Members Represented by the IAFF, Local 693 (Ordinance No. ORD-12-10)

Comm/Comm: Medical Marijuana Dispensary Licenses

Sabra Briere (Ward 1) also told her colleagues that she'd listened to their requests at the council's previous meeting, on April 2, 2012, that medical marijuana dispensary licenses be brought to the council for a vote. However, after further consultation with the city attorney, Stephen Postema, she reported that he's said he would not be able to provide adequate background information to the council on the issue until June. She wanted to let her colleagues know that she had checked, and that Postema was not prepared to move as quickly as she was.

Comm/Comm: Blight Removal

Stephen Kunselman (Ward 3) reported that the city's efforts at blight removal are working in his neighborhood, on Springbrook. He thanked everyone who supports blight removal and the city staff for making it happen.

Comm/Comm: Localized Flooding

During public commentary time, **Ellen Fisher** told the council she was speaking for herself and many of her neighbors in the Churchill Drive area. [It's an area on the west side of the city, east of I-94 and south of Scio Church Road.] She reminded councilmembers that some of them had heard from her before in letters she'd written. That night, she said she wanted to put a face to the message. She told the council that she and her husband had moved into their house on March 23, 1974 – 38 years ago. For 26 years, they had no problems, she reported. However, they'd experienced three localized floods in the neighborhood since 2000, two within the last two years.

Churchill Drive (highlighted in pink) was the subject of public commentary about localized flooding. It's located south of Scio Church Road and east of I-94. This screenshot is from the recent FEMA flood maps adopted by the city, which shows the floodplain (green) and floodway (blue) that exists in the neighborhood, but starting east of Churchill and extending eastward. (Image links to higher resolution file.)

She contended that three specific actions by the city of Ann Arbor were responsible for the flooding – which resulted in her home now serving as the "neighborhood detention pond." First, she said, residential development had been allowed north of Scio Church Road, which caused additional water to flow into the Churchill Downs neighborhood during bad storms. Second, she said, in 1998 the roads in the neighborhood (Wiltshire and Churchill) were resurfaced. But instead of removing older pavement, she said, new asphalt was just laid on top of the old. As a result of laying down new asphalt on top of the old, she described the crown of the road now as above the curb, and the curb as only two inches high. So any time the water gets deeper than two inches on the road during a storm, it's forced off the road into people's houses.

The third city action, she said, was the footing drain disconnection program implemented after the floods of 2000. Since that time, the city has known that the stormwater system in the Churchill Downs area is inadequate, she said. But in 2009 homeowners there had to participate in the footing drain disconnect program.

By way of background, the program requires disconnection of a property's footing drains to the sanitary sewer system, with a new connection made to the stormwater system. The move is meant to prevent the phenomenon of raw sewage backing up into people's basements – due to overloading the sanitary system, which is not designed to deal with the volume of water associated with storms. Fisher's contention is that the stormwater system in the neighborhood is also not adequate to handle the volume of water due to storms.

Fisher continued by describing another flood just a month ago, and showed the council a photo of her house, which she described as an island surrounded by water – 5-6 inches. Storm drain covers were blown off, and geysers shot up five feet into the air, she reported. Water flowed into their basement through the egress windows and up from the sump that was installed through the footing drain disconnect program.

The city of Ann Arbor has attributed this to an "act of god," she said. But she called the flood in her basement an "act of the city." She called on the city to accept responsibility. In the short term, she

Marcia Higgins (Ward 4) as she listens to Ellen Fisher's public comment on localized flooding issues. To Higgins' right (in green shirt) is Margie Teall (Ward 4). Fisher was speaking about flooding in Ward 4.

called for the city to solve the problem of water entering the basement through the sump and to cover the cost of cleanup and mitigation. In the long term, she said, the city needs to address flooding in the neighborhood. She presented the council with a petition signed by several residents of the neighborhood, many of whom were in the audience at city council chambers.

Lowell Fisher, Ellen Fisher's husband, spoke from his wheelchair. He told the council that the floods were taking an emotional and financial toll on him. The value of their home has plummeted, he said. They're afraid to restore their basement – so they're left with a basement they can't use. Because he can't visit all his children, they travel to visit him. They need their basement to host their children and grandchildren. Two years ago a flood cost them $20,000. But their claim for $5,000 in cleanup costs was denied. Nothing was done by the city to prevent another occurrence, he said. He stressed that the floods are not freak storms. There had been storms for the last 26 years prior to the occurrence of flooding problems. He concluded that it's time for the city to take action. More than a dozen people stood in the audience to show support during Fisher's remarks.

Comm/Comm: Smart Meters

Nanci Gerler alluded to a mayoral proclamation that led off the meeting, which established April 22, 2012 as Earth Day in Ann Arbor – the 42nd anniversary of the international observation of Earth Day, which was launched in Ann Arbor on March 10-14, 1970.

Gerler told the council she'd attended the first Earth Day and still has an Earth Day button somewhere in her house. She told the council she appreciated being a part of a community that values the environment and accessibility for those with disabilities. She warned the council that DTE's smart meters had been introduced in Ann Arbor like a Trojan horse, using the guise of sustainability. Only recently had the meters been installed in Ann Arbor, she said, but other parts of the state had a longer experience with them. She told the council that 18 other municipalities have passed resolutions and moratoriums on smart meters, due to questions health safety and invasion of privacy, she said. Why not Ann Arbor? she wondered. Ann Arbor is usually progressive on such issues.

Gerler described how DTE is making no exceptions, and does not give consumers the right to opt out. She said that she'd been told by the Michigan Public Service Commission that if she refuses to allow installation, she could have her electricity shut off, even if she pays in a timely fashion. She offered to work with councilmembers to bring them up to speed on the issue. She asked councilmembers to help her get the message out.

Darren Schmidt introduced himself as the president and CEO of the Nutritional Healing Center of Ann Arbor. He described how the center helps people improve their health through nutrition. He said that a few years ago he became aware that some of the fatigue, memory loss, sleep disorders, and illnesses including Parkinson's Disease could be attributed to "dirty electricity" and magnetic fields. [The council's agenda included a mayoral proclamation establishing April as Parkinson's Disease Awareness Month.] He showed the council a book titled "Dirty Electricity," which that concluded electromagnetic frequencies and radio frequencies are the No. 1 cause of cancer in the U.S. He cited another book, titled "Zapped," that provides ways to avoid electromagnetic pollution.

Schmidt said 3-5% of the population are extremely sensitive to magnetic fields and 35-50% are somewhat sensitive, but may not know it. Most doctors don't know anything about this condition, he said. He had stumbled across it because his patients need the best care possible and they're not constrained by pharmaceutical requirements. He also showed the council a letter from the American Academy of Environmental Medicine. The president-elect of that organization, he said, is Amy Dean, who's a doctor of osteopathic medicine (D.O.) and based in Ann Arbor. The AAEM on April 12 released its position paper on electromagnetic fields and radio frequency health effects, and that paper had called for immediate caution on installation of "smart meters." He compared installing "smart meters" in neighborhoods to "living in a microwave" that can't be turned off.

Comm/Comm: Affordable Services for Most Vulnerable

Thomas Partridge called on the council to fund services for the most vulnerable – from disabled citizens, to senior citizens, to the middle class – those who need job opportunities and access to public transportation to get to those jobs. He called for the nomination of Barack Obama for re-election as president of the United States.

Present: Jane Lumm, Mike Anglin, Margie Teall, Sabra Briere, Sandi Smith, Tony Derezinski, Stephen Kunselman, Marcia Higgins, John Hieftje, Christopher Taylor, Carsten Hohnke.

Next council meeting: Monday, May 7, 2012 at 7 p.m. in the second-floor council chambers at city hall, 301 E. Huron. [confirm date]

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Section: Center Column, Govt., Meeting Watch

The following terms describe the content of this article. Click on a term to see all articles described with that term: **.017 BAC**, **1320 S. University**, **AAA**, **airport runway extension**, **Ann Arbor city council meeting**, **localized flooding**, **retirement**, **rezoning**, **Tim Hortons**, **zoning**

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12 Comments

1. BY JIM REES
APRIL 21, 2012 at 8:24 pm | PERMALINK

Did the airport runway extension study take into account the donut imbalance that will result from having a Tim Horton's off the northeast end of the runway and no donuts off the southwest end?

On a more serious note, I was surprised to read in the Detroit Free Press that DTE has asked for a rate increase to pay for the new "smart" meters. I thought the whole idea was that they'd be cheaper because meter readers would no longer have to be sent out. If they end up costing us more than the old meters, what's the point?

2. BY TEACHERPATTI
APRIL 21, 2012 at 11:16 pm | PERMALINK

Um, is that stuff about the smart meters and cancer and that true? Cuz I'm kind of worried.

3. BY TOM WHITAKER
APRIL 22, 2012 at 11:03 am | PERMALINK

I'm not clear on the biosolids contract that was approved. Is the City PAYING $514K to have biosolids spread on farm fields, or is the City being PAID $514K for providing this "fertilizer?"

If the City is paying, how much more or less is this cost per gallon ($0.0321) than the cost of landfilling it?

4. BY DAVE ASKINS
APRIL 22, 2012 at 11:21 am | PERMALINK

Re: [3] It's the city's cost.

Assuming a weight of about 8 pounds a gallon, that works out to ((US$ 0.0321) / 8) * 2000 = 8.02500 U.S. dollars per ton.

From minutes of a March 2012 meeting of the "organics subcommittee" of the solid waste unit (comparing the cost of processing organics versus landfilling them) it looks like the city currently pays $26 per ton to put material in a landfill.

5. BY TOM WHITAKER
APRIL 22, 2012 at 10:30 pm | PERMALINK

Thanks, Dave.

While you were looking into that, I checked the web to see if Bio Tech Agronomics was affiliated with WeCare Organics, the firm running the City's compost facility. I could not find any connection between the two in the brief time I spent on it.

WeCare Organics blends biosolids into compost in other cities, and has affiliates that transport biosolids and make fertilizer products from blends of compost and biosolids. Some people expressed concern that WeCare would introduce biosolids into Ann Arbor's compost, but assurances were provided around the Council table that this would not happen and as far as I know, it hasn't happened.

6. BY EDWARD VIELMETTI
APRIL 23, 2012 at 12:03 am | PERMALINK

The "student press" alluded to in my commentary on minor-in-possession laws can be found starting here:

[link]

with this pull quote

"To combat the potential issue at the University, members of the Central Student Government — formerly known as the Michigan Student Assembly — are working on a proposal to implement medical amnesty at the University, a policy that would protect students from receiving an MIP if they call for alcohol-related medical attention for another person while also under the influence."

7. BY LIEBEZEIT
APRIL 23, 2012 at 5:14 am | PERMALINK

"He said that a few years ago he became aware that some of the fatigue, memory loss, sleep disorders, and illnesses including Parkinson's Disease could be attributed to "dirty electricity" and magnetic fields."

Hilarious…classic Ann Arbor.

8. BY JIM REES
APRIL 23, 2012 at 8:24 am | PERMALINK

If you are concerned about the electromagnetic fields from your electric service, there is a simple solution. Call up DTE and ask them to remove the meter.

9. BY DAVE ASKINS
APRIL 23, 2012 at 10:18 am | PERMALINK

Re: [8] Calling DTE and asking them to remove the meter.

Our smart meter was installed a few weeks ago. I called customer service just now to test whether a simple phone call could do the trick. According to the customer service representative I talked to, there's currently no provision for opting out either before or after the fact. However, she indicated that talks are taking place between DTE and the Michigan Public Service Commission about providing customers the ability to opt out. To be clear, I'm not actually interested in having the "smart meter" removed; I was just following up on Jim's suggestion.

10. BY DAVE ASKINS
APRIL 23, 2012 at 10:51 am | PERMALINK

And to follow up on [9], the "talks" that are taking place between DTE and MPSC can be more precisely described as follows, based on a conversation with MPSC just now.

On Jan. 12, MPSC issued an order requiring utilities to file information with MPSC about "smart meter" rollout plans, including estimated cost, funding, estimated savings, and non-monetary benefits, scientific information, and whether an opt out would be provided (included how costs associated with opt outs might be recovered.) The deadline for that filing was March 16, which DTE met. Public comment on that was open through April 16. The information filed in response to MPSC's order will all be complied into a report, supplemented with independent review of relevant literature, and produced by June 29. At that point, MPSC commissioners will have a document on the basis of which they could issue further orders or weigh future rate cases brought by DTE before the MPSC.

Also in the mix is pending House Bill 5439, which would legislatively provide for an opt-out by consumers and regulate how data collected by the meters is used.

11. BY JIM REES
APRIL 23, 2012 at 1:03 pm | PERMALINK

Dave, you misunderstood me. You are perfectly within your rights to have the meter removed, and if DTE won't do it, you can remove it yourself (safely, please!). You will then be left with no electromagnetic fields in your house from your DTE electric service. You will also have no electricity.

12. BY DAVE ASKINS
APRIL 23, 2012 at 1:09 pm | PERMALINK

Re: [11] Ah! Yes, I did misunderstand you.

Exhibit 21

FAA
Airports

Grant Assurances
Airport Sponsors

A. General.

1. These assurances shall be complied with in the performance of grant agreements for airport development, airport planning, and noise compatibility program grants for airport sponsors.

2. These assurances are required to be submitted as part of the project application by sponsors requesting funds under the provisions of Title 49, U.S.C., subtitle VII, as amended. As used herein, the term "public agency sponsor" means a public agency with control of a public-use airport; the term "private sponsor" means a private owner of a public-use airport; and the term "sponsor" includes both public agency sponsors and private sponsors.

3. Upon acceptance of this grant offer by the sponsor, these assurances are incorporated in and become part of this grant agreement.

B. Duration and Applicability.

1. **Airport development or Noise Compatibility Program Projects Undertaken by a Public Agency Sponsor**. The terms, conditions and assurances of this grant agreement shall remain in full force and effect throughout the useful life of the facilities developed or equipment acquired for an airport development or noise compatibility program project, or throughout the useful life of the project items installed within a facility under a noise compatibility program project, but in any event not to exceed twenty (20) years from the date of acceptance of a grant offer of Federal funds for the project. However, there shall be no limit on the duration of the assurances regarding Exclusive Rights and Airport Revenue so long as the airport is used as an airport. There shall be no limit on the duration of the terms, conditions, and assurances with respect to real property acquired with federal funds. Furthermore, the duration of the Civil Rights assurance shall be specified in the assurances.

2. **Airport Development or Noise Compatibility Projects Undertaken by a Private Sponsor**. The preceding paragraph 1 also applies to a private sponsor except that the useful life of project items installed within a facility or the useful life of the facilities developed or equipment acquired under an airport development or noise compatibility program project shall be no less than ten (10) years from the date of acceptance of Federal aid for the project.

3. **Airport Planning Undertaken by a Sponsor.** Unless otherwise specified in this grant agreement, only Assurances 1, 2, 3, 5, 6, 13, 18, 30, 32, 33, and 34 in section C apply to planning projects. The terms, conditions, and assurances of this grant agreement shall remain in full force and effect during the life of the project.

C. **Sponsor Certification.** The sponsor hereby assures and certifies, with respect to this grant that:

1. **General Federal Requirements.** It will comply with all applicable Federal laws, regulations, executive orders, policies, guidelines, and requirements as they relate to the application, acceptance and use of Federal funds for this project including but not limited to the following:

Federal Legislation

a. Title 49, U.S.C., subtitle VII, as amended.
b. Davis-Bacon Act - 40 U.S.C. 276(a), et seq.[1]
c. Federal Fair Labor Standards Act - 29 U.S.C. 201, et seq.
d. Hatch Act – 5 U.S.C. 1501, et seq.[2]
e. Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 Title 42 U.S.C. 4601, et seq.[1 2]
f. National Historic Preservation Act of 1966 - Section 106 - 16 U.S.C. 470(f).[1]
g. Archeological and Historic Preservation Act of 1974 - 16 U.S.C. 469 through 469c.[1]
h. Native Americans Grave Repatriation Act - 25 U.S.C. Section 3001, et seq.
i. Clean Air Act, P.L. 90-148, as amended.
j. Coastal Zone Management Act, P.L. 93-205, as amended.
k. Flood Disaster Protection Act of 1973 - Section 102(a) - 42 U.S.C. 4012a.[1]
l. Title 49, U.S.C., Section 303, (formerly known as Section 4(f))
m. Rehabilitation Act of 1973 - 29 U.S.C. 794.
n. Civil Rights Act of 1964 - Title VI - 42 U.S.C. 2000d through d-4.
o. Age Discrimination Act of 1975 - 42 U.S.C. 6101, et seq.
p. American Indian Religious Freedom Act, P.L. 95-341, as amended.
q. Architectural Barriers Act of 1968 -42 U.S.C. 4151, et seq.[1]
r. Power plant and Industrial Fuel Use Act of 1978 - Section 403- 2 U.S.C. 8373.[1]
s. Contract Work Hours and Safety Standards Act - 40 U.S.C. 327, et seq.[1]
t. Copeland Anti kickback Act - 18 U.S.C. 874.1
u. National Environmental Policy Act of 1969 - 42 U.S.C. 4321, et seq.[1]
v. Wild and Scenic Rivers Act, P.L. 90-542, as amended.
w. Single Audit Act of 1984 - 31 U.S.C. 7501, et seq.[2]
x. Drug-Free Workplace Act of 1988 - 41 U.S.C. 702 through 706.

Executive Orders

Executive Order 11246 - Equal Employment Opportunity[1]
Executive Order 11990 - Protection of Wetlands
Executive Order 11998 – Flood Plain Management
Executive Order 12372 - Intergovernmental Review of Federal Programs
Executive Order 12699 - Seismic Safety of Federal and Federally Assisted New Building Construction[1]
Executive Order 12898 - Environmental Justice

Federal Regulations

a. 14 CFR Part 13 - Investigative and Enforcement Procedures.
b. 14 CFR Part 16 - Rules of Practice For Federally Assisted Airport Enforcement Proceedings.
c. 14 CFR Part 150 - Airport noise compatibility planning.
d. 29 CFR Part 1 - Procedures for predetermination of wage rates.[1]
e. 29 CFR Part 3 - Contractors and subcontractors on public building or public work financed in whole or part by loans or grants from the United States.[1]
f. 29 CFR Part 5 - Labor standards provisions applicable to contracts covering federally financed and assisted construction (also labor standards provisions applicable to non-construction contracts subject to the Contract Work Hours and Safety Standards Act).[1]
g. 41 CFR Part 60 - Office of Federal Contract Compliance Programs, Equal Employment Opportunity, Department of Labor (Federal and federally assisted contracting requirements).[1]
h. 49 CFR Part 18 - Uniform administrative requirements for grants and cooperative agreements to state and local governments.[3]
i. 49 CFR Part 20 - New restrictions on lobbying.
j. 49 CFR Part 21 - Nondiscrimination in federally-assisted programs of the Department of Transportation - effectuation of Title VI of the Civil Rights Act of 1964.
k. 49 CFR Part 23 - Participation by Disadvantage Business Enterprise in Airport Concessions.
l. 49 CFR Part 24 - Uniform relocation assistance and real property acquisition for Federal and federally assisted programs.[1 2]
m. 49 CFR Part 26 – Participation By Disadvantaged Business Enterprises in Department of Transportation Programs.
n. 49 CFR Part 27 - Nondiscrimination on the basis of handicap in programs and activities receiving or benefiting from Federal financial assistance.[1]
o. 49 CFR Part 29 – Government wide debarment and suspension (nonprocurement) and government wide requirements for drug-free workplace (grants).
p. 49 CFR Part 30 - Denial of public works contracts to suppliers of goods and services of countries that deny procurement market access to U.S. contractors.

q. 49 CFR Part 41 - Seismic safety of Federal and federally assisted or regulated new building construction.[1]

Office of Management and Budget Circulars

a. A-87 - Cost Principles Applicable to Grants and Contracts with State and Local Governments.
b. A-133 - Audits of States, Local Governments, and Non-Profit Organizations

[1] These laws do not apply to airport planning sponsors.
[2] These laws do not apply to private sponsors.
[3] 49 CFR Part 18 and OMB Circular A-87 contain requirements for State and Local Governments receiving Federal assistance. Any requirement levied upon State and Local Governments by this regulation and circular shall also be applicable to private sponsors receiving Federal assistance under Title 49, United States Code.

Specific assurances required to be included in grant agreements by any of the above laws, regulations or circulars are incorporated by reference in this grant agreement.

2. Responsibility and Authority of the Sponsor.

a. **Public Agency Sponsor:** It has legal authority to apply for this grant, and to finance and carry out the proposed project; that a resolution, motion or similar action has been duly adopted or passed as an official act of the applicant's governing body authorizing the filing of the application, including all understandings and assurances contained therein, and directing and authorizing the person identified as the official representative of the applicant to act in connection with the application and to provide such additional information as may be required.
b. **Private Sponsor:** It has legal authority to apply for this grant and to finance and carry out the proposed project and comply with all terms, conditions, and assurances of this grant agreement. It shall designate an official representative and shall in writing direct and authorize that person to file this application, including all understandings and assurances contained therein; to act in connection with this application; and to provide such additional information as may be required.

3. Sponsor Fund Availability. It has sufficient funds available for that portion of the project costs which are not to be paid by the United States. It has sufficient funds available to assure operation and maintenance of items funded under this grant agreement which it will own or control.

4. Good Title.

a. It, a public agency or the Federal government, holds good title, satisfactory to the Secretary, to the landing area of the airport or site thereof, or will give assurance satisfactory to the Secretary that good title will be acquired.

b. For noise compatibility program projects to be carried out on the property of the sponsor, it holds good title satisfactory to the Secretary to that portion of the property upon which Federal funds will be expended or will give assurance to the Secretary that good title will be obtained.

5. Preserving Rights and Powers.

a. It will not take or permit any action which would operate to deprive it of any of the rights and powers necessary to perform any or all of the terms, conditions, and assurances in this grant agreement without the written approval of the Secretary, and will act promptly to acquire, extinguish or modify any outstanding rights or claims of right of others which would interfere with such performance by the sponsor. This shall be done in a manner acceptable to the Secretary.

b. It will not sell, lease, encumber, or otherwise transfer or dispose of any part of its title or other interests in the property shown on Exhibit A to this application or, for a noise compatibility program project, that portion of the property upon which Federal funds have been expended, for the duration of the terms, conditions, and assurances in this grant agreement without approval by the Secretary. If the transferee is found by the Secretary to be eligible under Title 49, United States Code, to assume the obligations of this grant agreement and to have the power, authority, and financial resources to carry out all such obligations, the sponsor shall insert in the contract or document transferring or disposing of the sponsor's interest, and make binding upon the transferee all of the terms, conditions, and assurances contained in this grant agreement.

c. For all noise compatibility program projects which are to be carried out by another unit of local government or are on property owned by a unit of local government other than the sponsor, it will enter into an agreement with that government. Except as otherwise specified by the Secretary, that agreement shall obligate that government to the same terms, conditions, and assurances that would be applicable to it if it applied directly to the FAA for a grant to undertake the noise compatibility program project. That agreement and changes thereto must be satisfactory to the Secretary. It will take steps to enforce this agreement against the local government if there is substantial non-compliance with the terms of the agreement.

d. For noise compatibility program projects to be carried out on privately owned property, it will enter into an agreement with the owner of that property which includes provisions specified by the Secretary. It will take steps to enforce this agreement against the property owner whenever there is substantial non-compliance with the terms of the agreement.

e. If the sponsor is a private sponsor, it will take steps satisfactory to the Secretary to ensure that the airport will continue to function as a public-use airport in accordance with these assurances for the duration of these assurances.

f. If an arrangement is made for management and operation of the airport by any agency or person other than the sponsor or an employee of the sponsor, the sponsor will reserve sufficient rights and authority to insure that the airport will be operated and maintained in accordance Title 49, United States Code, the regulations and the terms, conditions and assurances in this grant agreement and shall insure that such arrangement also requires compliance therewith.

g. Sponsors of commercial service airports will not permit or enter into any arrangement that results in permission for the owner or tenant of a property used as a residence, or zoned for residential use, to taxi an aircraft between that property and any location on airport. Sponsors of general aviation airports entering into any arrangement that results in permission for the owner of residential real property adjacent to or near the airport must comply with the requirements of Sec. 136 of Public Law 112-95 and the sponsor assurances.

6. **Consistency with Local Plans.** The project is reasonably consistent with plans (existing at the time of submission of this application) of public agencies that are authorized by the State in which the project is located to plan for the development of the area surrounding the airport.

7. **Consideration of Local Interest.** It has given fair consideration to the interest of communities in or near where the project may be located.

8. **Consultation with Users.** In making a decision to undertake any airport development project under Title 49, United States Code, it has undertaken reasonable consultations with affected parties using the airport at which project is proposed.

9. **Public Hearings.** In projects involving the location of an airport, an airport runway, or a major runway extension, it has afforded the opportunity for public hearings for the purpose of considering the economic, social, and environmental effects of the airport or runway location and its consistency with goals and objectives of such planning as has been carried out by the community and it shall, when requested by the Secretary, submit a copy of the transcript of such hearings to the Secretary. Further, for such projects, it has on its management board either voting representation from the communities where the project is located or has advised the communities that they have the right to petition the Secretary concerning a proposed project.

10. **Air and Water Quality Standards.** In projects involving airport location, a major runway extension, or runway location it will provide for the Governor of the state in which the project is located to certify in writing to the Secretary that the project will be located, designed, constructed, and operated so as to comply with applicable air and water quality standards. In any case where such standards have not been approved and where applicable air and water quality standards have been promulgated by the Administrator of the Environmental Protection Agency, certification shall be obtained from such Administrator. Notice of certification or refusal to certify shall be provided within sixty days after the project application has been received by the Secretary.

11. **Pavement Preventive Maintenance**. With respect to a project approved after January 1, 1995, for the replacement or reconstruction of pavement at the airport, it assures or certifies that it has implemented an effective airport pavement maintenance-management program and it assures that it will use such program for the useful life of any pavement constructed, reconstructed or repaired with Federal financial assistance at the airport. It will provide such reports on pavement condition and pavement management programs as the Secretary determines may be useful.

12. **Terminal Development Prerequisites.** For projects which include terminal development at a public use airport, as defined in Title 49, it has, on the date of submittal of the project grant application, all the safety equipment required for certification of such airport under section 44706 of Title 49, United States Code, and all the security equipment required by rule or regulation, and has provided for access to the passenger enplaning and deplaning area of such airport to passengers enplaning and deplaning from aircraft other than air carrier aircraft.

13. **Accounting System, Audit, and Record Keeping Requirements**.

    a. It shall keep all project accounts and records which fully disclose the amount and disposition by the recipient of the proceeds of this grant, the total cost of the project in connection with which this grant is given or used, and the amount or nature of that portion of the cost of the project supplied by other sources, and such other financial records pertinent to the project. The accounts and records shall be kept in accordance with an accounting system that will facilitate an effective audit in accordance with the Single Audit Act of 1984.

    b. It shall make available to the Secretary and the Comptroller General of the United States, or any of their duly authorized representatives, for the purpose of audit and examination, any books, documents, papers, and records of the recipient that are pertinent to this grant. The Secretary may require that an appropriate audit be conducted by a recipient. In any case in which an independent audit is made of the accounts of a sponsor relating to the disposition of the proceeds of a grant or relating to the project in connection with which this grant was given or used, it shall file a certified copy of such audit with the Comptroller General of the United States not later than six (6) months following the close of the fiscal year for which the audit was made.

14. **Minimum Wage Rates.** It shall include, in all contracts in excess of $2,000 for work on any projects funded under this grant agreement which involve labor, provisions establishing minimum rates of wages, to be predetermined by the Secretary of Labor, in accordance with the Davis-Bacon Act, as amended (40 U.S.C. 276a-276a-5), which contractors shall pay to skilled and unskilled labor, and such minimum rates shall be stated in the invitation for bids and shall be included in proposals or bids for the work.

15. **Veteran's Preference.** It shall include in all contracts for work on any project funded under this grant agreement which involve labor, such provisions as are necessary to insure that, in the employment of labor (except in executive, administrative, and supervisory positions), preference shall be given to Vietnam

era veterans, Persian Gulf veterans, Afghanistan-Iraq war veterans, disabled veterans, and small business concerns owned and controlled by disabled veterans as defined in Section 47112 of Title 49, United States Code. However, this preference shall apply only where the individuals are available and qualified to perform the work to which the employment relates.

16. **Conformity to Plans and Specifications.** It will execute the project subject to plans, specifications, and schedules approved by the Secretary. Such plans, specifications, and schedules shall be submitted to the Secretary prior to commencement of site preparation, construction, or other performance under this grant agreement, and, upon approval of the Secretary, shall be incorporated into this grant agreement. Any modification to the approved plans, specifications, and schedules shall also be subject to approval of the Secretary, and incorporated into this grant agreement.

17. **Construction Inspection and Approval.** It will provide and maintain competent technical supervision at the construction site throughout the project to assure that the work conforms to the plans, specifications, and schedules approved by the Secretary for the project. It shall subject the construction work on any project contained in an approved project application to inspection and approval by the Secretary and such work shall be in accordance with regulations and procedures prescribed by the Secretary. Such regulations and procedures shall require such cost and progress reporting by the sponsor or sponsors of such project as the Secretary shall deem necessary.

18. **Planning Projects.** In carrying out planning projects:

    a. It will execute the project in accordance with the approved program narrative contained in the project application or with the modifications similarly approved.
    b. It will furnish the Secretary with such periodic reports as required pertaining to the planning project and planning work activities.
    c. It will include in all published material prepared in connection with the planning project a notice that the material was prepared under a grant provided by the United States.
    d. It will make such material available for examination by the public, and agrees that no material prepared with funds under this project shall be subject to copyright in the United States or any other country.
    e. It will give the Secretary unrestricted authority to publish, disclose, distribute, and otherwise use any of the material prepared in connection with this grant.
    f. It will grant the Secretary the right to disapprove the sponsor's employment of specific consultants and their subcontractors to do all or any part of this project as well as the right to disapprove the proposed scope and cost of professional services.
    g. It will grant the Secretary the right to disapprove the use of the sponsor's employees to do all or any part of the project.
    h. It understands and agrees that the Secretary's approval of this project grant or the Secretary's approval of any planning material developed as part of

this grant does not constitute or imply any assurance or commitment on the part of the Secretary to approve any pending or future application for a Federal airport grant.

19. Operation and Maintenance.

a. The airport and all facilities which are necessary to serve the aeronautical users of the airport, other than facilities owned or controlled by the United States, shall be operated at all times in a safe and serviceable condition and in accordance with the minimum standards as may be required or prescribed by applicable Federal, state and local agencies for maintenance and operation. It will not cause or permit any activity or action thereon which would interfere with its use for airport purposes. It will suitably operate and maintain the airport and all facilities thereon or connected therewith, with due regard to climatic and flood conditions. Any proposal to temporarily close the airport for non-aeronautical purposes must first be approved by the Secretary. In furtherance of this assurance, the sponsor will have in effect arrangements for-

1) Operating the airport's aeronautical facilities whenever required;
2) Promptly marking and lighting hazards resulting from airport conditions, including temporary conditions; and
3) Promptly notifying airmen of any condition affecting aeronautical use of the airport. Nothing contained herein shall be construed to require that the airport be operated for aeronautical use during temporary periods when snow, flood or other climatic conditions interfere with such operation and maintenance. Further, nothing herein shall be construed as requiring the maintenance, repair, restoration, or replacement of any structure or facility which is substantially damaged or destroyed due to an act of God or other condition or circumstance beyond the control of the sponsor.

b. It will suitably operate and maintain noise compatibility program items that it owns or controls upon which Federal funds have been expended.

20. Hazard Removal and Mitigation. It will take appropriate action to assure that such terminal airspace as is required to protect instrument and visual operations to the airport (including established minimum flight altitudes) will be adequately cleared and protected by removing, lowering, relocating, marking, or lighting or otherwise mitigating existing airport hazards and by preventing the establishment or creation of future airport hazards.

21. Compatible Land Use. It will take appropriate action, to the extent reasonable, including the adoption of zoning laws, to restrict the use of land adjacent to or in the immediate vicinity of the airport to activities and purposes compatible with normal airport operations, including landing and takeoff of aircraft. In addition, if the project is for noise compatibility program implementation, it will not cause or permit any change in land use, within its jurisdiction, that will reduce its compatibility, with respect to the airport, of the noise compatibility program measures upon which Federal funds have been expended.

22. Economic Nondiscrimination.

a. It will make the airport available as an airport for public use on reasonable terms and without unjust discrimination to all types, kinds and classes of aeronautical activities, including commercial aeronautical activities offering services to the public at the airport.

b. In any agreement, contract, lease, or other arrangement under which a right or privilege at the airport is granted to any person, firm, or corporation to conduct or to engage in any aeronautical activity for furnishing services to the public at the airport, the sponsor will insert and enforce provisions requiring the contractor to-

  1) furnish said services on a reasonable, and not unjustly discriminatory, basis to all users thereof, and

  2) charge reasonable, and not unjustly discriminatory, prices for each unit or service, provided that the contractor may be allowed to make reasonable and nondiscriminatory discounts, rebates, or other similar types of price reductions to volume purchasers.

c. Each fixed-based operator at the airport shall be subject to the same rates, fees, rentals, and other charges as are uniformly applicable to all other fixed-based operators making the same or similar uses of such airport and utilizing the same or similar facilities.

d. Each air carrier using such airport shall have the right to service itself or to use any fixed-based operator that is authorized or permitted by the airport to serve any air carrier at such airport.

e. Each air carrier using such airport (whether as a tenant, non tenant, or subtenant of another air carrier tenant) shall be subject to such nondiscriminatory and substantially comparable rules, regulations, conditions, rates, fees, rentals, and other charges with respect to facilities directly and substantially related to providing air transportation as are applicable to all such air carriers which make similar use of such airport and utilize similar facilities, subject to reasonable classifications such as tenants or non tenants and signatory carriers and non signatory carriers. Classification or status as tenant or signatory shall not be unreasonably withheld by any airport provided an air carrier assumes obligations substantially similar to those already imposed on air carriers in such classification or status.

f. It will not exercise or grant any right or privilege which operates to prevent any person, firm, or corporation operating aircraft on the airport from performing any services on its own aircraft with its own employees [including, but not limited to maintenance, repair, and fueling] that it may choose to perform.

g. In the event the sponsor itself exercises any of the rights and privileges referred to in this assurance, the services involved will be provided on the same conditions as would apply to the furnishing of such services by commercial aeronautical service providers authorized by the sponsor under these provisions.

h. The sponsor may establish such reasonable, and not unjustly discriminatory, conditions to be met by all users of the airport as may be necessary for the safe and efficient operation of the airport.

i. The sponsor may prohibit or limit any given type, kind or class of aeronautical use of the airport if such action is necessary for the safe operation of the airport or necessary to serve the civil aviation needs of the public.

23. **Exclusive Rights.** It will permit no exclusive right for the use of the airport by any person providing, or intending to provide, aeronautical services to the public. For purposes of this paragraph, the providing of the services at an airport by a single fixed-based operator shall not be construed as an exclusive right if both of the following apply:

a. It would be unreasonably costly, burdensome, or impractical for more than one fixed-based operator to provide such services, and

b. If allowing more than one fixed-based operator to provide such services would require the reduction of space leased pursuant to an existing agreement between such single fixed-based operator and such airport. It further agrees that it will not, either directly or indirectly, grant or permit any person, firm, or corporation, the exclusive right at the airport to conduct any aeronautical activities, including, but not limited to charter flights, pilot training, aircraft rental and sightseeing, aerial photography, crop dusting, aerial advertising and surveying, air carrier operations, aircraft sales and services, sale of aviation petroleum products whether or not conducted in conjunction with other aeronautical activity, repair and maintenance of aircraft, sale of aircraft parts, and any other activities which because of their direct relationship to the operation of aircraft can be regarded as an aeronautical activity, and that it will terminate any exclusive right to conduct an aeronautical activity now existing at such an airport before the grant of any assistance under Title 49, United States Code.

24. **Fee and Rental Structure.** It will maintain a fee and rental structure for the facilities and services at the airport which will make the airport as self-sustaining as possible under the circumstances existing at the particular airport, taking into account such factors as the volume of traffic and economy of collection. No part of the Federal share of an airport development, airport planning or noise compatibility project for which a grant is made under Title 49, United States Code, the Airport and Airway Improvement Act of 1982, the Federal Airport Act or the Airport and Airway Development Act of 1970 shall be included in the rate basis in establishing fees, rates, and charges for users of that airport.

25. **Airport Revenues.**

a. All revenues generated by the airport and any local taxes on aviation fuel established after December 30, 1987, will be expended by it for the capital or operating costs of the airport; the local airport system; or other local facilities which are owned or operated by the owner or operator of the airport and which are directly and substantially related to the actual air transportation of passengers or property; or for noise mitigation purposes on or off the airport. The following exceptions apply to this paragraph:

1) If covenants or assurances in debt obligations issued before September 3, 1982, by the owner or operator of the airport, or provisions enacted before September 3, 1982, in governing statutes controlling the owner or operator's financing, provide for the use of the revenues from any of the airport owner or operator's facilities, including the airport, to support not only the airport but also the airport owner or operator's general debt obligations or other facilities, then this limitation on the use of all revenues generated by the airport (and, in the case of a public airport, local taxes on aviation fuel) shall not apply.

2) If the Secretary approves the sale of a privately owned airport to a public sponsor and provides funding for any portion of the public sponsor's acquisition of land, this limitation on the use of all revenues generated by the sale shall not apply to certain proceeds from the sale. This is conditioned on repayment to the Secretary by the private owner of an amount equal to the remaining unamortized portion (amortized over a 20-year period) of any airport improvement grant made to the private owner for any purpose other than land acquisition on or after October 1, 1996, plus an amount equal to the federal share of the current fair market value of any land acquired with an airport improvement grant made to that airport on or after October 1, 1996.

3) Certain revenue derived from or generated by mineral extraction, production, lease, or other means at a general aviation airport (as defined at Section 47102 of title 49 United States Code), if the FAA determines the airport sponsor meets the requirements set forth in Sec. 813 of Public Law 112-95.

b. As part of the annual audit required under the Single Audit Act of 1984, the sponsor will direct that the audit will review, and the resulting audit report will provide an opinion concerning, the use of airport revenue and taxes in paragraph (a), and indicating whether funds paid or transferred to the owner or operator are paid or transferred in a manner consistent with Title 49, United States Code and any other applicable provision of law, including any regulation promulgated by the Secretary or Administrator.

c. Any civil penalties or other sanctions will be imposed for violation of this assurance in accordance with the provisions of Section 47107 of Title 49, United States Code.

26. Reports and Inspections. It will:

a. submit to the Secretary such annual or special financial and operations reports as the Secretary may reasonably request and make such reports available to the public; make available to the public at reasonable times and places a report of the airport budget in a format prescribed by the Secretary;

b. for airport development projects, make the airport and all airport records and documents affecting the airport, including deeds, leases, operation and use agreements, regulations and other instruments, available for inspection by any duly authorized agent of the Secretary upon reasonable request;

c. for noise compatibility program projects, make records and documents relating to the project and continued compliance with the terms, conditions, and assurances of this grant agreement including deeds, leases, agreements, regulations, and other instruments, available for inspection by any duly authorized agent of the Secretary upon reasonable request; and

d. in a format and time prescribed by the Secretary, provide to the Secretary and make available to the public following each of its fiscal years, an annual report listing in detail:

   1) all amounts paid by the airport to any other unit of government and the purposes for which each such payment was made; and

   2) all services and property provided by the airport to other units of government and the amount of compensation received for provision of each such service and property.

27. Use by Government Aircraft. It will make available all of the facilities of the airport developed with Federal financial assistance and all those usable for landing and takeoff of aircraft to the United States for use by Government aircraft in common with other aircraft at all times without charge, except, if the use by Government aircraft is substantial, charge may be made for a reasonable share, proportional to such use, for the cost of operating and maintaining the facilities used. Unless otherwise determined by the Secretary, or otherwise agreed to by the sponsor and the using agency, substantial use of an airport by Government aircraft will be considered to exist when operations of such aircraft are in excess of those which, in the opinion of the Secretary, would unduly interfere with use of the landing areas by other authorized aircraft, or during any calendar month that –

a. Five (5) or more Government aircraft are regularly based at the airport or on land adjacent thereto; or

b. The total number of movements (counting each landing as a movement) of Government aircraft is 300 or more, or the gross accumulative weight of Government aircraft using the airport (the total movement of Government aircraft multiplied by gross weights of such aircraft) is in excess of five million pounds.

28. Land for Federal Facilities. It will furnish without cost to the Federal Government for use in connection with any air traffic control or air navigation activities, or weather-reporting and communication activities related to air traffic control, any areas of land or water, or estate therein, or rights in buildings of the sponsor as the Secretary considers necessary or desirable for construction, operation, and maintenance at Federal expense of space or facilities for such purposes. Such areas or any portion thereof will be made available as provided herein within four months after receipt of a written request from the Secretary.

29. Airport Layout Plan.

a. It will keep up to date at all times an airport layout plan of the airport showing (1) boundaries of the airport and all proposed additions thereto, together with the boundaries of all offsite areas owned or controlled by the sponsor for airport purposes and proposed additions thereto; (2) the location and nature of all existing and proposed airport facilities and structures (such as runways, taxiways, aprons, terminal buildings, hangars and roads), including all proposed extensions and reductions of existing airport facilities; (3) the location of all existing and proposed nonaviation areas and of all existing improvements thereon; and (4) all proposed and existing access points used to taxi aircraft across the airport's property boundary. Such airport layout plans and each amendment, revision, or modification thereof, shall be subject to the approval of the Secretary which approval shall be evidenced by the signature of a duly authorized representative of the Secretary on the face of the airport layout plan. The sponsor will not make or permit any changes or alterations in the airport or any of its facilities which are not in conformity with the airport layout plan as approved by the Secretary and which might, in the opinion of the Secretary, adversely affect the safety, utility or efficiency of the airport.

b. If a change or alteration in the airport or the facilities is made which the Secretary determines adversely affects the safety, utility, or efficiency of any federally owned, leased, or funded property on or off the airport and which is not in conformity with the airport layout plan as approved by the Secretary, the owner or operator will, if requested, by the Secretary (1) eliminate such adverse effect in a manner approved by the Secretary; or (2) bear all costs of relocating such property (or replacement thereof) to a site acceptable to the Secretary and all costs of restoring such property (or replacement thereof) to the level of safety, utility, efficiency, and cost of operation existing before the unapproved change in the airport or its facilities except in the case of a relocation or replacement of an existing airport facility due to a change in the Secretary's design standards beyond the control of the airport sponsor.

30. Civil Rights. It will comply with such rules as are promulgated to assure that no person shall, on the grounds of race, creed, color, national origin, sex, age, or handicap be excluded from participating in any activity conducted with or benefiting from funds received from this grant. This assurance obligates the sponsor for the period during which Federal financial assistance is extended to the program, except where Federal financial assistance is to provide, or is in the form of personal property or real property or interest therein or structures or improvements thereon in which case the assurance obligates the sponsor or any transferee for the longer of the following periods: (a) the period during which the property is used for a purpose for which Federal financial assistance is extended, or for another purpose involving the provision of similar services or benefits, or

(b) the period during which the sponsor retains ownership or possession of the property.

31. Disposal of Land.

a. For land purchased under a grant for airport noise compatibility purposes, including land serving as a noise buffer, it will dispose of the land, when the land is no longer needed for such purposes, at fair market value, at the earliest practicable time. That portion of the proceeds of such disposition which is proportionate to the United States' share of acquisition of such land will be, at the discretion of the Secretary, (1) reinvested in another project at the airport, or (2) transferred to another eligible airport as prescribed by the Secretary. The Secretary shall give preference to the following, in descending order, (1) reinvestment in an approved noise compatibility project, (2) reinvestment in an approved project that is eligible for grant funding under Section 47117(e) of title 49 United States Code, (3) reinvestment in an approved airport development project that is eligible for grant funding under Sections 47114, 47115, or 47117 of title 49 United States Code, (4) transferred to an eligible sponsor of another public airport to be reinvested in an approved noise compatibility project at that airport, and (5) paid to the Secretary for deposit in the Airport and Airway Trust Fund. If land acquired under a grant for noise compatibility purposes is leased at fair market value and consistent with noise buffering purposes, the lease will not be considered a disposal of the land. Revenues derived from such a lease may be used for an approved airport development project that would otherwise be eligible for grant funding or any permitted use of airport revenue.

b. For land purchased under a grant for airport development purposes (other than noise compatibility), it will, when the land is no longer needed for airport purposes, dispose of such land at fair market value or make available to the Secretary an amount equal to the United States' proportionate share of the fair market value of the land. That portion of the proceeds of such disposition which is proportionate to the United States' share of the cost of acquisition of such land will, (1) upon application to the Secretary, be reinvested or transferred to another eligible airport as prescribed by the Secretary. The Secretary shall give preference to the following, in descending order: (1) reinvestment in an approved noise compatibility project, (2) reinvestment in an approved project that is eligible for grant funding under Section 47117(e) of title 49 United States Code, (3) reinvestment in an approved airport development project that is eligible for grant funding under Sections 47114, 47115, or 47117 of title 49 United States Code, (4) transferred to an eligible sponsor of another public airport to be reinvested in an approved noise compatibility project at that airport, and (5) paid to the Secretary for deposit in the Airport and Airway Trust Fund.

c. Land shall be considered to be needed for airport purposes under this assurance if (1) it may be needed for aeronautical purposes (including runway protection zones) or serve as noise buffer land, and (2) the revenue from interim uses of such land contributes to the financial self-sufficiency of the airport. Further, land purchased with a grant received by an airport operator or owner before December 31, 1987, will be considered to be needed for airport purposes if the Secretary or Federal agency making such grant before December 31, 1987, was notified by the operator or owner of the uses of such land, did not object to such use, and the land continues to be used for that purpose, such use having commenced no later than December 15, 1989.

d. Disposition of such land under (a) (b) or (c) will be subject to the retention or reservation of any interest or right therein necessary to ensure that such land will only be used for purposes which are compatible with noise levels associated with operation of the airport.

32. **Engineering and Design Services.** It will award each contract, or sub-contract for program management, construction management, planning studies, feasibility studies, architectural services, preliminary engineering, design, engineering, surveying, mapping or related services with respect to the project in the same manner as a contract for architectural and engineering services is negotiated under Title IX of the Federal Property and Administrative Services Act of 1949 or an equivalent qualifications-based requirement **prescribed** for or by the sponsor of the airport.

33. **Foreign Market Restrictions.** It will not allow funds provided under this grant to be used to fund any project which uses any product or service of a foreign country during the period in which such foreign country is listed by the United States Trade Representative as denying fair and equitable market opportunities for products and suppliers of the United States in procurement and construction.

34. **Policies, Standards, and Specifications.** It will carry out the project in accordance with policies, standards, and specifications approved by the Secretary including but not limited to the advisory circulars listed in the Current FAA Advisory Circulars for AIP projects, dated ____________________ (the latest approved version as of this grant offer) and included in this grant, and in accordance with applicable state policies, standards, and specifications approved by the Secretary.

35. **Relocation and Real Property Acquisition.** (1) It will be guided in acquiring real property, to the greatest extent practicable under State law, by the land acquisition policies in Subpart B of 49 CFR Part 24 and will pay or reimburse property owners for necessary expenses as specified in Subpart B. (2) It will provide a relocation assistance program offering the services described in Subpart C and fair and reasonable relocation payments and assistance to displaced persons as required in Subpart D and E of 49 CFR Part 24. (3) It will make available within a reasonable period of time prior to displacement, comparable replacement dwellings to displaced persons in accordance with Subpart E of 49 CFR Part 24.

36. **Access By Intercity Buses**. The airport owner or operator will permit, to the maximum extent practicable, intercity buses or other modes of transportation to have access to the airport; however, it has no obligation to fund special facilities for intercity buses or for other modes of transportation.

37. **Disadvantaged Business Enterprises.** The recipient shall not discriminate on the basis of race, color, national origin or sex in the award and performance of any DOT-assisted contract or in the administration of its DBE program or the requirements of 49 CFR Part 26. The Recipient shall take all necessary and reasonable steps under 49 CFR Part 26 to ensure non discrimination in the award and administration of DOT-assisted contracts. The recipient's DBE program, as required by 49 CFR Part 26, and as approved by DOT, is incorporated by reference in this agreement. Implementation of this program is a legal obligation and failure to carry out its terms shall be treated as a violation of this agreement. Upon notification to the recipient of its failure to carry out its approved program, the Department may impose sanctions as provided for under Part 26 and may, in appropriate cases, refer the matter for enforcement under 18 U.S.C. 1001 and/or the Program Fraud Civil Remedies Act of 1986 (31 U.S.C. 3801).

38. **Hangar Construction.** If the airport owner or operator and a person who owns an aircraft agree that a hangar is to be constructed at the airport for the aircraft at the aircraft owner's expense, the airport owner or operator will grant to the aircraft owner for the hangar a long term lease that is subject to such terms and conditions on the hangar as the airport owner or operator may impose.

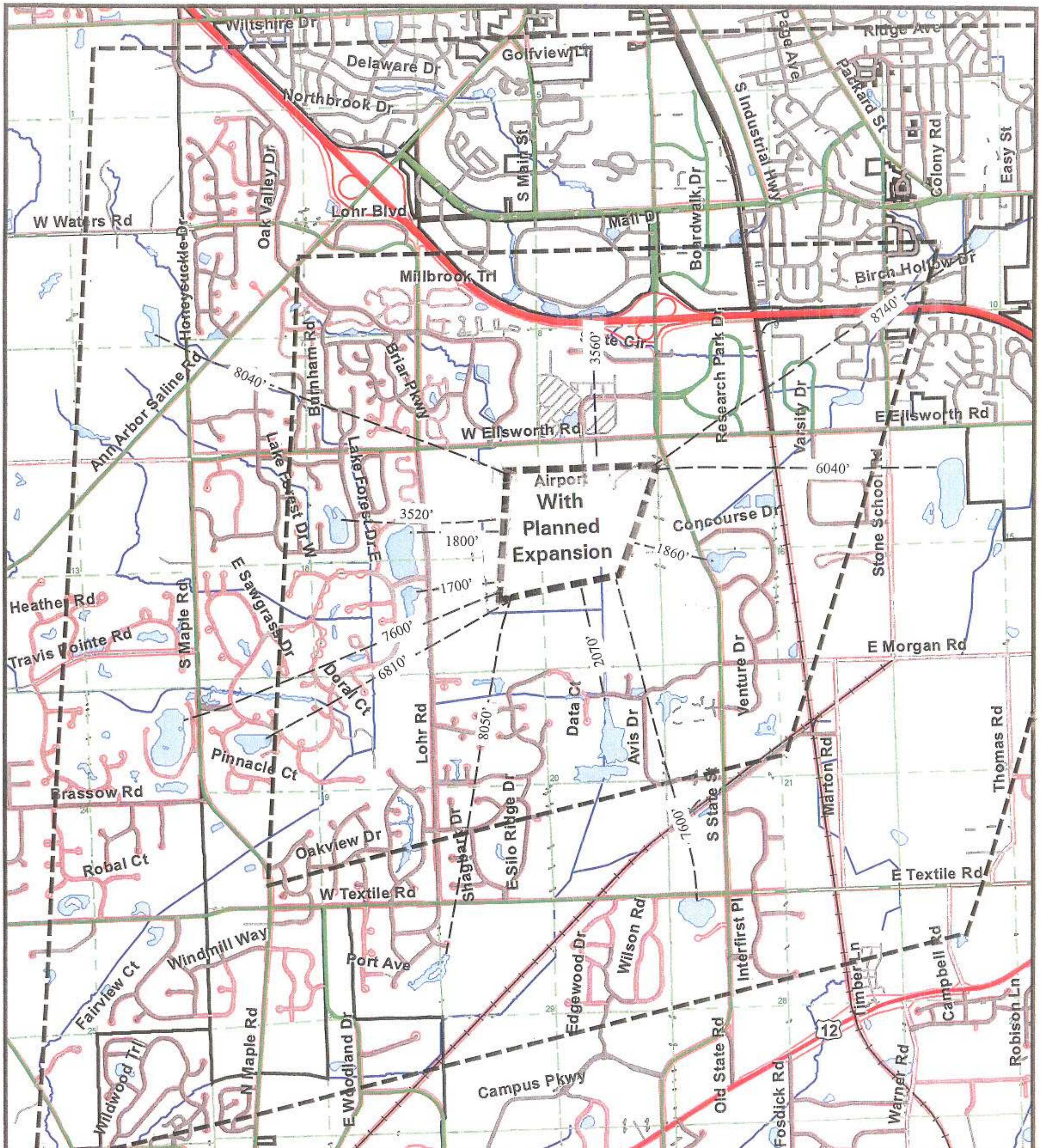
39. **Competitive Access.**

    a. If the airport owner or operator of a medium or large hub airport (as defined in section 47102 of title 49, U.S.C.) has been unable to accommodate one or more requests by an air carrier for access to gates or other facilities at that airport in order to allow the air carrier to provide service to the airport or to expand service at the airport, the airport owner or operator shall transmit a report to the Secretary that-

        1) Describes the requests;
        2) Provides an explanation as to why the requests could not be accommodated; and
        3) Provides a time frame within which, if any, the airport will be able to accommodate the requests.

    b. Such report shall be due on either February 1 or August 1 of each year if the airport has been unable to accommodate the request(s) in the six month period prior to the applicable due date.

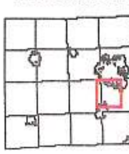
Exhibit 22



April 2010

GIS Map Print

Location Map



N

0 2,400 4,800

Feet

1 inch = 3,000 feet

Washtenaw County Michigan 1826

Geographic Information System

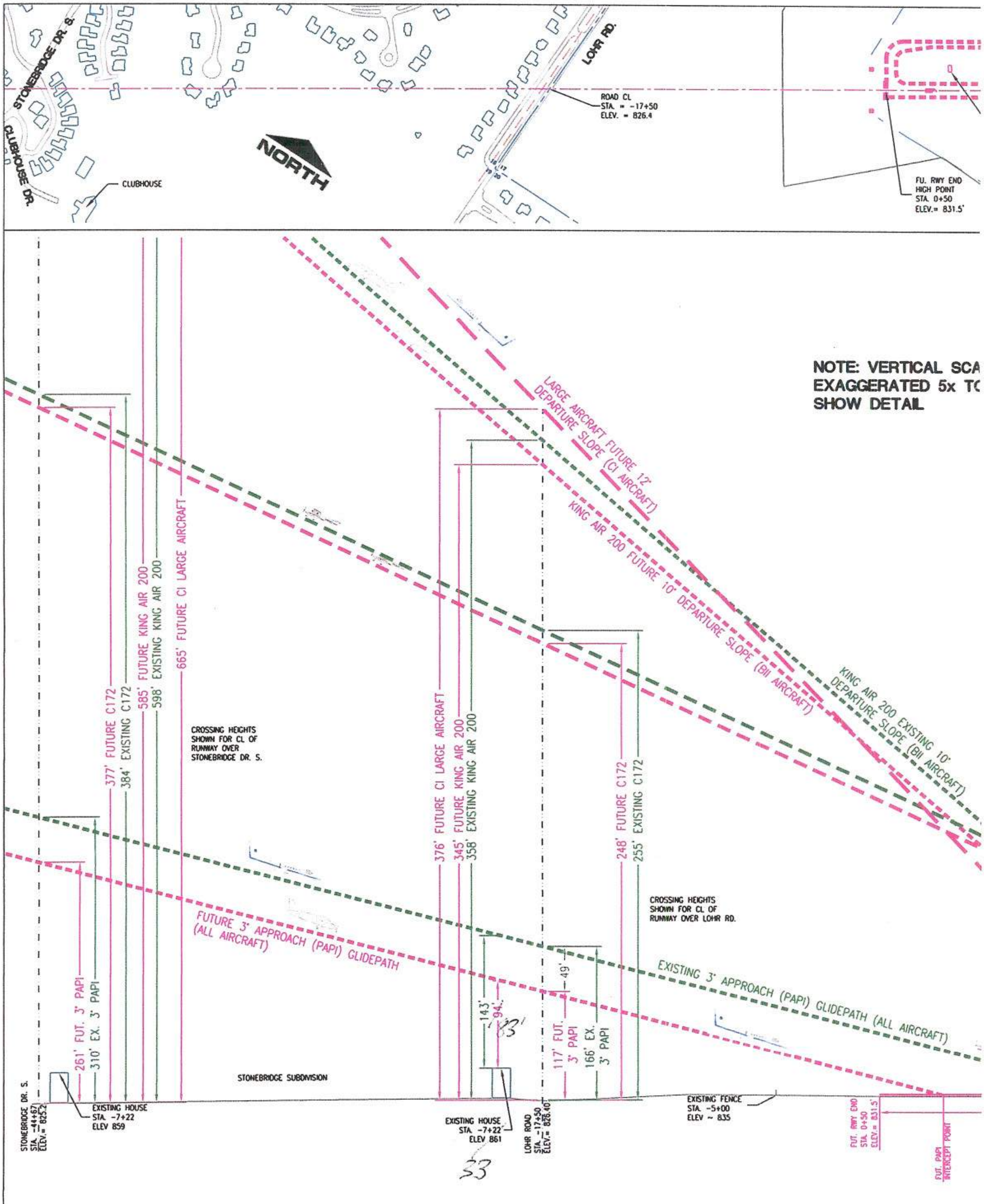
The information contained in this cadastral map is used to locate, identify and inventory parcels of land in Washtenaw County for appraisal and taxing purposes only and is not to be construed as a "survey description". The information is provided with the understanding that the conclusions drawn from such information are solely the responsibility of the user. Any assumption of legal status of this data is hereby disclaimed.

NOTE: PARCELS MAY NOT BE TO SCALE

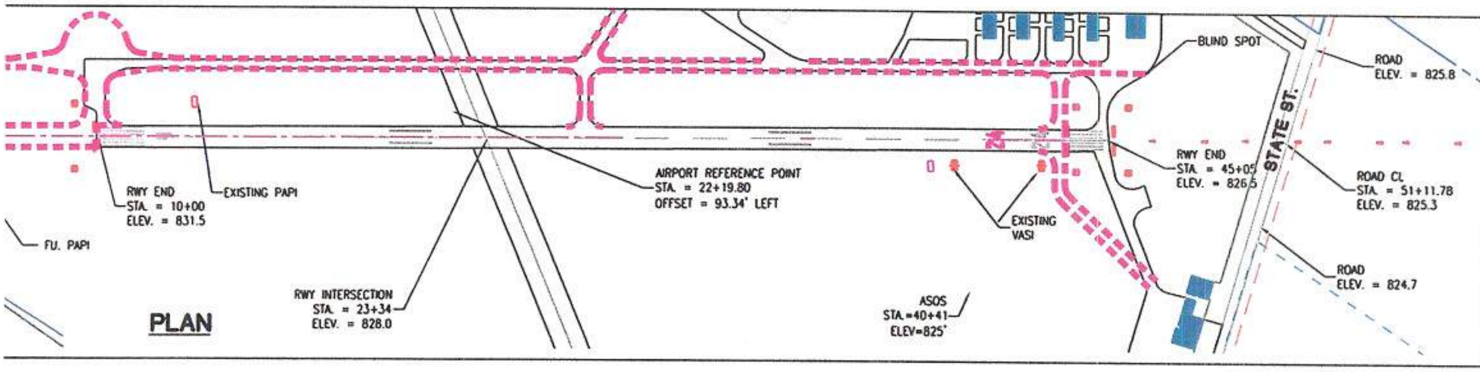
Date Printed: 04/01/2010

Committee for Preserving Community Quality

Exhibit 23



APPROACH AND DEPARTURE



APPROACHES

APPROACH SLOPE FOR ALL AIRCRAFT WOULD BE AT 3° ALONG THE PRECISION APPROACH PATH INDICATOR (PAPI).

APPROACH CLEARANCE (LOHR RD.)
166' EXISTING
117' PROPOSED EXTENSION

DEPARTURES

DEPARTURE SLOPES ARE SHOWN FOR 3 AIRCRAFT TYPES FOR THE 839' AIRPORT ELEVATION AT 83°F. CROSSING HEIGHTS SHOWN FOR CL OF RUNWAY OVER LOHR RD.

CESSNA 172 – AI SMALL AIRCRAFT
MAX. GROSS LOAD: 2,300 LBS
CLIMB RATE: 700 FT. PER MINUTE
CLIMB AIRSPEED: 73 KNOTS
CLIMB ANGLE: 5.4°
GROUND ROLL: 850 FT.
DEPARTURE CLEARANCE (LOHR RD.)
255' EXISTING
248' PROPOSED EXTENSION

KING AIR 200 – BII SMALL AIRCRAFT
MAX. GROSS LOAD: 12,5000 LBS
CLIMB RATE: 2,400 FT. PER MINUTE
CLIMB AIRSPEED: 125 KNOTS
CLIMB ANGLE: 10°
GROUND ROLL: 2200 FT.
DEPARTURE CLEARANCE (LOHR RD.)
358' EXISTING
345' PROPOSED EXTENSION

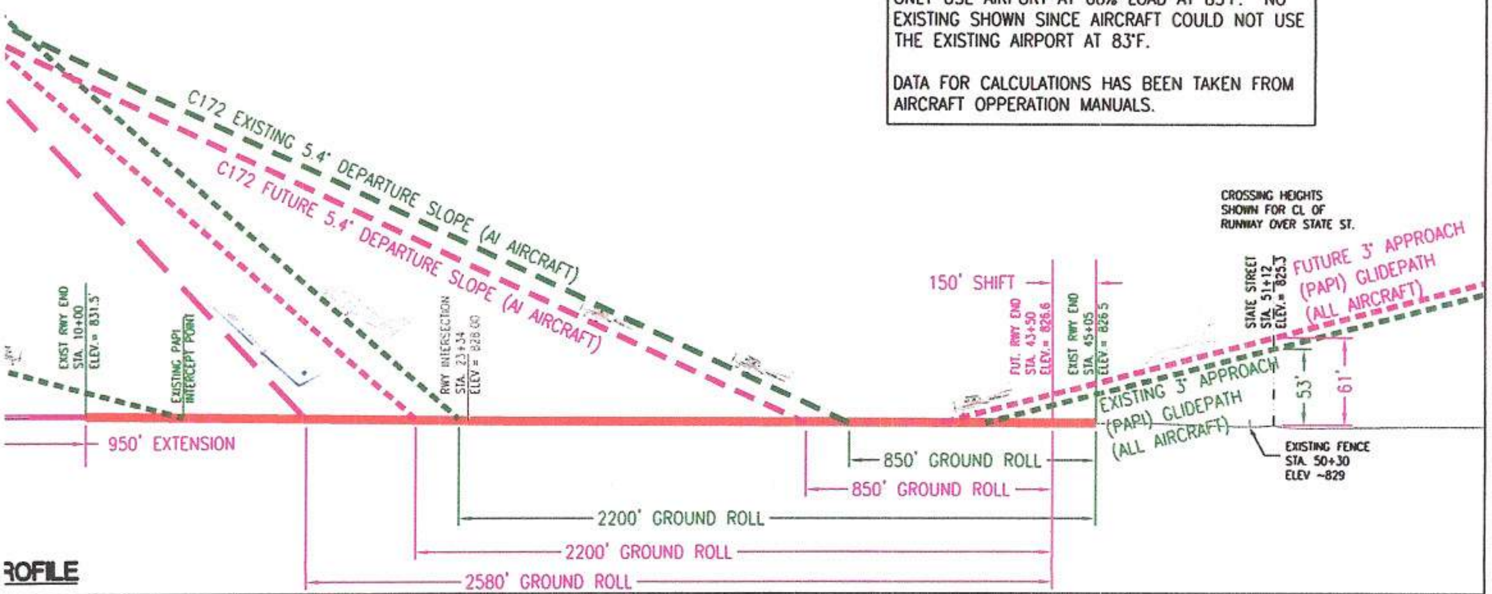
HAWKER 700A – CI LARGE AIRCRAFT
MAX. GROSS LOAD: 24,800 LBS*
CLIMB RATE: 3,000 FT. PER MINUTE
CLIMB AIRSPEED: 135 KNOTS
CLIMB ANGLE: 12°
GROUND ROLL: 2850 FT.
DEPARTURE CLEARANCE (LOHR RD.)
376' PROPOSED EXTENSION

* FOR FUTURE RUNWAY LENGTH AIRCRAFT COULD ONLY USE AIRPORT AT 60% LOAD AT 83°F. NO EXISTING SHOWN SINCE AIRCRAFT COULD NOT USE THE EXISTING AIRPORT AT 83°F.

DATA FOR CALCULATIONS HAS BEEN TAKEN FROM AIRCRAFT OPPERATION MANUALS.

TYPICAL CLIMB PERFORMANCE BY AIRCRAFT TYPE

AIRCRAFT TYPE	TYPICAL CLIMB ANGLE	TYPICAL CLIMB RATES
SINGLE ENGINE PISTON	4°–7°	500–1,000 FT/MIN
TWIN ENGINE PISTON	7°–9°	1,00–1,500 FT/MIN
TWIN ENGINE TURBOPROP	10°–11°	2,000–2,500 FT/MIN
JET	12°–16°	3,000–4,000 FT/MIN

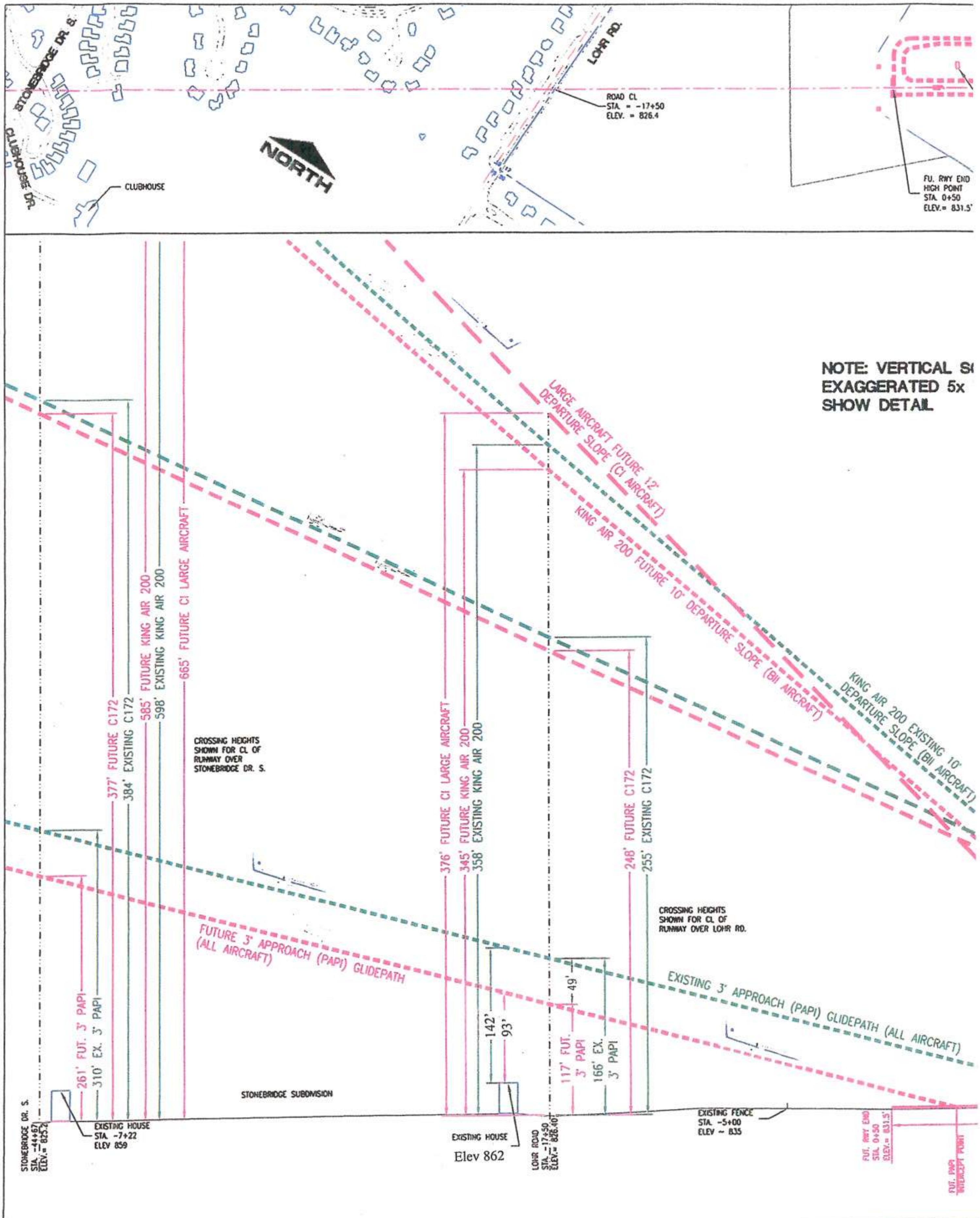


CLEARANCES

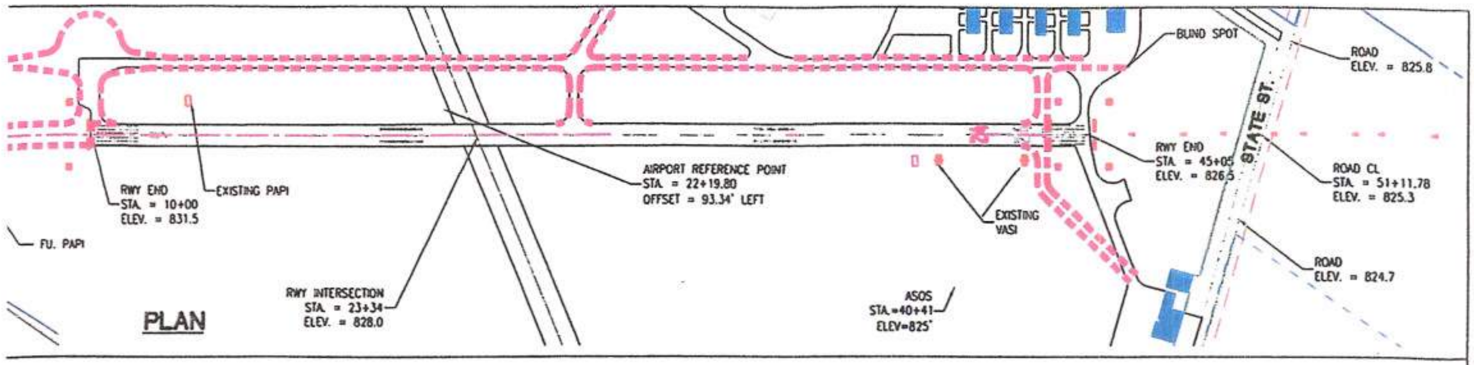
URS GRAND RAPIDS, MI. 3950 SPARKS DR. S.E. 616 574-8500

PROJECT NO. 12940723

ANN ARBOR MUNICIPAL AIRPORT



Corrected APPROACH AND DEPARTURE



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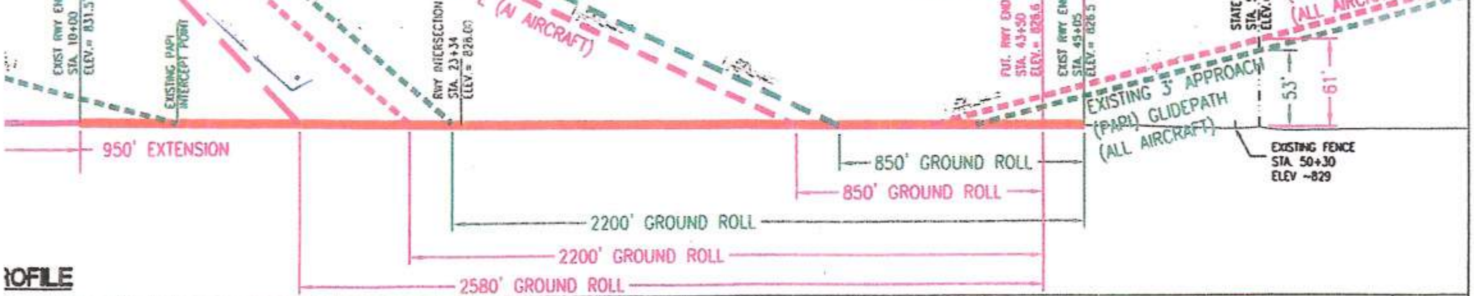


CLEARANCES

Base Map by: URS

GRAND RAPIDS, MI. PROJECT NO.

ANN ARBOR MUNICIPAL AIRPORT

Committee for Preserving Community Quality April 2010

Exhibit 24

Aircraft Emergency Landing: Stonebridge Golf Course – June 2009

Exhibit 25

National Transportation Safety Board FACTUAL REPORT AVIATION	NTSB ID: CHI01LA181	Aircraft Registration Number: N24898
	Occurrence Date: 06/21/2001	Most Critical Injury: Fatal
	Occurrence Type: Accident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone
Ann Arbor	MI	48103	1405	EDT

Airport Proximity: On Airport/Airstrip | Distance From Landing Facility:

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
Masko	Mustang MII	Airplane

Revenue Sightseeing Flight: No | Air Medical Transport Flight: No

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

*** Note: NTSB investigators may have traveled in support of this investigation and used data provided by various sources to prepare this aircraft accident report. ***

On June 21, 2001, at 1405 eastern daylight time, an amateur-built Masko Mustang MII, N24898, piloted by a commercial pilot, was destroyed when it impacted terrain following a loss of control while maneuvering in the traffic pattern at the Ann Arbor Municipal Airport (ARB), Ann Arbor, Michigan. The aircraft had just completed a touch and go and was turning from the upwind to the crosswind leg of the traffic pattern for runway 06 (3,500 feet by 75 feet, concrete). The local flight was being operated under the provisions of 14 CFR Part 91 and was not on a flight plan. Visual meteorological conditions prevailed at the time of the accident. The pilot and the pilot rated passenger received fatal injuries. The flight originated from ARB at 1353.

Witnesses to the accident saw the airplane make a steep right turn prior to spiraling to the ground.

A postaccident examination of the airplane revealed no anomalies that could be associated with a pre-impact condition.

The pilot held commercial and certified flight instructor certificates with airplane single engine land and instrument airplane ratings. The pilot also held a ground instructor certificate with advanced and instrument ratings. According to Federal Aviation Administration records, the pilot reported having 398 hours of flight time as of March 15, 2001. The pilot's logbook was not recovered.

The pilot rated passenger held a commercial pilot certificate with airplane single engine land and instrument airplane ratings. He held a certified flight instructor certificate with an airplane single engine land rating. The pilot rated passenger also held a ground instructor certificate with an advanced rating. According to Federal Aviation Administration records, the pilot rated passenger reported having 307 hours of flight time as of May 10, 2001. The pilot rated passenger's logbook was not recovered.

Toxicology tests performed on the pilot and pilot rated passenger were negative for all tests performed. Autopsies were performed on the pilot and pilot rated passenger by Washtenaw County on June 22, 2001.

It was reported that the airplane was purchased on June 16, 2001. The pilot was the flight instructor of the new owner. The owner was not aboard the airplane when the accident occurred.

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI01LA181
Occurrence Date: 06/21/2001
Occurrence Type: Accident

Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
ANN ARBOR MUNI	ARB	839 Ft. MSL	06	3500	75

Runway Surface Type: Concrete

Runway Surface Condition: Dry

Approach/Arrival Flown: NONE

VFR Approach/Landing: Touch and Go

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
Masko	Mustang MII	8

Airworthiness Certificate(s): Experimental (Special)

Landing Gear Type: Tailwheel

Amateur Built Acft?	Number of Seats:	Certified Max Gross Wt.	Number of Engines:
Yes	2	1500 LBS	1

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Reciprocating	Lycoming	O-320	150 HP

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
		Hours	Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?/Type	ELT Operated?	ELT Aided in Locating Accident Site?
Yes /	No	No

Owner/Operator Information

	Street Address	City	State	Zip Code
Registered Aircraft Owner: Craig W. Peterson	1841 Hiller Rd.	West Bloomfield	MI	48324
Operator of Aircraft: Craig W. Peterson	1841 Hiller Rd.	West Bloomfield	MI	48324

Operator Does Business As:

Operator Designator Code:

- Type of U.S. Certificate(s) Held: None

Air Carrier Operating Certificate(s):

Operating Certificate:

Operator Certificate:

Regulation Flight Conducted Under: Part 91: General Aviation

Type of Flight Operation Conducted: Personal

National Transportation Safety Board

FACTUAL REPORT AVIATION

NTSB ID: CHI01LA181

Occurrence Date: 06/21/2001

Occurrence Type: Accident

First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File		25

Sex: M | Seat Occupied: Left | Occupational Pilot? Civilian Pilot | Certificate Number:

Certificate(s): Flight Instructor; Commercial

Airplane Rating(s): Single-engine Land

Rotorcraft/Glider/LTA: None

Instrument Rating(s): Airplane

Instructor Rating(s): Airplane Single-engine; Instrument Airplane

Current Biennial Flight Review?

Medical Cert.: Class 2 | Medical Cert. Status: Valid Medical--no waivers/lim. | Date of Last Medical Exam: 10/2000

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	398									
Pilot In Command(PIC)										
Instructor										
Instruction Received										
Last 90 Days										
Last 30 Days										
Last 24 Hours										

Seatbelt Used? Yes | Shoulder Harness Used? Yes | Toxicology Performed? Yes | Second Pilot? Yes

Flight Plan/Itinerary

Type of Flight Plan Filed: None

Departure Point	State	Airport Identifier	Departure Time	Time Zone
Same as Accident/Incident Location		ARB	1353	EDT

Destination	State	Airport Identifier
Local Flight	MI	ARB

Type of Clearance: VFR

Type of Airspace: Class D

Weather Information

Source of Wx Information:

No record of briefing

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI01LA181
Occurrence Date: 06/21/2001
Occurrence Type: Accident

Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
ARB	1353	EDT	839 Ft. MSL	0 NM	0 Deg. Mag.

Sky/Lowest Cloud Condition: Clear Ft. AGL
Condition of Light: Day
Lowest Ceiling: Broken 8500 Ft. AGL
Visibility: 10 SM
Altimeter: 30.03 "Hg
Temperature: 19 °C
Dew Point: 15 °C
Weather Conditions at Accident Site: Visual Conditions
Wind Direction: 60
Wind Speed: 5
Wind Gusts:
Visibility (RVR): Ft.
Visibility (RVV) SM
Precip and/or Obscuration:

Accident Information

Aircraft Damage: Destroyed
Aircraft Fire: None
Aircraft Explosion None

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot	1				1
Second Pilot					
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants					
Other Crew					
Passengers	1				1
- TOTAL ABOARD -	2				2
Other Ground					
- GRAND TOTAL -	2				2

National Transportation Safety Board

FACTUAL REPORT
AVIATION

NTSB ID: CHI01LA181

Occurrence Date: 06/21/2001

Occurrence Type: Accident

Administrative Information

Investigator-In-Charge (IIC)

John M. Brannen

Additional Persons Participating in This Accident/Incident Investigation:

Lorenzo Rodney
FAA-Detroit, Michigan - FSDO
Belleville, MI

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI95FA050	Aircraft Registration Number: N1QF
Occurrence Date: 12/01/1994	Most Critical Injury: Fatal
Occurrence Type: Accident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone
ANN ARBOR	MI	48105	1007	CST

Airport Proximity: Off Airport/Airstrip | Distance From Landing Facility:

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
Agusta	A109A II /A109A II	Helicopter

Revenue Sightseeing Flight: No | Air Medical Transport Flight:

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

*** Note: NTSB investigators either traveled in support of this investigation or conducted a significant amount of investigative work without any travel, and used data obtained from various sources to prepare this aircraft accident report. ***

HISTORY OF FLIGHT

On December 1, 1994, about 1007 central standard time, an Agusta SPA A109A II, N1QF, operated by Metro Aviation, Inc., was destroyed when it collided with the terrain near Ann Arbor, Michigan. The commercial pilot and two passengers (medical evacuation crew members) were fatally injured. The 14 CFR Part 91 positioning flight departed the St. Joseph Hospital in visual meteorological conditions about 1003, en route to Howell, Michigan. The purpose of the flight was to pick up a patient at Howell, and return to St. Joseph's Hospital.

Prior to the morning of the accident N1QF was designated as the standby helicopter; however, the primary helicopter was scheduled for maintenance on the day of the accident, therefore essential equipment had to be moved from the primary craft to N1QF. Before the transfer could be accomplished, N1QF was required to prepare for dispatch on the accident flight. What was later described by a witness as a "hasty dispatch," necessitated a hurried departure to accomplish the transfer of equipment, complete a preflight,and other items necessary for a medical evacuation flight. The witness to the departure stated that a complete preflight was accomplished by the crew; although this witness did not actually have an opportunity to watch the entire preparation. The witness indicated that the start of the engines was "normal," with no delay in the engine start up. The flight departed at 1003.

At 1005 N1QF contacted the Ann Arbor, Federal Aviation Administration (FAA) Control Tower (ATCT), giving its position as one and one half miles east of St. Joseph's Hospital and requesting landing permission stating, in part, "I'd like to proceed inbound.. single engine landing, please." Six seconds later the flight was cleared into the class D surface area. Seven seconds later, N1QF responded stating, "Ah, disregard, I'm going down at this time." No additional information was transmitted, nor was the reason for the single engine landing stated. The pilot did not declare an emergency nor did he request assistance.

The pilot then contacted the dispatcher, at St. Joseph's Hospital and stated that he was going to land, "north of the university." The dispatcher requested the information be repeated and the pilot did so. There was no indication of any need for assistance, the nature of any emergency situation, nor was there any discussion of difficulties being experienced by the flight. Twenty-six seconds after the pilot's repeating the location to the dispatcher, he made a final transmission, indicating a crash was imminent.

Eyewitnesses observed the accident helicopter during the final few seconds of the flight. Two

Narrative (Continued)

witnesses stated that the helicopter was trailing smoke from the area of the engines. One witness indicted that the helicopter was maneuvering just prior to the impact and that during the final descent which he described as "dropped like a stone," it appeared the rotor blades were "not turning hardly at all." Witnesses reported that the helicopter was nearly silent just prior to ground impact and that there was no engine noise at all after impact.

OTHER DAMAGE

One small tree was damaged during the impact with the terrain.

PERSONAL INFORMATION

The pilot was born May 27, 1952, and was the holder of a commercial helicopter certificate number 2157108, with instrument helicopter privileges. At the time of the accident he had 5,000 hours flight time, with 3,500 hours of pilot in command time and 300 hours in the make and model of helicopter involved in the accident. He held a second class medical certificate issued June 9, 1994. His most recent biennial flight review was accomplished in an Agusta A109 on October 23, 1994.

AIRCRAFT INFORMATION

The helicopter was an Agusta SPA A109A II, serial number 7311, N1QF. The helicopter was maintained on an Approved Inspection Program. The most recent inspection occurred on June 13, 1994, with a total time in service of 1,870 hours. The helicopter had accumulated 57 hours since the inspection, at the time of the accident. The helicopter was last fueled on November 22, 1994.

WRECKAGE AND IMPACT INFORMATION

The helicopter impacted flat terrain in a commercial area, on a northeast heading. Ground scars and eyewitness reports indicated that the helicopter impacted in a near vertical direction with little forward motion. The landing gear was found in the extended (gear down) position. The helicopter was lying on its left side. The fuselage was crushed to about one-half the original height. The tail boom was partially separated from the fuselage from ground impact and impact with a small tree. Three of the main rotor blades were intact with little bending. The tail rotor assembly had impact damage only with no rotational damage evident. The main rotor head exhibited marks and damage consistent with blade coning impact.

The rotor system was inspected during the on scene phase of the investigation including the main and tail rotors, transmission and gearbox. No discrepancies were noted.

Both engines and the transmission exhibited little impact damage and were removed for further study. During the on-scene investigation both engines rotated and there was continuity throughout the gear train. No damage was visible in the output drive shafts on either engine. The fuel control pointer on the number 1 engine was at 30 degrees with the throttle handle at idle. The fuel control pointer on the number 2 engine was at 85 degrees with the throttle handle about mid-range. Fuel vacuum checks were done with engine number 1 having no leaks and engine number 2 having a leak traced to the fuel pump assembly.

MEDICAL AND PATHOLOGICAL INFORMATION

A post mortem examination of the pilot was conducted by the Washtenaw County (Michigan) Medical Examiner, on December 2, 1994. No contributing pre-existing pathology was found.

A toxicological examination of specimens from the pilot proved negative for those drugs screen.

Narrative (Continued)

TESTS AND RESEARCH

Fuel samples from the fueling source were found to be free of water and within limits for Jet-A1.

Fuel and oil samples from the helicopter were tested at the Allison lab and were found to be within limits for Jet-A1 fuel and MIL-L-23699E oil.

An examination of light bulb filaments revealed stretched filaments in the "Master Warning," "Master Caution," "Engine #1 Low RPM," "Engine #2 Low RPM." and "Low Rotor RPM" panels.

Both engines were test run at Allison on a production test stand on January 11, 1995. Number 1 engine was found to be within limits. Number 2 engine experienced excessive compressor vibration, therefore, the control components from that engine were tested on the number 1 engine which had been successfully run. The engine operation did not reach the limits falling about 2% below top limits.

The compressor for engine number 2 was disassembled and inspected. A visual inspection revealed unusual balance marks. The rotor was check balanced and it measured at 0.006 oz-in of unbalance. The limit should have been 0.001 oz-in. Although the exact mode of unbalance was not determined, experienced sources indicated that the unusual marks could not be associated with normal operation of the engine; however could be associated with impact artifact.

The individual components (originally) from engine number 2 were tested on October 11, 1995, and the fuel control was found to fall about 2% below the top limit. There was nothing found that would have prevented the engine from operating normally at the cruise setting.

Throughout the on-scene investigation and during the testing of components, nothing was found to indicate any reason that an engine should stop running inflight. Nothing was found in either engine to indicate an indication necessitating a need to manually shut down an engine inflight.

ADDITIONAL DATA/INFORMATION

Parties to the investigation were the FAA Flight Standards District Office, Belleville, Michigan; Agusta Aerospace Corporation, Philadelphia, Pennsylvania; Allison, Indianapolis, Indiana; Allied Signal Aerospace, South Bend, Indiana; and Metro Aviation Inc., Shreveport, Louisiana.

The helicopter wreckage was released to representatives of the owner on December 16, and December 22, 1994 and January 9, 1996.
Updated on Feb 2 2009 2:42PM

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI95FA050
Occurrence Date: 12/01/1994
Occurrence Type: Accident

Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
		Ft. MSL	0		

Runway Surface Type:

Runway Surface Condition:

Approach/Arrival Flown:

VFR Approach/Landing: Forced Landing

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
Agusta	A109A II /A109A II	7311

Airworthiness Certificate(s): Normal

Landing Gear Type: Retractable - Tricycle

Amateur Built Acft?	Number of Seats:	Certified Max Gross Wt.	Number of Engines:
No	4	5730 LBS	2

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Turbo Shaft	ALLISON	250-C20B	420 HP

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
AAIP	06/1994	57 Hours	1890 Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?/Type	ELT Operated?	ELT Aided in Locating Accident Site?
No		

Owner/Operator Information

Registered Aircraft Owner	Street Address	City	State	Zip Code
AGUSTA AEROSPACE CORP.	3050 RED LION RD.	PHILADELPHIA	PA	19114

Operator of Aircraft	Street Address	City	State	Zip Code
METRO AVIATION, INC.	P. O. BOX 7008	SHREVEPORT	LA	71137

Operator Does Business As: MIDWEST MED FLIGHT

Operator Designator Code: HDNA

- Type of U.S. Certificate(s) Held:

Air Carrier Operating Certificate(s): On-demand Air Taxi

Operating Certificate:

Operator Certificate:

Regulation Flight Conducted Under: Part 91: General Aviation

Type of Flight Operation Conducted: Positioning

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI95FA050

Occurrence Date: 12/01/1994

Occurrence Type: Accident

First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File	On File	42

Sex: M | Seat Occupied: Right | Occupational Pilot? Yes | Certificate Number: On File

Certificate(s): Commercial

Airplane Rating(s): None

Rotorcraft/Glider/LTA: Helicopter

Instrument Rating(s): Helicopter

Instructor Rating(s): None

Current Biennial Flight Review?

Medical Cert.: Class 2 | Medical Cert. Status: Valid Medical--no waivers/lim. | Date of Last Medical Exam: 06/1994

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	5000	300			500	150	160	5000		
Pilot In Command(PIC)	3500	300						3500		
Instructor										
Instruction Received										
Last 90 Days	32	32			11		3	32		
Last 30 Days	10	10			4		1	10		
Last 24 Hours	1	1					1	1		

Seatbelt Used? Yes | Shoulder Harness Used? Yes | Toxicology Performed? Yes | Second Pilot? No

Flight Plan/Itinerary

Type of Flight Plan Filed: Company VFR

Departure Point	State	Airport Identifier	Departure Time	Time Zone
Same as Accident/Incident Location		NONE	1003	EST

Destination	State	Airport Identifier
HOWELL	MI	NONE

Type of Clearance: None

Type of Airspace: Class D

Weather Information

Source of Wx Information:

No record of briefing

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI95FA050

Occurrence Date: 12/01/1994

Occurrence Type: Accident

Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
	0000		0 Ft. MSL	0 NM	0 Deg. Mag.

Sky/Lowest Cloud Condition: Unknown 0 Ft. AGL

Condition of Light: Day

Lowest Ceiling: Broken 12000 Ft. AGL

Visibility: 10 SM

Altimeter: "Hg

Temperature: -1 °C

Dew Point: °C

Weather Conditions at Accident Site: Visual Conditions

Wind Direction: 180

Wind Speed: 12

Wind Gusts: 16

Visibility (RVR): 0 Ft.

Visibility (RVV) 0 SM

Precip and/or Obscuration:
No Obscuration; No Precipitation

Accident Information

Aircraft Damage: Destroyed

Aircraft Fire: None

Aircraft Explosion None

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot	1				1
Second Pilot					
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants					
Other Crew					
Passengers	2				2
- TOTAL ABOARD -	3				3
Other Ground	0	0	0		0
- GRAND TOTAL -	3	0	0		3

National Transportation Safety Board

FACTUAL REPORT

AVIATION

NTSB ID: CHI95FA050

Occurrence Date: 12/01/1994

Occurrence Type: Accident

Administrative Information

Investigator-In-Charge (IIC)

STEPHEN A. WILSON

Additional Persons Participating in This Accident/Incident Investigation:

RICHARD G GASTRICH
BELLEVILLE, MI

PAOLO FERRERI
PHILADELPHIA, PA

SCOTT S SCHEURICH
INDIANAPOLIS, IN

MILTON K GELTZ
SHREVEPORT, LA

National Transportation Safety Board FACTUAL REPORT AVIATION	NTSB ID: CHI90FA003	Aircraft Registration Number: N9704J
	Occurrence Date: 10/07/1989	Most Critical Injury: Fatal
	Occurrence Type: Accident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone
ANN ARBOR	MI	48108	1201	EDT

Airport Proximity: On Airport/Airstrip | Distance From Landing Facility: 0

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
PIPER	PA-28-180 /PA-28-180	Airplane

Revenue Sightseeing Flight: No | Air Medical Transport Flight: No

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

*** Note: NTSB investigators either traveled in support of this investigation or conducted a significant amount of investigative work without any travel, and used data obtained from various sources to prepare this aircraft accident report. ***

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI90FA003
Occurrence Date: 10/07/1989
Occurrence Type: Accident

Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
ANN ARBOR	ARB	839 Ft. MSL	24	3500	75

Runway Surface Type: Asphalt

Runway Surface Condition: Dry

Approach/Arrival Flown: NONE

VFR Approach/Landing: Full Stop; Traffic Pattern

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
PIPER	PA-28-180 /PA-28-180	28-3894

Airworthiness Certificate(s):

Landing Gear Type: Tricycle

Amateur Built Acft?	Number of Seats:	Certified Max Gross Wt.	Number of Engines:
No	4	2400 LBS	1

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Reciprocating	LYCOMING	O-360-A4A	180 HP

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
Unknown		0 Hours	Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?/Type	ELT Operated?	ELT Aided in Locating Accident Site?
Yes /	Yes	

Owner/Operator Information

	Street Address		
Registered Aircraft Owner: DAVID B. ESTEP	952 E. 163RD PLACE		
	City	State	Zip Code
	SOUTH HOLLAND	IL	60473
Operator of Aircraft: DAVID B. ESTEP	Street Address: 952 E. 163RD PLACE		
	City	State	Zip Code
	SOUTH HOLLAND	IL	60473

Operator Does Business As:

Operator Designator Code:

- Type of U.S. Certificate(s) Held: None

Air Carrier Operating Certificate(s):

Operating Certificate:

Operator Certificate:

Regulation Flight Conducted Under: Part 91: General Aviation

Type of Flight Operation Conducted: Personal

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI90FA003

Occurrence Date: 10/07/1989

Occurrence Type: Accident

First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File		34

Sex: M | Seat Occupied: Unknown | Occupational Pilot? Unknown | Certificate Number: On File

Certificate(s): Private

Airplane Rating(s): Single-engine Land

Rotorcraft/Glider/LTA: None

Instrument Rating(s): None

Instructor Rating(s):

Current Biennial Flight Review?

Medical Cert.: Class 3 | Medical Cert. Status: Valid Medical--no waivers/lim. | Date of Last Medical Exam: 05/1989

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	72	7								
Pilot In Command(PIC)										
Instructor										
Instruction Received										
Last 90 Days										
Last 30 Days										
Last 24 Hours										

Seatbelt Used? Yes | Shoulder Harness Used? No | Toxicology Performed? Yes | Second Pilot? No

Flight Plan/Itinerary

Type of Flight Plan Filed: None

Departure Point	State	Airport Identifier	Departure Time	Time Zone
CHICAGO	IL	3HA	0900	CDT

Destination	State	Airport Identifier
Same as Accident/Incident Location		ARB

Type of Clearance: None

Type of Airspace:

Weather Information

Source of Wx Information:

Flight Service Station

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI90FA003

Occurrence Date: 10/07/1989

Occurrence Type: Accident

Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
ARB	1204	EDT	839 Ft. MSL	0 NM	0 Deg. Mag.

Sky/Lowest Cloud Condition: Unknown 0 Ft. AGL

Condition of Light: Day

Lowest Ceiling: Overcast 3000 Ft. AGL

Visibility: 20 SM

Altimeter: 30.00 "Hg

Temperature: -18 °C

Dew Point: -18 °C

Weather Conditions at Accident Site: Visual Conditions

Wind Direction: 300

Wind Speed: 8

Wind Gusts:

Visibility (RVR): 0 Ft.

Visibility (RVV) 0 SM

Precip and/or Obscuration:

Accident Information

Aircraft Damage: Destroyed

Aircraft Fire: None

Aircraft Explosion None

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot	1				1
Second Pilot					
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants					
Other Crew					
Passengers	2				2
- TOTAL ABOARD -	3				3
Other Ground	0	0	0		0
- GRAND TOTAL -	3	0	0		3

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI90FA003
Occurrence Date: 10/07/1989
Occurrence Type: Accident

Administrative Information

Investigator-In-Charge (IIC)

WILLIAM C. BRUCE

Additional Persons Participating in This Accident/Incident Investigation:

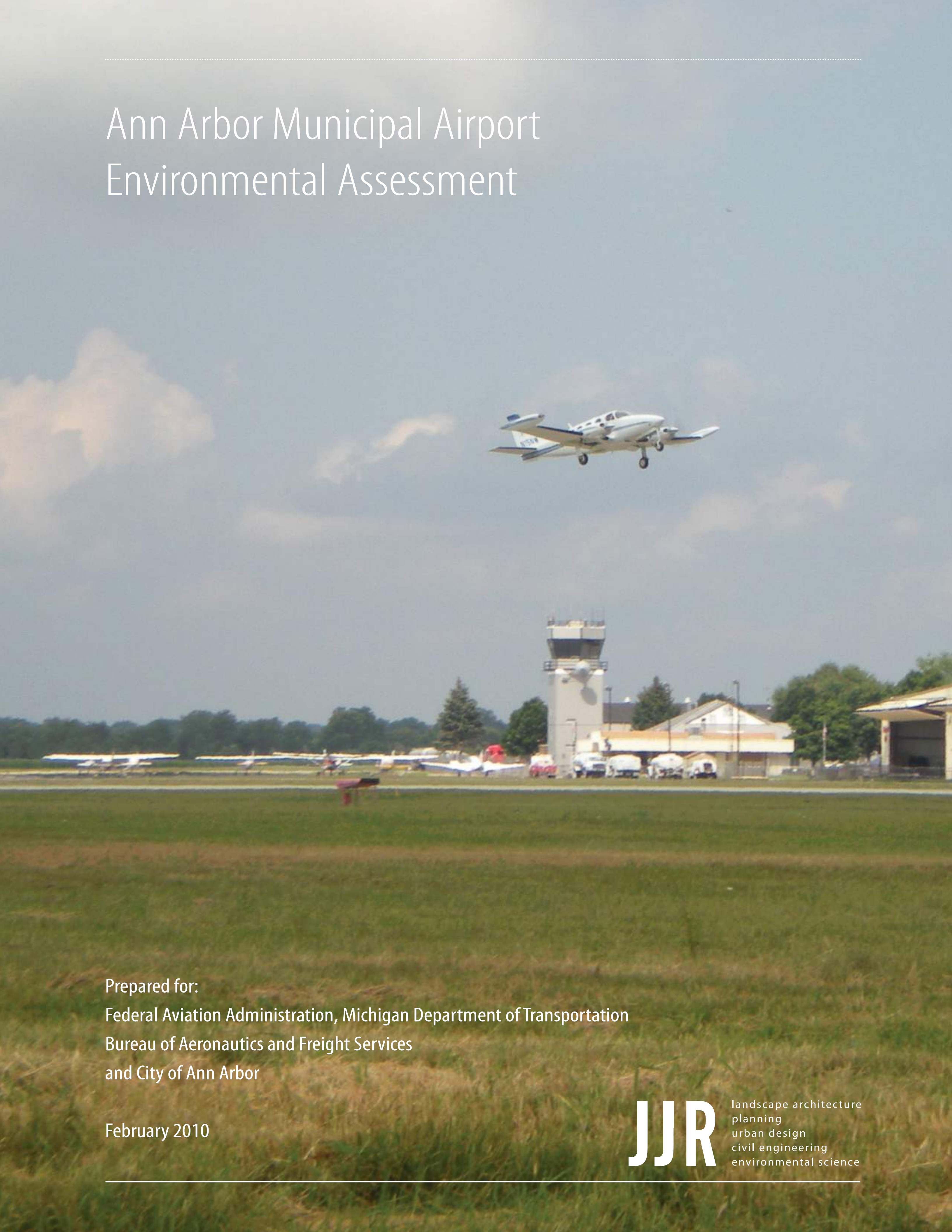
G. ERIKSON
WILLIAMSPORT, PA

J. CHADWELL
VERO BEACH, FL

R. JOHNSON

Exhibit 26

Ann Arbor Municipal Airport Environmental Assessment



Prepared for:
Federal Aviation Administration, Michigan Department of Transportation
Bureau of Aeronautics and Freight Services
and City of Ann Arbor

February 2010

JJR
landscape architecture
planning
urban design
civil engineering
environmental science

Environmental Assessment
for
Ann Arbor Municipal Airport
Ann Arbor, Michigan

Prepared for:

Michigan Department of Transportation
Bureau of Aeronautics and Freight Services
and
City of Ann Arbor

Prepared by:

JJR, LLC

This environmental assessment becomes a State of Michigan document when evaluated and signed by the responsible state official.

Responsible State Official	Date of Approval
Responsible Federal Official	Date of Approval

This Environmental Assessment describes the social, economic, and environmental impacts associated with the Preferred Alternative for implementing proposed improvements at the Ann Arbor Municipal Airport. The alternatives considered were: (1) No Build, (2) Use other airports, (3) Construct new airport, (4) Develop alternative modes of transportation, and (5) Runway 6/24 alternatives.

Comments on this Environmental Assessment should be received within 30 days of the date of publication and should be sent to Ms. Molly Lamrouex, Airports Division, MDOT Bureau of Aeronautics and Freight Services, 2700 Port Lansing Road, Lansing, Michigan 48906-2160.

ANN ARBOR MUNICIPAL AIRPORT
ENVIRONMENTAL ASSESSMENT

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Appendices

Section 1.
Executive Summary

The Ann Arbor Municipal Airport (ARB), owned and operated by the City of Ann Arbor, is located in Pittsfield Township, Washtenaw County, Michigan. ARB initiated preparation of an Environmental Assessment (EA) in 2009 to evaluate the potential impacts of implementing portions of proposed developments shown on the Federal Aviation Administration (FAA) approved Airport Layout Plan (ALP).

The proposed developments focus on extending and improving Runway 6/24, the primary runway, to address the needs of the existing critical aircraft that use the airport. Alternatives were developed to provide options for extending the existing 3,505-foot runway to 4,300-feet, while extending the existing parallel taxiway to the same length. Alternatives considered in this study included no build, use other airports, construct new airport, develop alternative modes of transportation, and Runway 6/24 alternatives.

The alternatives were evaluated based on their ability to meet the purpose and need of the project, the impact the alternative would have on the community and environment, and other limiting factors, such as cost. Based on this evaluation, a build alternative that involves shifting and extending the existing runway was selected as the Preferred Alternative.

Implementation of the Preferred Alternative would not require the acquisition of land, and no homes or businesses would be displaced. The Preferred Alternative would not impact wetlands, county drains, or floodplains. The proposed project would have a positive impact on interstate commerce to the immediate Ann Arbor area, as well as enhance the safety of airport operations.

Section 2.
Purpose and Need

2.1 PROJECT LOCATION AND DESCRIPTION

Note: The following information contains a large number of aviation-related acronyms. A glossary with definitions is included in Section 10 of this document.

Ann Arbor Municipal Airport (ARB) is a public-use, general aviation airport located in Washtenaw County, Michigan. The airport is located in Pittsfield Township and consists of approximately 837 acres. ARB is generally bound by Ellsworth Road to the north, State Road to the east, and Lohr Road to the west (Figure 2-1).

ARB is in close proximity to state highways including US-23, M-14, US-12, and I-94. Direct access to the airport is from Ellsworth and State Roads. The closest public-use airport is Willow Run Airport in Ypsilanti, which is approximately 12 miles to the east (approximately a 20 minute drive by automobile). The southeastern region of Michigan has a high level of commerce, and high levels of commercial, corporate, and general aviation air traffic.

The City of Ann Arbor owns and operates ARB. The city is responsible for contracting with the Fixed Base Operators (FBO), which are Solo Aviation, Ann Arbor Aviation Center, and Bijan Air. ARB's operating budget is an enterprise fund comprised solely of revenue generated by airport operations.

The primary runway, Runway 6/24, is 3,505-feet long by 75-feet wide and is oriented in a northeast/southwest direction. ARB has 22 permanent aviation service buildings, including the administration building, the FBOs, maintenance facilities, conventional box hangars, a privately owned hangar, and the FAA Air Traffic Control Tower (ATCT). The airport also provides 150 T-hangar spaces in an additional 13 T-hangar structures.

The current FAA-approved Airport Layout Plan (ALP) was updated in 2008 (Figure 2-2), and it incorporates the future development proposed in the Airport Capital Improvement Plan for ARB.

The proposed improvements from the ALP that are documented in this EA include:

- Shift and extend existing Runway 6/24, resulting in a runway that would be 4,300-feet long by 75-feet wide.
- Shift and extend the parallel taxiway to coincide with the revised Runway 6/24.
- Provide a new taxiway connector to the extended Runway 6 end.
- Provide a new taxiway connector and holding bay to the shifted Runway 24 end.

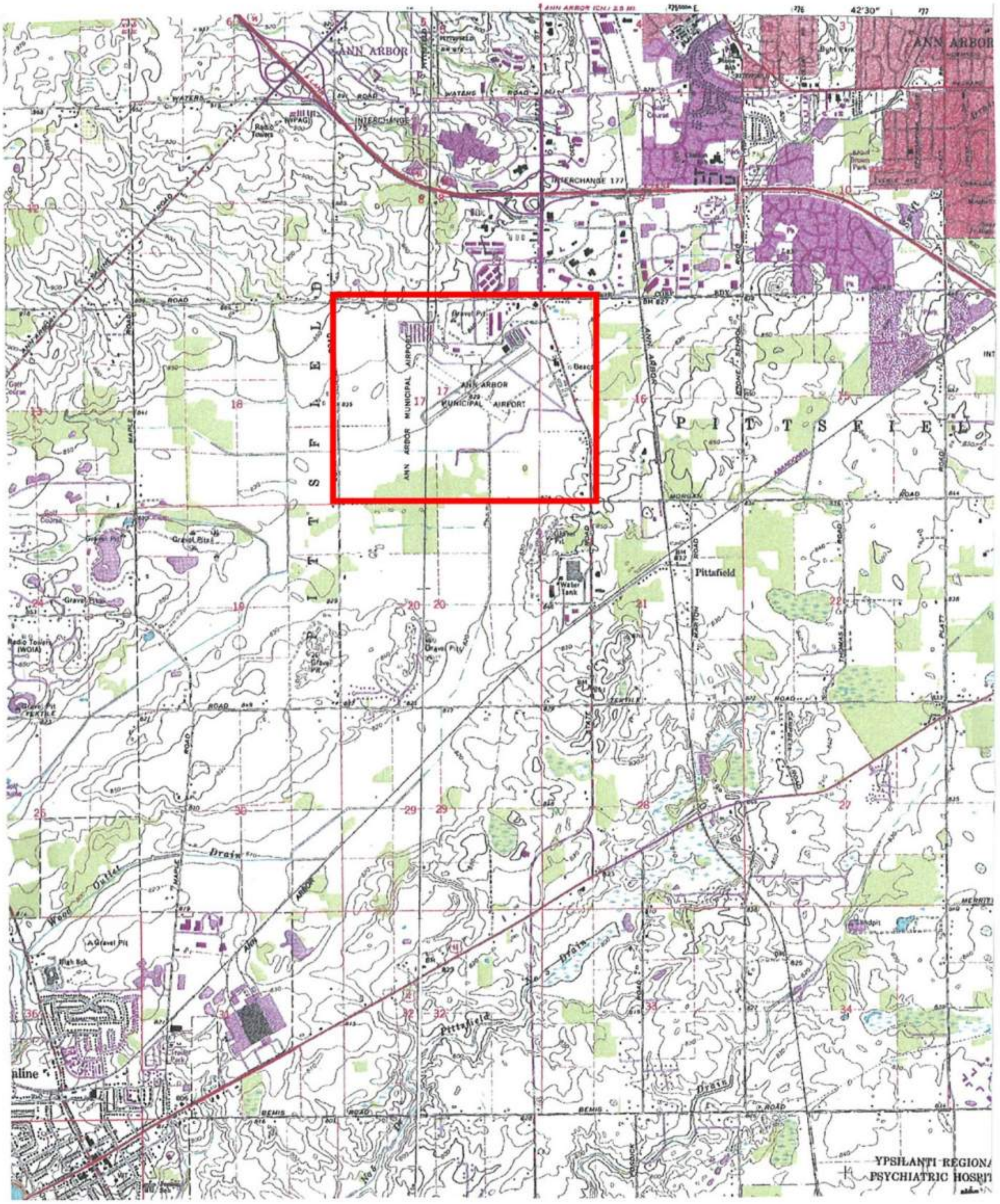

Figure 2.1: Location Map
Ann Arbor Municipal Airport Environmental Assessment

JJR

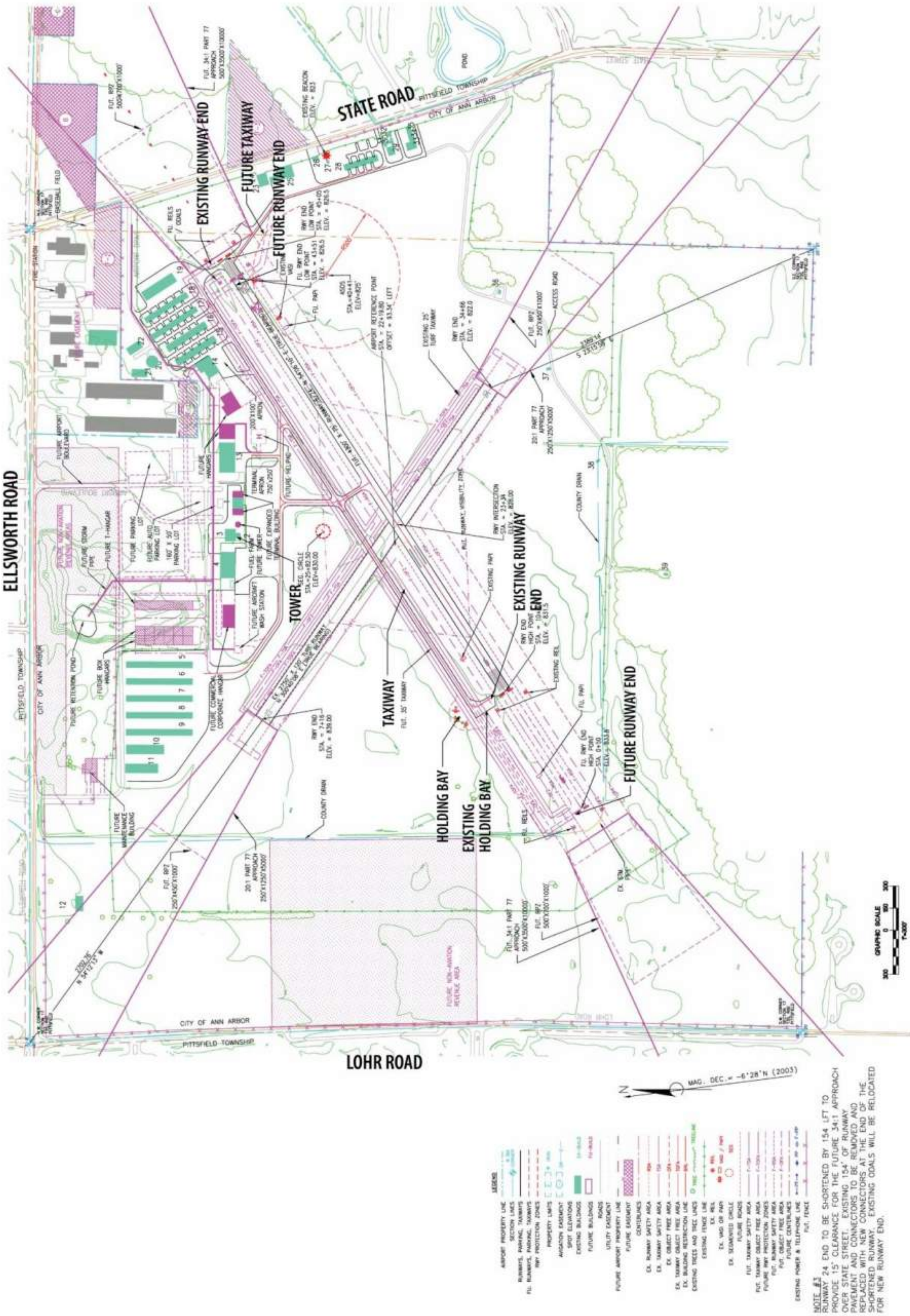

Figure 2.2: Airport Layout Plan
Ann Arbor Municipal Airport Environmental Assessment

2.2 PURPOSE AND NEED

The purpose of the proposed improvements at ARB is to provide facilities that more effectively and efficiently accommodate the *critical aircraft* that presently use the airport, as well as to enhance the operational safety of the airport.

The critical aircraft is defined by the FAA as the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport. In cases where the critical aircraft weigh less than 60,000 lbs, a classification of aircraft is used rather than a specific individual aircraft model.

A recent Airport User Survey has confirmed that the critical aircraft classification for ARB is “B-II Small Aircraft” (MDOT, 2009). Aircrafts in this category have runway approach speeds between 91 and 120 knots, wingspans between 49- and 79-feet, and maximum certificated takeoff weights of 12,500 lbs or less. A representative aircraft of this classification is the Beechcraft King Air 200, a twin-engine turboprop aircraft that typically seats 10-12 people, including the flight crew.

As stated in FAA Advisory Circular 150/5325-4B, “*The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions*.” Airplanes that are classified within an airport’s critical aircraft classification are considered by the FAA to be the regular use aircrafts of the primary runway.

Development of the primary runway at ARB to the recommended length of 4,300-feet would allow the majority of B-II Small classification aircraft to operate at their optimum capabilities (without weight restrictions). Interstate commerce into and out of a community can be negatively impacted if business aircraft are forced to operate with load restrictions (i.e. reductions in passengers, cargo, and fuel associated with aircraft range) due to lack of suitable runway length.

An origin-destination analysis was conducted on Instrument Flight Rules (IFR) flight plan records associated with ARB as part of the user survey process. Although the data analyzed did not include records of all operations conducted at ARB, it did confirm that there are a significant number of operations between ARB and distant locations throughout the country.

Flight operations were verified between ARB and at least 31 other states (approximately 63 percent of the continental US). Also, approximately 67 percent of the IFR flight plan records examined were between ARB and out-of-state locations. These factors are strong indicators of corporate flight activity associated with interstate commerce, as opposed to local pleasure flying by general aviation pilots. The large number of states that were linked to ARB is also a strong indicator of use of the airport by many corporations, as opposed to a single or few corporate users. Some of the larger corporations that were confirmed by the user survey as being users of ARB are Synergy International, Wells Fargo, Polaris Industries, Bombardier Aerospace, Avis Industrial Corporation, Thumb

Energy, NetJets, and AvFuel. NetJets provides on-demand air charter service and corporate aircraft fractional ownership opportunities to a large number of businesses located throughout the country. AvFuel Corporation, a nationwide supplier of aviation fuels and aviation support services, is headquartered in Ann Arbor and bases their Cessna 560 Excel Jet at ARB.

The City of Ann Arbor proposes to extend the existing 3,505-foot primary runway to 4,300-feet in total length in order to more effectively accommodate the critical aircraft that currently use the airport. The runway extension would enhance interstate commerce associated with business aviation, and the other proposed modifications would enhance the operational safety of ARB.

The objectives of the proposed project are to:

- Enhance interstate commerce by providing sufficient runway length to allow the majority of critical aircraft to operate without weight restrictions.
- Enhance operational safety by improving the FAA ATCT line-of-sight issues.
- Enhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24, over State Road.
- Reduce the occurrence of runway overrun incidents by small category A-I aircraft (local objective).
- Relocate and potentially upgrade the Runway 24 Approach Light System.

2.2.1 Safety Enhancement

The proposed 150-foot shift of the Runway 24 threshold to the west would enhance the safety of ground operations by taxiing aircraft. Currently, a hangar structure blocks the line-of-sight from the FAA ATCT to a portion of the parallel taxiway at the east end of the runway, including most of the taxiway hold area for departing aircrafts. While this situation is not considered hazardous, the proposed shift would enhance operational safety, and possibly prevent a runway incursion, by expanding the view of the hold area and parallel taxiway to ATCT personnel.

The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach surface to the east end of the runway (the current approach surface is the steeper 20:1). By keeping obstructions below the flatter 34:1 approach surface, an additional margin of safety is provided between approaching aircraft and any ground-based obstacles. This is particularly beneficial when aircraft are operating in low-visibility conditions. Provision of a clear 34:1 approach surface would also potentially allow visibility minimums to the Instrument Approach Procedure to Runway 24 to be lowered to 3/4 of a mile, as opposed to the current 1-mile visibility minimum. This would enhance the all-weather capability of the airport (and also interstate commerce) by allowing aircraft to continue to access the airport when weather conditions resulted in visibility dropping below the current 1-mile minimum.

Due to the proposed relocation of the Runway 24 threshold, it is also proposed that the existing runway approach light system be relocated accordingly. The airport currently uses an Omni-Directional Approach Lighting System (ODALS) to identify the approach end of Runway 24. The sequentially-flashing strobe lights assist pilots in identifying the runway threshold location and runway centerline alignment in low-visibility conditions. Since the FAA no longer installs ODALS, the current approach light system would potentially be upgraded and replaced with the newer Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF) as part of the relocation. The MALSF would serve the same function as the ODALS, and is structurally very similar.

2.2.2 Role of the Airport

ARB is a public-use facility that serves the local community by supporting economic development and public services. The following businesses and organizations are located at and operate from the airport and employ staff that supports the operations of the airport:

- Two fixed-wing FBOs;
- A helicopter FBO;
- Three national rental car agencies;
- Two flying clubs;
- Four flight schools and pilot training centers;
- FAA ATCT; and,
- Air taxi, aircraft sales, aviation insurance and aviation fueling businesses.

ARB serves the Ann Arbor medical and biomedical industries with professional air ambulance services, transporting patients, human organs, radio isotopes, and other biomedical products and services.

Community pilots and aircraft owners are members of nonprofit organizations providing “no charge” charitable gifts of flight time to citizens in need. Some of these organizations include Wings of Mercy, Angel Flight, and Dreams and Wings. Wings of Mercy has documented 292 fights into or out of ARB since 1992 including 51 flights in 2009.

ARB is included in the FAA’s National Plan of Integrated Airport Systems (NPIAS) as a general aviation airport. Not all public-use airports are included in this nationwide airport system plan. Inclusion in the NPIAS signifies that the FAA considers this airport an important part of the nation’s air transportation system, and it makes ARB eligible to receive federal grants as part of the FAA’s Airport Improvement Program.

ARB is also included in MDOT’s Michigan Airport System Plan (MASP) (MDOT, 2008). The MASP presents the results of an airport system planning process that has been aligned with the goals and objectives of MDOT’s State Long Range Plan. The MASP supports programming decisions and is useful in evaluating programming actions related to airport system and airport facility deficiencies.

As part of the MASP development, each of Michigan's public-use airports were assigned to one of three tiers based on their contribution to the state system goals. Tier 1 airports respond to essential/critical airport system goals. These airports should be developed to their full and appropriate level. Tier 2 airports complement the essential/critical airport system and/or respond to local community needs. Focus at these airports should be on maintaining infrastructure with a lesser emphasis on facility expansion. Tier 3 airports duplicate services provided by other airports and/or respond to specific needs of individuals and small business.

The MASP identifies ARB as a Tier 1 airport, with a current MASP classification of B-II. Basic standard developmental items for B-II category airports, as outlined in Table 40 of the MASP, are a paved primary runway of 4,300-feet in length by 75-feet wide, a paved parallel taxiway, appropriate runway lighting and visual aids, a runway approach protection plan, basic pilot and aircraft services, all-weather access, year-round access, and landside access. Although it is not a requirement, MDOT encourages all of Michigan's Tier 1 airport sponsors to consider development of their airports to comply with the basic development standards outlined in the MASP.

ARB currently meets all MASP basic development standards for category B-II airports, with the exception of runway length. The current primary runway is only 3,505-feet in length by 75-feet wide. An extension of the primary runway to 4,300-feet in length would result in the airport meeting all state-recommended standards for B-II category airports.

2.2.3 Aircraft Operations and Runway Length Recommendations

The Airport Reference Code (ARC) is a coding system developed by the FAA to correlate airport design criteria with the operational and physical characteristics of the airplane types that regularly use a particular airport. The critical aircraft, or grouping of aircraft, are generally the largest, most demanding types that conduct at least 500 operations per year at the airport. The ARC for each particular airport is determined based on two characteristics of the critical aircraft: the approach speed to the runway and the wingspan of the aircraft.

The first component, designated by letter A through E, is the critical aircraft's Approach Category. This is determined by the approach speed to the runway:

- Category A: Approach speed less than 91 knots.
- Category B: Approach speed 91 knots or more, but less than 121 knots.
- Category C: Approach speed 121 knots or more, but less than 141 knots.
- Category D: Approach speed 141 knots or more, but less than 166 knots.
- Category E: Approach speed 166 knots or more.

The second component, designated by Roman numeral I through VI, is the critical aircraft's Design Group. This is determined by the wingspan of the aircraft:

- Group I: Wingspan less than 49-feet.
- Group II: Wingspan 49-feet or more, but less than 79-feet.
- Group III: Wingspan 79-feet or more, but less than 118-feet.
- Group IV: Wingspan 118-feet or more, but less than 171-feet.
- Group V: Wingspan 171-feet or more, but less than 214-feet.
- Group VI: Wingspan 214-feet or more, but less than 261-feet.

The FAA has also established categories for aircraft based on their certificated Maximum Takeoff Weights (MTOW), which are determined by each specific aircraft's manufacturer. *Small Aircraft* are those with MTOWs of 12,500 lbs. or less. *Large Aircraft* are those with MTOWs greater than 12,500 lbs.

As previously mentioned, the airport user survey confirmed that the current critical aircraft category (and ARC) for ARB is "**B-II Small Aircraft**". Based on the findings of the user survey analysis, the primary runway length recommendations by MDOT and FAA are as follows:

<u>MDOT</u> – *Source: Michigan Airport System Plan (MASP 2008)* **4,300-feet**
Table 40 (*statewide standard for all ARC B-II airports*)

<u>FAA</u> – *Source: FAA Advisory Circular 150/5325-4B,* **4,200-feet***
"Runway Length Requirements for Airport Design"
Figure 2-2 (*airport-specific standard for ARB*)

** Note: The FAA runway length recommendation was obtained from Figure 2-2 in Advisory Circular 150/5325-4B. The following specifics for ARB were used in the determination:*
<u>Airport Elevation</u>: 839-feet above mean sea level
<u>Temperature</u>: 83 degrees F mean daily maximum temp, hottest month of year (July)

The FAA recommended runway length of 4,200-feet at ARB was obtained by calculation from FAA Advisory Circular 150/5325-4B, *"Runway Length Requirements for Airport Design"*, a publication that is used nationally by the agency. The resulting recommended runway lengths are airport-specific, and can vary by hundreds of-feet from site to site, depending on the specific airport elevations and mean daily maximum temperatures used in the calculations.

The MDOT recommendation of 4,300-feet is a statewide standard for all airports in the state with category B-II critical aircraft classifications. Since airport elevations and mean maximum temperatures do not vary significantly from airport to airport in Michigan, as opposed to many other states, MDOT uses a single runway length recommendation for all airports of the same critical aircraft classification.

The existing ARC shown on the current ALP for the airport is category B-II. This classification has been confirmed correct by the recent airport user survey. Even if the proposed extension to 4,300-feet is constructed, the ALP shows that the future ARC for the airport will remain category B-II.

2.2.4 Airport Operational Forecasts

Year 2007 was the onset year of planning activities associated with the potential extension of Runway 6/24, and the year in which the airport manager and FBOs were requested to collect based and itinerant aircraft operational data for the purpose of determining project justification. In order to maintain consistency, FlightAware operational records from target year 2007 were also examined during the user survey analytical process.

Actual total operations for year 2009 were recently published (January 2010) by the FAA for airports with ATCT. From the user survey operational data year 2007 through the most recent operational data year 2009, total annual operations at ARB have decreased approximately 21.8% (from 72,853 actual in 2007 to 57,004 actual in 2009). Since the operational totals were obtained from actual ATCT records, rather than estimates, they are considered very accurate.

By applying the 21.8% decrease in total annual operations at ARB from 2007 to 2009 to the user survey results, a very accurate estimate can be obtained for the current level of operations by B-II category critical aircraft. The user survey report documents a total of 750 actual annual operations by B-II category critical aircraft from survey data year 2007. A 21.8% decrease in this number is 586 - still well above the FAA's substantial use threshold of 500. Therefore, even with the current decrease in annual operations due to the economic recession, there is still justification at the present time for the runway extension.

The FAA's Terminal Area Forecast (TAF) shows year 2009 to be a low-point in total annual operations at ARB. The TAF projects total annual operations to continually increase every single year, from year 2010 through year 2030. Since the estimated 586 annual operations by B-II category aircraft in year 2009 confirm present justification for the runway extension, the continual increase in operations that are forecasted by the TAF confirm that justification for the runway extension is substantiated through year 2030.

The following actual and forecasted Total Operations at ARB, from year 2000 through year 2030, are from the FAA data sources listed below. The Estimated Category B-II Operations for each year have been calculated based on the percentage of actual B-II operations to actual total operations in survey data year 2007.

Table 2-1
Actual and Forecasted Total Operations at ARB

Year	Total Operations	Estimated Category B-II Operations
2000	104,342 *	1,074
2001	102,321 *	1,053
2002	91,414 *	941
2003	77,051 *	793
2004	65,516 *	674
2005	67,940 *	699
2006	71,785 *	739
2007	72,853 *	750***
2008	64,910 *	668
2009	57,004 *	586
2010	56,986 **	586
2011	57,514 **	592
2012	58,073 **	598
2013	58,639 **	604
2014	59,212 **	610
2015	59,791 **	616
2016	60,376 **	622
2017	60,968 **	628
2018	61,567 **	634
2019	62,173 **	640
2020	62,786 **	646
2021	63,405 **	653
2022	64,032 **	659
2023	64,666 **	666
2024	65,307 **	672
2025	65,956 **	679
2026	66,613 **	686
2027	67,277 **	693
2028	67,948 **	700
2029	68,627 **	706
2030	69,314 **	714

* = Actual Total Operations from FAA ATCT records
** = Forecasted Total Operations from FAA TAF
*** = Actual (from User Survey)

Forecasts from the MDOT MASP also project increasing total operations at ARB from years 2010 through 2030. The MDOT forecasts, which are independent of the FAA forecasts, further substantiate the mid-term and long-term FAA projections of a rebound in activity at ARB to near survey year 2007 operational levels.

AvFuel Corporation, which bases a B-II Large category Citation 560 Excel jet at ARB, has confirmed in writing that their operations at ARB increased from 211 actual operations in 2007 to 223 actual operations in 2008. Their Chief Pilot has also submitted written documentation that forecasts their future operational levels potentially increasing to 350 to 450 operations per year at ARB.

The FAA TAF forecast, MDOT MASP forecast, and AvFuel's operational forecast all provide support to the fact that survey year 2007 operational data that was analyzed in the user survey process is a very pertinent representation of estimated future operational levels at ARB.

2.2.5 Surrounding Land Uses

ARB is bordered by Ellsworth Road to the north, Lohr Road to the west, and State Road to the east. The primary runway is situated in a northeast/southwest direction. Residential, business, industrial, recreational, agricultural, and forested areas are located adjacent to the airport, and efforts were made during the analysis of alternatives to minimize impacts to these resources. Residential properties are located along Lohr Road and business properties are located along State and Ellsworth Roads. A perennial stream crosses through the airport property and flows to the south connecting to a county drain (Wood Outlet). A portion of the stream near the southwest end of the runway is enclosed in a concrete culvert.

2.2.6 Other Considerations

Aircraft performance information and runway length requirements for each airplane are contained in the individual airplane flight operating manual. As quoted from FAA Advisory Circular 150/5325-4B, Paragraph 206, "*This information is provided to assist the airplane operator in determining the runway length necessary to operate safely. Performance information from those manuals was selectively grouped and used to develop the runway length curves in Figures 2-1 and 2-2. The major parameters utilized for the development of these curves were the takeoff and landing distances for Figure 2-1 and the takeoff, landing, and accelerate-stop distances for Figure 2-2*." As stated earlier in this section, Figure 2-2 of the Advisory Circular was used to determine the FAA-recommended runway length for ARB.

The *accelerate-stop distance* concept referred to above is an important operating consideration. In this concept, the pilot not only considers the amount of runway needed for takeoff, but also the amount of runway needed to abort the takeoff while on the takeoff roll and bring the aircraft to a stop. In situations where pilots detect a problem with the aircraft while on the takeoff roll, they are forced to continue the takeoff and contend with the problem in the air if there is not enough runway remaining to bring the aircraft to a stop. By having enough remaining runway to safely abort a takeoff and stop the aircraft while still on the ground, a pilot would be able to avoid a potentially hazardous situation of taking to the air with a mechanically-deficient aircraft.

A local objective is to reduce the occurrence of runway overrun incidents. While overrun incidents are not officially recognized by the FAA or MDOT as justification for extending runways, there is merit to this local objective. The 11 overrun incident reports that were analyzed showed that most runway overruns at ARB involved small single-engine category A-I aircraft. These types of incidents often involve student pilots or low-time, relatively inexperienced pilots. There is no evidence in the incident reports that any of the aircraft which overran the end of the existing 3,505-foot runway exceeded the limits of the 300-foot long turf Runway Safety Area. Therefore, in each of these cases, the proposed 4,300-foot long runway would have provided sufficient length for the small category A-I aircraft to safely come to a stop while still on the runway pavement, without running off the runway end.

The considerations mentioned above do not imply that the existing 3,505-foot runway is unsafe in any regard. Accelerate-stop distance requirements can be accommodated on the existing runway if pilots of critical category aircraft operate at reduced load capacities. In the cases of the previous runway overrun incidents, the turf Runway Safety Areas to the existing runway performed as designed and provided a clear area for the overrunning aircraft to come to a stop. There were no reports of personal injuries, although there were reports of aircraft damage in several of the incidents.

2.2.7 Summary

The proposed shift and extension of primary Runway 6/24 at ARB would provide a runway configuration that more effectively accommodates the critical aircraft that presently use the facility. The proposed project would satisfy the FAA design objective of providing sufficient runway length to allow airplanes that regularly use it to operate without weight restrictions. The proposed project would also result in ARB achieving full compliance with all MDOT basic developmental standards outlined in the MASP 2008 for category B-II airports.

In particular, the proposed project would provide the following benefits:

- Enhance business aviation and interstate commerce by providing sufficient runway length to allow the majority of category B-II Small critical aircraft that currently use ARB to operate without load restrictions (i.e. reduction in passengers, cargo, and fuel associated with aircraft range).
- Enhance the safety of ground operations, and lessen the chances of a runway incursion, by expanding the view of the parallel taxiway and aircraft hold area to ATCT personnel.
- Improve the all-weather capability of ARB and enhance operational safety in low-visibility conditions by providing a clear 34:1 approach surface to Runway 24.
- Address the local objective of decreasing the number of runway overruns by small category A-I aircraft by providing approximately 800-feet of additional runway pavement.

Section 3.
Description of Alternatives

Alternatives have been developed to meet the goals of ARB, improve safety and efficiency, and serve current users. The existing airport facilities include the primary runway, Runway 6/24, which is 3,505-feet long and 75-feet wide, a taxiway system, FAA ATCT, and the terminal and hangar buildings. The terminal and hangar buildings are located north of the runway. The taxiway is a full parallel taxiway and there is a turf crosswind runway. See Figure 3-1 for an illustration of existing airport conditions.

The alternatives considered include: No Build (e.g., No Action), use other airports, construct new airport, and four build alternatives for Runway 6/24. The impacts of each alternative were considered along with the ability to meet the purpose and need. An analysis and illustrations of the alternatives follow, along with a summary of their associated impacts.

3.1 ALTERNATIVES CONSIDERED AND DISMISSED

During the evaluation of ARB and its future needs, several alternatives were evaluated. The following alternatives were not considered feasible and were dismissed from further study.

3.1.1 Use Other Airports

The closest public-use airport to ARB is Willow Run Airport, approximately 12 miles east, near the City of Ypsilanti. Runway lengths at Willow Run range from 5,995-feet to 7,526-feet. Surface travel time to this airport is approximately 20 minutes. Willow Run Airport is one of the largest cargo airports in the country, transferring approximately 400 million pounds of freight through the airport annually.

Other airports within 25 miles of ARB include New Hudson-Oakland Southwest Airport (approximately 21 miles north, 3,128-foot runway), Canton-Plymouth-Mettetal Airport (approximately 22 miles northeast, 2,303-foot runway), and Tecumseh-Myers-Divers Airport (approximately 23 miles southwest, 2,660-foot runway). All three of these airports have primary runways that are shorter than the existing 3,505-foot runway at ARB.

From an operational standpoint, Willow Run Airport is capable of accommodating any of the aircraft that currently fly into ARB. Although Willow Run offers longer runway lengths, and a precision Instrument Landing System (ILS) approach procedure, many corporate users still elect to fly into ARB instead of Willow Run. This demonstrates that a large number of operators of business aircraft value the close proximity of ARB to their corporate offices and business contacts over the larger facility at Willow Run. Use of ARB over Willow Run also provides increased economic benefits to the Ann Arbor-based FBOs, as well as nearby hotels, restaurants, and other businesses.

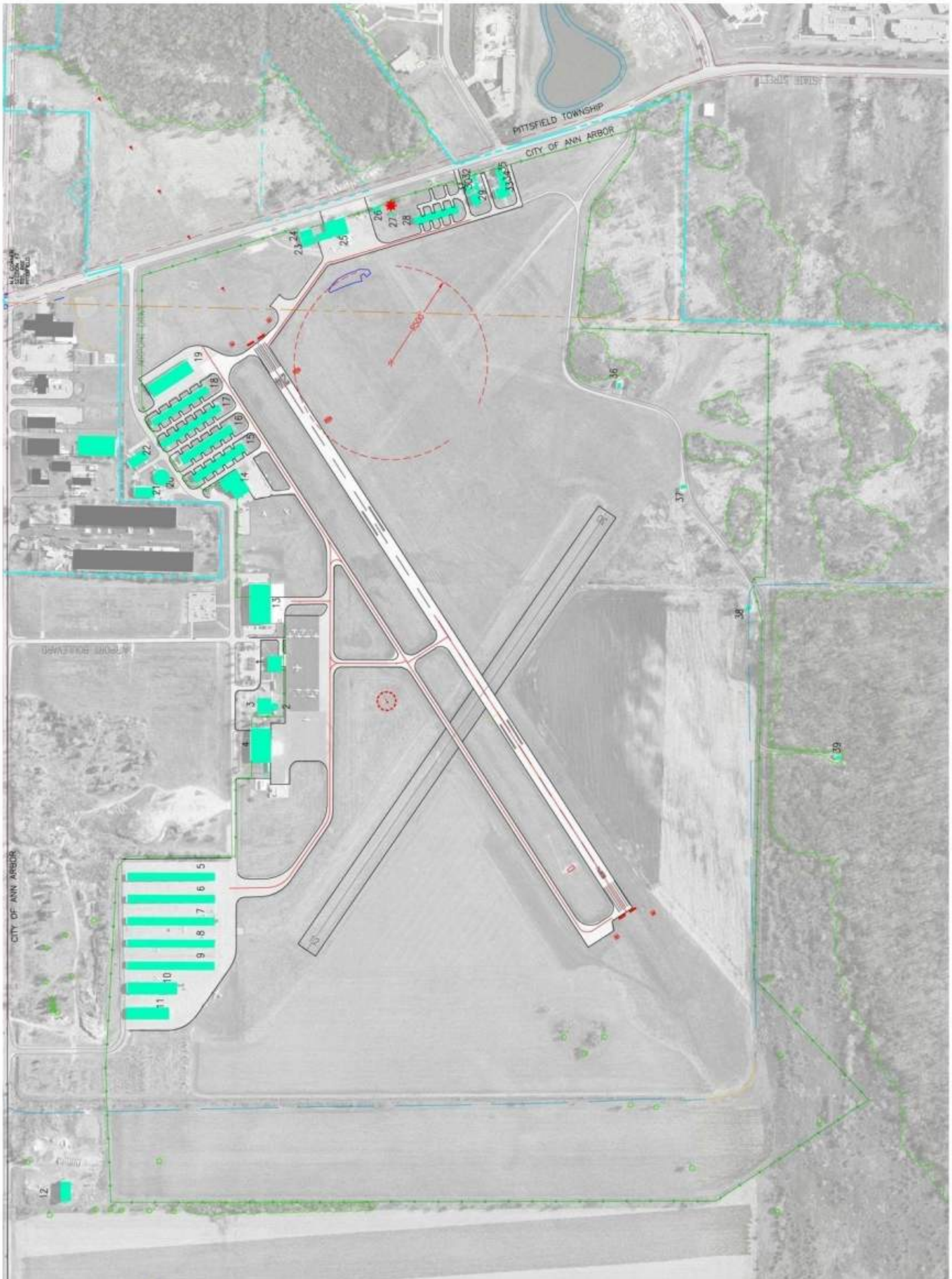

Figure 3.1: Existing Conditions
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Neither MDOT, nor the FAA, dictate to pilots which airports they can and cannot use. The decision on whether or not to use a particular airport is entirely up to the discretion of the pilot. Even with the availability of Willow Run, the recent airport user survey confirmed substantial use of ARB by B-II category aircrafts that are operated by many of the corporations listed in Section 2.2 of this document. The FAA design standards that are used nationally, as well as the MDOT basic development standards outlined in the MASP, are based on accommodating the existing critical aircraft that operate at each particular airport.

3.1.2 Construct New Airport

The existing airport is located in proximity to I-94, US-23, and M-14. ARB has been located at its current location since the 1920s. Many businesses have chosen their location to be in close proximity to ARB.

Relocating the operations of ARB to a new site would initially require acquisition of property comparable to, or larger than, the existing facility. While there may be sites that would physically accommodate the needs of a new airport, the costs associated with the relocation and the environmental consequences of a new airport would be greater than those expected with the expansion of ARB in its current location. It is anticipated that any site for relocation of the airport may require road closures, loss of farmlands, habitat disruption and displacement, residential relocations, and significant infrastructure improvements to provide a facility comparable to the existing airport.

It was determined that constructing a new airport would be a disruption to local businesses, considerably more expensive, and more environmentally damaging than the proposed project at the existing site. Consequently, this alternative was removed from further consideration.

3.1.3 Extend Runway to the East

This build alternative would involve extending Runway 6/24 to the east, holding the west end in its current location. The new runway would be 4,300-feet long and 75-feet wide. The parallel taxiway would also be extended to the east.

Extension of the runway pavement to the east would require the relocation of a considerable portion of State Road. Due to the FAA requirement of providing a clear Runway Safety Area, Object Free Area, and Runway Protection Zone in the approach area to the extended runway, there would also be a need to relocate a portion of Ellsworth Road, as well as the entire intersection of State Road and Ellsworth Road.

State Road and Ellsworth Road are highly traveled corridors. Any relocation would result in an impact to vehicular circulation, businesses, and residents in the area. A considerable amount of right-of-way would also have to be acquired in order to accommodate the relocated roadways, which would result in high costs and further impacts to the nearby businesses. In addition to these impacts, the relocation of State

Road would also severely impact the large wetland complex that is located on its east side.

3.2 ALTERNATIVES CARRIED FORWARD

The following alternatives were considered feasible and were carried forward for further evaluation.

3.2.1 No Build Alternative

The No Build Alternative assumes that no development would occur at ARB other than to maintain the existing facilities. The runway and taxiway would not be altered and no improvements to hangars or hangar access would occur beyond regularly scheduled maintenance.

3.2.2 Build Alternatives

When it was determined that extension of the primary runway was justified based on a determination of the airport's critical aircraft, several build alternatives were developed.

<u>Build Alternative 1 – Extend and Realign the Existing Runway</u>
The existing runway, Runway 6/24, would be realigned and extended to the southwest, holding the east end in its current location (Figure 3-2). The west end would be rotated five degrees counterclockwise. This alignment would maintain wind coverage needs, while moving the west approach away from some residential areas. The runway would be extended 800-feet to the southwest, resulting in a primary runway length of 4,300-feet with a width of 75-feet. The taxiway to the north would be extended to 4,300-feet, creating a full parallel taxiway. The taxiway and runway would have a 240-foot separation.

<u>Build Alternative 2 – Extend the Existing Runway to the West</u>
The existing runway, Runway 6/24, would be extended 800-feet to the west (Figure 3-3), holding the east end in its current location. The primary runway would be lengthened to 4,300-feet, maintaining the existing 75-foot width. As with Build Alternative 1, the existing taxiway would be extended, creating a full parallel taxiway. The taxiway and runway would have a 240-foot separation.

<u>Build Alternative 3 – Shift and Extend the Existing Runway to the West</u>
The east end of the runway would be shortened 150-feet to the west and the west end extended 950-feet to the west. The new runway would be extended a total of 800-feet, resulting in an overall runway length of 4,300-feet long and 75-feet wide (Figure 3-4). The parallel taxiway would be the same length as the runway, with a 240-foot separation.

Changes to the alignment of the primary runway are limited due to the layout of existing surface features and also by wind coverage. Desired wind coverage by FAA is 95 percent. Currently, Runways 6/24 and 13/31 provide 96.9 percent coverage with a maximum 10.5 knot cross wind component. Any change in runway alignment would need to be analyzed to determine the wind coverage.

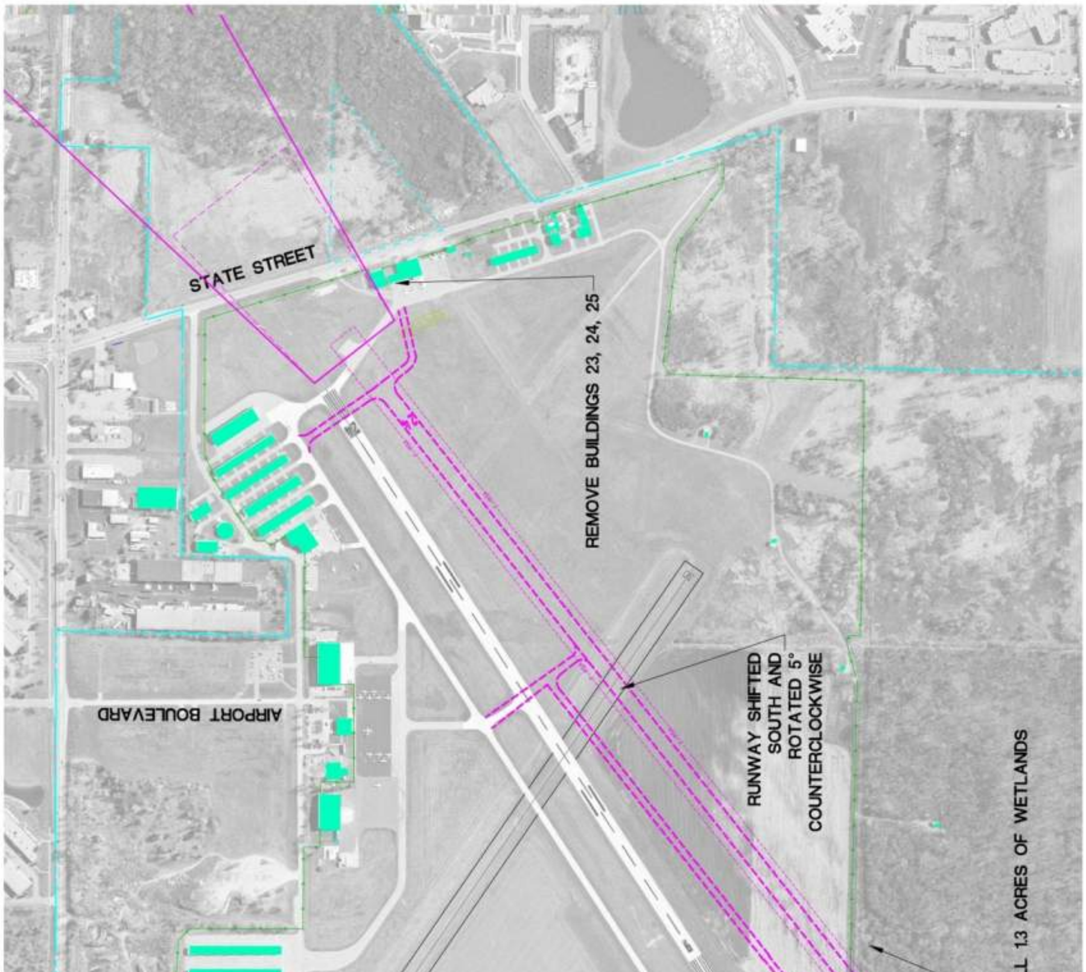

Figure 3.2: Build Alternative 1 - Extend and Realign the Existing Runway
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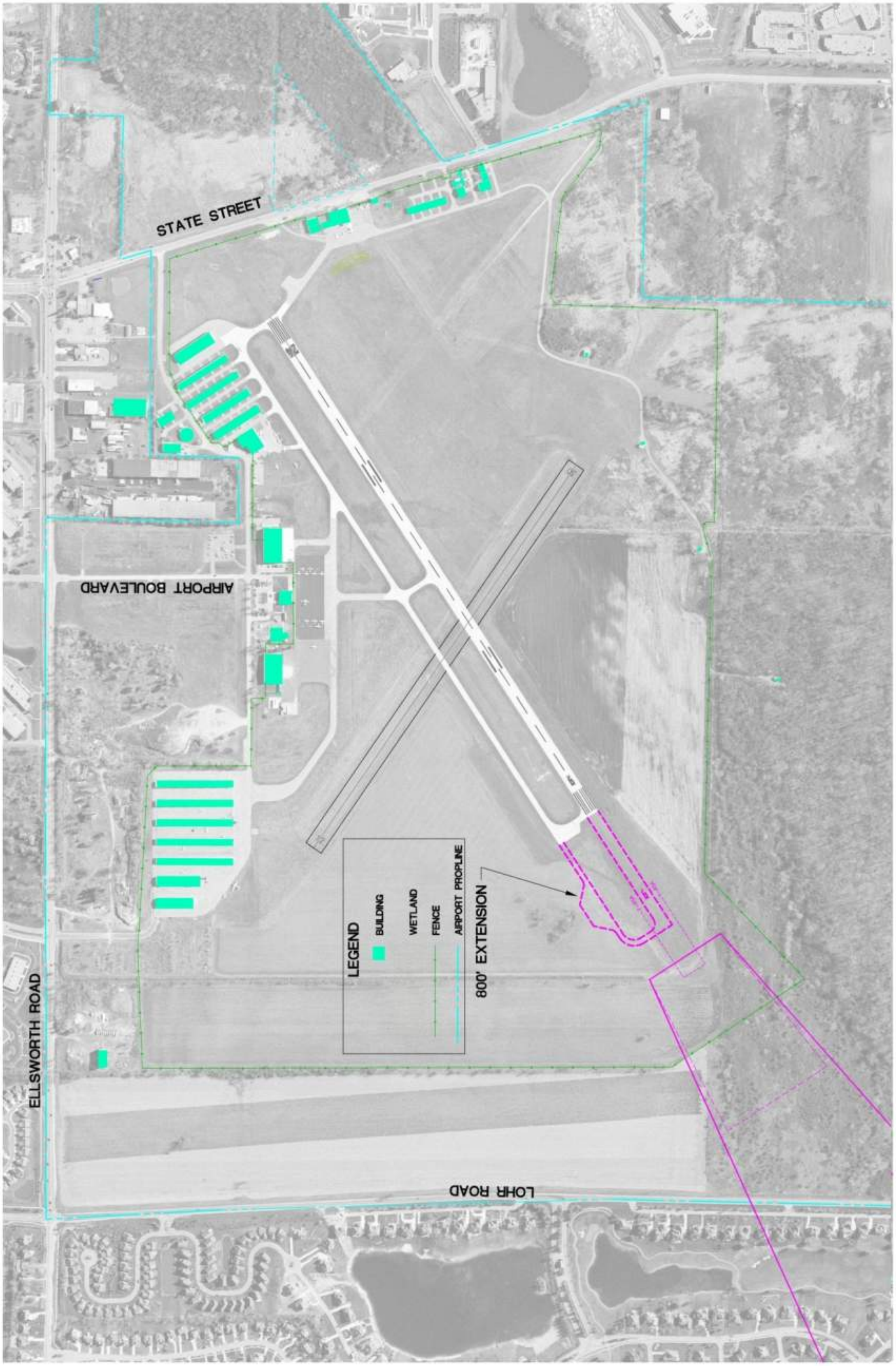

Figure 3.3: Build Alternative 2 - Extend the Existing Runway to the West
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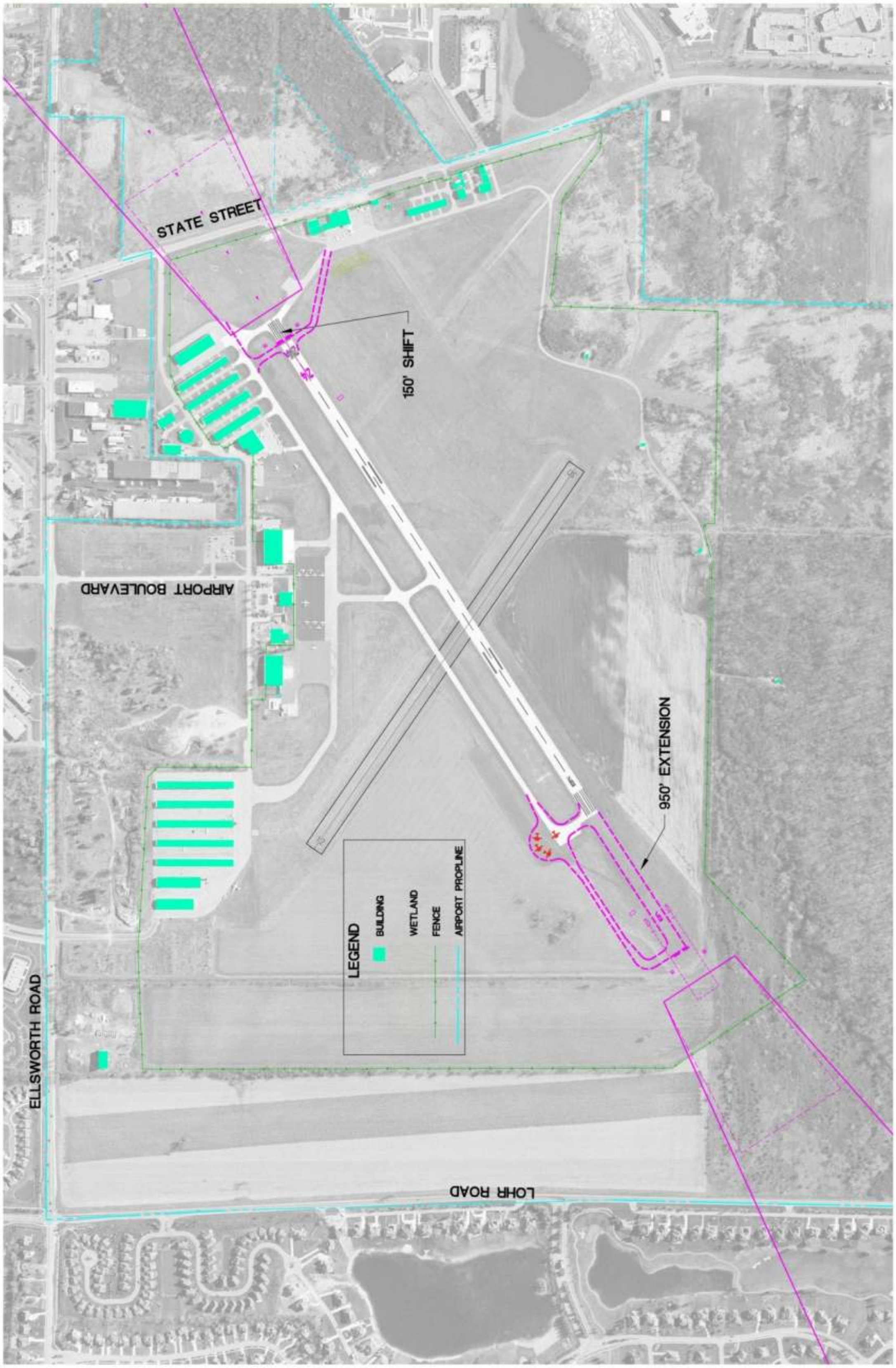

Figure 3.4: Build Alternative 3 - Shift and Extend Existing Runway to the West (Preferred Alternative)
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3.3 ALTERNATIVES EVALUATION

The alternatives were evaluated for: 1) ability to meet the purpose and need, and 2) extent of impacts to resources (Table 3-1). An alternative was rejected if it did not meet purpose and need, or had a high degree of impacts. The alternatives rejected and reasons for not being further considered follow.

Table 3-1
Summary of Alternatives Carried Forward

Evaluation Factors	Alternatives			
	No Build	1	2	3
Runway Length	3,500 ft.	4,300 ft.	4,300 ft.	4,300 ft.
Full Safety Areas	Yes	Yes	Yes	Yes
Stream Impact – length in feet	None	660	None	None
Direct Wetland Impacts	0 acres	1.3 acres	0 acres	0 acres
Tree clearing	0 acres	15 acres	0 acres	0 acres
Residential Displacements	0	0	0	0
Land Acquisition	0	8 acres	0	0
Airport Buildings Removed	None	3	None	None
Meets Purpose and Need	No	No	No	Yes

3.3.1 No Build Alternative

The No Build Alternative would be the least expensive alternative in the near future; however, it does not meet the objective of ARB to better serve current users, and to increase safety and efficiency. The existing runway length does not allow for the critical aircraft (B-II) to operate at their design capabilities without weight restrictions.

3.3.2 Build Alternative 1 – Extend and Realign the Existing Runway

Implementation of Build Alternative 1 would impact 1.3 acres of wetlands and extend the existing culvert of the stream by additional 660-feet. Fifteen acres of trees would need to be cleared at the west end of the new realigned runway. Three buildings at the east end of the runway would need to be removed. The property line would be 1,000-feet from the start of this approach. This would provide 50-feet of clearance at the 20:1 approach slope on this approach. Approximately 8 acres of land southwest of the runway would require an easement to clear the 20:1 approach in this area. This alternative was rejected due to the impacts to the natural resources and required land acquisition. In addition, this alternative would not allow for the future expansion of State Road, as recommended in the 2006 State Road Corridor Study.

3.3.3 Build Alternative 2 – Extend the Existing Runway to the West

Build Alternative 2 would not result in impacts to wetlands or the stream. No buildings at ARB would be removed. This alternative was rejected because it would not meet the purpose and need of the project. Keeping the east runway end in its current location would not address the tower line of sight issue or the need for a 34:1 approach on the east end. In addition, this would not allow for the future expansion of State Road, as recommended in the 2006 State Road Corridor Study.

3.3.4 Build Alternative 3 – Shift and Extend the Existing Runway to the West

Build Alternative 3 would avoid impacts to wetlands, the stream, and the buildings at ARB. This alternative would fully meet the project purpose and need. By both shifting and extending the runway, this would accommodate the existing users, improve the tower line of sight issue, and the 34:1 approach surface to Runway 24. This alternative would accommodate future widening of State Road, as recommended in the 2006 State Road Corridor Study.

3.4 PREFERRED ALTERNATIVE

Build Alternative 3 was selected as the Preferred Alternative. This alternative involves shifting and extending Runway 6/24 and the parallel taxiway (Figure 3-4). This alternative would have no significant impacts while meeting the objectives of the project's purpose and need.

This alternative would not impact wetlands or the stream. There would be no displacements, either residential or business, and no removal of buildings at ARB. A noise analysis was conducted to determine if there would be a change in the noise levels as a result of the proposed improvements. According to the noise impact analysis, the 65 Day-Night Average Sound Level (DNL) contour for the proposed runway does not extend beyond airport property and is not within 1000-feet of any residential structure. Therefore, no residents are living within areas exposed to noise levels above the 65 DNL. For more information regarding the noise analysis for this project, please refer to Section 4.1.

Of the alternatives analyzed, Build Alternative 3 is the one that best achieves the goals of the study, while providing the fewest impacts to the surrounding area. The goals include a more efficient accommodation of the critical aircraft that currently use the facility, as well as enhancement of airport operational safety. Operational safety would be enhanced by improving the line-of-sight from the FAA ATCT to the Runway 24 hold area, and by providing a clear 34:1 approach surface to the Runway 24 threshold.

Section 4.
Affected Environment and Environmental Consequences

This section describes existing conditions within ARB and the immediate surrounding areas. Potential environmental impacts associated with the Preferred Alternative are presented and described with regard to the following categories: noise analysis; compatible land use; socio-economics; air quality; historic resources; contaminated sites; and the physical and ecological environment.

There would be unavoidable short-term impacts associated with the Preferred Alternative; however, the project would have a positive impact on the operation and safety of ARB and its role in the community. The project would comply with all federal, state, and local laws and regulations.

4.1. NOISE ANALYSIS

An assessment of the project aircraft noise exposure in the areas surrounding the ARB is provided in this section. A more detailed and technical analysis is provided in Appendix B. Section 4.1.1 provides an overview of the methods used to develop noise exposure maps, and Section 4.1.2 presents the noise exposure maps, which identify the areas affected by aircraft noise.

4.1.1 Methodology

The evaluation of the ARB noise environment, and land use compatibility associated with airport noise, was conducted using the methodologies developed by the FAA and published in FAA Order 5050.4B, FAA Order 1050.1E, and title 14 Code of Federal Regulations (CFR) part 150.

For aviation noise analysis, the FAA has determined that the cumulative noise energy exposure of individuals to noise resulting from aviation activities must be established in terms of yearly DNL. DNL is a 24-hour time-weighted-average noise metric expressed in A-weighted decibels (dBA) that accounts for the noise levels of all individual aircraft events, the number of times those events occur, and the time of day which they occur. In order to represent the added intrusiveness of sounds occurring during nighttime hours (10:00 p.m. to 7:00 a.m.), DNL penalizes, or weights, events occurring during the nighttime periods by 10 dBA. This is due to the increased sensitivity to noise during normal sleeping hours and because ambient (without aircraft) sound levels during nighttime are typically about 10 dB lower than during daytime hours.

The FAA's Integrated Noise Model (INM) Version 7.0a was used to develop noise exposure contours in order to assess the noise impacts associated with the proposed extension of Runway 6/24. The INM has been FAA's standard tool since 1978 for determining the predicted noise impact in the vicinity of airports.

The INM incorporates the number of annual average daily daytime and nighttime flight and run-up operations, flight paths, run-up locations, and flight profiles of the aircraft along with its extensive internal database of aircraft noise and performance information, to calculate the DNL at many points on the ground around an airport. The noise exposure contours represent computer-generated lines connecting these points of equal noise levels resulting from aircraft operations.

The input data required in the INM to develop noise exposure contours includes:

- Aircraft operations
- Aircraft fleet
- Runway end utilization
- Ratio of daytime and nighttime aircraft operations
- Flight tracks

Aircraft operation data was collected from multiple sources, including:

- Flight Explorer®, computer software which obtains N-number (registration number), aircraft type, arrival and departure airport, and time of day from Air Traffic Control Tower radar data;
- USDOT, FAA Airport Master Record, Form 5010 July 2009;
- FAA Terminal Area Forecast (TAF) December 2008;
- FAA Air Traffic Activity Data System (ATADS) May 2009; and,
- Michigan Department of Transportation Airport User's Survey Report 2009.

INM-modeled annual operations for the 2009 existing condition, consisting of operations from April 2008 through March 2009, totaled 61,969 operations, which is approximately 169 daily operations. Jet operations accounted for approximately 2 percent of the total operations. Nighttime operations accounted for 4.2 percent of the total operations.

2014 future condition aircraft operations were obtained from the 2008 FAA TAF for ARB. Modeled annual operations for the 2014 future condition totaled 69,717 operations, or approximately 191 daily operations. The percent of night and jet operations would remain constant between the existing condition and the future years. In addition, fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives would remain static. The existing and future fleet mix with annual operations is shown in Appendix B as Table B-2.

Runway end utilization was based on discussions with the ATCT staff. Runway utilization is approximately 30 percent on Runway 6 (west end) and 70 percent on Runway 24 (east end). Discussions with ATCT staff also indicate that approximately 5 percent of single engine piston aircraft operations occur on Runway 12/30 with a 50/50 split (north end versus south end). Helicopters operate to and from the east edge of the terminal apron. Table B-3 in Appendix B provides runway utilization by aircraft category. The 2014 No-Action and Proposed Project Alternatives would maintain the same runway utilization.

Flight tracks are the aircraft's actual path through the air projected vertically onto the ground. Due to the level of operations occurring at ARB, a single arrival and departure track for each runway end was appropriate for the noise modeling. Straight out departures tracks were modeled for all runways. Straight in arrivals to Runway 12/30 were modeled and arrivals to Runway 6/24 followed the published instrument approach (Very High Frequency Omni Range (VOR)) procedures.

Unique helicopter and touch-and-go flight tracks were also modeled based on ATCT interviews. Eighty percent of the helicopter operations arrive from or depart to the north, with the remaining 20 percent distributed evenly between arrivals from and departures to the east, south, and west.

4.1.2 Aircraft Noise Exposure

The INM was used to develop 65, 70, and 75 DNL noise contours for the following scenarios:

- Existing conditions (Year 2009) – 6/24 Runway length 3,500 feet.
- No Action future conditions (Year 2014) – 6/24 Runway length 3,500 feet.
- Preferred Alternative future conditions (Year 2014) – 6/24 Runway length 4,300 feet.

DNL contours are a graphical representation of how the noise from the airport's average annual daily aircraft operations is distributed over the surrounding area. The INM can calculate sound levels at any specified point so that noise exposure at representative locations around an airport can be obtained.

The noise exposure maps developed by the INM program for the three scenarios are presented in Figure 4-1 through Figure 4-3.The noise contours (65, 70, and 75) for each scenario are super-imposed over an aerial. For the purposes of assessing the impacts related to aircraft noise, the contour maps were evaluated with respect to the number of dwelling units and number of people located within the 65 DNL contours. As stated in the FAA Order 1050.1E, Environmental Impacts: Policies and Procedures, "*A significant noise impact would occur if analysis shows that the proposed action will cause noise sensitive areas to experience an increase in noise of DNL 1.5 dB or more at or above DNL 65 dB noise exposure when compared to the no action alternative for the same timeframe*."

Existing Conditions

No homes or noise sensitive land uses are located within the 65 DNL contour for the existing conditions (Figure 4-1). The existing condition 65 DNL contour does not extend beyond airport property.

No Build Alternative (2014)

Noise exposure resulting from aircraft operations for the 2014 No Build Alternative does not impact homes or noise sensitive land uses (Figure 4-2). The 2014 No Build Alternative DNL 65 dBA noise contour does not extend beyond airport property.

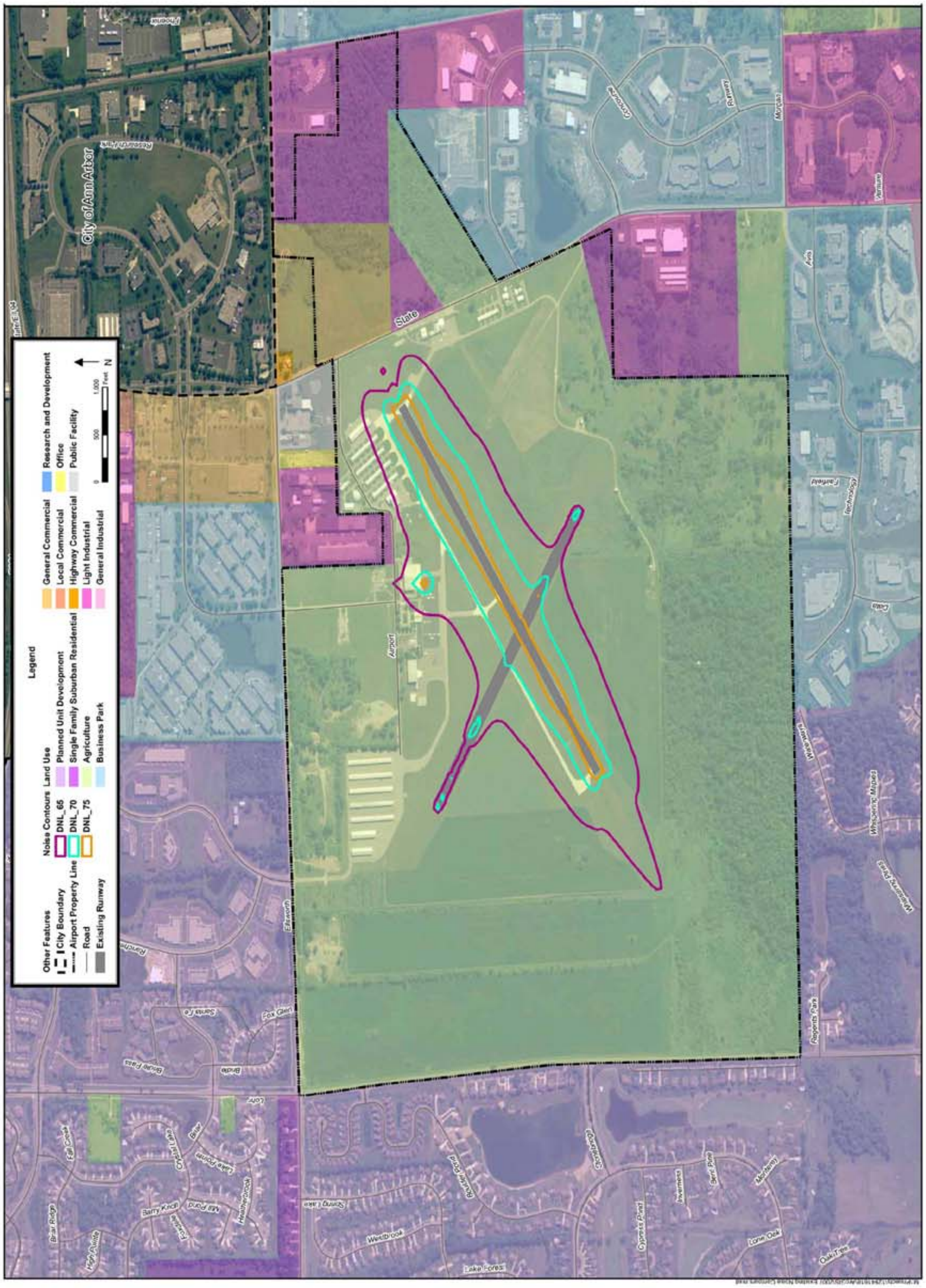

Figure 4.1: Noise Contour Map - Existing Conditions
Ann Arbor Municipal Airport Environmental Assessment

JJR

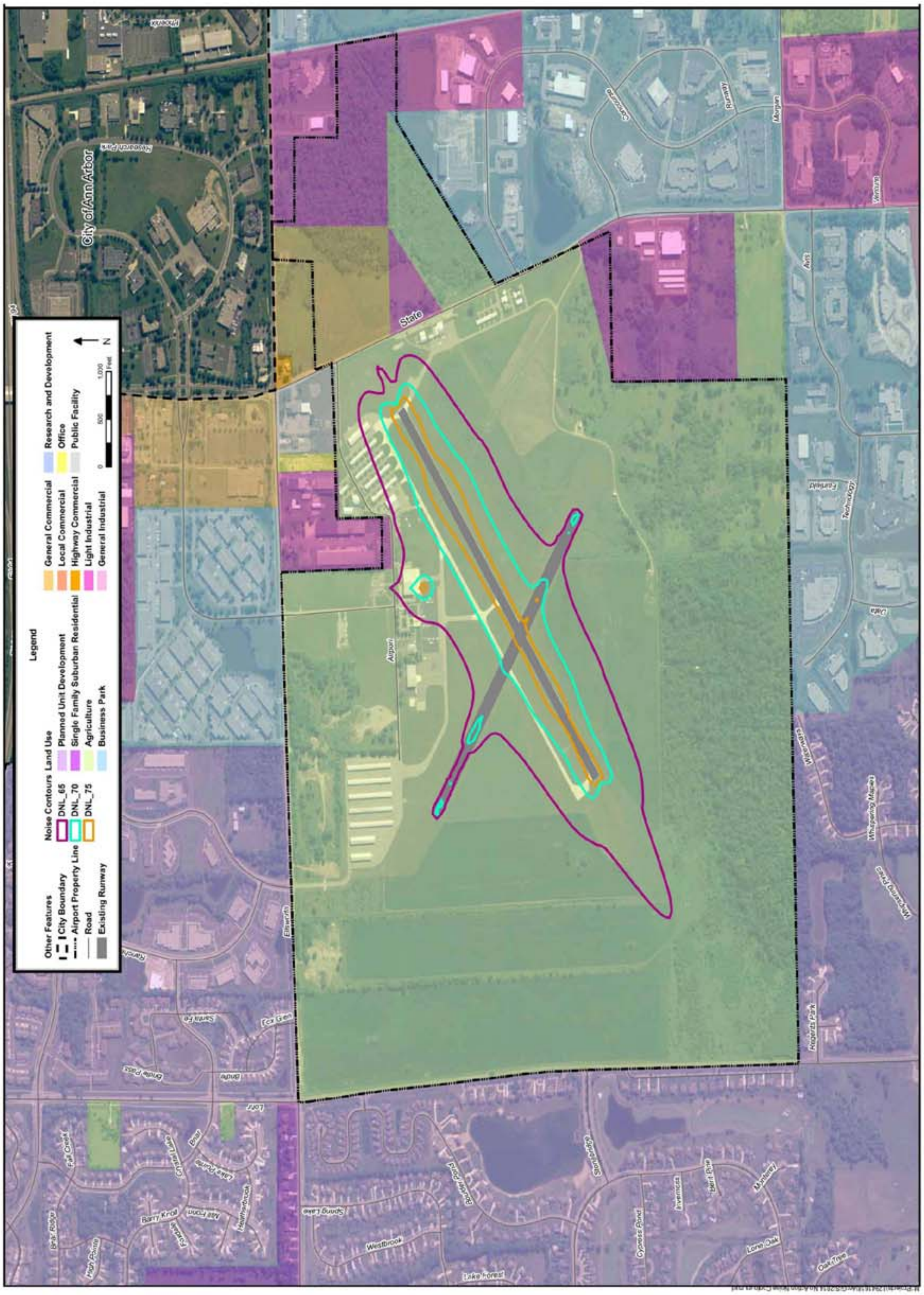

Figure 4.2: Noise Contour Map - No Build Alternative (2014)
Ann Arbor Municipal Airport Environmental Assessment

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Consequences of the Preferred Alternative

No homes or noise sensitive land uses are located within the 65 DNL contour for the Preferred Alternative future conditions (Figure 4-3). This 65 DNL noise contour does not extend beyond airport property. Therefore, no people are living within areas exposed to noise levels above the 65 DNL. The Preferred Alternative is not expected to have any significant aircraft noise impacts as defined in FAA Order 5050.4B.

Proposed Mitigation Measures

The proposed Runway 6/24 extension would not result in exposure of noise levels greater than 65 DNL to residents or noise sensitive land uses. Therefore, mitigation measures are not necessary or planned in association with the proposed runway extension.

4.2 COMPATIBLE LAND USE

Existing Conditions

Land use immediately surrounding ARB includes residential, commercial, industrial, recreational, undeveloped, and agricultural areas. Access to the airport is from either Ellsworth Road to the north or State Road to the east. Along Ellsworth Road, between Lohr Road and State Road, the land use is a mix of residential (Fox Glen) and commercial, including two research and business parks (Valley Ranch, Airport Plaza). The land use along Lohr Road is residential (Stonebridge) and agricultural. Along State Road south of Ellsworth Road is either undeveloped or commercial, including a research and business park: Runway Plaza. Residential areas (St. James Woods and Waterways) and a research and business park (Avis Farms) are located immediately to the south of ARB. Existing land use and zoning is illustrated in Figure 4-4 and 4-5, respectively.

The land surrounding ARB in Pittsfield Township is predominately zoned as planned unit development (PUD), business park, and light industrial (Pittsfield Township, 2009). Immediately to the west of ARB, along Lohr Road, these areas are zoned as PUD (Figure 4-5). The land east of ARB, along State Road, is zoned as either business park or light industrial (Figure 4-5). Lohr Road is a mix of residential and public facilities and public and private recreation/open space. Residential is also identified immediately south of ARB. There is also a small area identified as office south of Ellsworth Road near the northeastern airport boundary. The land adjacent to ARB, within the city limits, (north of Ellsworth Road and east of State Road) is zoned as either fringe commercial, research, or industrial (City of Ann Arbor, 2008) (Figure 4-6).

As illustrated in Figure 4-7, Pittsfield Township's future land use plan identifies the area along State Road, along most of Ellsworth Road, and immediately south of ARB as research and development (Pittsfield Township, 2008). At the corner of State Road and Ellsworth Road the area is identified as community commercial and local commercial. There is also a small area identified as office south of Ellsworth Road near the northeastern airport boundary.

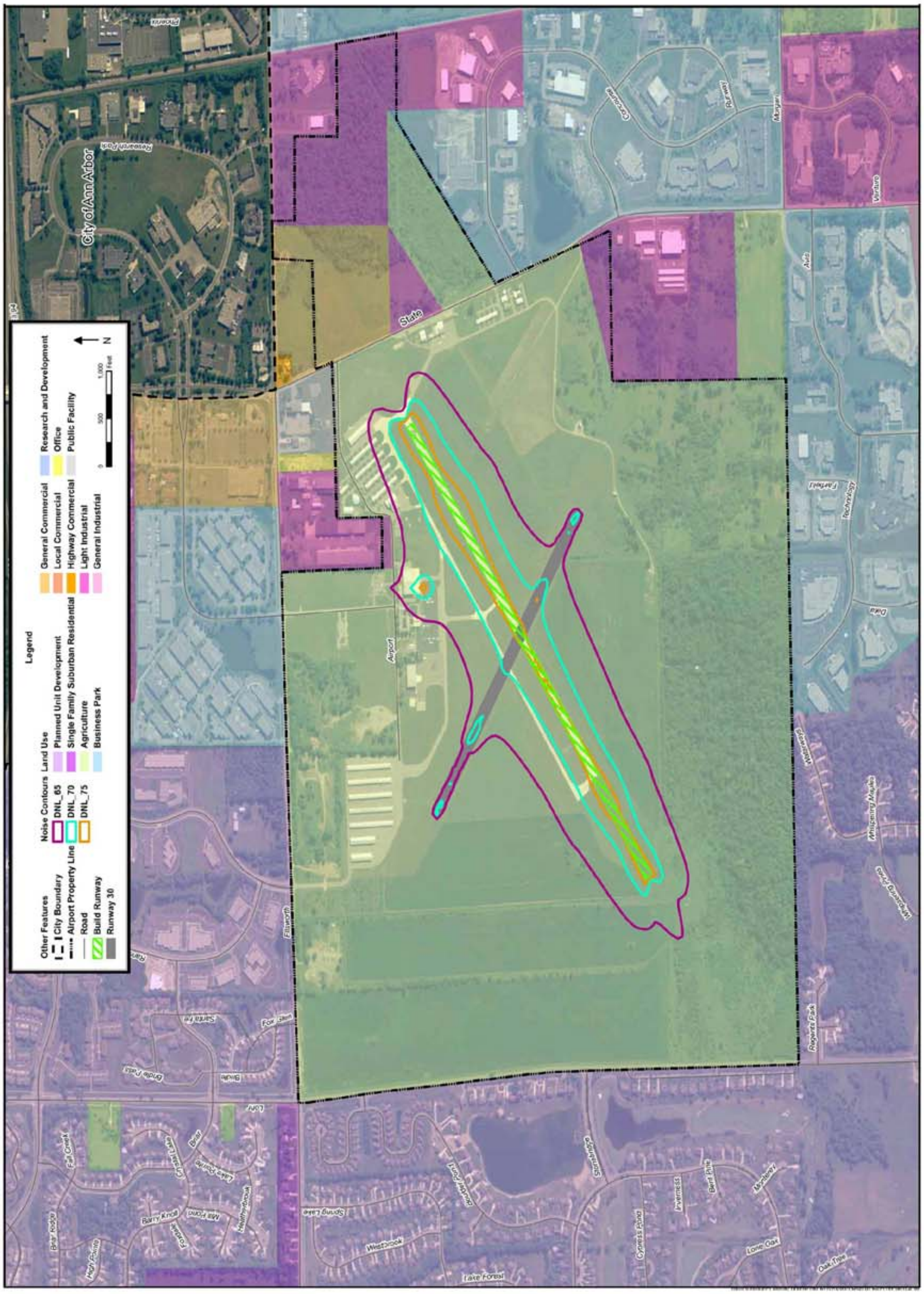

Figure 4.3: Noise Contour Map - Preferred Alternative (2014)
Ann Arbor Municipal Airport Environmental Assessment

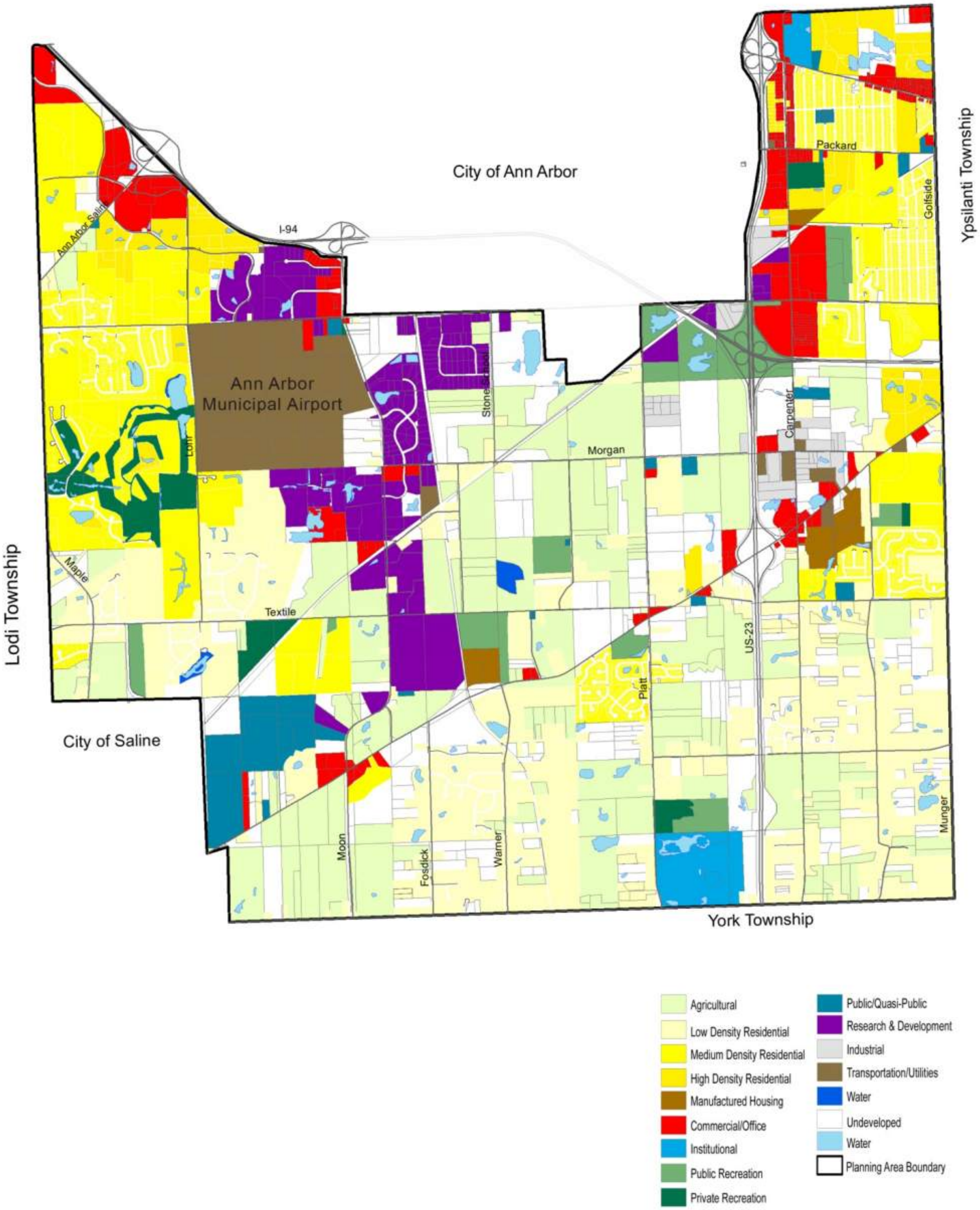

Figure 4.4: Pittsfield Township Existing Land Use
Ann Arbor Municipal Airport Environmental Assessment

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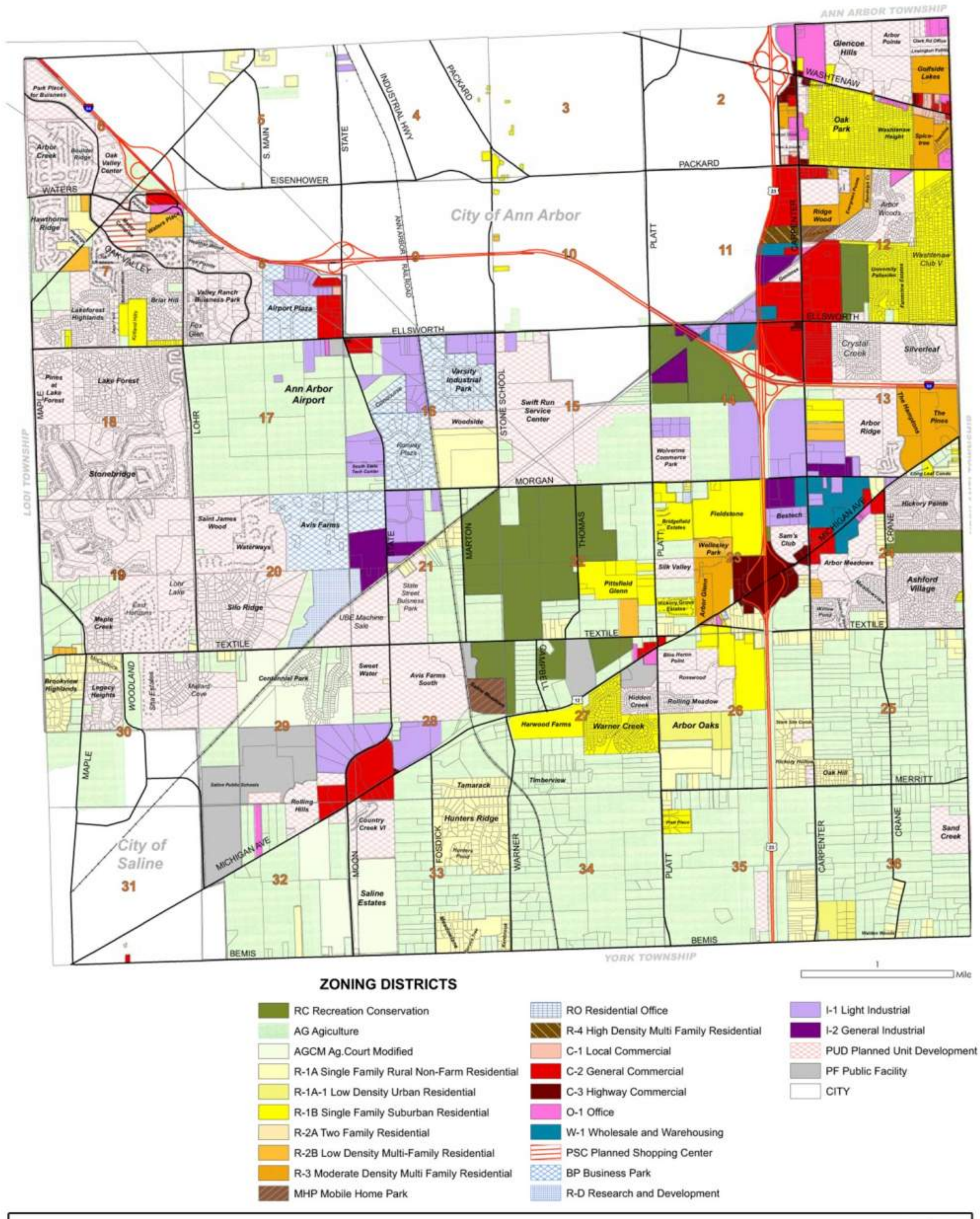

Figure 4.5: Pittsfield Township Zoning Map
Ann Arbor Municipal Airport Environmental Assessment

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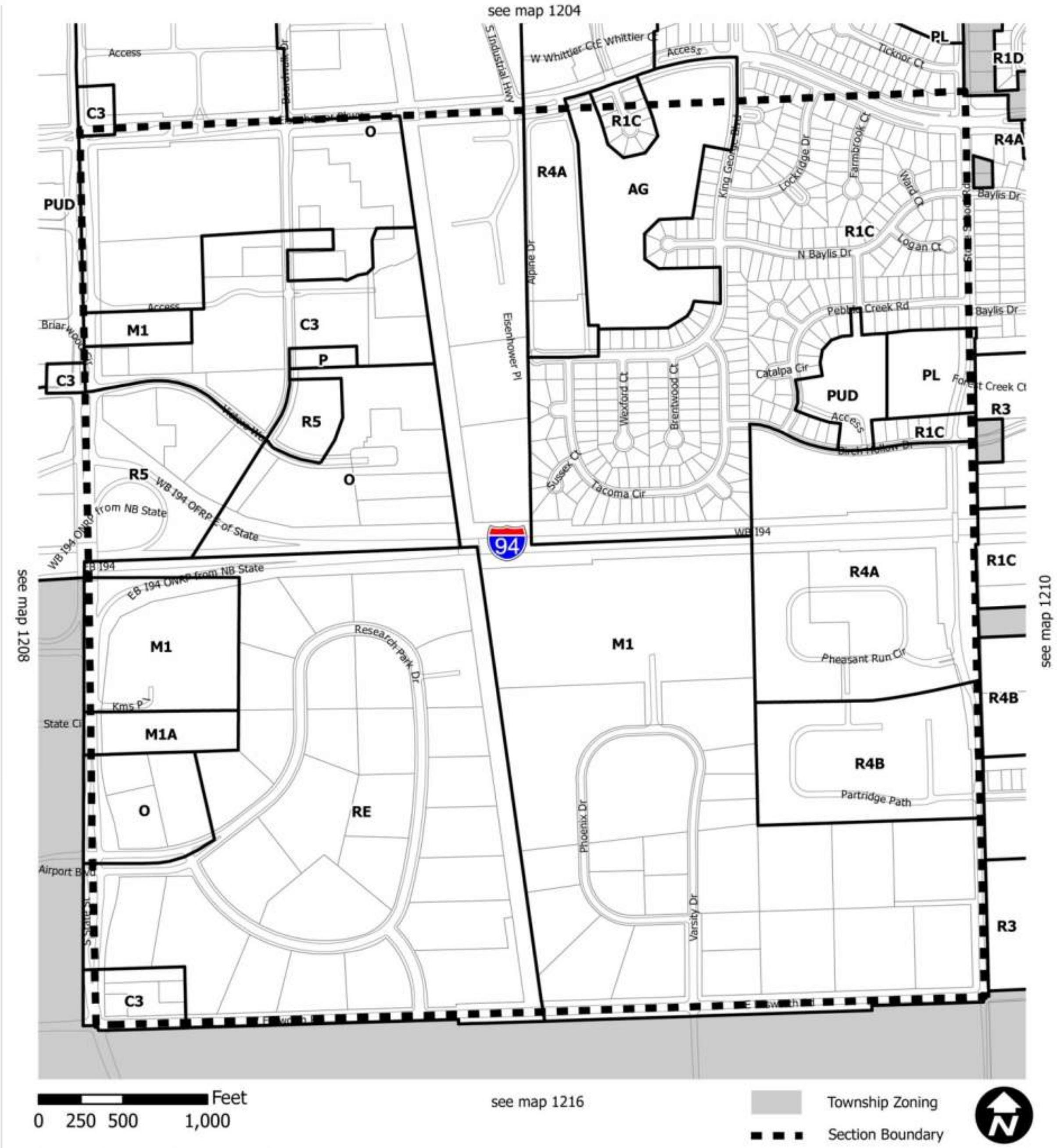

Zoning Distric Classifications

AG	Agricultral	R5	Motel-Hotel	C1A/R	Campus Business/Retail
R1A, R1B, R1C, R1D	1-Family Dwelling	R6	Mobile Home Park	C2A	Central Business
R2A	2-Family Dwelling	P	Parking	C2A/R	Commercial/Residential
R2B	2-Family Dwelling	PUD	Planned Urban Development	C2B	Business Service
R3	Townhouse Dwelling	O	Office	C3	Finge Commercial
R4A	Multiple-Family Dwelling	PL	Public Land	M1	Limited Industrial
R4B	Multiple-Family Dwelling	RE	Research	M1A	Light Industrial
R4C	Multiple-Family Dwelling	C1	Local Business	M2	Heavy Industrial
R4C/D	Multiple-Family Dwelling	C1A	Campus Business	ORL	Office/Research/Limited Industrial
R4D	Multiple-Family Dwelling	C1B	Community Convenience Center		

Figure 4.6: Ann Arbor Zoning Map
Ann Arbor Municipal Airport Environmental Assessment

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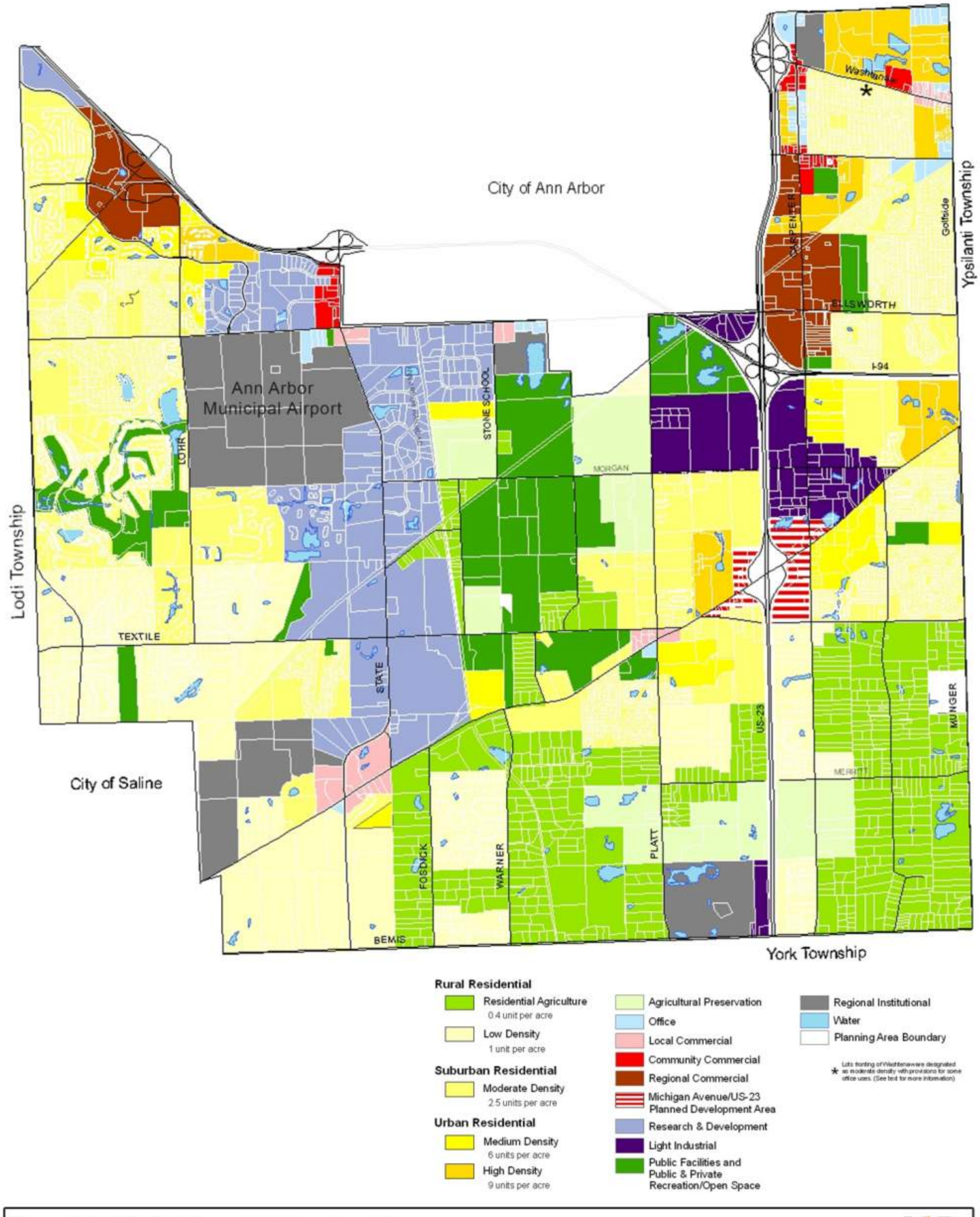

Figure 4.7: Pittsfield Township Future Land Use
Ann Arbor Municipal Airport Environmental Assessment

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Consequences of the Preferred Alternative
Aircraft noise is one of the major concerns of both airport operators and airport neighbors when evaluating impacts of a proposed airport development project. Estimates of noise effects resulting from aircraft operations can be interpreted in terms of the probable effect on human activities characteristic of specific land uses. Guidelines for evaluation of land use compatibility in aircraft noise exposure areas were developed by the FAA and are presented in Table B-1 in Appendix B. The guidelines reflect the average response of large groups of people to noise and might not reflect an individual's perception of an actual noise environment. Compatible or incompatible land use is determined by comparing the predicted or measured daily noise level at a specific site with the compatibility guidelines. According to FAA, all land uses are normally compatible with aircraft noise levels below 65 DNL. For noise exposure levels greater than 65 DNL, compatibility is dependent on land use. For example, commercial and manufacturing land uses are more tolerant of higher noise levels than a hospital or church. In general, most land uses are considered incompatible when noise levels exceed 75 DNL.

If the Preferred Alternative is implemented, the 65, 70, and 75 DNL contours would all still remain within airport property. As a result, the land use within the vicinity of ARB would remain compatible with the airport under the Preferred Alternative, which involves the extension of Runway 6/24.

The FAA and MDOT have reviewed the Runway Safety Area (RSA), Object Free Area (OFA), and Runway Protection Zone (RPZ) requirements for the approach areas of Runway 6/24. Even with the implementation of the Preferred Alternative, and the shift and extension of the runway to the southwest, the RSA, OFA, and RPZ in the southwest approach area will continue to remain totally clear of obstruction and entirely on airport property. Since the runway approach areas will continue to meet all FAA and MDOT safety standards, there is no indication that the development of the Preferred Alternative will result in increased hazards to people or structures on the ground. Existing and proposed land use adjacent to and in the immediate vicinity of ARB is compatible with normal airport operations.

4.3 INDUCED SOCIOECONOMIC IMPACTS

4.3.1 Community Displacement

No land would be acquired as either fee or easement acquisition and no displacements would occur as a result of the Preferred Alternative.

Consequences of the Preferred Alternative
There would be no community displacement impacts, no residential or business displacements, and no land acquisition resulting from the Preferred Alternatives.

4.3.2 Environmental Justice

Existing Conditions

The federal government's policy on nondiscrimination in all federally funded activities formally began with Title VI of the 1964 Civil Rights Act. Title VI requires all federal agencies to ensure that "No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance."

Further guidance was provided in 1994 with *Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*. The intent of the Executive Order is to identify and avoid disproportionately high and adverse human health or environmental effects on minority and low-income populations.

The presence of minority or low-income populations in the project area was determined by an evaluation of U.S. Census data, and Michigan State Housing Development Authority (MSHDA) data. ARB is owned and operated by Ann Arbor, yet is located in Pittsfield Township. Census data for the city and township was compared to Washtenaw County to make a determination regarding the presence of an environmental justice population.

<u>Minority Populations</u>

Race data from the 2000 U.S. Census (U.S. Census Bureau, 2009) was used to determine the presence of minority populations within the immediate area surrounding ARB. According to the Council on Environmental Quality (CEQ), minorities are defined as individuals who are members of the following population groups: American Indian or Alaskan Native, Asian or Pacific Islander, Black, not of Hispanic origin, or Hispanic (1997).

An analysis of the U.S. Census data indicates that minority populations are present near ARB, totaling 28 percent of the total population within the Pittsfield Township and 24 percent in the City of Ann Arbor. The percentage of minorities present in Washtenaw County totals 22 percent.

<u>Low-Income Populations</u>

U.S. Census economic data from the 2000 U.S. Census was used to determine the presence of low-income populations in the project area. The economic data identifies the income required to be below the poverty level and the number of people that are below that level. The U.S. Census Bureau measures poverty according to poverty thresholds, which is most simply defined as a measure of income inadequacy. This method of defining poverty thresholds was developed based on the income level that would cause a family to cut back on food expenditures sharply, assuming food expenses and non-food expenses would be cut at the same rate (Fisher, 1997).

According to the 2000 economic data, there is a percentage of the population below the poverty level near ARB, accounting for 9 percent of the total population in Pittsfield

Township and 17 percent in the City of Ann Arbor. These percentages are similar to 11 percent in Washtenaw County. Reviewing economic data at the block level indicates that in the immediate area surrounding ARB, there is a lower percentage of low-income populations, ranging from a high of 8 percent to a low of 0.7 percent.

Consequences of the Preferred Alternative

In conclusion, this project would not have a disproportionately high or adverse effect on either minority or low-income populations. All improvements at ARB would occur within the airport property. There would be no noise impacts or residential displacements. No property acquisition would occur as a result of the Preferred Alternative.

While there are not any environmental justice issues associated with the proposed improvements identified at this time, a continuing effort would be made to identify disproportionately high and adverse impacts to minority and low-income populations as this project advances. If such impacts are identified, every effort would be made to involve impacted groups in the project development process and to avoid or mitigate these impacts. A public hearing would be held to allow the public, local officials, and agencies to comment on the proposed improvements. The hearing would be advertised according to FAA guidelines. Section 5 provides a detailed discussion of all public involvement activities.

4.3.3 Community Cohesion and Community Facilities

Existing Conditions

As noted in Section 4.2, residential, commercial, industrial, recreational, undeveloped, and agricultural areas immediately surround ARB. The closest community facility is the Pittsfield Township Fire Station 3, which is located at 705 W. Ellsworth Road, just west of State Street. East of Fire Station 3 is the Pittsfield Community Center at 701 W. Ellsworth Road. This facility houses the Pittsfield Senior Center. Pittsfield Township Park, located south of the Senor Center, is a 7-acre park with an accessible pathway, a softball field, three t-ball fields, a playground, and picnic tables and grills. The Ann Arbor United Soccer Club operates seven soccer fields on city-owned land located at 801 Airport Road between the ARB entrance and Ellsworth Road.

Consequences of the Preferred Alternative

There would be no displacements as a result of the Preferred Alternative. All of the surrounding roads would remain open during and after construction, and there are no anticipated impacts to circulation. Noise levels would not be significantly increased and flight paths would not change. Therefore, the Preferred Alternative would not result in impacts to community cohesion or facilities.

4.3.4 Demographics

Existing Conditions

Population data for 1990 and 2000 were obtained from the U.S. Census Bureau. Historical data and the population projections for 2015 and 2025 were obtained from the

Southeast Michigan Council of Governments (SEMCOG) (SEMCOG, 2009). This information indicates that since 1970, overall, the population has grown in the Ann Arbor area (Table 4-1). Pittsfield Township has experienced the highest growth trend from 1970 through 2000 (Table 4-1). As shown, these growth trends are projected to continue through 2025 (SEMCOG, 2009).

Table 4-1
Ann Arbor Area Population (1970 – 2000) and Projections

Community	1970	1980	1990	2000	2015	2025
City of Ann Arbor	100,035	107,969	109,592	114,024	114,081	114,810
Pittsfield Township	8,073	12,986	17,668	30,167	34,969	35,750
Washtenaw County	234,103	264,740	282,937	322,895	353,327	361,715

Source: U.S. Census Bureau and SEMCOG

According to the U.S. Census, the total number of housing units has been increasing in the Ann Arbor area. In 1990, the City of Ann Arbor had 44,010 total housing units, which increased to 47,218 in 2000. Pittsfield Township had 7,794 total housing units in 1990, with an increase to 12,337 units in 2000 (Table 4-2).

Table 4-2
Summary of Demographic Data

	1990 Census		2000 Census	
	City of Ann Arbor	Pittsfield Township	City of Ann Arbor	Pittsfield Township
U.S. Census Population	109,592	17,668	114,042	30,167
Total Housing	44,010	7,794	47,218	12,337
Total Vacant Housing Units	2,353	774	1,525	520
Percent Vacant Housing Units	5%	10%	3%	4%
Total Owner Occupied Housing Units	17,996	2,791	20,685	6,620
Percent Owner Occupied Housing Units	41%	36%	44%	54%
Total Renter Occupied Housing Units	23,661	4,229	25,008	5,197
Percent Renter Occupied Housing Units	54%	54%	53%	42%
Average Household Income	$33,344	$34,639	$46,299	$61,292
Average Family Income	$50,192	$45,597	$71,293	$82,600
Per Capita Income	$17,786	$16,936	$26,419	$29,645

Source: U.S. Census Bureau

U.S. Census data indicate renter occupied housing dominates the housing stock in the City of Ann Arbor at 53 percent and owner occupied housing accounts for 44 percent. In Pittsfield Township, owner occupied housing dominates at 54 percent and renter occupied housing accounts for 42 percent.

According to U.S. Census data, average household, family, and per capita incomes within the Ann Arbor area exhibited substantial increases between 1990 and 2000 (Table 4-2). In 1990, the average household income was $33,344 in the City of Ann Arbor and $34,639 in Pittsfield Township. This increased to $46,299 in the City of Ann Arbor and $61,292 in Pittsfield Township in 2000, a change of 39 percent and 77 percent, respectively.

The per capita income showed similar trends with increases of 49 percent in the City of Ann Arbor, increasing from $17,786 in 1990 to $26,419 in 2000. Pittsfield Township increased 75 percent, from $16,936 in 1990 to $29,645 in 2000 (Table 4-2).

The racial composition of the area surrounding the airport is described in Section 4.3.2, Environmental Justice.

Consequences of the Preferred Alternative

Impacts to demographics associated with the Preferred Alternative are not expected. There would be no displacements as a result of the Preferred Alternative; therefore, little impact to the local area population, number of households, or racial make-up is anticipated. In addition, no impact to average incomes within the local area would be anticipated as a result of the Preferred Alternative.

4.3.5 Economics

Existing Conditions

Businesses within the area surrounding ARB are primarily industrial and commercial. Research and business parks that are located around the airport include:

- Valley Ranch
- Airport Plaza
- Ann Arbor Commerce Park
- Runway Plaza
- Columbia Center
- Avis Farms
- State Street Executive Park

These types of businesses often locate near airports and are dependent, or may be dependent, on the airport for transportation services.

At the airport, there are fixed-wing FBOs, a helicopter FBO, three national rental car agencies, two flying clubs, four flight schools and pilot training centers, city airport staff, FAA air traffic control tower, air taxi, aircraft sales, aviation insurance, and aviation fueling businesses.

Consequences of the Preferred Alternative
No businesses would be displaced as a result of the Preferred Alternative. Access would not be affected during airport construction. As a result, no negative economic impacts are anticipated to the surrounding businesses and the airport businesses. A positive result of the improvements is the ability for business owners to achieve improved fleet efficiency for critical aircraft my maximizing their passenger and/or cargo loads.

4.4 AIR QUALITY

Existing Conditions
Air pollutants are contaminants in the atmosphere. Many man-made pollutants are a direct result of the incomplete combustion of fuels including coal, oil, natural gas, and gasoline. The establishment of the National Ambient Air Quality Standards (NAAQS) by the Environmental Protection Agency (EPA) was directed in the Clean Air Act (CAA), and attainment and maintenance of the NAAQS was reinforced in later amendments. The goal of air quality monitoring and actions is to ensure that the air quality levels of the various pollutants do not exceed the set standards.

Under the 1990 CAA Amendments, the U.S. Department of Transportation cannot fund, authorize, or approve federal actions to support programs or projects that are not first found to conform to CAA requirements. The air quality provisions of the CAA, as amended, are intended to ensure the integration of air quality planning in all transportation-related projects.

The Air Quality Division of the Michigan Department of Environmental Quality (MDEQ) produces an Annual Air Quality Report, which outlines the attainment status of the state. According to the 2006 Air Quality Report the project study area is in attainment with the NAAQS for ambient concentrations of carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and coarse particulate matter (PM_{10}) (MDEQ, 2008).

Of growing concern is the impact of proposed projects on climate change. Greenhouse gases are those that trap heat in the earth's atmosphere. Both naturally occurring and anthropogenic (man-made) greenhouse gases include water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Research has shown that there is a direct link between fuel combustion and greenhouse gas emissions. A detailed air quality report can be found in Appendix C.

Consequences of the Preferred Alternative
MDOT Bureau of Aeronautics conducted an Air Quality Study (Landrum and Brown, 1996) of general aviation airports. Seven airports were selected as case study airports. The results of the case study were used to draw conclusions for all general aviation airports. Key findings of the study revealed that typical general aviation airports generate a low level of air pollutants. Comparisons of existing conditions at various airports with future build out conditions indicate that the net change in air emissions is still below standards. The report states that proposed projects at general aviation airports are not expected to cause or contribute to any new violations of the NAAQS.

There would be no revisions to the existing roadway system as a result of the Preferred Alternative. Consequently, the air model results for the Preferred Alternative would be identical to those for the No Build Condition. Since the No Build Condition analysis shows that no sites would exceed the one-hour or eight-hour NAAQS standard, the Preferred Alternative would also have no sites exceeding the NAAQS standard.

During construction, appropriate mitigation measures, such as covering and spraying stock piles with water, should be utilized to minimize potential short term negative impacts which may be experienced locally due to fugitive dust, construction vehicle exhaust, or other fumes related to construction materials and equipment.

Based on FAA data, operations activity at the ARB represents less than one (0.1) percent of U.S. aviation activity. Therefore, assuming that greenhouse gases occur in proportion to the level of activity, greenhouse gas emissions associated with existing and future aviation activity at ARB would be expected to represent less than 1 percent of U.S.-based greenhouse gases. Therefore, we would not expect the emissions of greenhouse gases from this project to be significant.

4.5 WATER RESOURCES

4.5.1 Surface Hydrology

Existing Conditions
An unnamed steam located on the ARB property (Figure 4-8) flows south through an open ditch. It is enclosed in a concrete culvert south and west of the existing runway. It then flows east through an open ditch ultimately to the Wood Outlet Drain to the south. The upstream drainage area of approximately 0.5 square miles north and west of the airport flows through multiple subdivisions and business parks prior to entering the airport property. The stream appears to be perennial in nature with low flow water levels 8 to 10 inches deep. The streambed is 2- to 3-feet wide and is composed mostly of silty clay. While the channel is deeply incised in some locations, flows are expected to be variable as indicated by eroded banks 2- to 3-feet high throughout the corridor. Water quality is likely degraded as surface water contributions from runoff over turf and numerous storm outlets draining adjacent parking lots and streets are common.

Consequences of the Preferred Alternative
The stream would not be altered as a result of the improvements at ARB. The enclosure would not be extended.

The amount of impervious surface on site would increase slightly due to the extension of the runway and the taxiway from the existing 7 percent of the 837 acres site to 7.4 percent. An approved Storm Water Pollution Prevention Program is in place for ARB. Implementation of appropriate best management practices (BMPs) would continue to control the rate of stormwater runoff and maintain water quality standards.

Figure 4.8: Existing Water Resources and Land Cover
Ann Arbor Municipal Airport Environmental Assessment

NOT TO SCALE

4.5.2 Geology, Groundwater, and Soils

Existing Conditions
Millstein (1987) identified nine bedrock formations in Washtenaw County. Coldwater Shale is the primary bedrock in central Washtenaw County, composed primarily of shale, with some limestone, dolomite, sandstone, and siltstone.

There are 14 soil mapping units in the project area (USDA, 1997). The soils south of the runway are predominately hydric soils, either Palms muck, Adrian muck, or Edwards muck. Matherton sandy loam, Fox sandy loam, and Wasepi sandy loam are the soils located in the area of the runway and to the north of the runway. The muck soils have a high water table with water often at the surface. The Fox soils have a water table at a depth of greater than 6-feet, and the Matherton and Wasepi soils have a water table at 1- to 2-feet below the surface (USDA, 1997).

ARB is located in a wellhead protection area known as the Three Fires Aquifer Wellhead Protection Area. The Three Fires Aquifer supplies the City of Ann Arbor with a portion of their public drinking water supply. Three of the City's municipal wells are located at ARB. The purpose of the protection area is to prevent contamination of the aquifer.

The City of Ann Arbor has plans to construct a new water supply line from the wells. No new wells are planned at this time.

Consequences of the Preferred Alternative
Surface and subsurface geological conditions do not represent a constraint to implementation of the Preferred Alternative and, consequently, would not be impacted. Based on coordination with the City of Ann Arbor, the proposed runway extension would not impact the water supply wells or the new water supply line (Bahl, 2009).

4.6 SECTION 4(f) RESOURCES

Existing Conditions
Section 4(f) of the Department of Transportation Act (1966) specifies that publicly-owned land, such as a park, recreational area, or wildlife and waterfowl refuge, of national, state, or local significance, or any land from a historic site of national, state, or local significance, may not be used for transportation projects unless there is no other prudent and feasible alternative. If there are no other prudent and feasible alternatives, the proposed project must include all possible efforts to minimize impacts to Section 4(f) properties.

A Pittsfield Township park is located along the northern airport property line. There are no historic resources within ARB and its surrounding areas that are considered Section 4(f) resources. The review process that has been used for evaluating the Section 4(f) properties has included coordination with the Michigan State Historic Preservation Office (SHPO) (Appendix D), and an archaeological resource survey (CCRG, 2009) that identified historic resources either currently listed on, or potentially eligible for listing on, the National Register of Historic Places (NRHP).

Consequences of the Preferred Alternative
The Preferred Alternative would not result in impacts to a publicly owned park, recreation area, or refuge, and ARB has coordinated with the SHPO to determine that there are no historic, archeological or architectural resources within the airport and its surrounding areas (Appendix D). The Pittsfield Township park would not be impacted and would not be acquired. No impacts to Section 4(f) resources are anticipated from the Preferred Alternative.

4.7 HISTORIC, ARCHEOLOGICAL, AND ARCHITECTURAL RESOURCES

Existing Conditions
An evaluation was conducted to determine the need for archaeological and/or above-ground surveys at ARB (CCRG, 2009). The evaluation included a field review of the area of the proposed improvements, a review of state archaeological files and above-ground resource files, and shovel tests at the site.

Consequences of the Preferred Alternative
ARB has coordinated with the SHPO to determine the presence of any historic, archeological, or architectural resources within the airport and its surrounding areas (Appendix D). Based on the file review and state files, no impact to historic, archeological or architectural resources is anticipated.

4.8 BIOTIC COMMUNITIES

Existing Conditions
Botanical communities within ARB and its immediately surrounding areas include active agricultural fields, unmown grassy meadows, a perennial stream, wet meadow, and a forested wetland. The developed portions of the airport property consist of structures, paved surfaces, a runway, access roads and parking lots, and maintained grassy areas.

Three predominant communities were observed on the property: upland, wet meadow, and forest (Figure 4-8). Plant species lists for these areas are shown in Appendix E. Most of the airport property and surrounding land has been altered by human activities. The least altered biotic communities are the grassy meadows surrounding the runway and the forested wetland to the south. The grassy meadow areas are only mowed periodically because of an agreement with the local Audubon Society.

The area at the end of the runway, where proposed expansion would occur, is kept mowed and the dominant plants in this area consisted of old field weeds and grassy species, with disturbed areas of bare dirt. Plants include rough-fruited cinquefoil (*Potentilla recta*), Canada thistle (*Circium arvense*), and an unidentified grass.

The sides of the stream contained upland weedy herbaceous species such as sweet clover (*Melilotus officinalis*), smooth brome (*Bromus inermis*), giant ragweed (*Ambrosia trifida*), Virginia creeper (*Parthenocissus quinquefolia*), lamb's quarters (*Chenopodium album*), riverbank grape (*Vitis riparia*), dame's rocket (*Hesperis matronalis*), teasel (*Dipsacus fullonum*), cow parsnip (*Heracleum maximum*), yellow goatsbeard (*Tragopogon pratensis*), yarrow (*Achillea millifolium*), a few reed canary grass, wheat or rye (*Triticum* or *Secale* spp), and mixed upland and wetland trees such as American elm (*Ulmus americana*), box elder (*Acer negundo*), staghorn sumac (*Rhus typhina*), Russian olive (*Eleagnus angustifolia*),buckthorn (*Rhamnus catharticus*) cottonwood (*Populus deltoides*), bur oak (*Quercus macrocarpa*), and American linden (*Tilia americana*).

Several examples of wildlife were observed, including robins (*Turdus migratorius*), goldfinch (*Carduelis tistis*), purple martins (*Progyne subis*), killdeer (*Charadrius viciferus*), and a mating pair of redtail hawks (*Buteo jamaicensis*). Other observations include evidence of rodent tunneling (field mice or voles) and pheasants (*Phasianus colchicus*) that were heard calling. Airport staff stated that coyote (*Canis latrans*) and white tail deer (*Odocoileus virginianus*) have been observed on the airport property as well as wild turkeys (*Meleagris gallopavo*). A comprehensive list of all the bird species observed by the Audubon Society at ARB is included in Appendix F.

Consequences of the Preferred Alternative

Implementation of the Preferred Alternative would require grading and construction of the extended runway. The areas to be impacted by grading are currently maintained and mowed for ARB or leased as agricultural land. A portion of the grading for the new taxiway near State Road would be in an area currently under restricted mowing per the agreement with the Audubon Society. The remaining areas would continue to be maintained with limited mowing as agreed by ARB and the Audubon Society. No trees would be cut or directly impacted by construction due to height obstructions.

The overall populations of wildlife species utilizing the area are not anticipated to be impacted as the maintenance of open grassy areas would continue. Wildlife may be temporarily impacted due to the presence of construction equipment in the vicinity.

4.9 THREATENED AND ENDANGERED SPECIES

Existing Conditions

Coordination with the US Fish and Wildlife Service (USFWS) (Appendix D) indicated that this agency has no records of federal-listed endangered, threatened, or otherwise significant species, natural plant communities, or natural features in the vicinity of ARB. The Michigan Department of Natural Resources (MDNR) indicated that Henslow's sparrow, state endangered, (*Ammodramus henslowii*) and Grasshopper sparrow, state special concern, (*Ammodramus savannarum*) are known to occur on or in the vicinity of the area. The presence of these species has been confirmed by the Audubon Society during their annual counts at ARB over the last three years.

All habitats within the project area have been impacted to varying degrees by human activities. No plant species listed as threatened or endangered by the MDNR or USFWS were found during the botanical survey conducted in June 2009.

Consequences of the Preferred Alternative

No known legally protected plants were observed within the project area. Grading for the new taxiway near State Road would be in an area currently under restricted mowing per the agreement with the Audubon Society. ARB revises the boundaries of this mowing agreement annually, with the Audubon Society, based on their most current bird count data. There would be no grading within agreed upon restricted mowing areas during the breeding season for either species which extends through late August for Henslow's sparrow and mid-July for Grasshopper sparrow.

4.10 WETLAND RESOURCES

Existing Conditions

Field surveys conducted in June 2009 revealed the presence of wetland vegetation at the east end of the runway. The MDEQ conducted a field visit in July 2009 to confirm whether the area would be classified as a wetland (Appendix D). A 5-acre area was reviewed for dominate vegetation, hydrology, and soils. A wetland was identified; however, the wetland does not constitute a wetland that is regulated by the state. The wetland is further than 500-feet from an inland lake, river, or stream, is less than 5 acres in size, and there is no surface connection with other wetlands in the area (MDEQ, 2009).

This area was a mix of mostly wetland species and scattered upland species, including reed canary grass (*Phalaris arundinacea*), sedge (*Carex granularis*), swamp milkweed (*Asclepias incarnata*), dandelion (*Taraxicum officinale*), sowthistle species (*Sonchus* sp.), buckthorn (*Rhamnus cathartica*), curly dock (*Rumex crispus*), and either goldenrod or aster species (*Solidago* or *Aster* sp.).

Consequences of the Preferred Alternative

The wetland at the east end of the runway would not be impacted by the proposed improvements, but it would be adjacent to the taxiway. This area would be protected with silt fence during construction and the 25-foot wetland buffer would be restored following construction.

4.11 FLOODPLAINS

Existing Conditions

An unnamed perennial stream is located within ARB, flowing to the south and ultimately connecting to the Wood Outlet Drain south of the airport. In accordance with FAA Order 5050.4B *Airport Environmental Handbook*, a review of the floodplains in the area and the impacts that may occur as a result of the development was undertaken.

Consequences of the Preferred Alternative

Review of the Federal Emergency Management Agencies (FEMA) flood boundary maps identified a floodplain boundary for the stream. The proposed grading for the expansion would not occur within the designated floodplain boundary and no fill would be placed in the floodplain. Therefore, there would be no impacts to the floodplain located within ARB.

4.12 COASTAL ZONE MANAGEMENT PROGRAM

The area surrounding ARB is not located within a coastal zone management area and, thus, the Preferred Alternative would have no impact on the Coastal Zone Management Program.

4.13 COASTAL BARRIERS

The area surrounding ARB is not located within a coastal zone management area, and the Preferred Alternative would have no impact on coastal barriers.

4.14 WILD AND SCENIC RIVERS

There are no waterbodies within the immediate vicinity of ARB that are designated as state or federal Wild and Scenic Rivers; therefore, the Preferred Alternative would have no impact on Wild and Scenic Rivers.

4.15 FARMLAND

ARB currently leases 168 acres of its property to a local farmer. If the Preferred Alternative is implemented, 18 acres of land would no longer be farmed. U.S. Department of Agriculture (USDA) requires a form, AD 1006, to be filed when agricultural land would be impacted. This agency estimates the total acres of prime and unique farmland, the total acres of statewide and local important farmland, and the percentage of farmland in the county to be converted. The relative overall value of farmland to be converted is also provided.

Prime farmlands are identified as land that has the best combination of physical and chemical characteristics for producing food, forage, fiber, and oilseed crops (USDA, 1983). Unique farmland is land, other than prime farmland, that has special characteristics, such as unique soil types and topographic features, which make it suitable for the production of specific high value crops. Land classified as prime or unique farmland is not necessarily actively farmed, it also may include other vegetated lands such as fallow fields and woodlands. Farmland of local importance includes those lands with nearly prime farmland characteristics that could economically produce high yields when treated and managed according to modern farming methods (USDA, 1983).

Consequences of the Preferred Alternative

ARB would not be acquiring any farmland for the proposed project. Based on coordination with the Washtenaw County Natural Resources Conservation Service (NRCS) (Appendix D), some prime farmland and farmland of local importance would be impacted by this project. The limits of grading have been minimized to the extent possible. The land outside of these limits would continue to be leased as farmland.

4.16 ENERGY SUPPLY AND NATURAL RESOURCES

Development of the Preferred Alternative would have the potential to increase the amount of air traffic utilizing ARB, which can potentially result in an increase in the amount of airplane fuel distributed by the airport and used by aircraft at the facility. A small amount of additional fuel would be used during construction of the runway and taxiway. However, these minimal increases in gas/fuel consumption are not considered significant.

ARB is installing approximately 250 LED taxiway lights which would decrease facility energy usage.

4.17 LIGHT EMISSIONS

The Preferred Alternative includes the addition of edge lights and the relocation of runway end identifier lights (REILS) to the end of the newly extended runway. Light emission impacts to adjacent homes would be minimized because lights within the light lane would be directed upwards. The REILS would be closer to Lohr Road and the adjacent homes; however, the existing lights would be replaced with a smaller LED unit.

Light emissions created by the Preferred Alternative are not considered significant. However, if impacts are noted, appropriate mitigation for the impacts would occur. Examples of mitigation include shielding the lights from below so that the light is reflected up to the sky or reducing light intensities, if the FAA makes a determination that a reduction would not affect the safety of the aircraft.

4.18 SOLID WASTE IMPACTS

Minimal waste would be generated during construction of the Preferred Alternative. No building demolition would occur. The existing runway and taxiway would remain and new material would be used for the extended portions of the runway and taxiway. The portions of the runway that would no longer be used would still exist, but marked accordingly. The nearest operational landfill is the Arbor Hills Landfill in Salem Township on 6 Mile Road in Northville, which is a Type II landfill that accepts household, commercial, and non-hazardous industrial waste. The Preferred Alternative would have minimal anticipated impact on nearby landfill facilities. In addition, these facilities have no impact on the Preferred Alternative given the distance separating them from ARB.

4.19 EXISTING AND FUTURE TRAFFIC CONDITIONS

The Preferred Alternative would not require either temporary or permanent closure of local roads surrounding ARB. During construction, it is expected that minor increases in traffic would occur from the construction crews traveling to and from ARB. Overall, the Preferred Alternative would have no significant impact on existing or future traffic volumes in the surrounding area.

4.20 CONSTRUCTION IMPACTS

The Preferred Alternative may result in temporary, localized air, water, and noise quality impacts during construction. Construction documents would identify specific environmental control methods to minimize air and water quality impacts. Air quality impacts, such as fugitive dust and exhaust from construction equipment, may be minimized by seeding disturbed areas, covering haul trucks, and wetting down construction areas. Sediment and erosion control measures would be used to minimize any water quality impacts during construction. Construction would comply with FAA specifications (FAA Advisory Circulars 150/5370-2C – Operational Safety on Airports During Construction, and 150/5370-10A Changes 1-12 – Standards for Specifying Construction of Airports), and State of Michigan regulations would be followed as required to prevent air pollution.

4.21 CONTAMINATED SITES REVIEW

Existing Conditions
A review of federal and state records was completed to identify known properties listed by state and/or federal agencies as either contaminated or sites of environmental concern (EDR, 2009). The intent of this review was to assist in the evaluation of study alternatives; the review was not a Phase I Environmental Site Assessment in accordance with American Society of Testing and Materials (ASTM) (Standard E1527-94). Several mapped sites were found on ARB or within the immediate area (within a one mile radius of the airport). These mostly include underground and above-ground storage tanks and small quantity generators.

There are no underground storage tanks on the airport property. ARB has two small (approximately 250 gallon) tanks that are used for maintenance operations. The City of Ann Arbor does not store or sell aviation fuel products.

The University of Michigan Flyers have an aboveground tank (approximately 3,000 gallons) with avgas (100LL fuel). Avfuel has three large aboveground tanks at ARB (approximately 20,000 gallons each) with avgas (100LL fuel) and Jet A fuel. Avfuel stores the aviation fuel and the FBO's sell it.

All fuel near the airport property is stored in tanks in accordance with MDEQ licensure guidelines and all tanks currently meet regulations.

Consequences of the Preferred Alternative

The Preferred Alternative is not anticipated to have an impact on known properties listed by state and/or federal agencies as either contaminated or sites of environmental concern. There would be no impacts to the fuel storage tanks during construction. Further, if contaminated soil is encountered during construction, proper disposal methods and construction procedures that minimize disturbance of contaminated soils would be utilized.

Section 5.
Environmental Consequences - Other Considerations

5.1 MITIGATION MEASURES

General Area and Project Information
ARB is planning to shift and extend Runway 6/24 and the parallel taxiway by approximately 800-feet.

Noise
The FAA's INM Version 7.0a was used to develop noise exposure contours in order to assess the noise impacts associated with the proposed extension of Runway 6/24. No homes or noise sensitive land uses are located within the 65 DNL contour for the Preferred Alternative future conditions. The Preferred Alternative is not expected to have any significant aircraft noise impacts; therefore, no mitigation is proposed.

Social Impacts and Community Disruption
There would be no land acquisition and no displacements as part of this project. If acquisition was required, it would follow the Uniform Relocation Assistance Act of 1970, as amended, and FAA AC 150/5100-17.

Wetland Impacts
Impacts to affected wetlands would require mitigation under Section 404 of the Clean Water Act, Executive Order 11990, and Part 303 of the Natural Resources and Environmental Protection Act (P. A. 451). When unavoidable impacts occur to regulated wetlands, both state and federal regulations require compensatory mitigation. The intent of the mitigation is the replacement of the lost functions of the wetland areas to be displaced. There would be no wetland impacts as a result of this project; therefore, no mitigation is required.

Threatened and Endangered Species
No known threatened or endangered species were identified within the project site; therefore, no mitigation is required.

5.2 DEGREE OF CONTROVERSY

During the course of this project, there has been input by local citizens regarding the need for the project and the potential impacts. Most of the input received focused on the need for the project and how it potentially would impact adjacent homes. A Citizen's Advisory Committee (CAC) was formed (see Section 6.2). These topics were presented and discussed during the CAC meetings. A public hearing would be held during the public comment period to allow the public an opportunity to comment on the proposed improvements and the EA. A more detailed discussion of public involvement activities can be found in Section 6.2.

Section 6.
Agency Coordination and Public Participation

Agency coordination was initiated early in this study. Input and feedback from agency representatives for this project was solicited via consultation and coordination with local, state, and federal regulatory and resource agencies, and the CAC. The public would be asked to provide feedback at a public hearing that would be held in early 2010.

6.1 AGENCY COORDINATION

Early agency coordination for the project began in 2009 with local, state, and federal agencies regarding issues such as threatened and endangered species, wetlands, farmland, and archeological and architectural resources. This has included consultation with the U.S. Fish and Wildlife Service (USFWS); U.S. Department of Agriculture (USDA); Natural Resources Conservation Service (NRCS); State Historic Preservation Office (SHPO); Michigan Department of Natural Resources (MDNR); U.S. Environmental Protection Agency (USEPA); and the Michigan Department of Environmental Quality (MDEQ) (Appendix D). Staff from MDOT – Airports Division and FAA – Detroit Airports District Office have also been consulted throughout the project.

In the project planning phase, coordination and correspondence has occurred with MDEQ. MDEQ conducted a site visit and a wetland delineation at ARB and provided a letter and wetland report documenting their findings (Appendix D).

Local tribes were also contacted. Response letters are provided in Appendix D.

6.2 PUBLIC PARTICIPATION

6.2.1 Citizen's Advisory Committee

The CAC was formed in spring 2009 and is comprised of 14 individuals representing a variety of affiliations including: local residents, local commercial and business establishments, pilots, and representatives from the City of Ann Arbor, and Pittsfield Townships. The CAC was formed to receive input from CAC members on project issues, to inform them of project activities and events, and to assist CAC members in communicating project activities to each member's constituents (affiliated organizations). Public participation was formally initiated with the first CAC meeting held in May 2009. This meeting focused on the proposed improvements to ARB, the purpose and need for these changes, and project history. At that meeting, questions and comments from CAC members included primarily on project justification and the history of the project.

The second CAC meeting was held in July 2009, and provided an update on the noise analysis, historic resources, plant communities, and wetlands. An overview of the User Survey Report was also provided. During this meeting, each CAC member was asked to provide an update on what they have been hearing from their constituency.

A third CAC meeting will be held in early 2010. This meeting will provide an update on the environmental studies along with a preview of the public hearing. Meeting summaries and a list of invitees and attendees for each CAC meeting were mailed to all meeting participants. A list of CAC members is provided in Appendix G.

6.2.2 Public Hearing

The Draft EA will be published and available for review for 30 days prior to the public hearing. The public comment period closes 10 days after the public hearing date. A legal notice will be published in the local Ann Arbor newspaper to announce the availability of the Draft EA and the date, time, and location of the public hearing.

Copies of the Draft EA will be forwarded to appropriate local, state, and federal regulatory and resource agencies and will be available for public review at ARB, Ann Arbor City Hall, Pittsfield Township Municipal office, and the Ann Arbor Public Library.

A public hearing on this study will be held in early 2010. The format of the public hearing will be an informal open house. The purpose of this hearing will be to provide the general public with information regarding the study purpose and need, alternatives considered, and selection of a Preferred Alternative. Exhibits and display stations will be set up to cover each aspect of the project, and the study team will be available to personally respond to questions regarding the proposed project. A public hearing handout will also be provided to attendees. Opportunities will be provided to submit both written and oral comments. All of the public and agency comments received will be reviewed and summarized in the Final EA.

Section 7. Conclusion

Based on the information in this EA and coordination with local, state, and federal regulatory agencies and the public, it is anticipated that this project will have no significant impact on the natural or human environment. If review and comment by the public and interested agencies support this determination, this EA will be forwarded to the Michigan Department of Transportation’s Bureau of Aeronautics and Freight Services and the Federal Aviation Administration with a request that a Finding of No Significant Impact (FONSI) be prepared and location/design approval be granted.

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Section 9.
List of Preparers

JJR, LLC

Neal Billetdeaux, Principal-in-Charge
Editor and quality assurance/quality control. 19 years experience. M.S. Landscape Architecture. B.S. Natural Resources. Registered Landscape Architect in Michigan.

Carol Schulte, Horticulturist/Environmental Specialist
Wetland delineation, permitting, and threatened and endangered species survey. 11 years experience. B.S. Horticulture, Michigan State University 1997. B.S. Biochemistry, Eastern Michigan University. 1981.

Joseph B. Wywrot, Civil Engineer
Air quality analysis. Thirteen years experience. M.S. Engineering, B.S. Engineering, University of Michigan. Registered Civil Engineer in Michigan.

JACOBSEN DANIELS ASSOCIATES, LLC

Amy Eckland, Environmental Specialist
Document production and editing. 12 years experience. M.S. Plant and Soil Science, B.S. Natural Resource Conservation and Management, University of Kentucky.

URS Corporation

Daniel Botto, Airport Environmental Planner
Aviation Noise Analysis. 10 years experience. B.S. Aviation Business Administration, Embry-Riddle Aeronautical University.

Section 10. Glossary

ACIP – Airport Capital Improvement Plan **–** The ACIP is a document that serves as the primary planning tool for identifying and prioritizing critical airport development and associated capital needs.

ADG – Airplane Design Group

ALP – Airport Layout Plan **–** The ALP is a set of drawings or an individual drawing that identifies future development at the airport. The ALP is part of the airport Master Plan.

ARB – Ann Arbor Municipal Airport

ARC – Airport Reference Code– The ARC is a coding system developed by the FAA to relate airport design criteria to the operational and physical characteristics of the airplane types that will operate at a particular airport.

ATCT – Air Traffic Control Tower

DNL – Day/Night Level (Noise)

EA – Environmental Assessment

EJ – Environmental Justice– An EJ is an Executive Order intended to identify and avoid disproportionately high and adverse human health or environmental effects on minority and low-income populations.

FAA – Federal Aviation Administration

Farmlands of State or Local Importance – The Natural Resources Conservation Service (NRCS) defines these farmlands as: "Those lands that are nearly prime and that economically produce high yields when treated and managed according to modern farming methods. Some may produce as high a yield as prime farmlands, if conditions are favorable." (USDA, 1983.)

FBO – Fixed Base Operator

FEMA – Flood Emergency Management Administration

FONSI – Finding of No Significant Impact

IFR – Instrument Flight Rules

ILS – Instrument Landing System

INM – Integrated Noise Model

MALSF - Medium Intensity Approach Lighting System with Sequenced Flashers

MASP – Michigan Airport System Plan

Master Plan – The airport Master Plan is a long-range planning (i.e., generally good for 20 years) document that inventories airport conditions, identifies facility requirements, and recommends future development. The Master Plan includes written text, as well as the ALP drawing(s) (see Airport Layout Plan above).

MDEQ – Michigan Department of Environmental Quality

MDNR – Michigan Department of Natural Resources

MDOT – Michigan Department of Transportation - Airports Division

Mitigation – Compensatory measures for impacts occurring as a result of an activity

MNFI – Michigan Natural Features Inventory

MSHDA – Michigan State Housing Development Authority

MTOW – Maximum Takeoff Weight

NAAQS – National Ambient Air Quality Standards

NEPA – National Environmental Policy Act

NPIAS – National Plan of Integrated Airport Systems

NRCS – Natural Resources Conservation Service (formerly the Soil Conservation Service)

ODALS - Omni-Directional Approach Lighting System

Prime Farmland – The NRCS has designated prime farmland as: "Land that has the best combination of physical and chemical characteristics for producing food, forage, fiber, and oilseed crops. The land could be crop, pasture, range, forest, or other uses, but does not include urban built-up land or water bodies, since these two are considered irreversible uses. It has soil quality, growing season, and moisture supply needed to economically produce/sustain high yields when treated and managed according to modern farming methods, including water management." (USDA, 1983.)

REILS – Runway End Identifier Lights.

RPZ – Runway Protection Zone – The RPZ is a three dimensional trapezoid, which controls the height of objects within the boundaries of this surface. These areas vary in size, depending on the type of approach category of a particular runway. The RPZ does not have to be cleared or graded, but does require air rights.

RSA – Runway Safety Area – The RSA is a prepared or suitable surface area that surrounds the runway in order to reduce the risk of damage to airplanes and injury to pilots and passengers in the event of an undershoot, overshoot, or excursion from the runway. This area, which parallels the runway, is 500 feet wide and preferably extends 1000 feet from the end of runway. The RSA must be clear of all objects and graded for aircraft and emergency vehicle use.

SHPO – State Historic Preservation Office

Site of Environmental Concern – An identified site of potential contamination due to the presence or handling of hazardous materials on site (e.g., site containing underground storage tanks).

Site of Environmental Contamination – Site of known contamination which falls under Michigan's Natural Resources and Environmental Protection Act 451, Part 201 (formerly Part 307) PA of 1994.

TAF – Terminal Area Forecast

Unique Farmlands – The NRCS has defined unique farmlands as: "Land other than prime farmland that is used for the production of specific high value food and fiber crops. These lands have a special combination of factors needed to economically produce sustained high quality yields of a specific crop when treated and managed according to modern farm methods. The special factors that make the land unique include soil quality, growing season, temperature, humidity, elevation, aspect, moisture supply, or other conditions such as nearness to market that favor growth of a specific crop. Moisture supply is the form of stored moisture, precipitation, or a developed irrigation system." (USDA, 1983.)

USEPA – United States Environmental Protection Agency

USFWS – United States Fish and Wildlife Service

VFR – Visual Flight Rules

Appendices

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Appendix A. User Survey Report

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Ann Arbor, Michigan
July, 2009

A-2. **Supplemental Report**
Airport User Survey
Ann Arbor Municipal Airport (ARB)
Ann Arbor, Michigan
December, 2009

Appendix A-1. **Airport User Survey Report**
Ann Arbor Municipal Airport (ARB)
Ann Arbor, Michigan
July, 2009

AIRPORT USER SURVEY REPORT

ANN ARBOR MUNICIPAL AIRPORT (ARB)
ANN ARBOR, MICHIGAN

July 2009

An airport user survey for Ann Arbor Municipal Airport (ARB) has been conducted by the Michigan Department of Transportation - Airports Division (MDOT). The purpose of the survey was to determine if there is justification of need for a proposed extension of primary Runway 6/24, based on current MDOT and Federal Aviation Administration (FAA) standards.

Runway 6/24 is presently 3,505 feet in length and 75 feet wide. The current Airport Layout Plan shows a proposed extension of this runway to an ultimate length of 4,300 feet.

Planning activities associated with the potential development of the extension began in 2007, and in that year the airport manager was requested to collect supporting aircraft operational data. Other data sources listed below were also examined as part of the survey analysis. In order to maintain consistency among the various data sources, only operational data from year 2007 was analyzed.

Based aircraft operational information was collected by Mr. Matthew Kulhanek, airport manager at ARB. The information provided was accurate as of October 18, 2007.

Itinerant (visiting) aircraft operational data was collected by the two Fixed Base Operators (FBOs) that are located on the airport. The FBOs are Solo Aviation and Ann Arbor Aviation Center. Their data collection processes were conducted over a six-month time frame, ranging from April 1, 2007 to September 30, 2007.

Records of operational activity at ARB for the entire calendar year 2007 were also obtained from the FlightAware flight tracking resource agency. FlightAware is a company that records and offers flight tracking information for both private and commercial air traffic in the United States.

During the user survey analysis, every aircraft-type listed in the various data sources was categorized according to FAA approach category, design group, and weight classifications. The various aircraft classifications and associated dimensional standards are shown on the next page. All of the operational records were carefully screened, counted, and cross-checked in order to eliminate the possibility of counting the same aircraft twice, if it was listed in more than one data source.

AIRCRAFT CLASSIFICATIONS (FAA):

APPROACH CATEGORY:

Category A:	Approach speed less than 91 knots.
Category B:	Approach speed 91 to 120 knots.
Category C:	Approach speed 121 to 140 knots.
Category D:	Approach speed 141 to 165 knots.
Category E:	Approach speed 166 knots +

DESIGN GROUP:

Group I:	Wingspan up to but not including 49 feet, tail height up to 20 feet.
Group II:	Wingspan 49 feet up to but not including 79 feet, tail heights 20 to 30 feet.
Group III:	Wingspan 79 feet up to but not including 118 feet, tail heights 30 to 45 ft.
Group IV:	Wingspan 118 feet up to but not including 171 feet, tail heights 45 to 60 ft.
Group V:	Wingspan 171 feet up to but not including 214 feet, tail heights 60 to 66 ft.
Group VI:	Wingspan 214 feet up to but not including 262 feet, tail heights 66 to 80 ft.

SMALL AIRPLANE:

An airplane of 12,500 lbs. or less maximum certificated takeoff weight.

LARGE AIRPLANE:

An airplane of more than 12,500 lbs. maximum certificated takeoff weight.

BASED AIRCRAFT ANALYSIS:

According to the Based Aircraft survey data compiled on October 18, 2007, there were 166 aircraft based at ARB. Five were helicopters, 152 were of the A-I classification, eight were of the B-I classification, and one (the only jet based at the airport) was of the B-II Large (greater than 12,500 lbs. maximum certificated takeoff weight) classification. An estimated 200 annual operations were performed by the jet aircraft.

An operation can be either a takeoff or a landing. Therefore, if a based aircraft departs the airport, and later returns, this equals a total of two operations even though it may have only been one actual flight.

Aircraft by FAA Classification:		Estimated Annual Operations:
Helicopter:	5	N/A
A-I:	152	*
A-II:	0	*
B-I:	8	*
B-II Small (<12,500 lbs.):	0	0
B-II Large (>12,500 lbs.):	1	200
C-I Large:	0	0
C-II Large:	0	0
Total:	166	

* Note: Estimated Annual Operations for A-I, A-II, and B-I classifications were not calculated as part of this analysis, as they are not a factor to the Critical Aircraft determination, nor do they provide justification for the proposed extension of the runway.

ITINERANT AIRCRAFT ANALYSIS:

Itinerant (visiting) aircraft are those that perform operations at a particular airport, but are actually based somewhere else. Itinerant aircraft information for ARB was compiled by the two FBOs that are located on the airport - Solo Aviation and Ann Arbor Aviation Center. The data sources were the pilot registration logs (airport registers) from each of their businesses. Since pilot sign-in is strictly voluntary, the registers do not account for all itinerant activity at ARB.

During the user survey analysis, two operations were awarded to each aircraft listed on the FBO airport registers. This is due to the FAA standard of considering each landing and subsequent takeoff by each visiting aircraft, two separate operations. Also, since the data was collected over a six-month time frame (April 1, 2007 to September 30, 2007) instead of a full year, operations were again multiplied by two in order to achieve an equivalent annual operational rate for the full calendar year 2007. This resulted in a total multiplier factor of four for each aircraft listed on the registers. This method is standard procedure during the analysis phase of all airport user surveys.

Data collected from the two FBOs is shown in the following tables. Note that aircraft operations that are already accounted for in the FlightAware database have not been included in the number of estimated annual operations listed in these tables. None of the estimated annual operations listed by the Solo Aviation FBO were performed by jet aircraft. Thirty-six of the operations listed by the Ann Arbor Aviation Center FBO were performed by jets.

FBO – Solo Aviation

Aircraft by FAA Classification:		Estimated Annual Operations:
Helicopter:	1	N/A
A-I:	183	*
A-II:	3	*
B-I:	40	*
B-II Small (<12,500 lbs.):	2 **	8 **
B-II Large (>12,500 lbs.):	2 **	8 **
C-I Large:	0	0
C-II Large:	0	0
Total:	231 **	

ITINERANT AIRCRAFT ANALYSIS (continued):

FBO – Ann Arbor Aviation Center

Aircraft by FAA Classification:		Estimated Annual Operations:
Helicopter:	3	N/A
A-I:	205	*
A-II:	13	*
B-I:	59	*
B-II Small (<12,500 lbs.):	5 **	20 **
B-II Large (>12,500 lbs.):	7 **	28 **
C-I Large:	3 **	12 **
C-II Large:	1 **	4 **
Total:	296 **	

* Note: Estimated Annual Operations for A-I, A-II, and B-I classifications were not calculated as part of this analysis, as they are not a factor to the Critical Aircraft determination, nor do they provide justification for the proposed extension of the runway.

** Note: Aircraft numbers and Estimated Annual Operations shown have been corrected to avoid duplication of records already included in the FlightAware database.

FLIGHTAWARE DATABASE ANALYSIS:

As stated earlier, FlightAware is a company that records and offers flight tracking information for both private and commercial air traffic in the United States. The company maintains records of all flight activity for which Instrument Flight Rule (IFR) flight plans have been filed by pilots. The company does not keep records of flight activity that is conducted without flight plans under Visual Flight Rule (VFR) conditions.

Aircraft owners are allowed the opportunity to block specific information from the FlightAware database for security and/or privacy reasons. Unfortunately, the aircraft-types, owner or corporate names, and aircraft registration numbers are not listed in the database when aircraft owners elect to block their information. Origin and destination airport locations and dates of flights are still listed in the database for the blocked operations.

FlightAware provided records that were associated with flight activity to and from ARB during the entire calendar year 2007. Out of over 4,300 records of flight operations, 274 had blocked information. Since the FlightAware records do not include VFR flight activity, and do not include specific aircraft information for the blocked operations, they do not provide a complete history of all activity at the airport.

Judging by the distant locations associated with many of the blocked operations, some of the aircraft flown were likely of the larger categories. However, since the aircraft-type was not provided for these operations, none of them are included in the annual operations listed below. Had aircraft-type information been available for the blocked operations, the resulting operational numbers would likely have been higher.

Annual operations for all classifications of B-II and greater were calculated and are listed in the table shown below. Sixty-nine of the annual operations listed in the FlightAware database were performed by jet aircraft.

FAA Classification:	Annual Operations Included in Database:
B-II Small (<12,500 lbs.):	265
B-II Large (>12,500 lbs.):	85
C-I Large:	0
C-II Large:	0

COMBINED TOTALS OF ALL DATA SOURCES FOR YEAR 2007:

FAA Classification:	Estimated Annual Operations:
B-II Small (<12,500 lbs.):	293
B-II Large (>12,500 lbs.):	321
C-I Large:	12
C-II Large:	4

TOTAL ESTIMATED ANNUAL OPERATIONS USED IN DETERMINATION OF CRITICAL AIRCRAFT CLASSIFICATION:

Total Annual Operations, "B-II Small and Greater": 630 (293+321+12+4)

Total Annual Operations, "B-II Large and Greater": 337 (321+12+4)

Total Annual Operations, "C-I Large and Greater": 16 (12+4)

Total Annual Operations, "C-II Large": 4

JET AIRCRAFT:	Estimated Annual Operations
Combined total from all classifications, including B-I:	**305**

CRITICAL AIRCRAFT DETERMINATION:

The Critical Aircraft is defined by the FAA as the most demanding aircraft-type that performs a minimum of 500 annual operations at a particular airport. In cases where the Critical Aircraft weigh less than 60,000 lbs, a classification of aircraft is used rather than a specific individual aircraft model.

As shown on the previous page, a total of **630** estimated annual operations were documented by aircraft in the "B-II Small and Greater" classification, which also includes some B-II Large, C-I Large, and C-II Large category aircraft. Since none of the greater categories had operational levels in excess of 500 at ARB, the current Critical Aircraft classification has been determined to be **B-II Small Aircraft**. Note that in establishing the 500-minimum annual operational threshold, it is standard procedure to also include operations from the greater categories in the determination of the Critical Aircraft classification.

Aircraft in the "B-II Small Aircraft" classification have approach speeds between 91 and 120 knots, wingspans between 49 and 79 feet, and maximum certificated takeoff weights of 12,500 lbs. or less. A representative aircraft of this class is the Beechcraft King Air 200, a twin-engine turboprop aircraft that typically seats 10-12 people, including the flight crew.

RUNWAY LENGTH RECOMMENDATIONS:

For airports with "B-II Small Aircraft" Critical Aircraft classifications, primary runway length recommendations by MDOT and FAA are as follows:

MDOT – *Source: Michigan Airport System Plan (MASP 2008):* **4,300 feet**
(statewide standard)

FAA – *Source: FAA Advisory Circular 150/5325-4B,* **4,200 feet** *
"Runway Length Requirements for Airport Design"
(airport-specific standard)

* *Note: The FAA runway length recommendation was obtained from Figure 2-2 in Advisory Circular 150/5325-4B. The following specifics for ARB were used in the determination: Airport Elevation: 839 feet above mean sea level*
Temperature: 83 degrees F mean daily maximum temp of hottest month of year (July)

RUNWAY LENGTH RECOMMENDATIONS (continued):

The FAA recommended runway length of 4,200 feet at ARB was obtained by calculation from FAA Advisory Circular 150/5325-4B, *"Runway Length Requirements for Airport Design"*, a publication that is used nationally by the agency. The resulting recommended runway lengths are airport-specific, and can vary by hundreds of feet from site to site, depending on the specific airport elevations and mean daily maximum temperatures used in the calculations.

The MDOT recommendation of 4,300 feet is a statewide standard for all airports in the state with B-II Small Critical Aircraft classifications. Since airport elevations and mean maximum temperatures do not vary significantly from airport to airport in Michigan, as opposed to many other states, MDOT uses a single runway length recommendation for all airports of the same Critical Aircraft classification. The FAA-Airports District Office that oversees the state of Michigan supports our statewide runway length recommendation of 4,300 feet for all airports classified with a B-II Small Aircraft reference code.

As stated in FAA Advisory Circular 150/5325-4B, "*The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions.*" Airplanes that are classified within an airport's Critical Aircraft category are considered by the FAA to be the "regular use" aircraft of the main primary runway.

Development of the primary runway at ARB to the recommended length of 4,300 feet would allow the majority of B-II Small classification aircraft to operate at their optimum capabilities (without weight restrictions). Interstate commerce into and out of a community can be negatively impacted if business aircraft are forced to operate with load restrictions (i.e. reductions in passengers, cargo, and fuel associated with aircraft range) due to lack of suitable runway length.

Extension of the runway to the recommended length would also enhance airport operational safety. A 4,300-foot long runway would not only provide enough runway for takeoff by most regular use (Critical Aircraft category) airplanes operating at optimum capabilities, but also provide additional runway for the purpose of bringing the aircraft to a stop in an aborted-takeoff situation. In situations where pilots detect a problem with the aircraft while on the takeoff roll, they are forced to continue the takeoff and contend with the problem in the air if there is not enough runway remaining to bring the aircraft to a stop. By having enough remaining runway to safely abort a takeoff and stop the aircraft while still on the ground, a pilot would be able to avoid a potentially hazardous situation of taking to the air with a mechanically-deficient aircraft.

CONCLUSION:

This user survey analysis has shown that justification of need for the proposed extension of Runway 6/24, based on a determination of the Critical Aircraft, has been substantiated according to MDOT and FAA standards. Even though records that were analyzed likely did not include all operations performed at ARB in 2007 by category B-II and greater aircraft, the operations that were substantiated with available information were more than sufficient to make the determination that the Critical Aircraft is of the "B-II Small Aircraft" classification. With this confirmation, we find the proposed project eligible to receive state and federal funding, and recommend that the airport sponsor proceed with the planning and environmental processes associated with the proposed extension of the primary runway to an overall length of 4,300 feet.

Mark W. Noel

Mark W. Noel, P.E., Manager
Project Development Section
MDOT – Airports Division

NOTE: *A Supplemental Report to this July 2009 Airport User Survey Report was issued in December 2009. The Supplemental Report provides additional details and updates to the information contained in this original report. The information published in the Supplemental Report provides additional justification to further support the findings and recommendations of this original July 2009 Airport User Survey Report.*

Appendix A-2. Supplemental Report
Airport User Survey
Ann Arbor Municipal Airport (ARB)
Ann Arbor, Michigan
December, 2009

SUPPLEMENTAL REPORT
AIRPORT USER SURVEY

ANN ARBOR MUNICIPAL AIRPORT (ARB)
ANN ARBOR, MICHIGAN

December 2009

This Supplemental Report is associated with the original Airport User Survey Report for Ann Arbor Municipal Airport (ARB), dated July 2009. The information contained in this supplement provides additional details and updates to the information contained in the original report.

Additional analysis of the aircraft operational data has resulted in the generation of supplemental information, three new exhibits, and updates to the numbers of annual operations performed by category B-II critical aircraft. The following paragraphs explain in detail the information provided in the new exhibits, as well as the supplemental information and updates to the operational numbers listed in the original user survey report.

EXHIBIT No. 1: *Annual Operations Analysis by Specific Aircraft Model*

This exhibit shows annual operations at ARB by specific aircraft model, rather than only by their FAA aircraft classification as shown in the original user survey report. The various aircraft models are listed in three separate tables, based upon groupings of their FAA classifications (B-II, C-I, and C-II).

Supplemental data associated with annual operations by the Beechcraft King Air C90 has been included in the B-II category table of this exhibit. Operations by this particular model of aircraft were not included in the original July 2009 Airport User Survey Report.

EXHIBIT No. 2: *Origin / Destination Analysis by State*

Exhibit No. 2 shows the results of an origin and destination analysis of aircraft operations conducted at ARB, based on examination of the FlightAware database from survey year 2007. Although 274 of the operations had aircraft model and ownership information blocked from the database at the aircraft owner's request, the origin and destination cities of each flight were still included.

The first column of the table shown in this exhibit lists 31 states (and Washington DC) from which operations into ARB originated, or operations out of ARB were going to as a destination. The second column lists operations attributed to each state by the 274 total operations with blocked aircraft and ownership records. The third and fourth columns list operations attributed to each state by B-II Small and B-II Large category aircraft. The last column lists the total number of operations attributed to each state.

The numbers of operations associated with each state are from the FlightAware Instrument Flight Rule (IFR) flight plan database only, and do not include records of all itinerant operations between ARB and other states. Nonetheless, the numbers shown in this exhibit confirm that in 2007, flight operations were conducted between ARB and at least 31 other states (approximately 63% of the continental US). Also, approximately 67% of the IFR flight records for the category B-II critical aircraft were between ARB and out-of-state locations. These factors confirm that there is a significant amount of flight operations being conducted at ARB that are either going to, or coming from, distant locations in other states.

<u>EXHIBIT No. 3</u>: ***Small 10-Seat Aircraft Analysis***

The table in this exhibit lists *Small* aircraft models (less than or equal to 12,500 lbs. maximum certificated takeoff weight) that have 10 or more passenger seats, and that conducted operations at ARB in survey year 2007. The numbers of annual operations listed in the table are from the FlightAware IFR flight plan database only, and do not include records of all operations by aircraft of this type. The FlightAware records show that there were 425 annual operations by Small 10-seat or higher aircraft.

Exhibit No. 3 also shows that there were 211 annual operations by *Large* category (greater than 12,500 lbs. maximum certificated takeoff weight) B-II aircraft from the Based Aircraft data source and another 85 annual operations by Large category B-II aircraft from the FlightAware data source. The number of annual operations performed by the Small 10-seat or higher aircraft and the Large category aircraft combined is shown as 721.

The operational numbers listed in Exhibit No. 3 do not include blocked FlightAware operations, Visual Flight Rule (VFR) operations, or operations logged by pilots on the Fixed Base Operator (FBO) airport registers. Although the information shown is only a partial representation of all applicable aircraft, the 721 annual operations that were substantiated significantly confirm that Figure 2-2 in FAA Advisory Circular 150/5325-4B is the appropriate chart to reference in the determination of the FAA-recommended runway length of 4,200 feet at ARB.

<u>UPDATED BASED AIRCRAFT ANALYSIS</u>:

The Based Aircraft Analysis of the original user survey report listed 200 estimated annual operations by AvFuel's B-II Large category aircraft (see page 3 of the original report). AvFuel's Chief Pilot has since confirmed in writing that the actual number of operations by their Cessna Citation XL 560 aircraft at ARB over the past three calendar years has been 224 operations in 2006, 211 operations in 2007, and 223 operations in 2008.

In order to maintain consistency with the other survey year 2007 operational records analyzed, Exhibit No. 1 of this Supplemental Report shows the 211 actual annual operations by this aircraft in the "Based Aircraft Data Source" column of the category B-II table, instead of the original estimate of 200.

<u>UPDATED ITINERANT AIRCRAFT ANALYSIS</u>: (FBO Data Sources)

Itinerant (visiting) aircraft operational data that was evaluated as part of the original user survey analysis was obtained from the pilot registration logs (airport registers) of two of the airport's FBOs - Solo Aviation and Ann Arbor Aviation Center. Data was examined for a six-month survey time frame, and cross-checked against FlightAware records in order to prevent counting the same aircraft twice. Any operations that were already included in the FlightAware records were not included in the operational totals that were generated from the FBO records.

The FBO records provided 40 additional operations by B-II and greater category aircraft (32 by category B-II aircraft, 6 by category C-I aircraft, and 2 by category C-II aircraft). Since this data was based on a six-month time frame instead of the full calendar year 2007, these 40 actual operations were prorated into an estimated equivalent annual rate of 80 operations. The additional 40 estimated operations were the only operations in the original user survey analysis that were obtained by prorating actual partial-year data into an estimated equivalent annual rate.

As part of the supplemental analysis, estimated operations that were originally generated as a result of prorating partial-year data were not considered in the determination of the annual operations at ARB. This eliminates the potential effect of seasonal variation in flight activity levels negatively influencing annual operational estimates. Only the 40 actual operations that were documented by the FBOs as having occurred within the six-month survey period were counted as valid operations, since they did in fact occur in 2007. No operations were attributed to the remaining six months.

Exhibit No. 1 of this supplemental report shows only the 40 actual documented operations (32 by category B-II aircraft, 6 by category C-I aircraft, and 2 by category C-II aircraft) in the column that is labeled "2 FBO Register Data Sources".

UPDATED FLIGHTAWARE DATABASE ANALYSIS:

The FlightAware database analysis that was performed for the original July 2009 Airport User Survey Report resulted in the determination of 265 actual annual operations by B-II Small aircraft, and another 85 actual annual operations by B-II Large aircraft (see page 6 of the original report). However, the resulting numbers did not include operations by the Beechcraft King Air C90 model.

The King Air C90 is a B-II Small category aircraft, with a wingspan of 50'3". Earlier versions of the King Air 90 models (A90 and B90) have wingspans of less than 49', and are therefore category B-I Small aircraft. Since the FlightAware records that were originally analyzed for ARB did not include information which identified the specific model of each King Air 90 operation, no operations by King Air 90s were included in the original user survey analysis and report.

Although the FlightAware records do not provide information regarding the specific model of each King Air 90 operation listed, they do provide the aircraft registration N-number of each aircraft. By entering the N-number into the computerized FAA aircraft registration database, the specific model of each King Air 90 operation was able to be determined. A total of 157 operations by the B-II Small category King Air C90 model have been identified, out of 220 operations by King Air 90 models of all types.

Exhibit No. 1 of this supplemental report shows the 157 King Air C90 operations included in the "Flight Aware Data Source" column of the category B-II table. By adding these operations to the 265 operations by B-II Small aircraft and 85 operations by B-II Large aircraft that were previously identified in the original user survey report, the updated total number of actual annual operations by B-II category aircraft obtained from the FlightAware data source is 507.

The FlightAware database also confirmed usage of the airport by many large corporations, in addition to AvFuel, which is the only one actually based at ARB. Some of the other corporate users of ARB include Synergy International, Wells Fargo, Polaris Industries, Bombardier Aerospace, Avis Industrial Corporation, Thumb Energy, and NetJets. NetJets provides on-demand air charter services and corporate aircraft fractional ownership opportunities to a large number of other corporations that are located throughout the country.

AIRCRAFT OPERATIONAL FORECASTS:

Year 2007 was the onset year of the current planning activities associated with the potential extension of Runway 6/24. At that time, the airport manager and FBOs were requested to collect based and itinerant aircraft operational data over the course of year 2007 for the purpose of determining project justification. This data was reviewed during the user survey analysis, which was conducted in early 2009.

FlightAware records for any given year are not published until that particular calendar year has ended, and all operations that took place during the course of that year counted. Since the user survey analysis was conducted in early 2009, the most current operational records available at the time from FlightAware were associated with calendar year 2008. Although year 2008 records were available, year 2007 records from FlightAware were used in the user survey analytical process. This was due to the importance of maintaining consistency of year of operational records in the analysis, and not combining operational data collected by the airport manager and FBOs over year 2007 with the more recent FlightAware records from year 2008. The FlightAware records, airport manager records, and FBO records from calendar year 2007 that were used in the user survey analysis were all only one-year old at the time, and still considered valid for use in determining project justification.

The FAA Terminal Area Forecast (TAF) does project a short-term approximate 22% decrease in total annual operations at ARB from user survey year 2007 through year 2009 (from 72,895 actual in 2007 to 56,956 estimated for 2009). However, beginning in year 2010, the TAF projects continuously increasing annual operations at ARB, from the year 2009 low-point through year 2030. Itinerant annual operations are even projected to surpass survey year 2007 levels prior to the end of the 2030 forecast period.

Even if the worst case short-term projected 22% decrease in total annual operations is applied to the user survey results, there is still significant justification for the runway extension. The user survey report documents a total of 750 actual annual operations by B-II category critical aircraft that justify the runway extension. A 22% decrease in this number is 585 - still well above the FAA's substantial use threshold of 500. And again, beginning in 2010, operations at ARB are projected by the FAA to begin increasing every single year from that point forward, through year 2030.

Forecasts from the MDOT Michigan Airport System Plan (MASP 2008) also project increasing itinerant and total operations at ARB from years 2010 through 2030. The MDOT forecasts further substantiate the mid-term and long-term FAA projections of a rebound in current operational activity at ARB to survey year 2007 levels.

AvFuel Corporation, which bases a B-II Large category Citation 560 Excel jet at ARB, has confirmed that their operations at ARB actually increased from 211 operations in 2007 to 223 operations in 2008. Their Chief Pilot estimates that their future operational levels could potentially increase to 350 to 450 operations per year at ARB.

The FAA TAF forecast, MDOT MASP forecast, and AvFuel's operational forecasts all provide support to the fact that survey year 2007 operational data is a very pertinent representation of estimated future operational levels at ARB.

SUMMARY:

The supplemental analysis that was conducted after publication of the July 2009 Airport User Survey Report has resulted in additional justification in support of extension of Runway 6/24 to 4,300' in length.

Further analysis of the FlightAware IFR flight plan database has confirmed 507 actual operations at ARB in survey year 2007 by B-II category aircraft. This number does not include operations in the FlightAware records with aircraft information blocked at the owner's request, or VFR operations that were conducted without flight plans. Judging by the high number of out-of-state origin and destination locations of operations listed in the blocked category (see Exhibit No. 2), it is very likely that many of the associated aircraft were of the B-II or greater categories. Therefore, actual operations at ARB by aircraft of these categories are likely considerably higher than the 507 substantiated operations obtained from the FlightAware database.

The 507 actual operations by B-II category aircraft that were obtained from the FlightAware database also do not include operations conducted by AvFuel's based Cessna Citation XL 560, or operations obtained from the two FBO airport registers. AvFuel has confirmed 211 actual operations at ARB in 2007 with their B-II category aircraft, and data provided by the FBOs has confirmed 32 actual operations in 2007 by B-II category aircraft.

In summary, the supplemental analysis of this user survey has confirmed a total of 750 actual annual operations at ARB by category B-II aircraft. FlightAware records also confirmed that operations by aircraft in this critical aircraft category were performed by many large corporations, some of which are listed on page 4 of this report.

CONCLUSION:

In the majority of airport user survey processes, determinations and recommendations are issued based on analysis of estimated annual operations obtained from various airport users. In conducting the user survey at ARB, the analysis focused on evaluation of actual annual operations performed at the airport. This is obviously a much more accurate method of calculating the total number of annual operations associated with the determination of the critical aircraft and Airport Reference Code. It also eliminates the possibility of an airport user inflating their estimated operational numbers, in the hopes of obtaining a longer runway that is not truly justified.

While the numbers listed in this report do not include every operation that occurred at ARB in survey year 2007 with B-II category aircraft, they do confirm substantial usage of the airport by aircraft of this critical aircraft category. The Origin/Destination Analysis has shown a significant number of operations between ARB and distant out-of-state locations, which is a very good indicator of corporate activity associated with interstate commerce, as opposed to pleasure flying by general aviation pilots. FlightAware records also confirmed usage of the airport by many large corporations.

The information contained in this Supplemental Report provides additional justification in support of the findings and recommendations of the original July 2009 Airport User Survey Report. The user survey analysis has shown that justification for the proposed extension of primary Runway 6/24 to 4,300-feet has been confirmed, and the proposed project has been determined to be eligible to receive state and federal funding.

Although justification for the proposed project has been substantiated according to current MDOT and FAA standards associated with runway length recommendations, neither agency requires that the runway be extended. It is ultimately – and entirely – the decision of the city of Ann Arbor whether or not to proceed with the development of the project.

Mark W. Noel

Mark W. Noel, P.E., Manager
Project Development Section
MDOT – Airports Division

ANN ARBOR MUNICIPAL AIRPORT USER SURVEY - SUPPLEMENTAL REPORT - DECEMBER 2009

EXHIBIT NO. 1

ANNUAL OPERATIONS ANALYSIS BY SPECIFIC AIRCRAFT MODEL

Aircraft Model	FAA Approach Category	FAA Design Group	FAA Weight Class	Seating	Maximum Takeoff Weight (lbs.)	Aircraft Engine Type	Flight-Aware Data Source	Based Aircraft Data Source	2 FBO Register Data Sources	Total Annual Operations by Model
Aero Commander 695	B	II	Small	<10	<12,500	Multi-Eng	4	0	0	4
Beechcraft King Air C90	B	II	Small	10+	<12,500	Multi-Eng	157	0	0	157
Beechcraft King Air 100	B	II	Small	10+	<12,500	Multi-Eng	39	0	2	41
Beechcraft King Air 200	B	II	Small	10+	<12,500	Multi-Eng	215	0	8	223
Cessna 441 Conquest II	B	II	Small	<10	<12,500	Multi-Eng	7	0	4	11
Beechcraft King Air 300	B	II	Large	10+	12,500+	Multi-Eng	11	0	8	19
Beechcraft King Air 350	B	II	Large	10+	12,500+	Multi-Eng	43	0	4	47
Cessna Citation II 550	B	II	Large	<10	12,500+	Jet	6	0	2	8
Cessna Citation XL 560	B	II	Large	<10	12,500+	Jet	25	211	2	238
Cessna Citation 680	B	II	Large	<10	12,500+	Jet	0	0	2	2
Total B-II Category Annual Operations							507	211	32	750

Learjet 25	C	I	Large	<10	12,500+	Jet	0	0	2	2
Learjet 31	C	I	Large	<10	12,500+	Jet	0	0	2	2
Learjet 45	C	I	Large	<10	12,500+	Jet	0	0	2	2
Total C-I Category Annual Operations							0	0	6	6

IAI Westwind 1125	C	II	Large	<10	12,500+	Jet	0	0	2	4
Total C-II Category Annual Operations							0	0	2	4

CRITICAL AIRCRAFT CATEGORY DETERMINATION: B-II (Based on 750 Total Annual Operations by Aircraft of this Category)

NOTE: The annual operations listed in the above tables are ACTUAL documented operations from calendar year 2007.
The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.
Operations recorded by the FBOs and listed above represent only a partial-year (six-month) time frame.

A total of 274 operations in the FlightAware database had aircraft model and ownership information blocked at the owner's request.
As a result, their operational numbers are NOT included in the information shown above.
Judging by the high number of out-of-state origin and destination locations of aircraft in the blocked category (see Exhibit No. 2), it is very likely that many of the associated aircraft were of the B-II and greater categories.
Therefore, actual operations at ARB by aircraft of these categories are likely considerably higher than the numbers shown above.

EXHIBIT NO. 2 **ORIGIN / DESTINATION ANALYSIS BY STATE**

Origin / Destination Analysis of IFR Aircraft Operations Between ARB and Other States
(Records from FlightAware 2007 Database)

	STATE	Aircraft Type & Category Blocked	B-II Small Category	B-II Large Category	Totals by State
1	Alabama	0	1	0	1
2	Arizona	1	0	0	1
3	Arkansas	2	1	0	3
4	Connecticut	5	2	0	7
5	Florida	29	3	3	35
6	Georgia	5	6	12	23
7	Illinois	25	64	5	94
8	Indiana	6	21	1	28
9	Iowa	1	20	3	24
10	Kansas	3	0	0	3
11	Kentucky	2	13	0	15
12	Maine	2	0	0	2
13	Maryland	1	3	7	11
14	Massachusetts	5	0	1	6
15	**Michigan**	**79**	**162**	**20**	**261**
16	Minnesota	2	3	2	7
17	Missouri	0	5	0	5
18	Nebraska	3	0	1	4
19	New Hampshire	1	2	0	3
20	New Jersey	9	2	4	15
21	New York	6	5	1	12
22	North Carolina	4	1	1	6
23	Ohio	16	38	13	67
24	Pennsylvania	14	23	4	41
25	South Carolina	0	4	0	4
26	South Dakota	4	18	0	22
27	Tennessee	2	5	0	7
28	Texas	30	0	0	30
29	Virginia	1	3	0	4
30	Washington DC	5	1	2	8
31	West Virginia	1	7	0	8
32	Wisconsin	10	9	4	23
	No Record	0	0	1	1
	Totals by Category	**274**	**422**	**85**	**781**

IFR Aircraft Operation Totals by Category:

Within Michigan	79	162	20	261
Outside of Michigan	195	260	64	519
No Record	0	0	1	1

NOTE: The numbers of operations listed above are ACTUAL documented operations from calendar year 2007. The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.

The numbers shown above are from the FlightAware IFR Flight Plan Database only, and do NOT include records of all itinerant operations between ARB and other states. Nonetheless, the numbers shown above confirm that in 2007, flight operations were conducted between ARB and at least 31 other states and Washington DC (approx 63% of the continental US). Approximately 67% of these IFR flight records were between ARB and out-of-state locations.

EXHIBIT NO. 3 **SMALL 10-SEAT AIRCRAFT ANALYSIS**

Small Airplanes Having 10 or More Passenger Seats (Records from FlightAware 2007 Database)							
Aircraft Model	**FAA Approach Category**	**FAA Design Group**	**FAA Weight Class**	**Seating**	**Maximum Takeoff Weight**	**Aircraft Engine Type**	**Annual Operations**
Cessna Caravan 208	A	II	Small	10+	<12,500	Single-Eng	11
Swearingen Merlin III	B	I	Small	10+	<12,500	Multi-Eng	3
Beechcraft King Air C90	B	II	Small	10+	<12,500	Multi-Eng	157
Beechcraft King Air 100	B	II	Small	10+	<12,500	Multi-Eng	39
Beechcraft King Air 200	B	II	Small	10+	<12,500	Multi-Eng	215

Total Small 10-Seat Aircraft Annual Operations **425**

Total B-II Large Category Aircraft Annual Operations

Based Aircraft Data Source (B-II Large):	**211**
FlightAware Data Source (B-II Large):	**85**

Grand Total Annual Operations at ARB Applicable to Figure 2-2 in FAA Advisory Circular 150/5325-4B: **721**

NOTE: The annual operations listed above are ACTUAL documented operations from canendar year 2007. The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.

The numbers shown in the table above are from the FlightAware IFR Flight Plan Database only, and do NOT include records of all small aircraft operations at ARB with 10-seat or greater aircraft models. Nonetheless, the above analysis confirms that Figure 2-2 in FAA AC 150/5325-4B is the appropriate chart to reference in the determination of the FAA-recommended runway length for Ann Arbor Municipal Airport.

Appendix B. Noise Analysis Report

(prepared by URS/July, 2009)

APPENDIX B-1

NOISE IMPACT ANALYSIS

B.1 AIRCRAFT NOISE

The compatibility of existing and planned land uses in the vicinity of an airport is usually associated with the extent of the airport's noise impacts. Airport development actions to accommodate fleet mix changes, the number of aircraft operations, or air traffic changes are examples of activities that can alter aviation-related noise impacts and affected land uses subjected to those impacts. This section describes the baseline noise environment and the associated land use compatibility.

B.1.1 APPLICABLE REGULATIONS

The evaluation of the Ann Arbor Municipal Airport (ARB) noise environment, and land use compatibility associated with airport noise, was conducted using the methodologies developed by the Federal Aviation Administration (FAA) and published in FAA Order 5050.4B, FAA Order 1050.1E, and title 14 Code of Federal Regulations (CFR) part 150.

For aviation noise analysis, the FAA has determined that the cumulative noise energy exposure of individuals to noise resulting from aviation activities must be established in terms of yearly day/night average sound level (DNL); this is FAA's primary metric. Title 14 CFR part 150 provides Federal compatible land use guidelines for several land uses as a function of DNL values. The ranges of DNL values in Table B-1 reflect the statistical variability for the responses of large groups of people to noise. Compatible or non-compatible land use is determined by comparing the predicted or measured DNL values at a site to the values listed in Table B-1. Land use compatibility with yearly day-night average sound levels is shown in Table B-1.

B.1.2 METHODOLOGY

Aircraft Noise Descriptors and Effects
The terms and metrics associated with aircraft noise relative to this analysis are complex and are discussed in detail in Appendix B-2 along with potential effects of aircraft noise. In general and in this document, noise or sound levels are expressed in terms of A-weighted decibels (dBA).

DNL is a 24-hour time-weighted-average noise metric expressed in dBA which accounts for the noise levels of all individual aircraft events, the number of times those events occur, and the time of day which they occur. DNL has two time periods: daytime (7:00 a.m. to 9:59 p.m.) and nighttime (10:00 p.m. to 6:59 a.m.). In order to represent the added intrusiveness of sounds occurring during nighttime hours, DNL penalizes, or weights, events occurring during the nighttime periods by 10 dBA.

Noise and Compatible Land Use Prediction Methodology
The Integrated Noise Model (INM) has been FAA's standard tool since 1978 for determining the predicted noise impact in the vicinity of airports. Statutory requirements for INM use are defined in FAA Order 1050.1E, *Environmental Impacts: Policies and Procedures*; Order 5050.4B, *National Environmental Policy Act (NEPA) Implementing Instructions for Airport Actions*; and title 14 CFR part 150, *Airport Noise Compatibility Planning*. INM Version 7.0a, released September 17, 2008, was the version used for this document (http://www.faa.gov/about/office_org/headquarters_offices/aep/models/ inm_model/).

The INM incorporates the number of annual average daily daytime and nighttime flight and run-up operations, flight paths, run-up locations, and flight profiles of the aircraft along with its extensive internal database of aircraft noise and performance information, to calculate the DNL at many points on the ground around an airport. From a grid of points, the INM contouring program draws contours of equal DNL to be superimposed onto land use maps. For this document, DNL contours of 65, 70, and 75 dBA were developed. DNL contours are a graphical representation of how the noise from the airport's average annual daily aircraft operations is distributed over the surrounding area. The INM can calculate sound levels at any specified point so that noise exposure at representative locations around an airport can be obtained.

TABLE B-1
LAND USE COMPATIBILITY WITH YEARLY DAY-NIGHT AVERAGE SOUND LEVELS

	Yearly Day-Night Average Sound Level (DNL)					
	Below 65 Decibels	65-70 Decibels	70-75 Decibels	75-80 Decibels	80-85 Decibels	Over 85 Decibels
Residential						
Residential (Other than mobile homes & transient lodges)	Y	N[1]	N[1]	N	N	N
Mobile Home Parks	Y	N	N	N	N	N
Transient Lodging	Y	N[1]	N[1]	N[1]	N	N
Public Use						
Schools	Y	N[1]	N[1]	N	N	N
Hospitals, Nursing Homes	Y	25	30	N	N	N
Churches, Auditoriums, Concert Halls	Y	25	30	N	N	N
Governmental Services	Y	Y	25	30	N	N
Transportation	Y	Y	Y[2]	Y[3]	Y[4]	Y[4]
Parking	Y	Y	Y[2]	Y[3]	Y[4]	N
Commercial Use						
Offices, Business & Professional	Y	Y	25	30	N	N
Wholesale & Retail Building Materials, Hardware & Farm Equipment	Y	Y	Y[2]	Y[3]	Y[4]	N
Retail Trade - General	Y	Y	25	30	N	N
Utilities	Y	Y	Y[2]	Y[3]	Y[4]	N
Communications	Y	Y	25	30	N	N
Manufacturing & Production						
Manufacturing, General	Y	Y	Y[2]	Y[3]	Y[4]	N
Photographic and Optical	Y	Y	25	30	N	N
Agriculture (Except Livestock) & Forestry	Y	Y[6]	Y[7]	Y[8]	Y[8]	Y[8]
Livestock Farming & Breeding	Y	Y[6]	Y[7]	N	N	N
Mining & Fishing, Resource Production & Extraction	Y	Y	Y	Y	Y	Y
Recreational						
Outdoor Sports Arenas, Spectator Sports	Y	Y[5]	Y[5]	N	N	N
Outdoor Music Shells, Amphitheaters	Y	N	N	N	N	N
Nature Exhibits & Zoos	Y	Y	N	N	N	N
Amusement, Parks, Resorts, Camps	Y	Y	Y	N	N	N
Golf Courses, Riding Stables, Water Recreation	Y	Y	25	30	N	N

NOTE: The responsibility for determining the acceptable and permissible land uses and the relationship between specific properties remains with the local authorities. FAA determinations under Part 150 are not intended to substitute Federally determined land use for those determined to be appropriate by local authorities in response to locally determined needs and values in achieving noise-compatible land uses.

KEY TO TABLE:

SLUCM	Standard Land Use Coding Manual.
Y (Yes)	Land Use and related structures are compatible without restrictions.
N (No)	Land Use and related structures are not compatible and should be prohibited.
NLR	Noise Level Reduction (outdoor to indoor) are to be achieved through incorporation of noise attenuation into the design and construction of structure.
25,30, or 35	Land use and related structures are generally compatible; measures to achieve NLR of 25, 30, or 35 dB must be incorporated in design and construction of structure.

[1] Where the community determines that residential or school uses must be allowed, measures to achieve outdoor to indoor NLR of at least 25 dB and 30 dB should be incorporated into building codes and be considered in individual approvals. Normal residential construction can be expected to provide a NLR of 20 dB, thus, the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation and closed windows year round. However, the use of NLR criteria will not eliminate outdoor noise problems

[2] Measures to achieve NLR of 25 dB must be incorporated into the design and construction of portions of the buildings where the public is received, office areas, noise-sensitive areas, or where the normal noise level is low.

[3] Measures to achieve NLR of 30 dB must be incorporated into the design and construction of portions of the buildings where the public is received, office areas, noise-sensitive areas, or where the normal noise level is low.

[4] Measures to achieve NLR of 35 dB must be incorporated into the design and construction of portions of the buildings where the public is received, office areas, noise-sensitive areas, or where the normal noise level is low.

[5] Land use compatible provided special sound reinforcement systems are installed.

[6] Residential buildings require an NLR of 25 dB.

[7] Residential buildings require an NLR of 30 dB.

[8] Residential buildings not permitted.

Noncompatible land use.

Source: Title 14 CFR part 150, Appendix A, Table 1, January 1998.

The INM is an average-value-model and is designed to estimate long-term average effects using average annual input conditions. Because of this, differences between predicated and measured values can occur because certain local acoustical variables are not averaged, or because they may not be explicitly modeled in INM. Difference may also occur due to errors or improper procedures employed during the collection of the measured data.

Examples of detailed local acoustical variables include:

- Temperature profiles;
- Wind gradients;
- Humidity effects;
- Ground absorption;
- Individual aircraft directivity patterns; and
- Sound diffraction caused by water, buildings, barriers, etc.

The results of the INM analysis provide a relative measure of noise levels around airfield facilities. When the calculations are made in a consistent manner, the INM is most accurate for comparing before and after noise effects resulting from forecast changes or alternative noise control actions. It allows noise levels to be predicted for such proposed projects without the actual implementation and noise monitoring of those actions.

B.1.3 DATA

Sources
Data was collected from multiple sources, examined, and utilized to ensure that this aircraft noise analysis provides an accurate depiction of the existing ARB aircraft noise environment. The data sources utilized for this analysis included:

- Flight Explorer®, computer software which obtains N-number (registration number), aircraft type, arrival and departure airport, and time of day from Air Traffic Control Tower radar data,
- USDOT, FAA Airport Master Record, Form 5010 July 2009;
- FAA Terminal Area Forecast (TAF) December 2008;
- FAA Air Traffic Activity Data System (ATADS) May 2009;
- Michigan Department of Transportation (MDOT) Airport User Survey Report 2009;
- National Oceanic and Atmospheric Administration, Climatography of the United States No. 81, 2002; and
- Ann Arbor Municipal Airport, Airport Layout Plan.

Modeled Aircraft Operations
This section describes the sources and derivation of the INM input data for the existing conditions, which are based on aircraft operations occurring from April 2008 through March 2009, and 2014 future conditions. Items also discussed includes the airport layout, weather, flight operations, fleet mix, runway use, flight tracks, and track use.

Airport Layout
ARB has a single paved runway, which is designated as Runway 06/24. It is 3,505 feet long by 75 feet wide. A full parallel taxiway system, 30 feet wide, supports this runway. The Proposed Project consists of extending Runway 06/24 795 feet to a length of 4,300 feet. There is a secondary turf runway, designated Runway 12/30. Runway 12/30 is 2,750 feet long by 110 feet wide with a 25 foot wide full length turf taxiway. The field elevation at ARB is approximately 829 feet above sea level. Apron and hangar facilities are available for based and transient aircraft.

Weather and Climate
The INM default for pressure, humidity, and headwind was not changed in the model. INM uses temperature, pressure, and headwind when computing procedural profiles. Humidity is only used in calculating atmospheric absorption. The average temperature at Ann Arbor, the University of Michigan, the closest monitoring station, is 49 degrees Fahrenheit (NOAA Climatography of the United States No. 81, 2002). The INM default airport pressure is 29.92 inches of mercury and the default humidity is 70% and the default average headwind is 8 knots.

Flight Operations
INM-modeled annual operations for the 2009 existing condition, consisting of operations from April 2008 through March 2009, totaled 61,969 operations, which is approximately 169 daily operations. Jet operations accounted for approximately 2 percent of the total operations. Nighttime operations accounted for 4.2 percent of the total operations. The total number of operations were obtained from the FAA's ATADS. Air taxi / commuter operations fleet mix was obtained from Flight Explorer® data and general aviation aircraft fleet mix was obtained from the MDOT Airport User's Survey.

2014 future condition aircraft operations were obtained from the 2008 FAA TAF for ARB. Modeled annual operations for the 2014 condition totaled 69,717 operations, or approximately 191 daily operations. It is assumed that the percent of night and jet operations will remain constant between the existing condition and the future years. In addition, it is also assumed that the fleet mix between the 2009 Existing Condition and the 2014 Future Alternatives will remain static. The existing and future fleet mix with annual operations is shown in Table B-2.

Table B-2
Fleet Mix and Annual Operations
Ann Arbor Municipal Airport
Runway Extension EA

Aircraft Category	INM Aircraft	Aircraft Name	Aircraft Type	Fleet Mix Percentage (%)		Annual			
				Itinerant	Local	Itinerant		Local	
						2009	2014	2009	2014
Air Taxi / Commuter	BEC58P	Beech 58 Baron	MEP	48.6	---	439	745	---	---
	CNA172	Cessna 172 Skyhawk	SEP	3.4	---	31	52	---	---
	CNA206	Cessna 206 Super Skywagon/Stationair	SEP	1.4	---	12	21	---	---
	CNA441	Cessna 441 Conquest II	TP	14.4	---	130	220	---	---
	CNA500	Cessna 500 / Citation II	Jet	1.4	---	12	21	---	---
	DC910	Douglas DC 9-10	Jet	0.7	---	6	10	---	---
	DHC6	de Havilland Dash 6*	TP	8.2	---	74	126	---	---
	GASEPF	Composite - Single Engine Fixed Pitch Prop	SEP	0.7	---	6	10	---	---
	GASEPV	Composite - Single Engine Variable Pitch Prop	SEP	4.1	---	37	63	---	---
	LEAR35	Lear 35	Jet	2.7	---	25	42	---	---
	MU3001	Mitsubishi 300-10 Diamond	Jet	2.7	---	25	42	---	---
	PA28	Piper 28 Cherokee	SEP	7.5	---	68	115	---	---
	PA31	Piper 31 Navajo	MEP	4.1	---	37	63	---	---
	Total			**100**	**---**	**902**	**1,532**	**---**	**---**
General Aviation	B206L	Bell 206L LongRanger	Helo	13.5	---	3,039	3,255	---	---
	BEC58P	Beech 58 Baron	MEP	5.6	6.8	1,269	1,360	2,585	2,954
	CIT3	Cessna Citation III	Jet	0.01	---	2	2	---	---
	CNA172	Cessna 172 Skyhawk	SEP	32.6	42.0	7,326	7,848	16,219	18,536
	CNA206	Cessna 206 Super Skywagon/Stationair	SEP	3.8	4.5	863	925	1,732	1,980
	CNA441	Cessna 441 Conquest II	Tp	0.6	0.3	126	135	113	129
	CNA500	Cessna 500 / Citation II	Jet	0.05	---	12	12	---	---
	CNA510	Cessna 510 Mustang	Jet	0.01	---	2	2	---	---
	DHC6	de Havilland Dash 6*	Tp	0.2	---	40	42	---	---
	GASEPF	Composite - Single Engine Fixed Pitch Prop	SEP	3.9	4.8	887	950	1,845	2,109
	GASEPV	Composite - Single Engine Variable Pitch Prop	SEP	10.3	11.9	2,315	2,480	4,613	5,272
	H500D	Hughes 500D	Helo	4.4	---	990	1,060	---	---
	IA1125	IAI Astra	Jet	0.01	---	2	2	---	---
	LEAR25	Lear 25	Jet	0.01	---	2	2	---	---
	LEAR35	Lear 35	Jet	0.01	---	3	4	---	---
	MU3001	Mitsubishi 300-10 Diamond	Jet	1.5	---	338	362	---	---
	PA28	Piper 28 Cherokee	SEP	23.1	29.7	5,180	5,550	11,472	13,111
	PA30	Piper 30 Twin Comanche	MEP	0.1	0.1	22	24	42	48
	PA31	Piper 31 Navajo	MEp	0.1	---	25	27	---	---
	R22	Robinson R22B	Helo	0.01	---	3	4	---	---
	SA365N	Aerospatiale (Eurocopter) SA-365N Dauphin	Helo	0.01	---	2	2	---	---
	Total			**100**	**100**	**22,446**	**24,047**	**38,621**	**44,138**
TOTAL				**---**	**---**	**23,348**	**25,579**	**38,621**	**44,138**

Source: Flight Explorer®, 2009
Michigan DOT ARB User's Survey, 2009,
URS Corporation 2009.

Note: Numbers may not add due to rounding
SEP – Single Engine Piston
MEP – Multi Engine Piston
Jet – Turbofan/Turbo Jet
TP – Turbo Prop

** de Havilland Dash 6 is INM substitution for the King Air 200, 300, and 350*

Runway Use
Runway use at ARB was determined through discussions with the Air Traffic Control Tower (ATCT) staff. Runway utilization is approximately 30/70 percent on Runway 06/24, respectively. Discussions with ATCT staff also indicate that approximately 5 percent of single engine piston aircraft operations occur on Runway 12/30 with a 50/50 split. Helicopters operate to and from the east edge of the terminal apron. Table B-3 provides runway utilization by aircraft category. The 2014 No Action and Proposed Project Alternatives will maintain the same runway utilization.

Table B-3
Runway Utilization
Ann Arbor Municipal Airport
Runway Extension EA

Aircraft Type	Runway Utilization[1]			
	06	24	12	30
Jet	30 %	70 %	---	---
Turboprop	30 %	70 %	---	---
Multi-Engine Piston	30 %	70 %	---	---
Single Engine Piston	27.5 %	67.5 %	2.5 %	2.5 %

Source: ARB Air Traffic Control Tower
Note: 1. Utilization applies to arrival, departure, and touch-and-go operations.

Flight Tracks and Utilization
Flight tracks are the aircraft's actual path through the air projected vertically onto the ground. Due to the level of operations occurring at ARB, a single arrival and departure track for each runway end was appropriate for the noise modeling. Straight out departures tracks were modeled for all runways. Straight in arrivals to Runway 12/30 were modeled and arrivals to Runway 6/24 followed the published VOR procedures.

Unique helicopter and touch-and-go flight tracks were also modeled based on ATCT interviews. 80 percent of the helicopter operations arrive from or depart to the north, with the remaining 20 percent distributed evenly between arrivals from and departures to the east, south, and west.

B.1.4 IMPACT ANALYSIS

Existing Conditions
Noise exposure resulting from aircraft operations in 2009 at ARB is depicted as DNL 65, 70, and 75 dBA contours, superimposed over the local aerial map of Ann Arbor, on Figure 4-1. The ARB 2009 existing condition DNL 65 dBA noise contour does not extend beyond airport property.

No Action Alternative
Noise exposure resulting from aircraft operations for the 2014 No Action Alternative ARB is depicted as DNL 65, 70, and 75 dBA contours, superimposed over the local aerial map of Ann Arbor, on Figure 4-2. The ARB 2014 No Action Alternative DNL 65 dBA noise contour does not extend beyond airport property.

Proposed Project
Noise exposure resulting from aircraft operations for the 2014 Proposed Project Alternative at ARB is depicted as DNL 65, 70, and 75 dBA contours, superimposed over the local aerial map of Ann Arbor, on Figure 4-3. The ARB 2014 Proposed Project Alternative DNL 65 dBA noise contour does not extend beyond airport property.

APPENDIX B-2

AIRCRAFT NOISE, NOISE METRICS & THE INTEGRATED NOISE MODEL

Appendix B-2 describes the various common noise metrics and human perceptions. It also describes the Integrated Noise Model (INM), and its required inputs.

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APPENDIX B-2

AIRCRAFT NOISE, NOISE METRICS & THE INTEGRATED NOISE MODEL

1.1 AIRCRAFT NOISE

Aircraft noise originates from the engines as well as the airframe or structure of aircraft. The engines are generally the most significant source of noise. While noise generated by propeller-driven aircraft can be annoying, jet aircraft are commonly the source of disturbing noise at airports. Two basic types of jet aircraft are operated today equipped with turbofan or turbojet engines. Aircraft flying faster than the speed of sound generate an intense pressure wave called a sonic boom, in addition to the propulsion and airframe noise.

Turbofan engines produce thrust as reaction to the rate at which high-velocity gas is exhausted from nozzles. The engine core consists of a compressor, combustion chambers, a turbine and a front fan. The major sources of noise include the core engine fan streams, the compressor, turbine blades and exhaust nozzles. In comparison, turbojet aircraft do not have the front fan component. It has been found in several cases that the sound energy produced by a turbojet engine is greater than that of a turbofan engine with an equivalent thrust rating.

The noise produced by jet aircraft flyovers is characterized by an increase in sound energy as the aircraft approaches, up to a maximum level. This sound level begins to lessen as the aircraft passes overhead and then decreases in a series of lesser peaks as the aircraft departs the area.

Noise produced by propeller driven aircraft and helicopters emanates from the blades and rotors. There are two components of this noise, namely vortex and periodic. Vortex noise is generated by the formation and shedding of vortices in the airflow past the blade. Periodic noise is produced by the oscillating pressure field in the air that results from the passage of air past the blade. Blade slap is an additional source of noise in helicopters. This is high-amplitude periodic noise and highly modulated vortex noise caused by fluctuating forces as one blade cuts through the tip vortices of another.

1.2 AIRCRAFT NOISE TERMINOLOGY

The Federal Aviation Administration (FAA) uses a variety of noise metrics to assess potential airport noise impacts. Different noise metrics can be used to describe individual noise events (e.g., a single operation of an aircraft taking off overhead) or groups of events (e.g., the cumulative effect of numerous aircraft operations, the collection of which creates a general noise environment or overall exposure level). Both types of descriptors are helpful in explaining how people tend to respond to a given noise condition. Descriptions of the metrics used in this Part 150 Study are provided in the following text.

Decibel, dB – Sound is a complex physical phenomenon consisting of many minute vibrations traveling through a medium, such as air. The human ear senses these vibrations as sound pressure. Because of the vast range of sound pressure or intensity detectable by the human ear, sound pressure level (SPL) is represented on a logarithmic scale known as decibels (dB). A SPL of 0 dB is approximately the threshold of human hearing and is barely audible under extremely quiet (laboratory-type) listening conditions. A person begins to feel a SPL of 120 dB inside the ear as discomfort, and pain begins at approximately 140 dB. Most environmental sounds have SPLs ranging from 30 to 100 dB.

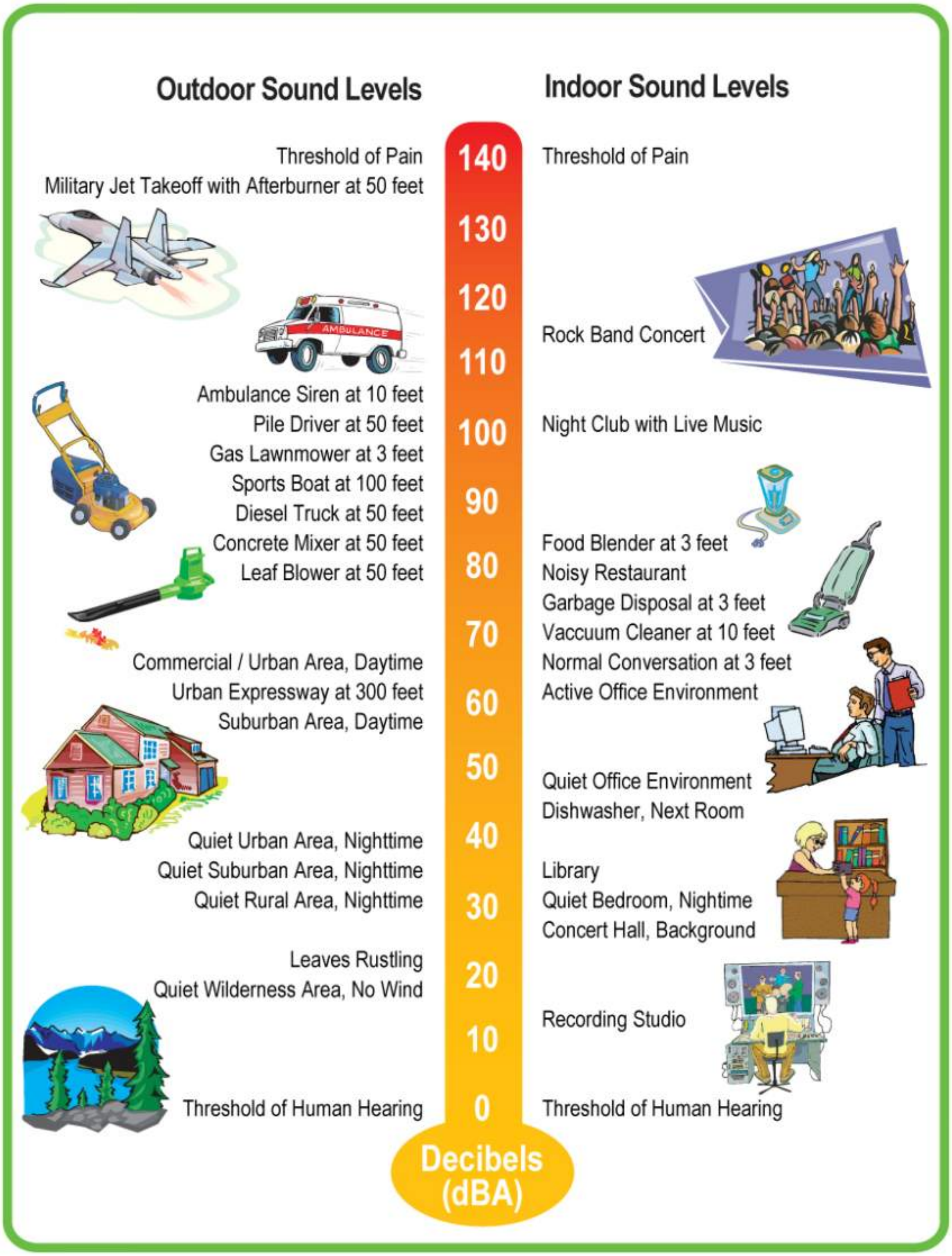
Because decibels are logarithmic, they cannot be added or subtracted directly like other (linear) numbers. For example, if two sound sources each produce 100 dB, when they are operated together they will produce 103 dB, not 200 dB. Four 100 dB sources operating together again double the sound energy, resulting in a total SPL of 106 dB, and so on. In addition, if one source is much louder than another, the two sources operating together will produce the same SPL as if the louder source were operating alone. For example, a 100 dB source plus an 80 dB source produces 100 dB when operating together. The louder source masks the quieter one.

Two useful rules to remember when comparing SPLs are: (1) most people perceive a 6 to 10 dB increase in SPL between two noise events to be about a doubling of loudness, and (2) changes in SPL of less than about 3 dB between two events are not easily detected outside of a laboratory.

A-Weighted Decibel, dBA – Frequency, or pitch, is a basic physical characteristic of sound and is expressed in units of cycles per second or hertz (Hz). The normal frequency range of hearing for most people extends from about 20 to 15,000 Hz. Because the human ear is more sensitive to middle and high frequencies (i.e., 1000 to 4000 Hz), a frequency weighting called “A” weighting is applied to the measurement of sound. The internationally standardized "A" filter approximates the sensitivity of the human ear and helps in assessing the perceived loudness of various sounds. For this Part 150 Study, all sound levels are A-weighted sound levels and the text typically omits the adjective "A-weighted".

Figure 1 charts common indoor and outdoor sound levels. A quiet rural area at nighttime may be 30 dBA or lower, while the operator of a typical gas lawn mower may experience a level of 90 dBA. Similarly, the level in a library may be 30 dBA or lower, while the listener at a rock band concert may experience levels near 110 dBA.

FIGURE 1
COMMON OUTDOOR AND INDOOR SOUND LEVELS



Source: URS Corp, 2008.

Maximum A-Weighted Noise Level, L_{max} – Sound levels vary with time. For example, the sound increases as an aircraft approaches, then falls and blends into the ambient, or background, as the aircraft recedes into the distance. Because of this variation, it is often convenient to describe a particular noise "event" by its highest or maximum sound level (L_{max}). It should be noted that L_{max} describes only one dimension of an event; it provides no information on the cumulative noise exposure generated by a sound source. In fact, two events with identical L_{max} levels may produce very different total noise exposures. One may be of very short duration, while the other may last much longer.

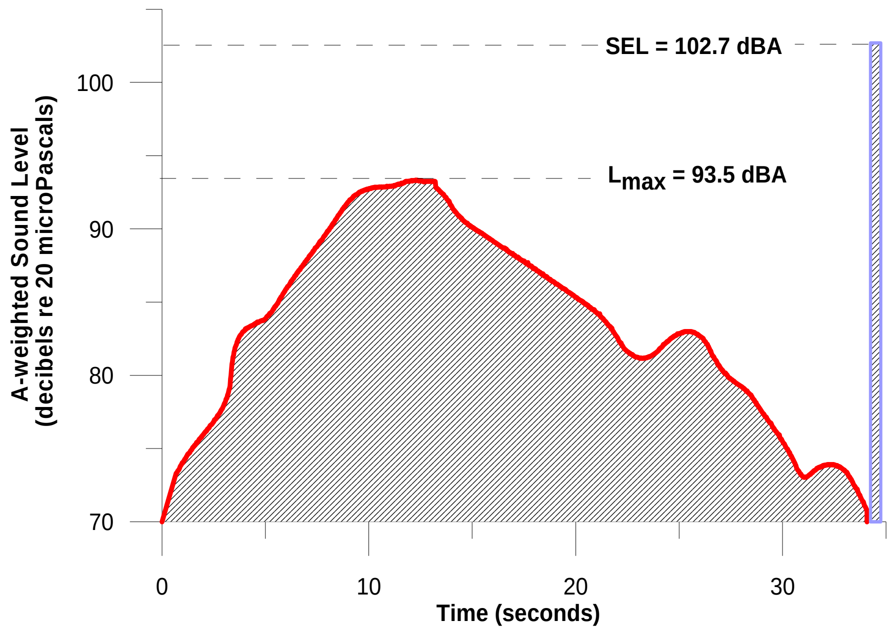
Sound Exposure Level, SEL – The most common measure of noise exposure for a single aircraft flyover event is the SEL. SEL is a summation of the A-weighted sound energy at a particular location over the true duration of a noise event, normalized to a fictional duration of one second. The true noise event duration is defined as the amount of time the noise event exceeds a specified level (that is at least 10 dB below the maximum value measured during the noise event). For noise events lasting more than one second, SEL does not directly represent the sound level heard at any given time, but rather provides a measure of the net impact of the entire acoustic event.

The normalization to the fictional duration of one second enables the comparison of noise events with differing true duration and/or maximum level. Because the SEL is normalized to one second, it will almost always be larger in magnitude than the L_{max} for the event. In fact, for most aircraft events, the SEL is about 7 to 12 dB higher than the L_{max}. Additionally, since it is a cumulative measure, a higher SEL can result from either a louder or longer event, or a combination thereof.

Since SEL combines an event's overall sound level along with its duration, SEL provides a comprehensive way to describe noise events for use in modeling and comparing noise environments. Computer noise models, such as the Integrated Noise Model (INM) that the FAA used for this PART 150 STUDY, base their computations on these SELs.

Figure 2 shows an event's "time history", or the variation of sound level with time. For typical sound events experienced by a stationary listener, like a person experiencing an aircraft flyover, the sound level rises as the source (or aircraft) approaches the listener, peaks and then diminishes as the aircraft flies away from the listener. The area under the time history curve represents the overall sound energy of the noise event. The L_{max} for the event shown in **Figure 2** was 93.5 dBA. Compressing the event's total sound energy into one second yields an SEL of 102.7 dBA.

FIGURE 2
COMPARISON OF MAXIMUM SOUND LEVEL (L_{MAX}) AND SOUND EXPOSURE LEVEL (SEL)



Source: URS Corporation, 2008.

<u>Equivalent Sound Level, L_{eq}</u> – Equivalent sound level (L_{eq}) is a measure of the noise exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest (e.g., an hour, an 8-hour school day, nighttime, or a full 24-hour day). However, because the length of the period can be different depending on the period of interest, the applicable period should always be identified or clearly understood when discussing this metric. Such durations are often identified through a subscript. For example, for an 8 hour or 24 hour day, $L_{eq(8)}$ or $L_{eq(24)}$ is used, respectively.

Conceptually, L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as the actual time-varying sound level with its normal "peaks" and "dips". In the context of noise from typical aircraft flight events, and as noted earlier for SEL, L_{eq} does not represent the sound level heard at any particular time, but rather represents the total sound exposure for the period of interest. Also, it should be noted that the "average" sound level suggested by L_{eq} is not an arithmetic value, but a logarithmic, or "energy-averaged," sound level. Thus, loud events tend to dominate the noise environment described by the L_{eq} metric.

<u>Day-Night Average Sound Level, DNL</u> – Time-average sound levels are measurements of sound averaged over a specified length of time. These levels provide a measure of the average sound energy during the measurement period. For the evaluation of community noise effects, and particularly aircraft noise effects, the Day-Night Average Sound Level (abbreviated DNL) is used. DNL logarithmically averages aircraft sound levels at a location over a complete 24-hour period, with a 10-decibel adjustment added to those noise events occurring between 10:00 p.m. and 7:00 a.m. (local time) the following morning. The FAA defines the 10:00 p.m. to 7:00 a.m. period as nighttime (or night) and the 7:00 a.m. to 10:00 p.m. period as daytime (or day). Because of the increased sensitivity to noise during normal sleeping hours and because ambient (without aircraft) sound levels during nighttime are typically about 10 dB lower than during daytime hours, the 10-decibel adjustment, or "penalty," represents the added intrusiveness of sounds occurring during nighttime hours.

DNL accounts for the noise levels (in terms of SEL) of all individual aircraft events, the number of times those events occur and the period of day/night in which they occur. Values of DNL can be measured with standard monitoring equipment or predicted with computer models such as the INM.

Typical DNL values for a variety of noise environments are shown in **Figure 3**. DNL values can be approximately 85 dBA outdoors under an aircraft flight path within a mile of a major airport and 40 dBA or less outdoors in a rural residential area.

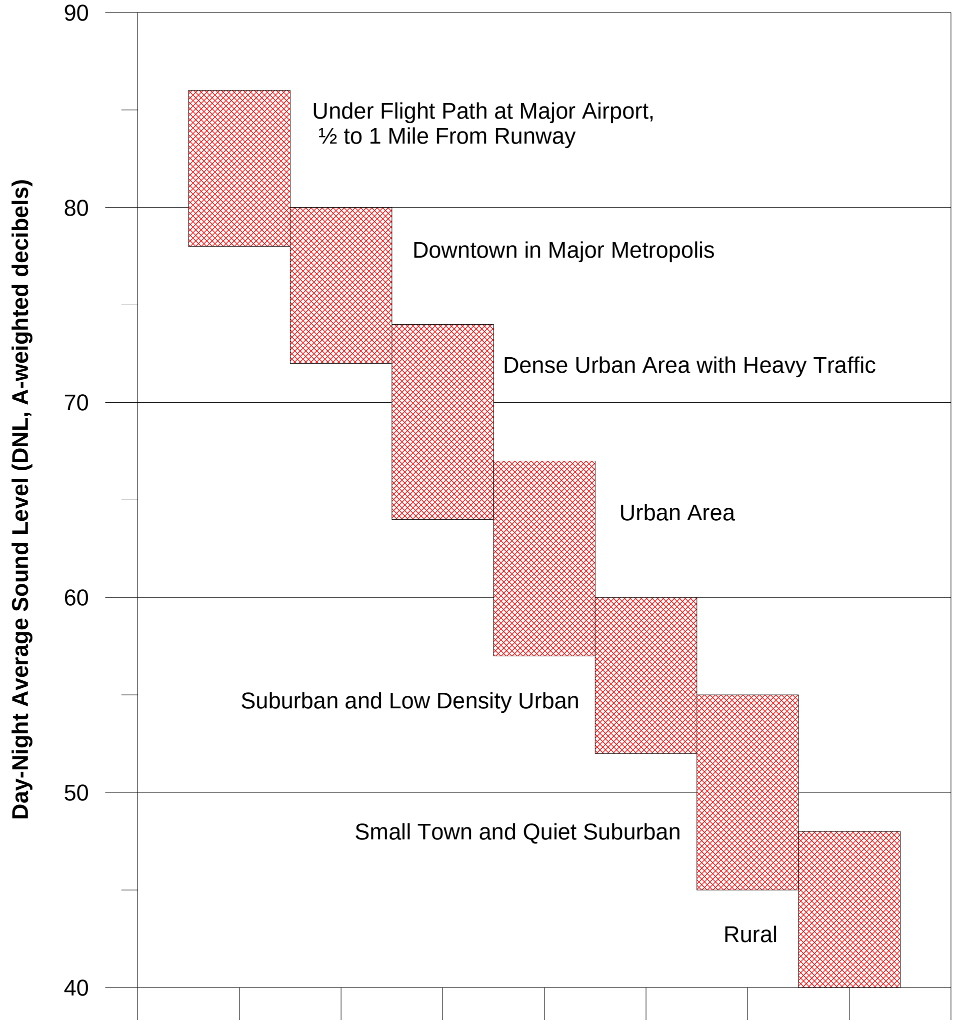
Due to the DNL descriptor's close correlation with the degree of community annoyance from aircraft noise, most federal agencies have formally adopted DNL for measuring and evaluating aircraft noise for land use planning and noise impact assessment. Federal committees such as the Federal Interagency Committee on Urban Noise (FICUN) and the Federal Interagency Committee on Noise (FICON), which include the Environmental Protection Agency (EPA), the FAA, Department of Defense, Department of Housing and Urban Development, and the Veterans Administration, found DNL to be the best metric for land use planning. They also found no new cumulative sound descriptors or metrics of sufficient scientific standing to substitute for DNL. Other cumulative metrics are used only to supplement, not replace, DNL. Furthermore, FAA Order 1050.1E, *Policies and Procedures for Considering Environmental Impacts*, requires DNL be used in describing cumulative noise exposure and in identifying aircraft noise/land use compatibility issues (EPA, 1974; FICUN, 1980; FICON, 1992; title 14 CFR part 150, 2004; FAA, 2006).

The accuracy and validity of DNL calculations depend on the basic information used in the calculations. At airports, the reliability of DNL calculations is affected by a number of uncertainties:

- The noise descriptions used in the DNL procedure represent the typical human response to aircraft noise. Since people vary in their response to noise and because the physical measure of noise accounts for only a portion of an individual's reaction to that noise, the DNL scale can show only an average response to aircraft noise that may be expected from a community.
- Future aviation activity levels such as the forecast number of operations, the operational fleet mix, the times of operation (day versus night) and flight tracks are estimates. Achievement of forecasted levels of activity cannot be assured.
- Aircraft acoustical and performance characteristics for new aircraft designs are estimates.

<u>Outdoor vs. Indoor Noise Levels</u> – INM calculates outdoor noise levels, while some of the supplemental noise analysis effects are based on noise levels experienced indoors. In order to convert outdoor noise levels to indoor noise levels, an Outdoor-to-Indoor Noise Level Reduction (OILR) is identified. The indoor noise level is equal to the outdoor noise level minus the OILR. Based on accepted research, typical OILR values range between 15 dBA to 25 dBA, depending on the structure and whether windows are open or closed (Wyle, 1989).

FIGURE 3
TYPICAL RANGE OF OUTDOOR COMMUNITY DAY-NIGHT AVERAGE SOUND LEVELS



Source: U.S. Department of Defense. Departments of the Air Force, the Army, and the Navy, 1978. *Planning in the Noise Environment.* AFM 19-10. TM 5-803-2, and NAVFAC P-970. Washington, D.C.,: U.S. DoD.

1.3 EFFECTS OF AIRCRAFT NOISE ON PEOPLE

The most common effects regarding aircraft noise are related to annoyance and activity interference (e.g., speech disruption and sleep interference). These effects have been studied extensively and relationships between various noise metrics and effects have been established. The following sections summarize these effects, and the noise metrics that are used to describe them.

1.3.1 Speech Interference

Speech interference is the most readily quantified adverse effect of noise, and speech is the activity most often affected by environmental noise. The levels of noise that interfere with listening to a desired sound, such as speech, music, or television, can be defined in terms of the level of noise required to mask the desired sound. Such levels have been quantified for speech communications by directly measuring the interference with speech. Several studies have been conducted over the last 30 years resulting in various noise level criteria for speech interference.

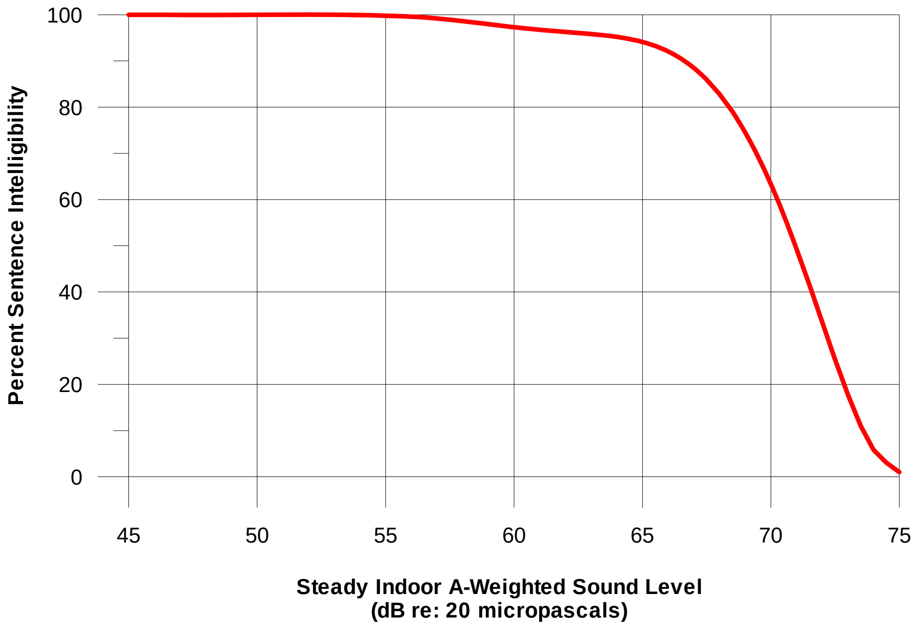
As an aircraft approaches and its sound level increases, speech becomes harder to hear. As the ambient level increases, the speaker must raise his/her voice, or the individuals must get closer together to continue talking. For typical communication distances of 3 or 4 feet (1 to 1.5 meters), acceptable outdoor conversations can be carried on in a normal voice as long as the ambient noise outdoors is less than about 65 dBA (FICON, 1992). If the noise exceeds this level, intelligibility would be lost unless vocal effort was increased or communication distance was decreased.

Indoor speech interference can be expressed as a percentage of sentence intelligibility between two average adults with normal hearing, speaking fluently in relaxed conversation approximately one meter apart in a typical living room or bedroom (EPA, 1974). Intelligibility pertains to the percentage of speech units correctly understood out of those transmitted, and specifies the type of speech material used, i.e. sentence or word intelligibility (ANSI, 1994). As shown in Figure 4, the percentage of sentence intelligibility is a non-linear function of the (steady) indoor ambient or background sound level (energy-average equivalent sound level (L_{eq})). For an average adult with normal hearing and fluency in the language, steady ambient indoor sound levels of up to 45 dBA L_{eq} are expected to allow 100 percent intelligibility of sentences. The curve shows 99 percent sentence intelligibility for L_{eq} at or below 54 dBA and less than 10 percent intelligibility for L_{eq} greater than 73 dBA. It should be noted that the function is especially sensitive to changes in sound level between 65 dBA and 75 dBA. As an example of the sensitivity, a 1 dBA increase in background sound level from 70 dBA to 71 dBA results in a 14 percent decrease in sentence intelligibility. In contrast, a 1 dBA increase in background sound level from 60 dBA to 61 dBA results in less than 1 percent decrease in sentence intelligibility.

The noise from aircraft events is not continuous, but consists of individual events where the noise level can greatly exceed the background level for a limited period as the aircraft flies over. Since speech interference in the presence of aircraft noise is essentially determined by the magnitude and frequency of individual aircraft flyover events, a time-averaged metric (such as L_{eq}) alone, is not necessarily appropriate when setting standards regarding acceptable levels. In addition to the background levels described above, single event criteria, which account for those sporadic intermittent noisy events, are also essential to specifying speech interference criteria. In order for two people to communicate reasonably using normal voice levels indoors, the background noise level should not exceed 60 dBA

(EPA, 1974). In other words, an indoor noise event that exceeds 60 dBA has the potential to cause speech and communication disruption (Eagan, 2007).

Figure 4
PERCENT SENTENCE INTELLIGIBILITY FOR INDOOR SPEECH



Source: U.S. Environmental Protection Agency, 1974.

1.3.2 Effect on Children's Learning

An important application of speech interference criteria is in the classroom where the percent of words (rather than whole sentences) transmitted and received, commonly referred to as 'word intelligibility,' is critical. For teachers to be clearly understood by their students, it is important that regular voice communication is clear and uninterrupted. Not only does the steady background sound level have to be low enough for the teacher to be clearly heard, but intermittent outdoor noise events also need to be unobtrusive. The steady ambient level, the level of voice communication, and the single event level (e.g., aircraft over-flights) that might interfere with speech in the classroom are measures that can be evaluated to quantify the potential for speech interference in the classroom.

Accounting for the typically intermittent nature of aircraft noise where speech is impaired only for the short time when the aircraft noise is close to its maximum value, different researchers and regulatory organizations have recommended maximum allowable indoor noise levels ranging between 40 and 60 dBA L_{max}. (Lind, et. al., 1998; Sharp and Plotkin, 1984; Wesler, 1986; WHO, 1999; ASLHA, 1995; ANSI, 2002). A single event noise level of 50 dBA L_{max} correlates to 90 percent of the words being understood by students with normal hearing and no special needs seated throughout a classroom (Lind, et. al., 1998). At-risk students may be adversely affected at lower sound levels.

ANSI has developed a standard for classrooms that states that the sound level during the noisiest hour should not exceed a one-hour average L_{eq} of 40 dBA for schools exposed to intermittent noise sources such as aircraft noise (ANSI, 2002). The standard further states that the hourly L_{eq} should not be exceeded for more than 10 percent of the noisiest hour (i.e., L_{eq} should not exceed L_{10}). FAA Order 5100.38C, Airport Improvement Program Handbook, Chapter 7, Section 2, Paragraph 812c(1) indicates that schools should have an A-weighted L_{eq} of 45 dB, or less, during school hours, in the classroom environment. Facilities not typically disrupted by aircraft, such as gymnasiums, cafeterias, or hallways, are not usually eligible for noise insulation. However, ANSI recommends that schools have a maximum one-hour average A-weighted unsteady background noise level of L_{eq} of 40 dB, or less, during school hours. Ancillary spaces, such as gymnasiums and cafeterias are recommended to have a maximum L_{eq} of 45 dB.

1.3.3 Sleep Disturbance

The EPA identified an indoor DNL of 45 dB as necessary to protect against sleep interference (EPA, 1974). Prior to and after the EPA's 1974 guidelines, research on sleep disruption from noise has led to widely varying observations. In part, this is because: (1) sleep can be disturbed without causing awakening, (2) the deeper the sleep the more noise it takes to cause arousal, (3) the tendency to awaken increases with age, and (4) the person's previous exposure to the intruding noise and other physiological, psychological, and situational factors. The most readily measurable effect of noise on a sleeping person is the number of arousals or awakenings.

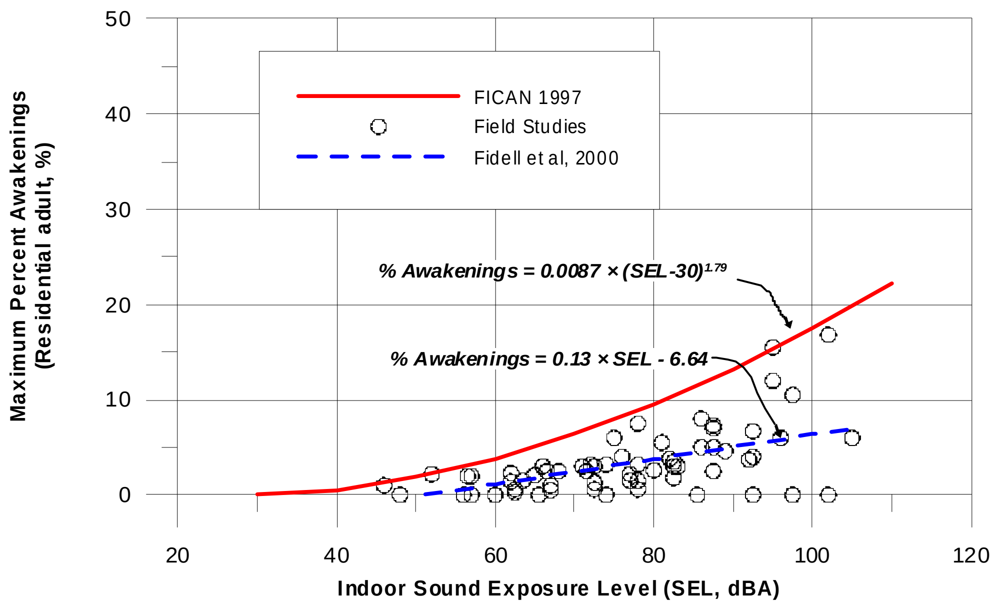
A study performed in 1992 by the Civil Aviation Policy Directorate of the Department of Transportation in the United Kingdom concluded that average sleep disturbance rates (those that are unrelated to outdoor noise) are unlikely to be affected by aircraft noise at outdoor levels below an L_{max} of 80 dBA (Ollerhead, 1992). At higher levels of 80-95 dBA L_{max} the chance of the average person being awakened is about 1 in 75. The study concludes that there is no evidence to suggest that aircraft noise at these levels is likely to increase the overall rates of sleep disturbance experienced during normal sleep. However, the authors emphasize that these conclusions are based on 'average' effects, and that there are more susceptible individuals and there are periods during the night when people are more sensitive to noise, especially during the lighter stages of sleep.

In June 1997, the U.S. Federal Interagency Committee on Aviation Noise (FICAN) reviewed the sleep disturbance issue along with data from the 1992 FICON recommendations (which was primarily the result of many laboratory studies) and presented a new sleep disturbance dose-response prediction curve (FICAN, 1997) as the recommended tool for analysis of potential sleep disturbance for residential areas. The FICAN curve, shown in Figure A-5, was based on data from field studies of major civilian and military airports. For an indoor SEL of 60 dBA, Figure 5 predicts a maximum of approximately 5 percent of the exposed residential population would be behaviorally awakened. FICAN cautions that this curve should only be applied to long-term adult residents.

The focus of this research was the human response to individual SELs rather than the response to multiple events in the same night. The relationship of SEL and percent awakenings presented in the figure is for each event, not a cumulative percent awakening for all events during a sleep period.

Other studies indicate that for a good night's sleep, the number of noise occurrences plays a role as important as the level of the noise. Vallet & Vernet (1991) recommend that, to avoid any adverse effects on sleep, indoor noise levels should not exceed approximately 45 dBA L_{max} more than 10-15 times per night and that lower levels might be appropriate to provide protection for sensitive people. This L_{max} level is equivalent to an SEL of approximately 55 dBA indoors.

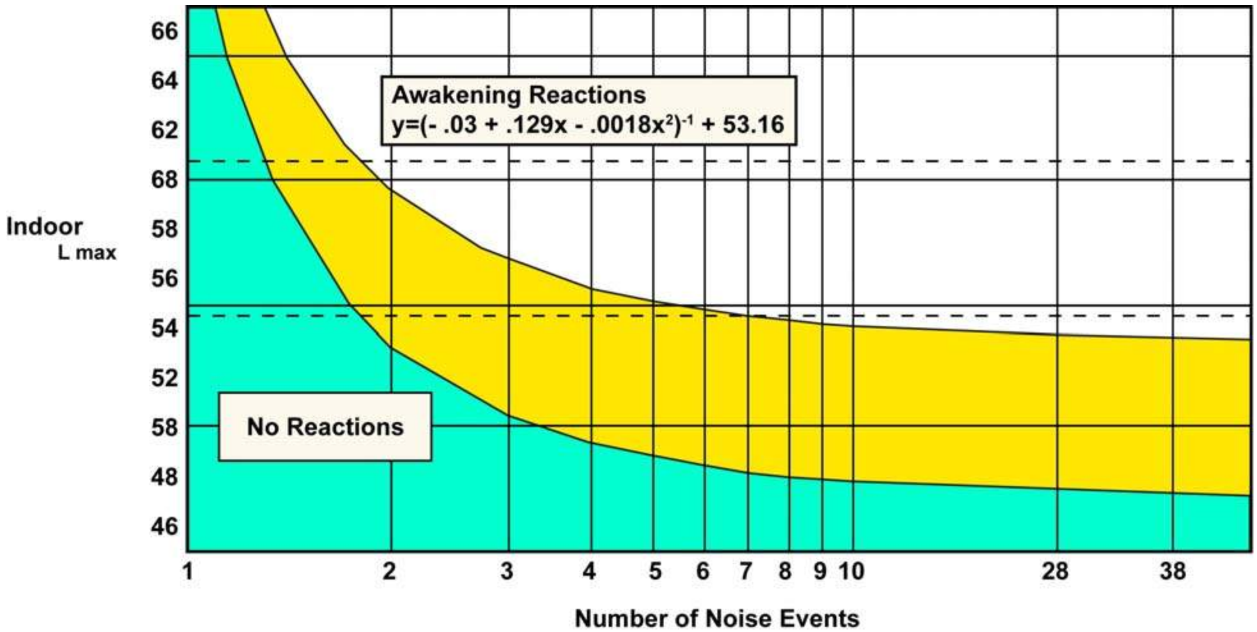
FIGURE 5
SLEEP DISTURBANCE DOSE-RESPONSE RELATIONSHIP



Source: FICAN, 1997; Fidell, et. al., 2000;

Griefahn (1978) suggests that awakenings from aircraft overflights are dependent upon the number of events and their sound levels. Figure 6 illustrates Griefahn's compilation of data indicating the number of events and noise level that constitute a threshold for sleep. The data in her research were based on levels at which the most sensitive 10 percent of the population would be disturbed, and includes a correction to these levels to represent the most sensitive sleep state and age group. The lower curve represents the indoor noise level (expressed in terms of L_{max}) and number of noise event combinations at which fewer than 10 percent of the population will show signs of sleep interference. The upper curve indicates the level at which more than 90 percent of the population will be awakened for the given combination of noise levels and noise events. Griefahn suggests that, to avoid any long-term health effects, the upper curve should not be exceeded. The bottom curve represents a preferred, preventative goal. The curves indicate that nearly 90 percent of people will show signs of sleep interference in the presence of 10 to 30 flights per night at an approximate indoor L_{max} of 54 dB. They also show that for the same number of flights but at an indoor L_{max} of 48 dB, the percentage of the most sensitive population affected is much lower, at less than 10 percent, (with 'no reaction' for the less sensitive population).

FIGURE 6
NUMBER OF AWAKENINGS AS A FUNCTION OF MAXIMUM INDOOR NOISE LEVEL



Source: Griefahn, B. (1990). "Critical Loads for Noise Exposure During the Night," InterNoise 90, pg. 1165.

1.3.4 Vibration from Aircraft Operations

The effects of vibration in a residence are observed in two ways; it is felt by the occupant, or it causes physical damage to the structure. Subjective detection can be one of direct perception from rattling of windows and ornaments, or dislodgement of hanging pictures and other loose objects. Structural damage may be either architectural (cosmetic or minor effects) such as plaster cracking, movement or dislodgements of wall tiles, cracked glass, etc., or major, such as cracking walls, complete collapsing of ceilings, etc., which is generally considered to impair the function or use of the dwelling.

Research has shown that vibration can be felt at levels well below those considered to cause structural damage. Complaints from occupants are usually due to the belief that if vibration can be felt, then it is likely to cause damage. Residents living in proximity to airports often complain that aircraft operations cause vibration induced damage to their homes. Research has also shown however, that the slamming of doors or footfalls within a building can produce vibration levels above those produced by aircraft activities (Reverb Acoustics Noise and Vibration Consultants, 2005).

Since people spend the majority of time indoors, the perceptions of aircraft noise leading to annoyance or complaint response and potentially to structural/architectural effects are directly and indirectly affected by the building structure. The acoustic loads resulting from aircraft noise can induce vibration in the structure, which can in turn, result in radiation of noise into its interior, rattling of items in contact with the structure, the perception of the occupants that the structure is vibrating, and the assumption that the vibration is causing structural/architectural effects. Consequently, the response of buildings, particularly older residential structures, to aircraft noise and the resulting effects on human and structural response has been the subject of considerable research.

C-weighted metrics appear to correlate well with subjective evaluations of low frequency noise from aircraft operations (Fidell, et al, 2002; Eagan, 2006). Perceptible wall vibrations in homes are likely to occur for C-weighted levels between 75 and 80 dB (Eagan, 2006). The likelihood of rattle due to low frequency noise increases notably for C-weighted levels within the range of 75 to 80 dB (Hubbard, 1982, Fidell, et. al, 2002). Rattle always occurs above a threshold of roughly 97 dB L_{max} (Hodgdon, 2007). In addition, C-weighting is the only weighting scale currently in the Integrated Noise Model (INM) that addresses low-frequency noise. However, it should be noted that INM predictions are based on extrapolation of A-weighted aircraft sound levels. The same data are used in C-weighted predictions by simply reverse filtering the A-weighted levels. The predictions do not extend to frequencies less than 50 Hz where much of rattle and structural response can be attributed. This is a major limitation of INM C-weighted predictions for vibration assessment.

Generally, fixed-wing subsonic aircraft do not generate vibration levels of a frequency or intensity high enough to result in damage to structures. It has been found that exposure to normal weather conditions, such as thunder and wind, usually have more potential to result in significant structural vibration than aircraft (FAA, 1985). Two studies involving the measurement of vibration levels resulting from aircraft operations upon sensitive historic structures concluded that aircraft operations did not result in significant structural vibration.

1.4 FAA METHODOLOGY FOR EVALUATING AIRCRAFT NOISE

1.4.1 Impact Analysis Criteria and Thresholds

The evaluation of the Key West International Airport (KWIA) airport noise environment was completed using the methodologies and standards specified in title 14 CFR Part 150 (Part 150, 2004). The following paragraphs summarize the pertinent requirements of these documents applicable to conducting a noise analysis and how they were applied in this NEM.

The regulations and guidance documents require that the cumulative noise energy exposure of individuals to noise resulting from aviation activities be established in terms of yearly day/night average sound level (DNL) as the FAA's primary metric. All detailed noise analyses must be performed using the most current version of the FAA's Integrated Noise Model (INM). For this analysis, INM, Version 7.0a, was used to model aircraft noise exposure.

The noise analysis was conducted to reflect current conditions (2008) and forecast conditions (2013). This analysis includes maps and other means to depict land uses within the noise impact area. The addition of flight tracks is helpful in illustrating where aircraft normally fly.

The following information was disclosed for the current conditions (2008) and forecast conditions (2013).

1. The number of people living or residences within each noise contour above DNL 65 for both the Existing and Future Noise Exposure Map (NEM).
2. The location and number of noise sensitive uses (e.g., schools, churches, hospitals, parks, recreation areas) exposed to DNL 65 or greater for both the Existing and Future NEM.
3. Mitigation measures in effect or proposed and their relationship to the Existing and Future NEM.

1.4.2 The Integrated Noise Model

Noise contours generated by the FAA's INM do not depict a strict demarcation of where the noise levels end or begin. Their purpose is to describe the generally expected noise exposure. It must be recognized that although the INM is the current state-of-the-art aircraft noise modeling software, input variables to the INM require several simplifying assumptions to be made, such as: aircraft types flown, flight track utilization, day/night operational patterns, and arrival/departures profiles flown. Further, the noise contours represent average annual conditions rather than single event occurrences. Noise exposure on any one day may be greater or less than the average day. The noise model is useful for comparison of noise impacts between scenarios and provides a consistent and reasonable method to conduct airport noise compatibility planning.

The INM has been the FAA's standard tool since 1978 for determining the predicted noise impact near airports. The FAA developed the INM computer model and it is the required method to predict airport noise contours. The FAA continually enhances the INM to take advantage of increased computer speed, to incorporate new aircraft types into the aircraft noise database, and to improve its noise computation algorithms. INM Version 7.0a was used to produce the noise contours and to analyze noise levels at sensitive sites.

INM includes the capability to turn off lateral attenuation for helicopters and propeller aircraft, in order to simulate propagation over acoustically hard surfaces such as water or rocks. This capability was utilized to take into account the effect of the water surrounding the airport.

The model produces noise exposure contours that are used for land use compatibility maps. Its program includes built in tools for comparing contours and utilities that facilitate easy export to Geographic Information Systems (GIS). The model can also calculate predicted noise at specific sites such as hospitals, schools, or other sensitive locations. For these grid points, the model reports detailed information for the analyst to determine which events contribute most significantly to the noise at that location.

The INM is a computer model that, during an average 24-hour period, accounts for each aircraft flight along flight tracks leading to or from the airport, or overflying the area of interest. Flight track definitions are coupled with information in the program database relating to noise levels at varying distances and flight performance data for each distinct type of aircraft selected. In general, the model computes noise levels at regular grid locations at ground level around the airport and within the area of interest. The distance to each aircraft in flight is computed, and the associated noise exposure of each aircraft flying along each flight track within the vicinity of the grid location is determined. The logarithmic acoustical energy levels for each individual aircraft are then summed for each grid location. The model can create contours of specific noise levels based on the acoustical energy summed at each of the grid points. The cumulative values of noise exposure at each grid location are used to interpolate contours of equal noise exposure. The model can also compute noise levels at user-defined points on the ground.

The noise analyses must be performed using the INM standard and default data, unless there is sufficient justification for modification. Modification to standard or default data requires written approval from the FAA's Office of Environment and Energy (AEE). Standard INM modeling of departure operations begins at the start of takeoff roll and ends when aircraft reach an altitude of 10,000 feet above field elevation (AFE). Standard modeling of arrival operations begins when the aircraft is at an altitude of 6,000 feet and ends when the aircraft land and completes the application of reverse thrust.

All computer model input data should reasonably reflect current and forecasted conditions. User-supplied information required to run the model includes:

- A physical description of the airport layout, including location, length and orientation of all runways, and airport elevation,
- The aircraft fleet mix for the average day,
- The number of daytime flight and run-up operations (7 a.m. to 9:59 p.m.),
- The number of nighttime flight and run-up operations (10 p.m. to 6:59 a.m.),
- Runway utilization rates,
- Primary departure and arrival flight tracks, and

- Flight track utilization rates.

1.4.2.1 Aircraft Operations and Fleet Mix

Fleet mix defines the various types of aircraft and allows development of very specific input data, such as engine type, title 14 CFR part 36 Noise Stage Certification, gross weight, and departure stage length. The INM aircraft database contains actual noise and performance data for 253 types of aircraft. Although the INM aircraft database provides a large selection of aircraft to model, it does not contain every known aircraft. For this reason, the FAA has developed an official aircraft substitution list, containing 259 types of aircraft, which allows the modeler to substitute similar aircraft when necessary for modeling purposes. These substitutions represent a very close estimate of the noise produced by the actual aircraft. All modeled aircraft in this study are either a true representative of an aircraft type or an FAA approved substitution.

1.4.2.2 Time of Day

The time of day that aircraft operations occur is a very important factor in the calculation of cumulative noise exposure. The DNL treats nighttime (10:00 p.m. to 6:59 a.m.) noise differently from daytime (7:00 a.m. to 9:59 p.m.) noise. DNL multiplies each nighttime operation by 10. This weighting of the operations effectively adds 10 dB to the A-weighted levels of each nighttime operation. This weighting factor is applied to account for people's greater sensitivity to nighttime noise. In addition, events during the night are often more intrusive because the ambient sound levels during this time are usually lower than daytime ambient sound levels.

1.4.2.3 Runway Utilization

Runway use refers to the frequency with which aircraft utilize each runway during the course of a year as dictated or permitted by wind, weather, aircraft weight, and noise considerations. The more often a runway is used throughout the year, the more noise is created in areas located off each end of that runway.

1.4.2.4 Flight Tracks and Flight Track Utilization

Flight tracks depict the actual path of aircraft over the ground for aircraft arrival, departure, closed pattern (touch-and-go), and overflight operations. In order to calculate the annual average noise exposure, it is necessary to identify the predominant arrival, departure and pattern flight tracks for each runway, and the number of aircraft that used each runway and flight track. These are significant factors in determining the extent and shape of the noise contours and noise levels at noise-sensitive receptors.

The use of individual flight tracks is dependent on a variety of factors including Air Traffic Control procedures, the aircraft's origin or destination, aircraft performance, weather conditions, and any noise abatement policies.

INM representative flight tracks at KWIA were developed by analyzing radar data, and by field observation. These tracks are meant to be representative of the highest concentration of actual flight tracks at KWIA. Modeled flight tracks do not represent the precise paths flown by all aircraft utilizing KWIA. Instead, they represent the primary flight corridors for the aircraft using the airport.

1.4.2.5 Aircraft Profiles

The INM default database includes profiles modeling aircraft departures up to 10,000 feet above field elevation (AFE) and arrivals from 6,000 feet AFE.

Arrival Profiles

The INM contains one approach profile for most standard aircraft, which represents a 3-degree descent from an altitude of 6,000 feet above field elevation. Some standard general aviation aircraft also have an approach profile representing a 5-degree descent. The assumptions used in the INM are based upon "average" operational data; flight procedures etc. and standard practice is to assign standard 3-degree INM approach profiles. All arrival profiles used in this study are INM default profiles.

Departure Profiles

The INM relies on the trip length of a given flight to determine the departure weight and associated departure profile. Default procedural profiles are assumed. Three default procedural profiles are available, these are the "Standard," "ICAO-A," and "ICAO-B" departure profiles. The assumptions used in the INM are based upon "average" operational data; aircraft passenger load factors, fuel reserves, flight procedures etc. and standard practice is to assign INM profiles based on trip length. In some cases, the analysis of aircraft departure weight is also used. All departure profiles used in this study are INM default profiles, and stage length is based on trip length.

1.4.2.6 Departure Stage Length

The INM database contains several departure profiles for each fixed-wing aircraft type representing the varying performance characteristics for that aircraft at a particular takeoff weight. Use of appropriate departure profiles is an important component of calculating DNL noise exposure contours. Historically, it has been easier to obtain trip length data than average weight data, so the INM uses "departure stage length" to best represent typical aircraft takeoff weight.

Departure stage length is the distance between the departure airport and the destination airport. As the departure stage length increases, the aircraft's required fuel load and takeoff weight also increase. The increase in takeoff weight equates to a decrease in aircraft takeoff and climb performance. A decrease in aircraft performance results in a longer takeoff departure roll and decreased climb rates. These performance characteristics produce increased noise exposure impacts. The aircraft's noise impacts are greater because the aircraft is producing noise closer to the ground longer. The departure stage lengths are defined in Table 1.

TABLE 1
INM 7.0 STAGE LENGTH DISTANCES

Stage Number	Distance (nm)
1	0-500
2	501-1,000
3	1,001-1,500
4	1,501-2,500
5	2,501-3,500
6	3,501-4,500
7	4,501-5,500
8	5,501-6,500
9	> 6,500

Source: FAA INM Version 7.0 User's Guide

1.4.2.7 Noise Model Outputs

INM has many output capabilities. Charts, graphics, and tables can be viewed, exported, or printed. The most common outputs are the noise contours that INM produces. Additionally, there are many other outputs, such as aircraft performance characteristics, grid point analyses for several noise metrics, and input characteristics such as runways and flight tracks. A complete description of model outputs can be found in the INM Users Guide (FAA, 2007).

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Appendix C. Air Quality Analysis Report
(prepared by JJR/April 2009)

Technical Memorandum: Air Quality Analysis
Ann Arbor Municipal Airport Environmental Assessment

April 9, 2009
JJR No. 50178.000

Pollutant Health Effects

Air pollutants are contaminants in the atmosphere. Many man-made pollutants are a direct result of the incomplete combustion of fuels including coal, oil, natural gas, and gasoline. The principal factors affecting air pollution concentrations with respect to transportation projects are traffic, emissions factors, roadway type, terrain, meteorological parameters, and ambient air quality. The air pollutants listed here are the most common when dealing with transportation projects.

Carbon Monoxide (2006 Annual Air Quality Report for Michigan, MDEQ, page 4)

Carbon monoxide (CO) is a colorless, odorless, and poisonous gas created when fuel does not burn completely. The primary sources for outdoor exposure to CO are the exhaust from automobiles, industrial processes, non-transportation fuel combustion, and natural sources such as forest fires. Elevated levels of CO can cause visual impairment, interfere with mental acuity, and decrease work performance in the completion of complex tasks. High CO pollution levels can affect anyone; however, people who suffer from cardiovascular disease are most at risk.

Ozone (2006 Annual Air Quality Report for Michigan, MDEQ, page 5)

Ozone (O_3), a key ingredient in urban smog is created at ground-level by photochemical reactions involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. Major sources of NO_x and VOCs are engine exhaust, emissions from industrial facilities, combustion from power plants, gasoline vapors, chemical solvents, and biogenic emissions from natural sources. Elevated O_3 exposure can irritate a person’s airways, reduce lung function, aggravate asthma and chronic lung diseases, and inflame and damage the cells lining the lungs. O_3 may also reduce the immune system’s ability to fight off bacterial infections in the respiratory system, and long-term, repeated exposure may cause permanent lung damage.

Nitrogen Dioxide (2006 Annual Air Quality Report for Michigan, MDEQ, page 5)

Nitrogen dioxide (NO_2) is a highly reactive gas that is formed through the oxidation of nitric oxide. The major sources of man-made NO2 emissions come from high-temperature combustion processes. Evidence suggests that long-term exposures to NO2 may lead to increased susceptibility to respiratory infection and may cause structural alterations in the lungs.

Particulate Matter (2006 Annual Air Quality Report for Michigan, MDEQ, page 6)

Particulate Matter (PM) is a general term used for a mixture of solid particles and liquid droplets found in the air which is further categorized according to size. PM_{10} are “coarse particles” less than 10 μm in diameter and $PM_{2.5}$ are much smaller “fine particles” equal to or less than 2.5 μm in diameter. PM_{10} consists of primary particles that can originate from power plants, various manufacturing processes, wood stoves and fireplaces, fugitive dust sources, and forest fires. $PM_{2.5}$ can come directly from primary particle emissions or through secondary reactions that include VOCs, SO_2, and NO_x emissions originating from power plants, motor vehicles, industrial facilities, and other types of combustion sources. Exposure to PM affects breathing and the cellular defenses of the lungs, aggravates existing respiratory and cardiovascular ailments, and has been linked with heart and lung disease.

Sulfur Dioxide (2006 Annual Air Quality Report for Michigan, MDEQ, page 6)

Sulfur dioxide (SO_2) is formed by the burning of sulfur-containing material and can react with other atmospheric chemicals to form sulfuric acid. In liquid form, it is found in clouds, fog, rain, aerosol particles, and in surface films on these particles. Coal burning power plants are the largest source of SO_2 emissions. SO_2 is also emitted from smelters, petroleum refineries, pulp and paper mills, transportation sources, and steel mills. Where SO_2 is emitted, PM is often emitted too. Exposure to elevated levels of SO_2 aggravates existing cardiovascular and pulmonary disease. SO_2 and PM together may cause respiratory illness, alteration in the body's defense and clearance mechanisms, and aggravation of existing cardiovascular disease. SO_2 and NO_x together are the major precursors to acid rain, which is associated with the acidification of soils, lakes, and streams and accelerated corrosion of buildings and monuments.

Lead (2006 Annual Air Quality Report for Michigan, MDEQ, page 4)

Lead (Pb) is a highly toxic metal found in coal, oil, and waste oil. It is also found in municipal solid waste and sewage sludge incineration and may be released to the atmosphere during their combustion. The highest air concentrations of Pb are found in the vicinity of smelters and battery manufacturers. Other industrial sources include Pb glass, Portland cement, and solder production. Pb primarily accumulates in the blood, bones, and soft tissues of the body, and can adversely affect the kidneys, liver, nervous system, and other organs.

Regulatory Standards

The Clean Air Act of 1970, the 1977 Clean Air Act Amendments and the 1990 Clean Air Act Amendments (CAAA) are the applicable regulations that govern air quality for the project area. Under the CAAA, the U. S. Department of Transportation cannot fund, authorize, or approve Federal actions to support programs or projects that are not first found to conform to the Clean Air Act requirements. The air quality provisions of the Clean Air Act (CAA), as amended, are intended to ensure the integration of air quality planning in all transportation-related projects.

The establishment of the National Ambient Air Quality Standards (NAAQS) by the Environmental Protection Agency (EPA) was directed in the Clean Air Act, and their attainment and maintenance was reinforced in later amendments. The goal of air quality monitoring and actions is to ensure that the air quality levels of the various pollutants do not exceed the set standards. These standards are summarized in Table 1.

Table 1: National Ambient Air Quality Standards (NAAQS)

Criteria Pollutant	Primary (Health Related)		Secondary (Welfare Related)	
	Type of Average	Standard Level Concentration	Type of Average	Standard Level Concentration
Carbon Monoxide, CO	8-hour 1-hour	9 ppm (10 mg/m^3) 35 ppm (40 mg/m^3)	No Secondary Standard	
Lead, Pb	Maximum Quarterly Average	1.5 μg/m^3	Same as Primary Standard	
Nitrogen Dioxide, NO_2	Annual Arithmetic Mean	0.053 ppm (100 μg/m^3)	Same as Primary Standard	
Ozone, O_3	4th Highest 8-Hour Daily Maximum	0.085 ppm (157 μg/m^3)	Same as Primary Standard	
Particulate Matter, PM_{10}	24-Hour	150 μg/m^3	Same as Primary Standard	
Particulate Matter, $PM_{2.5}$	Annual Arithmetic Mean	15 μg/m^3	Same as Primary Standard	
	98th percentile 24-hour	35 μg/m^3		
Sulfur Dioxide, SO_2	Annual Arithmetic Mean	0.03 ppm (80 μg/m^3)	3-Hour	0.5 ppm (1300 μg/m^3)
	24-Hour	0.14 ppm (365 μg/m^3)		

Attainment Status

The Air Quality Division of the Michigan Department of Environmental Quality (MDEQ) produces an Annual Air Quality Report, which outlines the attainment status of the state. According to the 2006 Air Quality Report the project study area is in attainment with the NAAQS for ambient concentrations of carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and coarse particulate matter (PM_{10}).

Ozone

All Michigan counties are now designated as attainment for the 1-hour O_3 NAAQS. The 1-hour standard has since been revoked by the EPA. In 1997, EPA issued the average-based 8-hour ozone NAAQS (attained when the 3-year average of the 4th highest value is below 0.085 ppm). In 2004, utilizing 2001-2003 monitoring data, EPA designated 25 counties in Michigan as nonattainment for the 8-hour O_3 NAAQS, of which Washtenaw County was included. A nonattainment designation indicates that the area does not meet the national health-based standard, or contributes to violations of the standard in another area. Upon review of the O_3 data collected for the period of 2004-2006, Washtenaw County is now meeting the 8-hour O_3 NAAQS and is designated as marginal nonattainment. The MDEQ Air Quality Division has requested re-designation of Washtenaw County to attainment

Particulate Matter

EPA promulgated the $PM_{2.5}$ NAAQS on July 18, 1997. In the January 5, 2005 Federal Register (FR), EPA announced their $PM_{2.5}$ designations, effective April 5, 2005, utilizing the 2001-2003 three year annual average data. Based upon this data, Washtenaw County was designated as nonattainment for $PM_{2.5}$. As stated in the FR notice, States were allowed to submit 2004 $PM_{2.5}$ quality-assured monitoring data, calculate the 2002-2004 three-year annual average, and request changes in attainment status if this data and supporting rationale showed an area should instead be designated attainment.

On February 22, 2005, MDEQ submitted documentation demonstrating that monitors in the counties surrounding Wayne County (Livingston, Oakland, Macomb, Monroe, St. Clair, and Washtenaw Counties) are not violating the standard and that Wayne County is the only county showing nonattainment. The MDEQ submittal also included information supporting the conclusion that air pollution emissions in the surrounding six counties do not cause the nonattainment levels in Wayne County. However, the EPA denied Michigan's request for reconsideration as they believe the surrounding counties contribute to the overall air quality violations at the Wayne County monitors. The Southeast Michigan Council of Governments (SEMCOG) and the MDEQ are currently developing an emissions control strategy to bring the region into attainment by 2010 as required by the EPA.

Air Traffic Modeling Parameters

The Federal Aviation Administration (FAA) created the Air Quality Procedures for Civilian Airports & Air Force Bases in an effort to aid in assessing the impacts at airports and air bases. Included in the procedures is a flow chart that can be used to determine whether a NAAQS analysis is required. The first step in the flow chart is to determine whether the proposed action is located in a nonattainment or maintenance area. As stated previously, the project area is currently designated as marginal nonattainment for ozone and nonattainment for particulate matter.

Since the project area is in a nonattainment area the next step is to determine whether the proposed project is exempt or presumed to conform. For this analysis, it will be assumed that the project is neither exempt nor presumed to conform.

The next step is to determine whether direct emissions will occur as a result of the proposed project. The FAA defines a direct emission as "an effect that is caused by the implementation and/or operation of an action that occurs at the same time and place" (Air Quality Procedures for Civilian Airports & Air Force Bases, 1997, page xvi). The proposed project is the extension of an existing runway. It can be assumed that direct emissions are already occurring and will increase as a result of increased usage of the airport.

Once it is determined whether direct emissions are occurring, it needs to be determined whether indirect emissions are reasonably feasible as a result of the proposed project. The FAA defines an indirect emission as "those caused by the implementation and/or operation of an action, are reasonably foreseeable, but which occur later in time and/or are farther removed in distance from the action itself" (Air Quality Procedures for Civilian Airports & Air Force Bases, 1997, page xviii). For this project, it can be assumed that no indirect emissions will occur. Therefore, the total emissions are equal to the direct emissions.

After determining whether any indirect emissions occur, an analysis of the airport activity is examined. The Ann Arbor Municipal Airport is considered to be a general aviation airport. For this type of airport, if the activity is forecasted to be 180,000 yearly operations, an NAAQS assessment is required. The yearly activity for the AAMA is expected to be approximately 70,000 operations per year. Consequently, an NAAQS assessment will not be required.

After examining the direct and indirect emissions, a conformity assessment may also need to be performed based on whether the net emissions exceed general conformity threshold levels and are regionally significant. The Michigan Department of Transportation Bureau of Aeronautics completed the Michigan Airports Air Quality Study in May 1996. In this study, an air pollutant emission inventory was created for seven general aviation airports based on their proposed development. The air pollutant emission inventory indicates that the emissions from all of the airports studied would be well below the general conformity threshold rates. Since the AAMA is comparable in size and activity to the seven airports studied, it can be assumed that the emissions resulting from the proposed project will not exceed the general conformity threshold levels and will not be regionally significant. Therefore, a conformity determination is not required and the proposed project is presumed to conform to the state implementation plan.

Automobile Modeling Parameters

As stated previously, Washtenaw County is designated as being in attainment with the NAAQS for carbon monoxide. The primary NAAQS for CO are 35 parts per million (ppm) for the maximum one-hour concentration, and nine ppm for the maximum eight-hour concentration. To be in attainment with the NAAQS, these concentrations may not be exceeded more than once annually at a given site. In order to determine whether the proposed project will be in attainment with the NAAQS, a micro-scale air quality analysis was conducted. Through this analysis, maximum one-hour CO concentrations for the Existing Condition (2008) and the No Build Condition and Proposed Alternative in the design year (2030) were estimated.

The calculation of CO concentrations was performed through the use of two computer models. The first model, MOBILE6.2.03, developed by the Environmental Protection Agency (EPA), provided the means for calculating vehicular emission factors for the range of expected vehicle types. The second model CAL3QHC, which is also known as the California Line Source Dispersion Model is used to calculate CO concentrations at receptor sites. The EPA has improved upon this program in order to allow analysis of air quality conditions at road intersections, where highest concentrations of pollutants are typically found.

The emission factors determined through MOBILE6.2, in addition to receptor locations, peak hourly traffic volumes, meteorological conditions and roadway geometry constituted the input data for CAL3QHC. The aforementioned parameters were conservatively selected in order to represent a worst-case scenario for each of the conditions. Background CO concentrations were obtained from the MDEQ's 2006 Air Quality Report.   Since there is not a single monitoring site near the project site, the average of the highest recorded value for all nine sites was used for the background concentrations. The resulting one-hour background concentration used in the model was 3.0 ppm.

Locations along the various road corridors were selected for analysis of air quality conditions. Locations were chosen based upon existing traffic volumes and future projections, nearby proximity of sensitive receptors, and representative location within the overall project vicinity. Layout plans, air photos, and site observations were used to determine the locations of sensitive receptors near the studied intersections. The sensitive receptors included residential properties and open spaces (see Figure X).

Traffic volumes were obtained from the SEMCOG website and the Washtenaw Area Transportation Study (WATS) website for the existing condition. WATS also determined the increase in the traffic volumes for the future conditions. According to their models, State Street and Lohr Road will experience a cumulative increase in traffic volume of 3.3% for the future condition. Similarly, Ellsworth Road will experience a cumulative increase in traffic volume of 3.7% for the future condition.

A persistence factor is the ratio between the 8-hour and 1-hour CO concentration and is used to estimate the 8-hour CO concentration based on the 1-hour CO concentration. Three seasons of monitoring data were obtained from the MDEQ's Air Quality Reports and are tabulated in Table 2. The persistence factor for each station and each year was calculated by dividing the 8-hour CO concentration by the 1-hour CO concentration. The average of all of the persistence factors was calculated to be 0.70, which compares well with tabulated values for urban locations. Therefore, the 8-hour CO concentrations were determined by multiplying the persistence factor of 0.70 by the 1-hour CO concentrations as calculated by CAL3QHC.

Table 2: Persistence Factor

Station	One-Hour CO Concentration (ppm)			Eight-Hour Concentration (ppm)			Persistence Factor		
	2004	2005	2006	2004	2005	2006	2004	2005	2006
Otisville	1.1	--	--	0.6	--	--	0.55	--	--
Grand Rapids	3.0	2.8	2.7	2.2	2.0	2.0	0.73	0.71	0.74
Warren	3.3	4.8	3.5	2.1	2.5	3.0	0.64	0.52	0.86
Oak Park	4.1	3.7	3.1	2.4	2.2	2.6	0.59	0.59	0.84
Seney	--	0.8	--	--	0.7	--	--	0.88	--
Allen Park	3.6	2.5	3.9	3.1	1.8	3.2	0.86	0.72	0.82
Detroit-Linwood	4.1	3.7	3.7	2.6	2.6	2.8	0.63	0.70	0.76
Livonia	1.4	2.1	2.9	1.2	1.7	1.3	0.86	0.81	0.45
Detroit-Newberry	--	2.9	--	--	1.8	--	--	0.62	--
Detroit-W. Lafayette	--	2.8	1.5	--	1.8	1.0	--	0.64	0.67
Yearly Average	2.9	2.9	3.0	2.0	1.9	2.3	0.69	0.69	0.73
Category Average	3.0			2.1			0.70		

Automobile Modeling Results

Existing Condition

CAL3QHC was used with the existing road centerlines and traffic volumes to determine one-hour CO levels. The maximum one-hour CO concentration is 5.2 ppm and the average concentration is 3.6 ppm. No receptors exceed the NAAQS one-hour standard of 35 ppm. The persistence factor calculated previously was used to determine the eight-hour CO concentrations from the one-hour concentrations. The resulting maximum eight-hour concentration is 3.6 ppm and the average concentration is 2.5 ppm. No receptors exceed the NAAQS eight hour standard of 9 ppm.

No-Build Condition

The increased traffic volumes (as determined by WATS) were adjusted in the CAL3QHC model to the 2030 values to determine the future CO concentrations. With the increased traffic, the model shows that there will be no significant increase in the CO concentrations. The maximum one-hour concentration remains at 5.2 ppm, and the maximum eight-hour concentration remains at 3.6 ppm. No receptors exceed the NAAQS one-hour or eight-hour standards. The average one-hour CO concentration is 3.6 ppm, the average eight-hour CO concentration is 2.5 ppm, both of which are identical to the averages for the Existing Condition. Twenty seven receptors experience an increase in one-hour and eight-hour concentrations with a maximum one-hour increase of 0.3 ppm and a maximum eight-hour increase of 0.2 ppm.

Consequences of the Preferred Alternative
There will be no revisions to the existing roadway system as a result of the Preferred Alternative. Consequently, the air model results for the Preferred Alternative will be identical to those for the No-Build Condition. Since the No-Build Condition analysis shows that no sites will exceed the one-hour or eight-hour NAAQS standard, the Preferred Alternative also will have no sites exceeding the NAAQS standard.

During construction, appropriate mitigation measures, such as covering and spraying stock piles with water, should be utilized to minimize potential short term negative impacts which may be experienced locally due to fugitive dust, construction vehicle exhaust, or other fumes related to construction materials and equipment.

Affected Environment

Climate Change/Greenhouse Gases

Of growing concern is the impact of proposed projects on climate change. Greenhouse gases are those that trap heat in the earth's atmosphere. Both naturally occurring and anthropogenic (man-made) greenhouse gases include water vapor (H_2O), carbon dioxide (CO_2),[1] methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).[2]

Research has shown that there is a direct link between fuel combustion and greenhouse gas emissions. Therefore, sources that require fuel or power at an airport are the primary sources that would generate greenhouse gases. Aircraft are probably the most often cited air pollutant source, but they produce the same types of emissions as cars. Aircraft jet engines, like many other vehicle engines, produce carbon dioxide (CO_2), water vapor (H_2O), nitrogen oxides (NO*x*), carbon monoxide (CO), oxides of sulfur (SO*x*), unburned or partially combusted hydrocarbons (also known as volatile organic compounds (VOCs)), particulates, and other trace compounds.

According to most international reviews, aviation emissions comprise a small but potentially important percentage of anthropogenic (human-made) greenhouse gases and other emissions that contribute to global warming. The Intergovernmental Panel on Climate Change (IPCC) estimates that global aircraft emissions account for about 3.5 percent of the total quantity of greenhouse gas from human activities.[3] In terms of U.S. contribution, the U.S. General Accounting Office (GAO) reports that aviation accounts "for about 3 percent of total U.S. greenhouse gas emissions from human sources" compared with other industrial sources, including the remainder of the transportation sector (23 percent) and industry (41 percent).[4]

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[1] All greenhouse gas inventories measure carbon dioxide emissions, but beyond carbon dioxide different inventories include different greenhouse gases (GHGs).
[2] Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. For example, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons) or sulfur (sulfur hexafluoride: SF_6).
[3] IPCC Report as referenced in U.S. General Accounting Office (GAO) *Environment: Aviation's Effects on the Global Atmosphere Are Potentially Significant and Expected to Grow*; GAO/RCED-00-57, February 2000, p. 4.
[4] Ibid, p. 14; GAO cites available EPA data from 1997.

The scientific community is developing areas of further study to enable them to more precisely estimate aviation's effects on the global atmosphere. The FAA is currently leading or participating in several efforts intended to clarify the role that commercial aviation plays in greenhouse gases and climate change. The most comprehensive and multi-year program geared towards quantifying climate change effects of aviation is the Aviation Climate Change Research Initiative (ACCRI) funded by FAA and NASA. ACCRI will reduce key scientific uncertainties in quantifying aviation-related climate impacts and provide timely scientific input to inform policy-making decisions. FAA also funds Project 12 of the Partnership for AiR Transportation Noise & Emissions Reduction (PARTNER) Center of Excellence research initiative to quantify the effects of aircraft exhaust and contrails on global and U.S. climate and atmospheric composition. Finally, the Transportation Research Board's (TRB) Airport Cooperative Research Program (ACRP) project 02-06 is preparing a guidebook on preparing airport greenhouse gas emission inventories. The results of this effort are expected to be out in late 2008.

Environmental Consequences

Based on FAA data, operations activity at the Ann Arbor Municipal Airport represents less than 0.1 percent of U.S. aviation activity. Therefore, assuming that greenhouse gases occur in proportion to the level of activity, greenhouse gas emissions associated with existing and future aviation activity at the Ann Arbor Municipal Airport would be expected to represent less than 0.1 percent of U.S.-based greenhouse gases. Therefore, we would not expect the emissions of greenhouse gases from this project to be significant.

Cumulative Effects

Because aviation activity at the Ann Arbor Municipal Airport represents such as small amount of U.S. and global emissions, and the related uncertainties involving the assessment of such emissions regionally and globally, the incremental contribution of this proposed action cannot be adequately assessed given the current state of the science and assessment

Appendix D. Agency Coordination

D-1. Michigan Department of Natural Resources,
May 12, 2009

D-2. U.S. Department of the Interior Fish and Wildlife Service
June 3, 2009

D-3. Michign Department of Agriculture
April 7, 2009

D-4. Michigan Department of Environmental Quality,
June 2, 2009

D-5. Michigan Department of Environmental Quality,
July 22, 2009

D-6. U.S. Environmental Protection Agency
May 20, 2009

D-7. USDA NRCS
September 3, 2009

D-8. Michigan SHPO
October 20, 2009

D-9. Saginaw Chippewa Indian Tribe of Michigan
May 19, 2009

D-10. Little Traverse Bay Bands of Odawa Indians
May 7, 2009

JENNIFER M. GRANHOLM
GOVERNOR

STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES
LANSING

REBECCA A. HUMPHRIES
DIRECTOR

May 12, 2009

Ms. Amy Eckland
JJR, LLC
110 Miller Avenue
Ann Arbor, MI 48104

RE: Proposed Environmental Assessment for Ann Arbor Municipal Airport

Dear Ms Eckland:

The location of the proposed project was checked against known localities for rare species and unique natural features, which are recorded in a statewide database. This continuously updated database is a comprehensive source of information on Michigan's endangered, threatened and special concern species, exemplary natural communities and other unique natural features. Records in the database indicate that a qualified observer has documented the presence of special natural features at a site. The absence of records may mean that a site has not been surveyed. The only way to obtain a definitive statement on the presence of rare species is to have a competent biologist perform a field survey.

Under Act 451 of 1994, the Natural Resources and Environmental Protection Act, Part 365, Endangered Species Protection, "a person shall not take, possess, transport, ...fish, plants, and wildlife indigenous to the state and determined to be endangered or threatened," unless first receiving an Endangered Species Permit from the Department of Natural Resources, Wildlife Division. *Responsibility to protect endangered and threatened species is not limited to the list below. Other species may be present that have not been recorded in the database.*

The presence of threatened or endangered species does not preclude activities or development, but may require alterations in the project plan. Special concern species are not protected under endangered species legislation, but recommendations regarding their protection may be provided. Protection of special concern species will help prevent them from declining to the point of being listed as threatened or endangered in the future.

The following is a summary of the results for the project in Washtenaw County, sections 16, 17, T3S R6E.

The following list includes unique features that are known to occur on or near the site(s) and may be impacted by the project.

common name	status	scientific name
Henslow's sparrow	**state endangered**	***Ammodramus henslowii***
Grasshopper sparrow	**special concern**	***Ammodramus savannarum***

The **Henslow's sparrow** has been known to occur in the area. Henslow's sparrow require grasslands to breed. Today, this means grassy fields, pastures, hayfields and meadows with

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scattered shrubs. They are often found in damp/moist low-lying locations. Henslow's arrive in Michigan in early April and are on their breeding ground by late to early May. Two broods are common during the breeding season, which means nesting can last into August. Fall migration begins in late September to mid-October.

The **grasshopper sparrow** has been known to occur in the area. Grasshopper sparrow's can be found in native prairies, cultivated fields, old fields, hayfields, pastures and open savanna. The nest is generally well concealed on the ground by overhanging vegetation. Spring arrival occurs in April and May and by mid-May grasshopper sparrow's are on their breeding ground. Two broods are a possible during the breeding season, which means nesting can last into August. Fall migration is complete by late October.

In summary, the project site may include suitable habitat for the above listed species. Potential impacts might include direct destruction of species and disturbance of critical habitat.

Thank you for your advance coordination in addressing the protection of Michigan's natural resource heritage. If you have further questions, please call me at 517-373-1263 or e-mail at SargentL@michigan.gov .

Sincerely,

Lori G. Sargent
Endangered Species Specialist
Wildlife Division

United States Department of the Interior

FISH AND WILDLIFE SERVICE
East Lansing Field Office (ES)
2651 Coolidge Road, Suite 101
East Lansing, Michigan 48823-6316

MDOT AERONAUTICS
JUN 04 2009
AIRPORTS DIVISION

IN REPLY REFER TO:

June 3, 2009

Ms. Molly Lamrouex, Environmental Specialist
Aeronautics and Freight Services
Michigan Department of Transportation
2700 E. Airport Service Drive
Lansing, Michigan 48906

Re: Early Coordination for Proposed Improvements at Ann Arbor Municipal Airport, Washtenaw County, Michigan

Dear Ms. Lamrouex:

We are responding to your May 4, 2009, request for early coordination regarding the subject project. We submit these comments in accordance with section 7 of the Endangered Species Act of 1973, as amended (Act), and the National Environmental Policy Act (NEPA).

Wetlands

For information on the location of wetlands, please visit the National Wetland Inventory (NWI) wetland map website (National Map Viewer) at *http://nmviewogc.cr.usgs.gov/viewer.htm*. Pursuant to state law and the federal Clean Water Act, the State of Michigan regulates certain activities in wetlands. Development that would impact wetlands may require a permit for which this office may have review authority. In the review of these permit applications, we may concur (with or without stipulations) or object to permit issuance depending upon whether the proposed work may impact public trust fish and wildlife resources.

Migratory Birds

Under the Migratory Bird Treaty Act of 1918, as amended, it is unlawful to take, capture, kill, or possess migratory birds, their nests, eggs, and young. For proposed projects that may contain habitat suitable for nesting by migratory bird species, including song birds and/or raptors, we recommend you schedule construction activities or remove potential habitat or nesting structures before the initiation of spring nesting or after the breeding season has ended to avoid take of migratory birds, eggs, young, and/or active nests. Generally, we recommend that any habitat disturbance occur before April 15 or after August 1 to minimize potential impacts to migratory birds, but please be aware that some species may initiate nesting before April 15.

Scanned 6-8-09

Endangered Species

For endangered and threatened species list requests and section 7 consultations with the U.S. Fish and Wildlife Service, please refer to our endangered species and technical assistance website, located at *http://www.fws.gov/midwest/endangered/section7/index.htm*. In some cases, you may be able to conclude the endangered species review process without contacting this office.

We appreciate the opportunity to provide comments at this early stage of project planning. Please direct any questions to Barbara Hosler of this office at 517/351-6326 or the above address.

Sincerely,

Barbara Hosler

for Craig A. Czarnecki
Field Supervisor

STATE OF MICHIGAN
DEPARTMENT OF AGRICULTURE
LANSING

JENNIFER M. GRANHOLM
GOVERNOR

DON KOIVISTO
DIRECTOR

April 7, 2009

Ms. Amy Eckland
JJR, LLC
110 Miller Avenue
Ann Arbor, MI 48104

Dear Ms. Eckland:

RE: Ann Arbor Municipal Airport – JJR Project No. 50178.000

Our office has reviewed your request dated March 30, 2009 regarding the above-referenced project and finds that there are no Farmland Development Rights Agreements on any property within the project boundaries.

Therefore, we conclude that there will be no project impacts on land enrolled in this program.

Thank you for the opportunity to review this project.

Sincerely,

Jarrod Thelen, Resource Analyst
Farmland & Open Space Preservation
Environmental Stewardship Division
517-373-3328

JT:lls

JENNIFER M. GRANHOLM
GOVERNOR

STEVEN E. CHESTER
DIRECTOR

June 2, 2009

Ms. Molly Lamrouex, Environmental Liaison
Michigan Department of Transportation
Aeronautics and Freight Services
2700 Port Lansing Road
Lansing, Michigan 48906

Dear Ms. Lamrouex:

SUBJECT: Michigan Department of Environmental Quality (MDEQ) File Number 09-81-5002
Early Coordination – Ann Arbor Municipal Airport, Washtenaw County, Michigan

The MDEQ, Land and Water Management Division (LWMD) has completed review of your May 4, 2009, request for early coordination comments for the Ann Arbor Municipal Airport located in Section 17, T3S, R6E, of Washtenaw County, Michigan. Your letter indicates that you are in the process of preparing an Environmental Assessment (EA) for the proposed project, which includes determining the feasibility of shifting and extending the primary runway and parallel taxiway 950 feet to the southwest. Based on the general information provided, we have the following comments.

1) All natural resource features, including lakes, streams, and wetlands, should be identified as part of your investigation. Any alternatives that are developed need to evaluate the potential impact on these and other resources. Steps should be taken to identify feasible and prudent alternatives to avoid and/or minimize any potential impacts to the natural resources.

2) There appears to be a drain/stream located at the southwest corner of the airport property. Any impacts to this drain/stream would require a permit under Part 301, Inland Lakes and Streams, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA). Under Part 301, we recommend that new structures fully span the bankfull channel when feasible. Our preference is for streams or drains to be relocated instead of enclosed where the impacts can not be avoided.

3) The drainage area of the small drain is less than 2 square miles; therefore, a permit would not be required under the State's Floodplain Regulatory Authority found in Part 31, Water Resources Protection, of the NREPA.

4) It is not clear if any wetlands would be impacted by the proposed project. Available maps do appear to indicate the presence of hydric soils near the airport. If there are wetlands impacts, they should be field verified, and their types, functions, and values properly described. Impacts to wetlands will require a permit under Part 303, Wetlands Protection, of the NREPA. Mitigation will be required for any unavoidable impacts to wetlands. We do not regulate the clearing of vegetation but would require a permit under Part 303, Wetlands Protection, of the NREPA for any grading, filling, draining, or

grubbing where stumps are removed. Cut vegetation should be removed from any wetland areas. Additional information on wetlands and the mitigation requirements can be found at www.michigan.gov/deqwetlands.

5) A special interest search of our databases indicates that there is a potential State Threatened plant and Endangered animal in section 17, T3S, R6E. If these species are within your project area, you will be required to coordinate the potential impacts with Ms. Lori Sargent, Michigan Department of Natural Resources, at 517-373-9418.

6) Our database search also indicates potential Part 201 sites located in section 17, T3S, R6E. Please contact Mr. Mitch Adelman at 517-780-7690 of the Remediation and Redevelopment Division in the LWMD's Jackson District Office for further information.

7) A National Pollution Discharge Elimination System (NPDES) permit will be required for storm water discharges associated with construction activities in accordance with Rule 2190 promulgated in accordance with Part 31, Water Resources Protection, of the NREPA.

8) A permit will be required under Part 91, Soil Erosion and Sedimentation Control, of the NREPA. Part 91 permits are generally issued by the county or, in some instances, the local municipality. If the earth change involves two or more Part 91 permitting entities, the MDEQ issues the Part 91 permit.

As the project planning becomes better defined, we may have additional comments.

Thank you for the opportunity to review and provide comments. If you have any questions or need to schedule a field review, please contact Mr. Alex Sanchez at 517-335-3473, or you may contact me.

Sincerely,

Gerald W. Fulcher, Jr., P.E., Chief
Transportation and Flood Hazard Unit
Land and Water Management Division
517-335-3172

cc: Ms. Sherry Kamke, USEPA
Mr. Craig Czarnecki, USFWS
Mr. John Konik, USACE
Mr. Brad Davidson, FAA
Ms. Lori Sargent, MDNR
Mr. Mitch Adelman, MDEQ
Ms Mary Vanderlaan, MDEQ
Mr. Alex Sanchez, MDEQ

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

JENNIFER M. GRANHOLM
GOVERNOR

STEVEN E. CHESTER
DIRECTOR

July 22, 2009

MDOT AERONAUTICS
JUL 28 2009
AIRPORTS DIVISION

Michigan Department of Transportation
Attn: Ms. Molly Lamrouex
2700 Port Lansing Rd.
Lansing, MI 48909

Dear Ms. Lamrouex:

SUBJECT: Express Wetland Identification Report
Wetland Identification File Number: 09-81-0001-WA

The Department of Environmental Quality (DEQ) conducted a Level 2 Express Wetland Identification Review of 5 acres of an approximately 300-acre property (Property Tax Identification Number Ann Arbor Municipal Airport) located in Town 03S, Range 06E, Section 17, Pittsfield Township, Washtenaw County on July 21, 2009. The wetland review was conducted in accordance with Part 303, Wetlands Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA); and Rule 4 (1), Wetland Identification and Assessment (R 281.924) of the Administrative Rules for Part 303. This is a report of our findings in response to your Wetland Identification Application.

Based on our site review, which included a review of the dominant vegetation, hydrology, and soils, as well as an in-office review of pertinent information, the DEQ finds that the 5-acre review area does not contain wetland regulated by the state. The wetland within the review area is not regulated by the state since it is not within 500 feet of an inland lake or stream or within 1,000 feet of the Great Lakes or their connecting waters. The DEQ lacks jurisdiction under Part 303 for activities occurring within the Wetland Identification Review area.

Please be aware that this Wetland Identification Report does not constitute a determination of the presence of wetland that may be regulated under local ordinances or federal law. The U.S. Army Corps of Engineers (USACE) retains regulatory authority over certain wetlands pursuant to Section 404 of the Clean Water Act (CWA), and specifically those wetlands associated with navigable waters of the state. Navigable waters are generally the Great Lakes, their connecting waters, and portions of river systems and lakes connected to these waters. In other areas of the State, the DEQ is responsible for identification of wetland boundaries for purposes of compliance with the CWA under an agreement with the U.S. Environmental Protection Agency.

Your Wetland Identification Review area does not appear to be within those areas regulated by the USACE. However, should you desire more information, please contact the USACE at 313-226-2218.

This Wetland Identification Report is limited to findings pursuant to Part 303 and does not constitute a determination of jurisdiction under other DEQ administered programs. Any land use activities undertaken within the review area may be subject to regulation pursuant to the NREPA under the following parts.

Floodplain Regulatory Authority found in Part 31, Water Resources Protection
Part 91, Soil Erosion and Sedimentation Control
Part 301, Inland Lakes and Streams

The findings contained in this report do not convey, provide, or otherwise imply approval of any governing act, ordinance, or regulation, nor does it waive the obligation to acquire any applicable state, county, local, or federal approvals. This Wetland Identification Report is not a permit for any activity that requires a permit from the DEQ.

The findings contained in this report are binding on the DEQ until July 21, 2012, a period of three years from the date of this Wetland Identification Report. Please contact me if you have any questions regarding this report.

Sincerely,

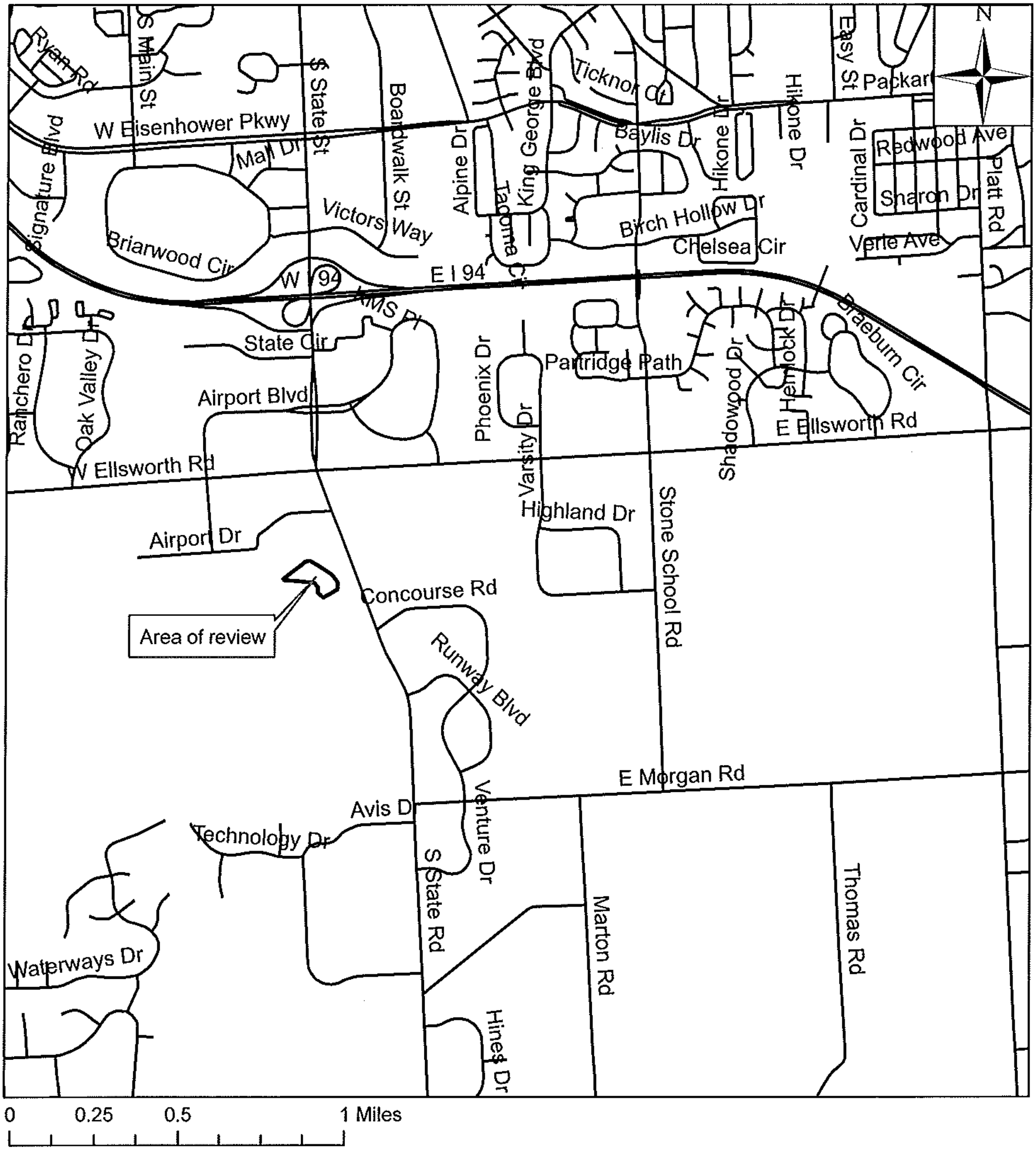
Peg Bostwick for

Todd Losee
Wetland Identification Program Coordinator
Land and Water Management Division
517-335-3457

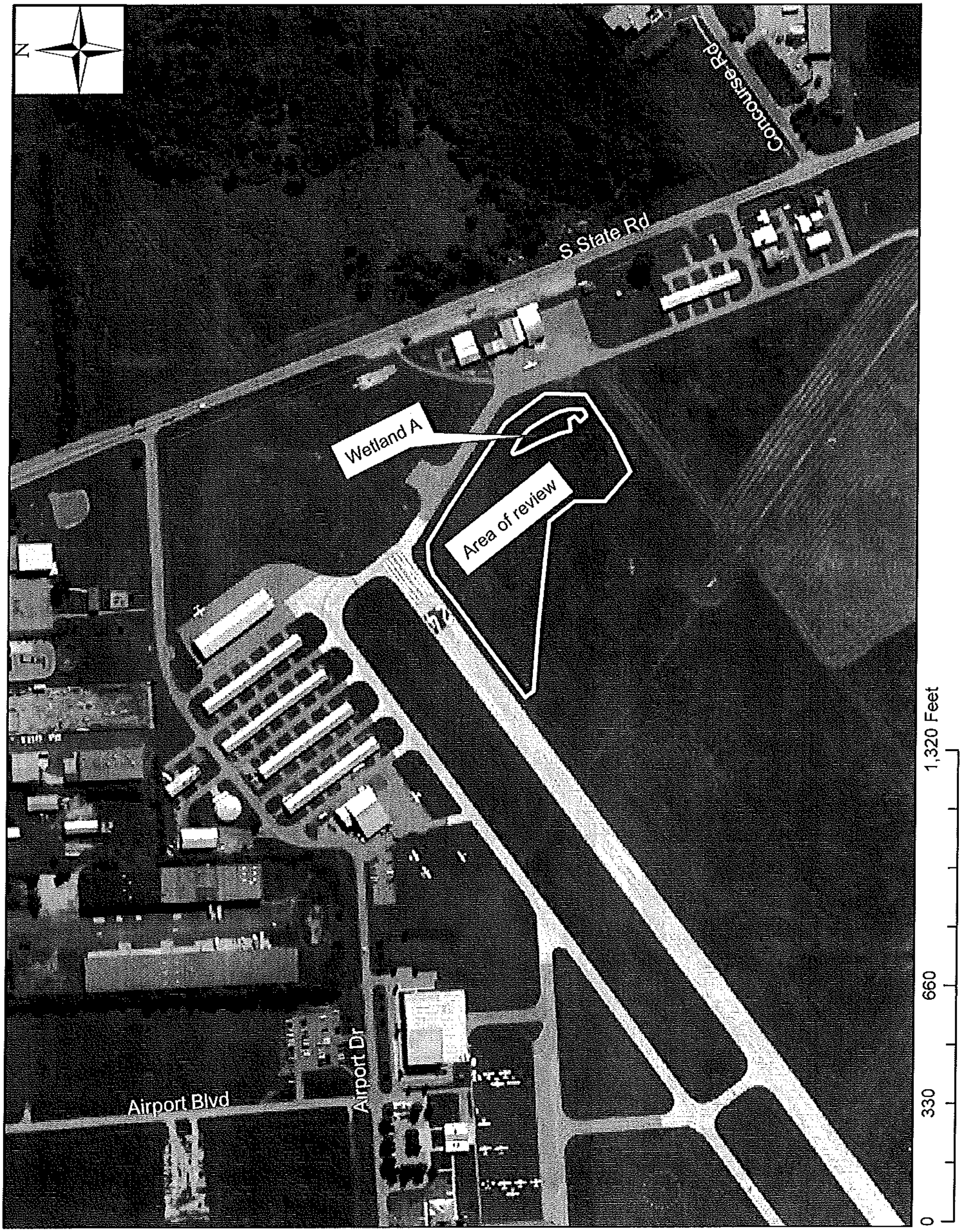
Enclosures

cc: Washtenaw County CEA
Washtenaw County Health Department
Pittsfield Township Clerk
Mr. Matt Kulhanek, City of Ann Arbor
Mr. Justin Pung, DEQ
Mr. Todd Losee, DEQ

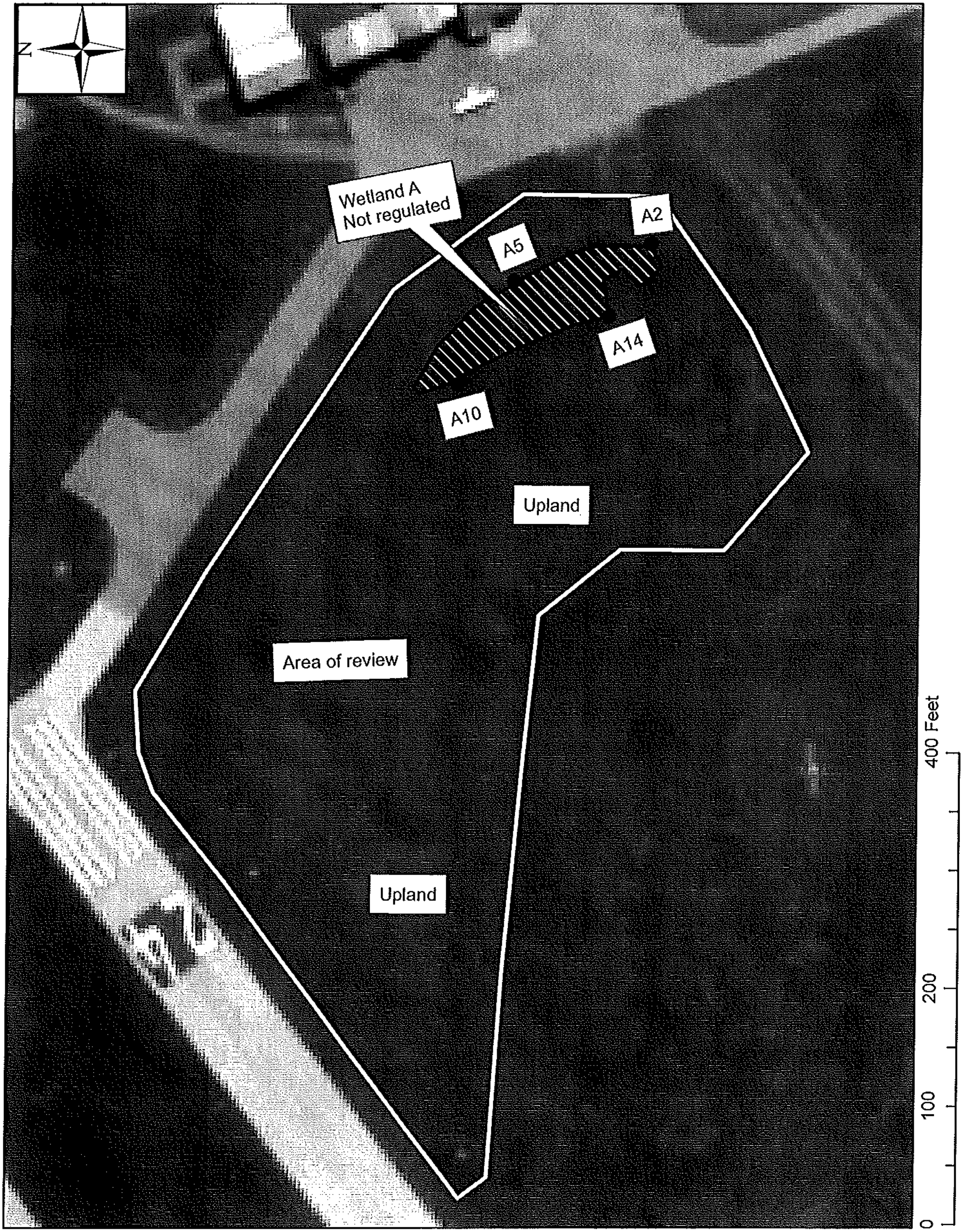
Michigan Dept. of Transportation
09-81-0001-WA



Site location map



Area of review in relation to the Ann Arbor Airport



Wetland A, the only wetland within the area of review, is not regulated.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

MDOT AERONAUTICS
MAY 25 2009
AIRPORTS DIVISION

MAY 20 2009

REPLY TO THE ATTENTION OF:
E-19J

Ms. Molly Lamrouex
Michigan Department of Transportation
Bureau of Aeronautics and Freight Services
2700 Port Lansing Road
Lansing, MI 48906

Re: Request for Early Coordination Review of Proposed Improvements for the Ann Arbor Municipal Airport, Washtenaw County, Michigan

Dear Ms. Lamrouex:

The NEPA Implementation Section has received you May 4, 2009 letter requesting information for the Ann Arbor Municipal Airport, Washtenaw County, Michigan. Under the National Environmental Policy Act (NEPA) and Section 309 of the Clean Air Act; U.S. EPA reviews and comments on major federal actions and other actions with environmental impacts when resources permit.

We understand the project will likely include a shift and extension of the primary runway and the parallel taxiway 950 feet to the southwest. Based on the information that you provided to us it is likely that the project will impact wetlands and forested areas.

As with any project, it is important to avoid impacts to wetlands and other natural resources. EPA and other resource agencies will assume that there are other alternatives that reduce environmental impacts, especially if the project is likely to adversely impact high quality wetlands and other natural resources. Therefore, we encourage you to thoroughly explain the project's purpose and need and rigorously explore alternatives that either do not affect or otherwise minimizes impacts to sensitive resources such as wetlands, floodplains, and streams.

Please provide us with information about this project as it progresses. Please contact Ms. Sherry Kamke at 312-353-5794 if you have any questions.

Sincerely,

Kenneth A. Westlake, Supervisor
NEPA Implementation
Office of Enforcement and Compliance Assurance

United States Department of Agriculture

NRCS

Helping People Help the Land

Natural Resources Conservation Service
7203 Jackson Road
Ann Arbor, MI 48103-9506
T (734) 761-6722 x3 F (734) 662-1686 www.mi.nrcs.usda.gov

September 3, 2009

Amy Eckland- Associate, JJR
110 Miller Avenue
Ann Arbor, MI 48104

RE: Ann Arbor Municipal Airport

Dear Eckland,

The Farmland Conversion Impact Rating form (AD-1006) for the proposed Ann Arbor Municipal Airport runway expansion is attached. The portions of the form to be filled out by NRCS are completed.

Some prime and farmland of local importance would be impacted by this project. If the project proceeds, I would urge you to utilize NRCS standards and specifications for conservation practices, as listed in the NRCS Electronic Field Office Technical Guide. This may be found at www.mi.nrcs.usda.gov.

Please don't hesitate contacting me if you have any questions.

Steve Olds
District Conservationist
USDA NRCS
Washtenaw and Wayne Counties

U.S. Department of Agriculture

FARMLAND CONVERSION IMPACT RATING

PART I *(To be completed by Federal Agency)*	Date Of Land Evaluation Request 9/1/09
Name Of Project Ann Arbor Municipal Airport	Federal Agency Involved Federal Aviation Administration
Proposed Land Use Airport	County And State Washtenaw County, Michigan
PART II *(To be completed by NRCS)*	Date Request Received By NRCS 9/1/09

Does the site contain prime, unique, statewide or local important farmland? *(If no, the FPPA does not apply -- do not complete additional parts of this form).*		Yes ☑	No ☐	Acres Irrigated 4181	Average Farm Size 179
Major Crop(s) corn, soybeans, wheat	Farmable Land In Govt. Jurisdiction Acres: %			Amount Of Farmland As Defined in FPPA Acres: 163,000 % 35	
Name Of Land Evaluation System Used LESA	Name Of Local Site Assessment System NA			Date Land Evaluation Returned By NRCS 9/3/09	

	Maximum Points	Site A	Site B	Site C	Site D
PART III *(To be completed by Federal Agency)*		Alternative Site Rating			
A. Total Acres To Be Converted Directly		18.0			
B. Total Acres To Be Converted Indirectly		0.0			
C. Total Acres In Site		18.0	0.0	0.0	0.0
PART IV *(To be completed by NRCS)* Land Evaluation Information					
A. Total Acres Prime And Unique Farmland		8.7			
B. Total Acres Statewide And Local Important Farmland		9.3			
C. Percentage Of Farmland In County Or Local Govt. Unit To Be Converted		0.01			
D. Percentage Of Farmland In Govt. Jurisdiction With Same Or Higher Relative Value		34.0			
PART V *(To be completed by NRCS)* Land Evaluation Criterion Relative Value Of Farmland To Be Converted *(Scale of 0 to 100 Points)*		84.2	0	0	0
PART VI *(To be completed by Federal Agency)* Site Assessment Criteria *(These criteria are explained in 7 CFR 658.5(b)*	Maximum Points				
1. Area In Nonurban Use	15	0			
2. Perimeter In Nonurban Use	10	0			
3. Percent Of Site Being Farmed	20	1			
4. Protection Provided By State And Local Government	20	20			
5. Distance From Urban Builtup Area	15	0			
6. Distance To Urban Support Services	15	0			
7. Size Of Present Farm Unit Compared To Average	10	10			
8. Creation Of Nonfarmable Farmland	10	0			
9. Availability Of Farm Support Services	5	5			
10. On-Farm Investments	20	5			
11. Effects Of Conversion On Farm Support Services	10	0			
12. Compatibility With Existing Agricultural Use	10	0			
TOTAL SITE ASSESSMENT POINTS	160	41	0	0	0
PART VII *(To be completed by Federal Agency)*					
Relative Value Of Farmland *(From Part V)*	100	84.2	0	0	0
Total Site Assessment *(From Part VI above or a local site assessment)*	160	41	0	0	0
TOTAL POINTS *(Total of above 2 lines)*	260	125	0	0	0

Site Selected:	Date Of Selection	Was A Local Site Assessment Used? Yes ☐ No ☐

Reason For Selection:

(See Instructions on reverse side)

This form was electronically produced by National Production Services Staff

Form AD-1006 (10-83)

Grading limits
Grading limits
Ann Arbor Municipal Airport
Airport Dr
Airport Dr
S State Rd
W Ellsworth Rd
Lohr Rd
Regents Park Ct
Waterways Dr
Technology Dr
Data Ct
Fairfield Ct
Avis Dr
Bridle Pass
Glen Dr

STATE OF MICHIGAN
DEPARTMENT OF HISTORY, ARTS AND LIBRARIES
LANSING

JENNIFER GRANHOLM
GOVERNOR

MARK HOFFMAN
ACTING DIRECTOR

RECEIVED
OCT 27 2009
FAA. DETROIT ADO

October 20, 2009

BRAD DAVIDSON
FEDERAL AVIATION ADMINISTRATION
DETROIT AIRPORTS DISTRICT OFFICE
11677 SOUTH WAYNE ROAD SUITE 107
ROMULUS MI 48174

RE: ER-5410 Ann Arbor Municipal Airport – Runway Extension, Section 17, T3S, R6E, Pittsfield Township, Washtenaw County (FAA)

Dear Mr. Davidson:

Under the authority of Section 106 of the National Historic Preservation Act of 1966, as amended, we have reviewed the above-cited undertaking at the location noted above. Based on the information provided for our review, it is the opinion of the State Historic Preservation Officer (SHPO) that **no historic properties are affected** within the area of potential effects of this undertaking.

The views of the public are essential to informed decision making in the Section 106 process. Federal Agency Officials or their delegated authorities must plan to involve the public in a manner that reflects the nature and complexity of the undertaking, its effects on historic properties and other provisions per 36 CFR § 800.2(d). We remind you that Federal Agency Officials or their delegated authorities are required to consult with the appropriate Indian tribe and/or Tribal Historic Preservation Officer (THPO) when the undertaking may occur on or affect any historic properties on tribal lands. **In all cases**, whether the project occurs on tribal lands or not, Federal Agency Officials or their delegated authorities are also required to make a reasonable and good faith effort to identify any Indian tribes or Native Hawaiian organizations that might attach religious and cultural significance to historic properties in the area of potential effects and invite them to be consulting parties per 36 CFR § 800.2(c-f).

This letter evidences the FAA's compliance with 36 CFR § 800.4 "Identification of historic properties", and the fulfillment of the FAA's responsibility to notify the SHPO, as a consulting party in the Section 106 process, under 36 CFR § 800.4(d)(1) "No historic properties affected".

The State Historic Preservation Office is not the office of record for this undertaking. You are therefore asked to maintain a copy of this letter with your environmental review record for this undertaking. If the scope of work changes in any way, or if artifacts or bones are discovered, please notify this office immediately.

If you have any questions, please contact Brian Grennell, Environmental Review Specialist, at (517) 335-2721 or by email at ER@michigan.gov. **Please reference our project number in all communication with this office regarding this undertaking.** Thank you for this opportunity to review and comment, and for your cooperation.

Sincerely,

Martha MacFarlane Faes
Environmental Review Coordinator

for Brian D. Conway
State Historic Preservation Officer

MMF: JRH: BGG: kam

Copy: Kent Taylor, CCRG

STATE HISTORIC PRESERVATION OFFICE, MICHIGAN HISTORICAL CENTER
702 WEST KALAMAZOO STREET • P.O. BOX 30740 • LANSING, MICHIGAN 48909-8240
(517) 373-1630
www.michigan.gov/hal

From: "Esther Helms" <EHelms@sagchip.org>
To: LamrouexM@michigan.gov
Date: 5/19/2009 9:38:42AM
Subject: Section 17 Washtenaw County, Early Coordination Review of Proposed Improvements, Ann Arbor Municipal Airport, Washtenaw County, MI

May 19, 2009

Molly Lamrouex

Environmental Liaison

MDOT-Aeronautics and Freight Services

RE: Section 17 Washtenaw County, Early Coordination Review of Proposed Improvements, Ann Arbor Municipal Airport, Washtenaw County, MI

Dear Ms. Lamrouex;

This letter is in response to the above referenced project.

At this time we do not have any information concerning the presence of any Indian Traditional Cultural Properties, Sacred Sites or other Significant Properties to the projected project area(s). This is not to say that such a site may not exist, just that this office does not have any available information of the area(s) at this time.

This office would be willing to assist if in the future or during the construction there is an inadvertent discovery of Native American human remains or burial objects. Feel free to call my office if you have any questions or requests at 989-775-4730.

We thank you for including this Tribe in your plans.

Sincerely,

William Johnson /elh

Curator

Ziibiwing Center of Anishinabe Culture & Lifeways

Saginaw Chippewa Indian Tribe of Michigan

Little Traverse Bay Bands of Odawa Indians
Archives, Records and Cultural Preservation Department
7500 Odawa Circle, Harbor Springs, Michigan 49740
(231) 242-1450 phone (231) 242-1455 fax

May 7, 2009

Ms. Molly Lamrouex
MDOT
Bureau of Aeronautics and Freight Services
Airports Division
2700 Port Lansing Rd.
Lansing, MI 48906-2160

Re: Proposed Improvement Ann Arbor Municipal Airport, Washtenaw County, MI

Dear Ms. Lamrouex:

At this time, we do not have any information concerning the presence of any Indian Traditional Cultural Properties, Sacred Sites, or Other Significant Properties in the designated area of the proposed construction site in Ann Arbor, MI. This is not to say that such site does not exist, just this office does not have any available information indicating that a site is present using our current documentation of the area. If contact could be made with the closest tribe, that being the Huron Band of Potawatomi Indians, they could possibly provide more information.

However, this office would be more then willing to assist, if in the future or during construction, there is an inadvertent discovery of Native American human remains or burial objects. I have enclosed a Site Reference Form that our office uses in the event of a discovery in order to speed the process. Please contact me if you have any further question or requests. I can be reached at (231)242-1453.

We thank you for including our tribe in your plans.

Miigwetch (thank you)

Winnay Wemigwase

Winnay Wemigwase
Director
Archives/Records and Cultural Preservation
Little Traverse Bay Band of Odawa Indians

Site Reference Form

Date of Discovery:____________________ Today's Date:__________________

Owner/Site Representative:____
Street Address: ____
City: __________________________State:________________________Zip:___________
Location: ____
Phone:_____________________________________Fax:____________________________

Site Information:
Street Address:____
City:____________________________State:________________________Zip:__________

Location and Circumstance of Discovery: Time of Discovery:________am/pm

____
____
____
____

Contacts Made:
Law Enforcement Department:____
Investigating Officer:____
Phone:____________________________________Fax:_____________________________
Date of police report:___________________Time on report:_________________am/pm

Other contacts (w/phone #):

____
____

Native American Burial (please circle) yes_______ no_______
Confirmed by:________________________ Phone:__________________Fax:_________________
Release Status:____

Little Traverse Bay Bands of Odawa Indians Tribal NAGPRA Contacts:

Eric Hemenway
Research & Repatriation Assistant
(231) 242-1527ph/ ehemenway@ltbbodawa-nsn.gov

Winnay Wemigwase
Director, Archives/Records &Cultural Preservation
(231) 242-1453ph/ wwemigwase@ltbbodawa-nsn.gov

7500 Odawa Circle, Harbor Springs, Michigan 49740

Appendix E. Field Observation Report

(June 2009)

FIELD OBSERVATION REPORT

Ann Arbor Airport, Ann Arbor, MI	6-10-09	6-19-09
SITE LOCATION	DATE	ISSUE DATE
Ann Arbor Airport Runway Expansion	50178.000	
PROJECT NAME	PROJECT NUMBER	
Carol Schulte	None	
ISSUED BY	SIGNATURE	

PARTICIPANTS	COMPANY
Carol Schulte	JJR
Tom Lee	Ann Arbor Airport

The Ann Arbor Airport was visited to investigate presence of wetlands, wildlife habitat, threatened or endangered species, and general plant communities within the limits of grading of proposed expansion areas. The site is located south of Ellsworth Road, west of State Street in Ann Arbor, MI, Washtenaw County. Tom Lee of the Airport accompanied Carol to unlock gates and allow access to the site. Pictures were taken of the site and are available for reference. Figure 1 is attached that shows airport layout as well as pertinent areas referenced in this report.

The weather during the site visit was mostly cloudy and in the high 60's.

Most of the soil south of the runway consists of Palms muck, a hydric soil. These areas contain either unmown grassy meadows or are being farmed in corn. South of the cropped area is a large forested wetland complex that was not investigated at this time. The area northwest of the runway consists of Fox and Matherton sandy loam soils and is very rocky. This area is also being farmed in corn by the same farmer.

The first area reviewed was at the east end of Runway 24 where the runway is proposed to shift southwest approximately 150'. Tom stated that generally the airport mows approximately 100' from the runway, but in this area it may be less than that because of a pledge to the local Audobon Society to keep some areas unmown for nesting meadow birds. This area was a mix of mostly wetland species and scattered upland species, including: plots of reed canary grass (*Phalaris arundinacea*), half a dozen (+/-) sedge (*Carex granularis*) plants, a few swamp milkweed (*Asclepias incarnata*), dandelion (*Taraxicum officinale*), sowthistle species (*Sonchus* sp.), buckthorn (*Rhamnus cathartica*), curly dock (*Rumex crispus*), and either goldenrod or aster species (*Solidago* or *Aster* sp.).

A County drain runs north-south on the west side of the property, then makes a turn at the end of the runway to run toward the east. The ditch is open except at the end of the runway, where it runs underground in an L-shaped culvert. The sides of the ditch on the west side are steep are approximately 6' +/- deep, but the ditch was dry in this area with only small areas of standing water on the south side. The south side ditch does not appear to have been maintained and the ditch itself is almost undefined in some areas. The standing water was tinted blue, although it was not determined what caused the tinting. The sides of the ditches contained upland weedy herbaceous species such as sweet clover (*Melilotus officinalis*), smooth brome (*Bromus inermis*), giant ragweed (*Ambrosia trifida*), Virginia creeper (*Parthenocissus quinquefolia*), lamb's quarters (*Chenopodium album*), riverbank grape (*Vitis riparia*), dame's rocket (*Hesperis matronalis*), teasel (*Dipsacus fullonum*), cow parsnip (*Heracleum maximum*), yellow goatsbeard (*Tragopogon pratensis*), yarrow (*Achillea* *millifolium*), a few reed canary grass, wheat or rye (*Triticum* or *Secale* spp), and mixed upland and wetland trees such as American elm (*Ulmus americana*), box elder (*Acer negundo*), staghorn sumac (*Rhus typhina*), Russian olive (*Eleagnus angustifolia*),buckthorn (*Rhamnus catharticus*) cottonwood (*Populus deltoides*), bur oak (*Quercus macrocarpa*), and American linden (*Tilia americana*).

The area at the end of the runway where proposed expansion will occur was investigated. This area is kept mowed and the dominant plants in this area consisted of old field weeds and grassy species, with disturbed areas of bare dirt. Plants include rough-fruited cinquefoil (*Potentilla recta*), Canada thistle (*Circium arvense*), and an unidentified grass.

Near the weather station northwest of the end of the existing runway is a gravel borrow pit, excavated, according to Tom, for a foundation for the north hangars. While this area is artificially low and the dominant tree is a large multi-trunked willow (Salix sp.), the area is not considered a wetland. The ground plain is covered with mostly burdock (*Arctium minus*) with a few dame's rocket garlic mustard (*Alliaria petiolata*), along with buckthorn, box elder, smooth brome, and one poison hemlock plant (*Conium maculatum*). Concrete rubble and other wood debris has been dumped in the low area. In an adjacent area that is higher in elevation than the borrow pit and could be a leftover spoil pile, the area is dominated by poison hemlock and stinging nettle (*Urtica dioica*), a dead ash (*Fraxinus pennsylvanica*), and several black walnuts (*Juglens nigra*).

Several examples of wildlife were observed during the short field visit; there was evidence of rodent tunneling (field mice or voles) in last year's duff at the take-off zone for Runway 24 (see Photo 2). Pheasants (*Phasianus colchicus*) were heard calling just west of the site and later in the southern portion of the site. Robins (*Turdus migratorius*), goldfinch (*Carduelis tistis*), purple martins (*Progyne subis*), and killdeer (*Charadrius viciferus*) were observed, and a mating pair of redtail hawks (*Buteo jamaicensis*) were seen flying out of the bur oak near the end of the runway. Tom stated that a pack of coyote (*Canis latrans*) have been observed on the airport property as well as wild turkeys (*Meleagris gallopavo*).

There are no regulated wetlands on the site. Although the roughly 1000 square foot area near the runway take-off zone is dominated by wetland plants and contains hydric soils, the MDEQ would likely decline jurisdiction because it is further than 500 feet from an inland lake, river, or stream, is less than 5 acres in size, and there is no surface connection with other wetlands in the area.

No threatened or endangered species or special wildlife habitat were found at the proposed impact sites.

Photo 1. Plots of reed canary grass near east end of Runway 24. 6-10-09.

Photo 2. Evidence of rodent tunneling near east end of Runway 24.
6-10-09.

Photo 3. Drainage ditch on west end of project site where ditch goes into culvert. 6-10-09.

Photos 4 and 5. Drainage ditch on south end of project where it emerges from culvert. 6-10-09.

Photo 6. Gravel borrow pit near weather station. 6-10-09.

P:/50178/000/Admin/Proj Mgmt/field reports/Field Report 6-10-09.docx

cc:

Appendix F. Audubon Society Bird Species Observed List

Breeding Bird Survey - Airport Fields
Maximum Breeding Status by Year

City of Ann Arbor, Natural Area Preservation

	Common Name	Status	2006	2007	2008
	Mallard	1	0	0	1
	Great Blue Heron	1	0	0	1
	Upland Sandpiper	1	1	1	0
	Killdeer	2	2	2	2
	Ring-necked Pheasant	2	0	0	2
	Rock Pigeon	2	2	0	0
	Mourning Dove	2	2	2	2
	Red-tailed Hawk	1	0	0	1
	American Kestrel	2	1	0	2
	N. Flicker	1	0	1	1
	Eastern Kingbird	1	0	0	1
	Willow Flycatcher	2	0	0	2
	Horned Lark	2	2	2	0
	Blue Jay	1	0	0	1
	American Crow	1	0	0	1
	European Starling	3	0	0	3
	Bobolink	3	0	3	3
	Brown-headed Cowbird	2	0	0	2
	Red-winged Blackbird	3	3	0	3
	Eastern Meadowlark	3	3	3	3
	American Goldfinch	2	0	2	2
	Savannah Sparrow	3	3	3	2
SC	Grasshopper Sparrow	2	0	0	2
T	Henslows Sparrow	2	0	2	0
	Song Sparrow	2	2	0	2
	N. Cardinal	2	2	0	0
	Rose-breasted Grosbeak	2	1	0	2
	Indigo Bunting	2	0	0	2

		Status	2006	2007	2008
	Cliff Swallow	1	0	1	0
	Barn Swallow	2	0	2	2
	Tree Swallow	1	0	0	1
	Red-eyed Vireo	1	0	0	1
	Warbling Vireo	1	0	0	1
	Yellow Warbler	2	2	0	2
	Common Yellowthroat	2	0	1	2
	Gray Catbird	2	0	0	2
	Wood Thrush	1	0	1	0
	American Robin	2	2	2	2

Total Number of Species **38** 14 15 31

SC = special concern T = threatened E = endangered **Status:** 1 = observed only 2 = probable breeding 3 = confirmed breeding

Appendix G. Citizens Advisory Council Member List

Citizens Advisory Committee

Ann Arbor Municipal Airport Environmental Assessment

Name	Representing
Matt Kulhanek, Manager	Ann Arbor Municipal Airport
Mark Perry	AA Airport Advisory Committee
Kristine Martin	5th Ward Resident
Ray Hunter	4th Ward Resident
Jack Moghadam	3rd Ward Resident
Tony Derezinski	2nd Ward Resident
Jad Donaldson	Pilot-Avfuel
Ray Stocking	Washtenaw Audubon Society
David Schrader	FAA Safety Team
Shlomo Castell	Stonebridge Community Association
Jan Godek, Supervisor	Lodi Township
Barb Fuller, Deputy Supervisor	Pittsfield Township
Kristin Judge	Washtenaw County Commissioner, 7th District

Appendix H. Public Notices

H-1. Press Release, City of Ann Arbor
April 20, 2009

H-2. FAA Notice of Intent, Federal Register
June 17, 2009

CITY OF ANN ARBOR, MICHIGAN
100 North Fifth Ave. P.O. Box 8647
Ann Arbor, Michigan 48104-8647
www.a2gov.org

PRESS RELEASE

For Immediate Release

CONTACT: Matt Kulhanek,
Fleet and Facility Manager, (734)794-6312,
mjkulhanek@a2gov.org, or
Amy Eckland, JJR, (734) 669-2687,
amy.eckland@jjr-us.com

ANN ARBOR AIRPORT LAUNCHES ENVIRONMENTAL ASSESSMENT PLANNING EFFORT

ANN ARBOR, Mich., April 20, 2009 — The City of Ann Arbor is initiating the preparation of an Environmental Assessment (EA) to determine the potential impacts of lengthening the primary runway at the Ann Arbor Airport at 801 Airport Drive from 3,500' to 4,300' and a shift of the runway 150' to the southwest. The assessment results will determine potential impacts to noise levels, air quality, water quality, wetlands, floodplains, plant and wildlife, light emissions, historical and cultural resources, social, and socioeconomic factors. No runway changes will be approved until this environmental clearance process is completed.

A 12 member volunteer Citizen Advisory Council (CAC) will kick-off a series of meetings in early May as part of the assessment team. The CAC members will serve as representatives for area residents, pilots, and local municipalities. The CAC will assist with the review and discussion of the airport studies. Interested members of the public also may follow the status of the airport study via online newsletter updates, press releases, meeting notices, and by attending the public hearing. To help address questions related to the process and the potential runway improvement, two Frequently Asked Questions (FAQ) handouts have been posted on the city's airport web page. The condensed FAQ version is geared more toward non-aviation individuals. The technical FAQ version is longer and contains more detail including the specific references to various aviation regulations and practices. To sign up for periodic updates on this project, visit the airport page on the city's Web site, www.a2gov.org: select "Airport" from the "Government" drop-down menu, and then click the red envelope to subscribe.

The EA is expected to take approximately eight months to complete. The scope of the EA is defined by state and federal regulations and, upon completion, must be approved by the Michigan Department of Transportation – Bureau of Aeronautics (MDOT-Aero) and the Federal Aviation Administration. A public hearing on the findings of the EA is required by law. Public comments received will be made part of the final EA document.

The overall project consists of completing an EA documenting the potential impacts related to an 800' runway safety extension and a shift of the runway 150' to the southwest. These modifications were depicted on the Airport Layout Plan approved by city council in September 2008. The full scope of the EA will be completed by two consulting firms, JJR and URS Corporation Great Lakes. JJR, through their Ann Arbor office, will be the lead consulting firm for the EA, including the public involvement and coordination. URS Corporation, the airport's design engineer, will be preparing preliminary engineering on the runway extension and completing other technical tasks in support of the EA and JJR.

Ann Arbor has 114,000 residents, spans 27.7 square miles, and was named the No. 1 Healthiest Hometown in the U.S. by AARP The Magazine *in 2008. Other notable recognitions include: No. 27 of the top 100 U.S. cities to live in by* CNN/Money Magazine *in 2008, as well as the fourth smartest city in the U.S. by* Forbes Magazine. *The city's mission statement reads: The city of Ann Arbor is committed to providing excellent municipal services that enhance the quality of life for all through the intelligent use of resources while valuing an open environment that fosters, fair, sensitive and respectful treatment of all employees and the community we serve.*

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car owners relative to identification marks on railroad equipment. FRA, railroads, and the public refer to the stenciling to identify freight cars.

Annual Estimated Burden Hours: 18,750 hours.

Title: Rear-End Marking Devices.

OMB Control Number: 2130–0523.

Type of Request: Extension of a currently approved collection.

Affected Public: Railroads.

Abstract: The collection of information is set forth under 49 CFR Part 221 which requires railroads to furnish a detailed description of the type of marking device to be used for the trailing end of rear cars in order to ensure rear cars meet minimum standards for visibility and display. Railroads are required to furnish a certification that the device has been tested in accordance with current "Guidelines For Testing of Rear End Marking Devices." Additionally, railroads are required to furnish detailed test records which include the testing organizations, description of tests, number of samples tested, and the test results in order to demonstrate compliance with the performance standard.

Annual Estimated Burden Hours: 89 hours.

Title: Locomotive Certification (Noise Compliance Regulations).

OMB Control Number: 2130–0527.

Type of Request: Extension of a currently approved collection.

Affected Public: Railroads.

Abstract: Part 210 of title 49 of the United States Code of Federal Regulations (CFR) pertains to FRA's noise enforcement procedures which encompass rail yard noise source standards published by the Environmental Protection Agency (EPA). EPA has the authority to set these standards under the Noise Control Act of 1972. The information collected by FRA under Part 210 is necessary to ensure compliance with EPA noise standards for new locomotives.

Annual Estimated Burden Hours: 2,767 hours.

ADDRESSES: Send comments regarding these information collections to the Office of Information and Regulatory Affairs, Office of Management and Budget, 725 Seventeenth Street, NW., Washington, DC, 20503, *Attention:* FRA Desk Officer. Alternatively, comments may be sent via e-mail to the Office of Information and Regulatory Affairs (OIRA), Office of Management and Budget, at the following address: *oira_submissions@omb.eop.gov.*

Comments are invited on the following: Whether the proposed collections of information are necessary for the proper performance of the functions of the Department, including whether the information will have practical utility; the accuracy of the Department's estimates of the burden of the proposed information collections; ways to enhance the quality, utility, and clarity of the information to be collected; and ways to minimize the burden of the collections of information on respondents, including the use of automated collection techniques or other forms of information technology.

A comment to OMB is best assured of having its full effect if OMB receives it within 30 days of publication of this notice in the **Federal Register**.

Authority: 44 U.S.C. 3501–3520.

Issued in Washington, DC, on June 11, 2009.

Donna M. Alwine,

Acting Director, Office of Financial Management, Federal Railroad Administration.

[FR Doc. E9–14254 Filed 6–16–09; 8:45 am]

BILLING CODE 4910–06–P

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

FAA Notice of Intent to Prepare an Environmental Assessment; Ann Arbor Municipal Airport, Ann Arbor, MI

AGENCY: The Federal Aviation Administration, Department of Transportation.

ACTION: Notice of Intent to prepare an Environmental Assessment (EA) and conduct Citizen Advisory Meetings.

SUMMARY: The FAA has delegated selected responsibilities for compliance with the National Environmental Policy Act to the MDOT as part of the State Block Grant Program authorized under Title 49 U.S.C., Section 47128. This notice is to advise the public pursuant to the National Environmental Policy Act of 1969, as amended, (NEPA) 42 U.S.C. 4332(2)(c) that MDOT intends to prepare an EA for the proposed extension of runway 6/24 at the Ann Arbor Municipal Airport. While not required for an EA, the FAA and MDOT are issuing this Notice of Intent to facilitate public involvement. This EA will assess the potential environmental impacts resulting from the proposed extension of runway 6/24 from 3,500 feet to 4,300 feet. All reasonable alternatives will be considered including a no action alternative.

FOR FURTHER INFORMATION CONTACT: Ms. Molly Lamrouex, Environmental Specialist, Bureau of Aeronautics and Freight Services, MDOT, 2700 Port Lansing Road, Lansing, Michigan (517) 335–9866.

SUPPLEMENTARY INFORMATION: The EA will include analysis which will be used to evaluate the potential environmental impacts in the study area. During scoping, and upon publication of a draft EA and a final EA, MDOT will be coordinating with federal, state and local agencies, as well as the public, to obtain comments and suggestions regarding the EA for the proposed project. The EA will assess potential impacts and reasonable alternatives including a no action alternative pursuant to NEPA; FAA Order 1050.1E, Policies and Procedures for Considering Environmental Impacts; FAA Order 5050.4B, National Environmental Policy Act (NEPA) Implementing Instructions for Airport Actions; and the President's Council on Environmental Quality (CEQ) Regulations implementing the provisions of NEPA, and other appropriate Agency guidance.

Public Input Process: During development of the draft EA, a series of meetings to provide for public input will be held to identify potentially significant issues or impacts related to the proposed action that should be analyzed in the EA. For more information regarding the meetings for public input contact Molly Lamrouex, MDOT Bureau of Aeronautics and Freight Services, (517) 335–9866.

Issued in Romulus, Michigan, June 4, 2009.

Matthew J. Thys,

Manager, Detroit Airports District Office, Great Lakes Region.

[FR Doc. E9–14167 Filed 6–16–09; 8:45 am]

BILLING CODE 4910–13–P

DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

Petition for Exemption From the Vehicle Theft Prevention Standard; Nissan

AGENCY: National Highway Traffic Safety Administration (NHTSA) Department of Transportation (DOT).

ACTION: Grant of petition for exemption.

SUMMARY: This document grants in full the Nissan North America, Inc.'s (Nissan) petition for an exemption of the Murano vehicle line in accordance with 49 CFR Part 543, *Exemption from the Theft Prevention Standard.* This petition is granted because the agency has determined that the antitheft device to be placed on the line as standard equipment is likely to be as effective in

Exhibit 27

SUPPLEMENTAL REPORT
AIRPORT USER SURVEY

ANN ARBOR MUNICIPAL AIRPORT (ARB)
ANN ARBOR, MICHIGAN

December 2009

This Supplemental Report is associated with the original Airport User Survey Report for Ann Arbor Municipal Airport (ARB), dated July 2009. The information contained in this supplement provides additional details and updates to the information contained in the original report.

Additional analysis of the aircraft operational data has resulted in the generation of supplemental information, three new exhibits, and updates to the numbers of annual operations performed by category B-II critical aircraft. The following paragraphs explain in detail the information provided in the new exhibits, as well as the supplemental information and updates to the operational numbers listed in the original user survey report.

EXHIBIT No. 1: *Annual Operations Analysis by Specific Aircraft Model*

This exhibit shows annual operations at ARB by specific aircraft model, rather than only by their FAA aircraft classification as shown in the original user survey report. The various aircraft models are listed in three separate tables, based upon groupings of their FAA classifications (B-II, C-I, and C-II).

Supplemental data associated with annual operations by the Beechcraft King Air C90 has been included in the B-II category table of this exhibit. Operations by this particular model of aircraft were not included in the original July 2009 Airport User Survey Report.

EXHIBIT No. 2: *Origin / Destination Analysis by State*

Exhibit No. 2 shows the results of an origin and destination analysis of aircraft operations conducted at ARB, based on examination of the FlightAware database from survey year 2007. Although 274 of the operations had aircraft model and ownership information blocked from the database at the aircraft owner's request, the origin and destination cities of each flight were still included.

The first column of the table shown in this exhibit lists 31 states (and Washington DC) from which operations into ARB originated, or operations out of ARB were going to as a destination. The second column lists operations attributed to each state by the 274 total operations with blocked aircraft and ownership records. The third and fourth columns list operations attributed to each state by B-II Small and B-II Large category aircraft. The last column lists the total number of operations attributed to each state.

The numbers of operations associated with each state are from the FlightAware Instrument Flight Rule (IFR) flight plan database only, and do not include records of all itinerant operations between ARB and other states. Nonetheless, the numbers shown in this exhibit confirm that in 2007, flight operations were conducted between ARB and at least 31 other states (approximately 63% of the continental US). Also, approximately 67% of the IFR flight records for the category B-II critical aircraft were between ARB and out-of-state locations. These factors confirm that there is a significant amount of flight operations being conducted at ARB that are either going to, or coming from, distant locations in other states.

EXHIBIT No. 3: *Small 10-Seat Aircraft Analysis*

The table in this exhibit lists *Small* aircraft models (less than or equal to 12,500 lbs. maximum certificated takeoff weight) that have 10 or more passenger seats, and that conducted operations at ARB in survey year 2007. The numbers of annual operations listed in the table are from the FlightAware IFR flight plan database only, and do not include records of all operations by aircraft of this type. The FlightAware records show that there were 425 annual operations by Small 10-seat or higher aircraft.

Exhibit No. 3 also shows that there were 211 annual operations by *Large* category (greater than 12,500 lbs. maximum certificated takeoff weight) B-II aircraft from the Based Aircraft data source and another 85 annual operations by Large category B-II aircraft from the FlightAware data source. The number of annual operations performed by the Small 10-seat or higher aircraft and the Large category aircraft combined is shown as 721.

The operational numbers listed in Exhibit No. 3 do not include blocked FlightAware operations, Visual Flight Rule (VFR) operations, or operations logged by pilots on the Fixed Base Operator (FBO) airport registers. Although the information shown is only a partial representation of all applicable aircraft, the 721 annual operations that were substantiated significantly confirm that Figure 2-2 in FAA Advisory Circular 150/5325-4B is the appropriate chart to reference in the determination of the FAA-recommended runway length of 4,200 feet at ARB.

UPDATED BASED AIRCRAFT ANALYSIS:

The Based Aircraft Analysis of the original user survey report listed 200 estimated annual operations by AvFuel's B-II Large category aircraft (see page 3 of the original report). AvFuel's Chief Pilot has since confirmed in writing that the actual number of operations by their Cessna Citation XL 560 aircraft at ARB over the past three calendar years has been 224 operations in 2006, 211 operations in 2007, and 223 operations in 2008.

In order to maintain consistency with the other survey year 2007 operational records analyzed, Exhibit No. 1 of this Supplemental Report shows the 211 actual annual operations by this aircraft in the "Based Aircraft Data Source" column of the category B-II table, instead of the original estimate of 200.

UPDATED ITINERANT AIRCRAFT ANALYSIS: (FBO Data Sources)

Itinerant (visiting) aircraft operational data that was evaluated as part of the original user survey analysis was obtained from the pilot registration logs (airport registers) of two of the airport's FBOs - Solo Aviation and Ann Arbor Aviation Center. Data was examined for a six-month survey time frame, and cross-checked against FlightAware records in order to prevent counting the same aircraft twice. Any operations that were already included in the FlightAware records were not included in the operational totals that were generated from the FBO records.

The FBO records provided 40 additional operations by B-II and greater category aircraft (32 by category B-II aircraft, 6 by category C-I aircraft, and 2 by category C-II aircraft). Since this data was based on a six-month time frame instead of the full calendar year 2007, these 40 actual operations were prorated into an estimated equivalent annual rate of 80 operations. The additional 40 estimated operations were the only operations in the original user survey analysis that were obtained by prorating actual partial-year data into an estimated equivalent annual rate.

As part of the supplemental analysis, estimated operations that were originally generated as a result of prorating partial-year data were not considered in the determination of the annual operations at ARB. This eliminates the potential effect of seasonal variation in flight activity levels negatively influencing annual operational estimates. Only the 40 actual operations that were documented by the FBOs as having occurred within the six-month survey period were counted as valid operations, since they did in fact occur in 2007. No operations were attributed to the remaining six months.

Exhibit No. 1 of this supplemental report shows only the 40 actual documented operations (32 by category B-II aircraft, 6 by category C-I aircraft, and 2 by category C-II aircraft) in the column that is labeled "2 FBO Register Data Sources".

UPDATED FLIGHTAWARE DATABASE ANALYSIS:

The FlightAware database analysis that was performed for the original July 2009 Airport User Survey Report resulted in the determination of 265 actual annual operations by B-II Small aircraft, and another 85 actual annual operations by B-II Large aircraft (see page 6 of the original report). However, the resulting numbers did not include operations by the Beechcraft King Air C90 model.

The King Air C90 is a B-II Small category aircraft, with a wingspan of 50'3". Earlier versions of the King Air 90 models (A90 and B90) have wingspans of less than 49', and are therefore category B-I Small aircraft. Since the FlightAware records that were originally analyzed for ARB did not include information which identified the specific model of each King Air 90 operation, no operations by King Air 90s were included in the original user survey analysis and report.

Although the FlightAware records do not provide information regarding the specific model of each King Air 90 operation listed, they do provide the aircraft registration N-number of each aircraft. By entering the N-number into the computerized FAA aircraft registration database, the specific model of each King Air 90 operation was able to be determined. A total of 157 operations by the B-II Small category King Air C90 model have been identified, out of 220 operations by King Air 90 models of all types.

Exhibit No. 1 of this supplemental report shows the 157 King Air C90 operations included in the "Flight Aware Data Source" column of the category B-II table. By adding these operations to the 265 operations by B-II Small aircraft and 85 operations by B-II Large aircraft that were previously identified in the original user survey report, the updated total number of actual annual operations by B-II category aircraft obtained from the FlightAware data source is 507.

The FlightAware database also confirmed usage of the airport by many large corporations, in addition to AvFuel, which is the only one actually based at ARB. Some of the other corporate users of ARB include Synergy International, Wells Fargo, Polaris Industries, Bombardier Aerospace, Avis Industrial Corporation, Thumb Energy, and NetJets. NetJets provides on-demand air charter services and corporate aircraft fractional ownership opportunities to a large number of other corporations that are located throughout the country.

AIRCRAFT OPERATIONAL FORECASTS:

Year 2007 was the onset year of the current planning activities associated with the potential extension of Runway 6/24. At that time, the airport manager and FBOs were requested to collect based and itinerant aircraft operational data over the course of year 2007 for the purpose of determining project justification. This data was reviewed during the user survey analysis, which was conducted in early 2009.

FlightAware records for any given year are not published until that particular calendar year has ended, and all operations that took place during the course of that year counted. Since the user survey analysis was conducted in early 2009, the most current operational records available at the time from FlightAware were associated with calendar year 2008. Although year 2008 records were available, year 2007 records from FlightAware were used in the user survey analytical process. This was due to the importance of maintaining consistency of year of operational records in the analysis, and not combining operational data collected by the airport manager and FBOs over year 2007 with the more recent FlightAware records from year 2008. The FlightAware records, airport manager records, and FBO records from calendar year 2007 that were used in the user survey analysis were all only one-year old at the time, and still considered valid for use in determining project justification.

The FAA Terminal Area Forecast (TAF) does project a short-term approximate 22% decrease in total annual operations at ARB from user survey year 2007 through year 2009 (from 72,895 actual in 2007 to 56,956 estimated for 2009). However, beginning in year 2010, the TAF projects continuously increasing annual operations at ARB, from the year 2009 low-point through year 2030. Itinerant annual operations are even projected to surpass survey year 2007 levels prior to the end of the 2030 forecast period.

Even if the worst case short-term projected 22% decrease in total annual operations is applied to the user survey results, there is still significant justification for the runway extension. The user survey report documents a total of 750 actual annual operations by B-II category critical aircraft that justify the runway extension. A 22% decrease in this number is 585 - still well above the FAA's substantial use threshold of 500. And again, beginning in 2010, operations at ARB are projected by the FAA to begin increasing every single year from that point forward, through year 2030.

Forecasts from the MDOT Michigan Airport System Plan (MASP 2008) also project increasing itinerant and total operations at ARB from years 2010 through 2030. The MDOT forecasts further substantiate the mid-term and long-term FAA projections of a rebound in current operational activity at ARB to survey year 2007 levels.

AvFuel Corporation, which bases a B-II Large category Citation 560 Excel jet at ARB, has confirmed that their operations at ARB actually increased from 211 operations in 2007 to 223 operations in 2008. Their Chief Pilot estimates that their future operational levels could potentially increase to 350 to 450 operations per year at ARB.

The FAA TAF forecast, MDOT MASP forecast, and AvFuel's operational forecasts all provide support to the fact that survey year 2007 operational data is a very pertinent representation of estimated future operational levels at ARB.

SUMMARY:

The supplemental analysis that was conducted after publication of the July 2009 Airport User Survey Report has resulted in additional justification in support of extension of Runway 6/24 to 4,300' in length.

Further analysis of the FlightAware IFR flight plan database has confirmed 507 actual operations at ARB in survey year 2007 by B-II category aircraft. This number does not include operations in the FlightAware records with aircraft information blocked at the owner's request, or VFR operations that were conducted without flight plans. Judging by the high number of out-of-state origin and destination locations of operations listed in the blocked category (see Exhibit No. 2), it is very likely that many of the associated aircraft were of the B-II or greater categories. Therefore, actual operations at ARB by aircraft of these categories are likely considerably higher than the 507 substantiated operations obtained from the FlightAware database.

The 507 actual operations by B-II category aircraft that were obtained from the FlightAware database also do not include operations conducted by AvFuel's based Cessna Citation XL 560, or operations obtained from the two FBO airport registers. AvFuel has confirmed 211 actual operations at ARB in 2007 with their B-II category aircraft, and data provided by the FBOs has confirmed 32 actual operations in 2007 by B-II category aircraft.

In summary, the supplemental analysis of this user survey has confirmed a total of 750 actual annual operations at ARB by category B-II aircraft. FlightAware records also confirmed that operations by aircraft in this critical aircraft category were performed by many large corporations, some of which are listed on page 4 of this report.

CONCLUSION:

In the majority of airport user survey processes, determinations and recommendations are issued based on analysis of estimated annual operations obtained from various airport users. In conducting the user survey at ARB, the analysis focused on evaluation of actual annual operations performed at the airport. This is obviously a much more accurate method of calculating the total number of annual operations associated with the determination of the critical aircraft and Airport Reference Code. It also eliminates the possibility of an airport user inflating their estimated operational numbers, in the hopes of obtaining a longer runway that is not truly justified.

While the numbers listed in this report do not include every operation that occurred at ARB in survey year 2007 with B-II category aircraft, they do confirm substantial usage of the airport by aircraft of this critical aircraft category. The Origin/Destination Analysis has shown a significant number of operations between ARB and distant out-of-state locations, which is a very good indicator of corporate activity associated with interstate commerce, as opposed to pleasure flying by general aviation pilots. FlightAware records also confirmed usage of the airport by many large corporations.

The information contained in this Supplemental Report provides additional justification in support of the findings and recommendations of the original July 2009 Airport User Survey Report. The user survey analysis has shown that justification for the proposed extension of primary Runway 6/24 to 4,300-feet has been confirmed, and the proposed project has been determined to be eligible to receive state and federal funding.

Although justification for the proposed project has been substantiated according to current MDOT and FAA standards associated with runway length recommendations, neither agency requires that the runway be extended. It is ultimately – and entirely – the decision of the city of Ann Arbor whether or not to proceed with the development of the project.

Mark W. Noel

Mark W. Noel, P.E., Manager
Project Development Section
MDOT – Airports Division

ANN ARBOR MUNICIPAL AIRPORT USER SURVEY - SUPPLEMENTAL REPORT - DECEMBER 2009

EXHIBIT NO. 1

ANNUAL OPERATIONS ANALYSIS BY SPECIFIC AIRCRAFT MODEL

Aircraft Model	FAA Approach Category	FAA Design Group	FAA Weight Class	Seating	Maximum Takeoff Weight (lbs.)	Aircraft Engine Type	Flight-Aware Data Source	Based Aircraft Data Source	2 FBO Register Data Sources	Total Annual Operations by Model
Aero Commander 695	B	II	Small	<10	<12,500	Multi-Eng	4	0	0	4
Beechcraft King Air C90	B	II	Small	10+	<12,500	Multi-Eng	157	0	0	157
Beechcraft King Air 100	B	II	Small	10+	<12,500	Multi-Eng	39	0	2	41
Beechcraft King Air 200	B	II	Small	10+	<12,500	Multi-Eng	215	0	8	223
Cessna 441 Conquest II	B	II	Small	<10	<12,500	Multi-Eng	7	0	4	11
Beechcraft King Air 300	B	II	Large	10+	12,500+	Multi-Eng	11	0	8	19
Beechcraft King Air 350	B	II	Large	10+	12,500+	Multi-Eng	43	0	4	47
Cessna Citation II 550	B	II	Large	<10	12,500+	Jet	6	0	2	8
Cessna Citation XL 560	B	II	Large	<10	12,500+	Jet	25	211	2	238
Cessna Citation 680	B	II	Large	<10	12,500+	Jet	0	0	2	2
Total B-II Category Annual Operations							507	211	32	750

Learjet 25	C	I	Large	<10	12,500+	Jet	0	0	2	2
Learjet 31	C	I	Large	<10	12,500+	Jet	0	0	2	2
Learjet 45	C	I	Large	<10	12,500+	Jet	0	0	2	2
Total C-I Category Annual Operations							0	0	6	6

IAI Westwind 1125	C	II	Large	<10	12,500+	Jet	0	0	2	4
Total C-II Category Annual Operations							0	0	2	4

CRITICAL AIRCRAFT CATEGORY DETERMINATION: B-II (Based on 750 Total Annual Operations by Aircraft of this Category)

NOTE: The annual operations listed in the above tables are ACTUAL documented operations from calendar year 2007.
The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.
Operations recorded by the FBOs and listed above represent only a partial-year (six-month) time frame.

A total of 274 operations in the FlightAware database had aircraft model and ownership information blocked at the owner's request.
As a result, their operational numbers are NOT included in the information shown above.
Judging by the high number of out-of-state origin and destination locations of aircraft in the blocked category (see Exhibit No. 2), it is very likely that many of the associated aircraft were of the B-II and greater categories.
Therefore, actual operations at ARB by aircraft of these categories are likely considerably higher than the numbers shown above.

EXHIBIT NO. 2 **ORIGIN / DESTINATION ANALYSIS BY STATE**

Origin / Destination Analysis of IFR Aircraft Operations Between ARB and Other States
(Records from FlightAware 2007 Database)

	STATE	Aircraft Type & Category Blocked	B-II Small Category	B-II Large Category	Totals by State
1	Alabama	0	1	0	1
2	Arizona	1	0	0	1
3	Arkansas	2	1	0	3
4	Connecticut	5	2	0	7
5	Florida	29	3	3	35
6	Georgia	5	6	12	23
7	Illinois	25	64	5	94
8	Indiana	6	21	1	28
9	Iowa	1	20	3	24
10	Kansas	3	0	0	3
11	Kentucky	2	13	0	15
12	Maine	2	0	0	2
13	Maryland	1	3	7	11
14	Massachusetts	5	0	1	6
15	**Michigan**	**79**	**162**	**20**	**261**
16	Minnesota	2	3	2	7
17	Missouri	0	5	0	5
18	Nebraska	3	0	1	4
19	New Hampshire	1	2	0	3
20	New Jersey	9	2	4	15
21	New York	6	5	1	12
22	North Carolina	4	1	1	6
23	Ohio	16	38	13	67
24	Pennsylvania	14	23	4	41
25	South Carolina	0	4	0	4
26	South Dakota	4	18	0	22
27	Tennessee	2	5	0	7
28	Texas	30	0	0	30
29	Virginia	1	3	0	4
30	Washington DC	5	1	2	8
31	West Virginia	1	7	0	8
32	Wisconsin	10	9	4	23
	No Record	0	0	1	1
	Totals by Category	**274**	**422**	**85**	**781**

IFR Aircraft Operation Totals by Category:

Within Michigan	79	162	20	261
Outside of Michigan	195	260	64	519
No Record	0	0	1	1

NOTE: The numbers of operations listed above are ACTUAL documented operations from calendar year 2007. The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.

The numbers shown above are from the FlightAware IFR Flight Plan Database only, and do NOT include records of all itinerant operations between ARB and other states. Nonetheless, the numbers shown above confirm that in 2007, flight operations were conducted between ARB and at least 31 other states and Washington DC (approx 63% of the continental US). Approximately 67% of these IFR flight records were between ARB and out-of-state locations.

EXHIBIT NO. 3 SMALL 10-SEAT AIRCRAFT ANALYSIS

Small Airplanes Having 10 or More Passenger Seats
(Records from FlightAware 2007 Database)

Aircraft Model	FAA Approach Category	FAA Design Group	FAA Weight Class	Seating	Maximum Takeoff Weight	Aircraft Engine Type	Annual Operations
Cessna Caravan 208	A	II	Small	10+	<12,500	Single-Eng	11
Swearingen Merlin III	B	I	Small	10+	<12,500	Multi-Eng	3
Beechcraft King Air C90	B	II	Small	10+	<12,500	Multi-Eng	157
Beechcraft King Air 100	B	II	Small	10+	<12,500	Multi-Eng	39
Beechcraft King Air 200	B	II	Small	10+	<12,500	Multi-Eng	215

Total Small 10-Seat Aircraft Annual Operations **425**

Total B-II Large Category Aircraft Annual Operations

Based Aircraft Data Source (B-II Large): **211**
FlightAware Data Source (B-II Large): **85**

Grand Total Annual Operations at ARB Applicable to Figure 2-2 in FAA Advisory Circular 150/5325-4B: **721**

NOTE: The annual operations listed above are ACTUAL documented operations from canendar year 2007.
The numbers do NOT include any ESTIMATED operations obtained through proration of partial-year data, or other methods.

The numbers shown in the table above are from the FlightAware IFR Flight Plan Database only, and do NOT include records of all small aircraft operations at ARB with 10-seat or greater aircraft models. Nonetheless, the above analysis confirms that Figure 2-2 in FAA AC 150/5325-4B is the appropriate chart to reference in the determination of the FAA-recommended runway length for Ann Arbor Municipal Airport.

Exhibit 28

http://www.epa.gov/airquality/greenbk/anay_mi.html
Last updated on 12/14/2012

Green Book

You are here: EPA Home Green Book Nonattainment Status for Each County by Year for Michigan

Nonattainment Status for Each County by Year for Michigan

As of December 14, 2012
Listed by County, Pollutant, then Area

Select a State: AK | AL | AR | AZ | CA | CO | CT | DC | DE | FL | GA | GU | IA | ID | IL | IN | KS | KY | LA | MA | MD | ME | MI | MN | MO | MS | MT | NC | NE | NH | NJ | NM | NV | NY | OH | OR | PA | PR | RI | SC | TN | TX | UT | VA | WA | WI | WV | WY |

Important Notes

County	Pollutant	AreaName	Nonattainment in Year	Redesignation to Maintenance	Classification	Cty NA Whole/ Part	Population (2010)	FIPS State/ Cnty
MICHIGAN								
Allegan Co	8-Hr Ozone 1997	Allegan Co, MI	040506070809	09/24/2010	Former Subpart 1	Whole	111,408	26/005
Benzie Co	8-Hr Ozone 1997	Benzie Co, MI	040506	05/16/2007	Former Subpart 1	Whole	17,525	26/019
Berrien Co	8-Hr Ozone 1997	Benton Harbor, MI	040506	05/16/2007	Former Subpart 1	Whole	156,813	26/021
Calhoun Co	8-Hr Ozone 1997	Kalamazoo-Battle Creek, MI	040506	05/16/2007	Former Subpart 1	Whole	136,146	26/025
Cass Co	8-Hr Ozone 1997	Cass Co, MI	040506	05/16/2007	Marginal	Whole	52,293	26/027
Clinton Co	8-Hr Ozone 1997	Lansing-East Lansing, MI	040506	05/16/2007	Former Subpart 1	Whole	75,382	26/037
Eaton Co	8-Hr Ozone 1997	Lansing-East Lansing, MI	040506	05/16/2007	Former Subpart 1	Whole	107,759	26/045
Genesee Co	8-Hr Ozone 1997	Flint, MI	040506	05/16/2007	Former Subpart 1	Whole	425,790	26/049
Huron Co	8-Hr Ozone 1997	Huron Co, MI	040506	05/16/2007	Former Subpart 1	Whole	33,118	26/063
Ingham Co	8-Hr Ozone 1997	Lansing-East Lansing, MI	040506	05/16/2007	Former Subpart 1	Whole	280,895	26/065
Ionia Co	Lead 2008	Belding, MI	1112	/ /		Part	1,890	26/067
Kalamazoo Co	8-Hr Ozone 1997	Kalamazoo-Battle Creek, MI	040506	05/16/2007	Former Subpart 1	Whole	250,331	26/077
Kent Co	8-Hr Ozone 1997	Grand Rapids, MI	040506	05/16/2007	Former Subpart 1	Whole	602,622	26/081
Lapeer Co	8-Hr Ozone 1997	Flint, MI	040506	05/16/2007	Former Subpart 1	Whole	88,319	26/087
Lenawee Co	8-Hr Ozone 1997	Detroit-Ann Arbor, MI	0405060708	06/29/2009	Marginal	Whole	99,892	26/091
Livingston Co	8-Hr Ozone 1997	Detroit-Ann Arbor, MI	0405060708	06/29/2009	Marginal	Whole	180,967	26/093
Livingston Co	PM-2.5 1997	Detroit-Ann Arbor, MI	0506070809101112	/ /		Whole	180,967	26/093
Livingston Co	PM-2.5 2006	Detroit-Ann Arbor, MI	09101112	/ /		Whole	180,967	26/093
Macomb Co	8-Hr Ozone 1997	Detroit-Ann Arbor, MI	0405060708	06/29/2009	Marginal	Whole	840,978	26/099
Macomb Co	CO	Detroit, MI	92939495969798	08/30/1999	Not Classified	Part	295,428	26/099
Macomb Co	PM-2.5 1997	Detroit-Ann Arbor, MI	0506070809101112	/ /		Whole	840,978	26/099
Macomb Co	PM-2.5 2006	Detroit-Ann Arbor, MI	09101112	/ /		Whole	840,978	26/099
Mason Co	8-Hr Ozone 1997	Mason Co, MI	040506	05/16/2007	Former Subpart 1	Whole	28,705	26/105
Monroe Co	8-Hr Ozone 1997	Detroit-Ann Arbor, MI	0405060708	06/29/2009	Marginal	Whole	152,021	26/115
Monroe Co	PM-2.5 1997	Detroit-Ann Arbor, MI	0506070809101112	/ /		Whole	152,021	26/115

Monroe Co	PM-2.5 2006	Detroit-Ann Arbor, MI	09101112	/ /		Whole	152,021	26/115
Muskegon Co	8-Hr Ozone 1997	Muskegon, MI	040506	05/16/2007	Marginal	Whole	172,188	26/121
Oakland Co	8-Hr Ozone 1997	Detroit-Ann Arbor, MI	0405060708	06/29/2009	Marginal	Whole	1,202,362	26/125
Oakland Co	CO	Detroit, MI	92939495969798	08/30/1999	Not Classified	Part	435,027	26/125
Oakland Co	PM-2.5 1997	Detroit-Ann Arbor, MI	0506070809101112	/ /		Whole	1,202,362	26/125
Oakland Co	PM-2.5 2006	Detroit-Ann Arbor, MI	09101112	/ /		Whole	1,202,362	26/125
Ottawa Co	8-Hr Ozone 1997	Grand Rapids, MI	040506	05/16/2007	Former Subpart 1	Whole	263,801	26/139
St Clair Co	8-Hr Ozone 1997	Detroit-Ann Arbor, MI	0405060708	06/29/2009	Marginal	Whole	163,040	26/147
St Clair Co	PM-2.5 1997	Detroit-Ann Arbor, MI	0506070809101112	/ /		Whole	163,040	26/147
St Clair Co	PM-2.5 2006	Detroit-Ann Arbor, MI	09101112	/ /		Whole	163,040	26/147
Van Buren Co	8-Hr Ozone 1997	Kalamazoo-Battle Creek, MI	040506	05/16/2007	Former Subpart 1	Whole	76,258	26/159
Washtenaw Co	8-Hr Ozone 1997	Detroit-Ann Arbor, MI	0405060708	06/29/2009	Marginal	Whole	344,791	26/161
Washtenaw Co	PM-2.5 1997	Detroit-Ann Arbor, MI	0506070809101112	/ /		Whole	344,791	26/161
Washtenaw Co	PM-2.5 2006	Detroit-Ann Arbor, MI	09101112	/ /		Whole	344,791	26/161
Wayne Co	8-Hr Ozone 1997	Detroit-Ann Arbor, MI	0405060708	06/29/2009	Marginal	Whole	1,820,584	26/163
Wayne Co	CO	Detroit, MI	92939495969798	08/30/1999	Not Classified	Part	651,784	26/163
Wayne Co	PM-10	Wayne Co, MI	92939495	10/04/1996	Moderate	Part	713,777	26/163
Wayne Co	PM-2.5 1997	Detroit-Ann Arbor, MI	0506070809101112	/ /		Whole	1,820,584	26/163
Wayne Co	PM-2.5 2006	Detroit-Ann Arbor, MI	09101112	/ /		Whole	1,820,584	26/163

Important Notes

Go Top

Exhibit 29

2008 DRINKING WATER QUALITY REPORT

Ann Arbor Public Services 2008
Annual Report on Drinking Water

Construction of Barton Dam - 1927

http://www.a2gov.org/government/publicservices

The staff of Ann Arbor Public Services is strongly committed to bringing you the best drinking water possible. We take pride in not only meeting all federal and state drinking water regulations, but in reaching higher goals. We participate in voluntary programs which improve our organization and establish more stringent water quality goals. Our monitoring programs far exceed those required to assure the quality of your drinking water. The USEPA requires water utilities provide the following information to their customers as part of their Annual Water Quality Report. This information is generic and may or may not apply to Ann Arbor drinking water. If you have any questions on this language, you may contact the USEPA Safe Drinking Water Hotline at (800) 426-4791.

Water Supply and Treatment

The Ann Arbor water supply is comprised of both surface and ground water sources. About 85% of the water supply comes from the Huron River. The remaining 15% comes from multiple wells located south of Ann Arbor. The water from both the sources is blended at the water treatment plant. Since we use a surface water supply, (Huron River water), the United States Environmental Protection Agency (USEPA) and the Michigan Department of Environmental Quality (MDEQ) regulations require it to be treated, filtered and disinfected to ensure that any harmful substances are removed. When treatment is complete, the water is pumped to homes, schools and businesses in Ann Arbor as well as to Ann Arbor and Scio townships for resale to their customers.

The following is the official USEPA language on Cryptosporidium: *Cryptosporidium is a protozoan parasite that is too small to be seen without a microscope. It is sometimes found in some surface waters, especially when the waters contain a high amount of fecal waste from run-off or other activities. Those who are infected with this parasite can experience gastrointestinal illness.*

USEPA and the Centers for Disease Control have published guidelines on ways to reduce the risk of Cryptosporidium infection. The guidelines are available from the Safe Drinking Water Hotline at (800) 426-4791.

Samples have been collected from the source and no detectable levels of Cryptosporidium were found.

The following is the official USEPA language on contaminants that may be in untreated water: *The sources of drinking water - both tap water and bottled water include: rivers, lakes, streams, ponds, reservoirs, springs and wells. As water travels over the surface of the land and through the ground, it dissolves naturally occurring minerals and can pick up substances resulting from the presence of animals or from human activity.*

Contaminants that might be expected to be in source water - untreated water - include: microbial contaminants, such as viruses and bacteria; inorganic contaminants, such as salts and metals; pesticides and herbicides; organic chemical contaminants; including synthetic and volatile organic chemicals; and radioactive contaminants, which can be naturally occurring.

In order to ensure tap water is safe to drink, the EPA prescribes regulations which limit the amount of certain contaminants in water provided by public water systems. Food and Drug Administration regulations establish limits for contaminants in bottled water, which must provide the same protection for public health.

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the EPA Safe Drinking Water Hotline at (800) 426-4791.

The following is the official USEPA language on low resistance to infection: *Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly and infants can be particularly at risk from infections. These people should seek advice from their health care providers. Environmental Protection Agency / Centers for Disease Control guidelines on appropriate means to lessen the risk of infection from Cryptosporidium and other microbial contaminants are available from the Safe Drinking Water Hotline at (800) 426-4791.*

Spotlight on Water Emergencies

Q: How will I know if my water isn't safe to drink?
A: If there is a chance your water may not be safe to drink, you will be notified by newspaper, mail, radio, TV, or hand-delivery. The notice will describe any precautions you need to take, such as boiling your water. There are 4 possible types of emergency notifications: Boil Water Advisory, Boil Water Notice, Do Not Drink Notice and Do Not Use Notice.

To receive free emergency notifications from the City of Ann Arbor, sign up for the free CodeRed phone alert service, as posted on the city's front Web page at www.a2gov.org. You can also sign up for emergency e-mail updates through the "red envelope" option on the city's front Web page.

Q: What is a Boil Water Advisory? Is it the same as a Boil Water Notice?
A: A Boil Water Advisory is a public statement advising customers to boil tap water before consuming it. Advisories are issued when an event occurs that may cause the water distribution system to become contaminated, such as a loss of pressure from a water main break or back siphonage event. An advisory does not mean that the water is contaminated, but that there is a chance contamination has occurred. Customers should take appropriate precautions until water quality can be determined. An advisory is different from a Boil Water Notice, which is issued when contamination is confirmed in the water system.

Q: What should I do during a Boil Water Advisory or Notice?
A: You should boil tap water vigorously for at least one minute (the minute starts when the water begins to bubble). Wait for the water to cool before using it. This includes water used for brushing teeth, making ice, washing raw foods, preparation of drinks, and water for pets. If preferred. customers can use bottled water. You may store boiled water in the refrigerator in a clean container. Boiling removes harmful bacteria in the water that may cause illness. You should throw away ice made during the time the advisory or notice was issued, as freezing does not kill bacteria.

You should flush the piping inside your home once the advisory or notice has been lifted. Follow these guidelines for flushing:

" Run all cold water faucets in your home for one minute
" To flush automatic ice makers, make and discard several batches of ice
" Run drinking water fountains for one minute

Q: Do I still need to boil my water if I have a filter system on my faucet or refrigerator?
A: Most point-of-use filters are designed to improve the taste and odor of water and will not remove harmful bacteria. Thus, it is recommend that you boil your water or use bottled water even if you have a filtering system. You can learn about the capability of your filter by contacting the manufacturer or NSF International, an independent testing group located in Ann Arbor (734-769-8010).

Q: Is the water safe for washing dishes, laundry , and bathing during a Boil Water Advisory or Notice?
A: The water is safe for washing dishes, but you should use hot, soapy water (you may add one tablespoon of bleach per gallon as a precaution) and rinse dishes in boiled water. There are no restrictions on doing laundry or bathing.

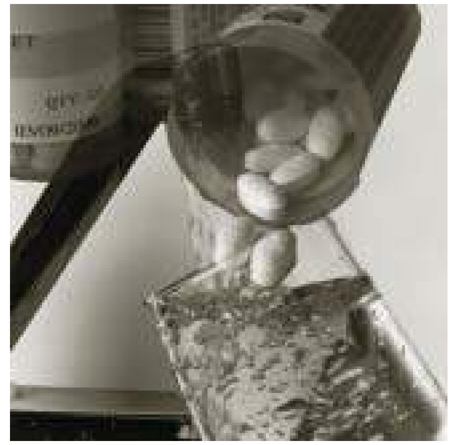
Q: How long must a Boil Water Advisory or Notice be in effect?
A: An advisory or notice will remain in effect until test samples show the water is safe to drink. Testing for bacteria requires 24 hours to complete. As a result, advisories and notices will be in effect for at least 24 hours.

Q: What are total coliform bacteria?
A: Total coliform bacteria are a collection of microorganisms that are naturally present in the environment. Coliform bacteria are found in soil, water and the intestines of warm blooded animals. Coliform bacteria are not harmful themselves, but are used as an indicator that other, potential disease causing organisms may be present. The water treatment process effectively kills coliform bacteria. However, events such as a water main break or a loss of pressure in the water distribution system may allow these bacteria to enter water lines through cracks in pipes or back-siphoning from a residential plumbing system. Boiling water vigorously for one minute will kill these bacteria and make water safe to drink.

Q: What is a Do Not Drink Notice?
A: A Do Not Drink Notice will be issued when the water contains a chemical contaminant that cannot be removed by boiling. In this case, bottled water should be used for drinking or cooking.

Q: What is a Do Not Use Notice?
A: A Do Not Use Notice will be issued if there is a contaminant in the water that may be inhaled or otherwise harmful on contact. In this case, bottled water should be used for all water consumption, including bathing, cooking and laundry.

Pharmaceuticals in Drinking Water?



Q: Has the city of Ann Arbor ever tested our water for pharmaceuticals and personal care products (PPCP)?

A: Yes. Through grants from the Michigan Department of Environmental Quality (MDEQ) in 2004 and 2005, the City completed studies to determine if these contaminants were present in our water. We tested both our source water and finished drinking water for the presence of 33 pharmaceutical and personal care products (PPCP). Of the 33 contaminants, 12 were detected in finished water. All results were in the parts per trillion range.

In 2008, the City of Ann Arbor tested the finished drinking for 8 endocrine disrupting compounds, including Bisphenol A (BPA). None of these compounds were found to be present in the drinking water.

To read the City's PPCP study reports or to see the 2008 endocrine disrupting chemical test results, please visit our webpage:
http://www.a2gov.org/government/publicservices/water_treatment/Pages/default.aspx

To help prevent PPCPs from entering the drinking water supply, never flush any drugs down the toilet. Take unused over the counter and prescription medications back to participating pharmacies for disposal, or wrap medication in in plasitc bags, seal with duct tape and then dispose in the trash. For information about proper disposal, visit www.dontflushdrugs.com

Source Water Assessment and Protection Plan

The City of Ann Arbor has completed a Source Water Assessment and Protection Plan. This plan determines the protection areas for all of our sources of supply, assesses the potential for contamination and develops plans for improving protection of those areas. The assessments for both the river and groundwater supplies included determining the susceptibility, or relative potential of contamination impacting each source of supply. A six-tiered scale was used to rate the potential for contamination. The scale ranges from “very low” to “high”.. The susceptibility rating is based on the geologic sensitivity and the number and types of potential contaminant sources located within our source water protection areas. The susceptibility of the Huron River supply was rated “high” and the wells were rated “moderate”.

New Process at the Ann Arbor Water Treatment Plant

On June 8, 2001, the United States Environmental Protection Agency (USEPA) published the Filter Backwash Recycle Rule (FBRR). This rule regulates the point at which water can be reused and added to the treatment process at water treatment plants. The intent of this rule is to reduce the potential of passing Cryptosporidium oocysts and other biological pathogens such as bacteria and viruses into the finished drinking water.

The City of Ann Arbor uses filters in its treatment process to remove micron size contaminants from its raw water sources. These filters must be cleaned every few days by backwashing-or running water through the filters in reverse at a high rate to remove embedded particles and biological pathogens. This backwash water contains concentrated contaminants that, prior to this rule and the subsequent improvements made at the Ann Arbor Water Treatment Plant, were recycled to the front end of the plant and mixed with the water coming from the city's wells and the Huron River. This water is then treated with the raw water prior to distribution with the treated drinking water. Because the backwashing process is at such a high rate, this causes surges in the flow through the plant when filters are washed. These surges can create a situation of inconsistencies in the treatment process and potentially lead to contaminants making it through the treatment process into the finished drinking water.

The FBRR rule required Ann Arbor to add a new process to the Water Treatment Plant to address this surging of flow caused by backwashing filters. The city was required to add a 750,000 gallon concrete tank and associated pump station to hold the backwash water before it is pumped back into the plant for treatment at a low controlled rate. This new process was completed and put on line in the end of 2008. This process has resulted in more reliable treatment of the city's drinking water and better water quality.

Water Quality Test Results

The following regulated substances were detected in some samples.

Please note that some substances, such as monochloramine and fluoride, are added to the water to improve health. All the detected substances are well within stringent Federal and State limits.

Definitions: The following tables contain scientific terms and measures, some of which may require explanation.

- **Maximum Contaminant Level (MCL):** The highest level of a contaminant that is allowed in drinking water. MCL's are set as close to the Maximum Contaminant Level Goal as feasible using the best available treatment technology.
- **Maximum Contaminant Level Goal (MCLG):** The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLG's allow for a margin of safety.
- **mg/l:** milligrams per liter or parts per million - or one ounce in 7,350 gallons of water
- **µg/l:** micrograms per liter or parts per billion - or one ounce in 7,350,000 gallons of water
- **na:** not applicable
- **Avg:** Regulatory compliance with some MCLs are based on running annual average of monthly or quarterly samples.
- **ND:** Non detectable

Regulated at the Water Treatment Plant

Regulated Substance	Highest Level Detected	Range of Individual Samples	MCL	MCLG	Source of Contamination
Fluoride	1.26 mg/l	ND – 1.26 mg/l	4 mg/l	4 mg/l	Added to water to promote strong teeth. Erosion of natural deposits. Discharge from fertilizer factories.
Nitrate	0.5 mg/l	0.34 – 0.5 mg/l	10 mg/l	10 mg/l	Run-off from fertilizer use. Leaching from septic tanks and sewage. Erosion of natural deposits.
Bromate	2 µg/l avg	ND – 6 µg/l	10 µg/l	0 µg/l	By-product of ozone disinfection of drinking water.
Total Organic Carbon	30.1% Removal[1]	30.1–72.6% Removal	<25% Removal	na	Naturally occurring
Barium	19 µg/l	na	2000 µg/l	2000 µg/l	Erosion of natural deposits
Chromium	2.1 µg/l	na	100 µg/l	100 µg/l	Erosion of natural deposits

[1] Poorest removal corresponds to highest concentration

Monochloramine - Regulated at the Distribution System

Definitions:

- **Maximum Residual Disinfectant Level (MRDL):** The highest level of disinfectant allowed in drinking water.
- **Maximum Residual Disinfectant Level Goal (MRDLG):** The level of disinfectant in drinking water below which there is no known or expected risk to health. MRDLG's allow for a margin of safety.

Regulated Substance	Highest Level Detected	Range of Individual Samples	MRDL	MRDLG	Source of Contamination
Monochloramine	2.7 mg/l avg	2.4 –2.9 mg/l	4 mg/l	4 mg/l	Disinfectant added at Water Plant

Turbidity - Regulated at the Water Treatment Plant

Definitions:

- **Turbidity:** A measure of cloudiness of water. The Ann Arbor Water Treatment staff monitors it because it is a good indicator of the effectiveness of the filtration system. Turbidity must be less than 0.3 NTU in at least 95% of the measurements taken throughout each month. It must never exceed 1.0 NTU.
- **Nephelometric Turbidity Unit (NTU):** A measure of light scattered from particles in the water.
- **Treatment Technique (TT):** A process intended to reduce the level of a contaminant in drinking water.

Regulated Element	95th Percentile TT achieved (max)	95th Percentile TT required	95th Percentile TT voluntary goal	Lowest % of samples within requirements	Single highest measurement	Source of Contamination
Turbidity	0.17 NTU	0.3 NTU	0.1 NTU	0	0.35 NTU	Soil Runoff

Water Quality Test Results

The following regulated substances were detected in some samples.

Copper and Lead - Regulated at the Customer's Tap - All samples collected and analyzed were well within the strict Federal and State limits. The data is from the 2008 testing conducted in accordance with regulations. If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. The City of Ann Arbor is responsible for providing high quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at: http://www.epa.gov/safewater/lead. The City of Ann Arbor sampled 54 homes and 2 of these homes exceeded the action level for lead.

Definitions:

- **Action Level (AL):** The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.
- **Action Level Goal (ALG):** The level of a contaminant in drinking water below which there is no known or expected risk to health. ALG's allow for a margin of safety.

Regulated Substance	Detection Level at the 96th Percentile	AL	ALG	Source of Contamination
Lead - 2008 Customers plumbing	8 µg/l	15 µg/l	0 µg/l	Corrosion of household plumbing systems Erosion of natural deposits

Regulated in the Distribution System

Regulated Substance	Highest Level Detected	Range of Individual Samples	MCL	MCLG	Source of Contamination
Total Coliform	Detected in 1.43% of all samples taken in August	ND – 1.43%	Detected in not more than 5% of samples taken monthly	0	Naturally occurring in the environment
Total Trihalomethanes	[1] 17.8 µg/l avg	0.76– 6.8 µg/l	80 µg/l	0 µg/l	By-product of drinking water disinfection
Total Haloacetic Acids	[1] 11 µg/l avg	1.1 – 9 µg/l	60 µg/l	0 µg/l	By-product of drinking water disinfection

[1] Highest running annual average of last four quarters include sample results from 2007

These tests also showed the following characteristics in our water. Federal and State standards have yet to be established and all results are within limits accepted by most public health officials.

Non-regulated Substance	Average	Range of Individual Samples	Source of Contamination
Hardness	142 mg/l	99 – 200 mg/l	Naturally occurring minerals; controlled by water treatment process
pH	9.3	9.1 – 9.5	Controlled by water treatment process
Aldehydes	8 µg/l	ND – 33 µg/l	By-product of drinking water ozonation
1,4-Dioxane	ND	ND	Groundwater contamination from manufacturing process and landfills
Perchlorate	0.08 µg/l	na	Groundwater contamination from manufacturing process
Sodium	55 mg/l	42–72 mg/l	Naturally occurring minerals; run-off of road salt into surface water; caustic soda used in water treatment process; bleach used in water treatment process

Notice of Violations

We are required to monitor your drinking water for specific contaminants on a regular basis as required by USEPA and MDEQ. In addition to all required testing, we voluntarily monitor more frequently and for many additional potential contaminants. Results of regular monitoring are an indicator of whether or not our drinking water meets health standards. During 2008 we did not monitor or test for endothall during the required sampling period. Additionally, we did not monitor our wells in the first quarter for Volatile Organic chemicals (VOCs) and we also failed to monitor one of the four wells in the third quarter for VOCs. These violations **do not** pose a threat to the quality of the city's water. The table below lists the contaminants we did not properly test for during 2008:

Contaminant	Required sampling frequency	Number of taken samples	When all samples should have been taken	Date sample was taken
Endothall	1 / year	0	4/1/2008 - 9/30/2008	11/17/2008
VOCs	4 / quarter	0	1/1/2008 - 3/31/08	4/18/2008
VOCs	4 / quarter	3	7/31/2008 - 9/30/08	10/16/2008

On January 8, 2008, one of the 26 water filters unexpectedly discharged water with high turbidity into one of the water treatment plant's two filtered water chambers. Turbidity standards were exceeded at the water treatment plant for 42 minutes. Bacteriological testing of water samples indicated that the safety of the city's drinking water was not jeopardized during the event. A notice of the incidence was mailed to customers on January 28, 2008.

Additional Information & Contacts

The City of Ann Arbor Water Treatment Plant conducts extensive routine monitoring of water quality. Our testing program far exceeds current regulatory requirements and we are vigilant against potential threats to our water system.

The Public Services Area Administrator attends the Ann Arbor City Council meetings to provide information on the water system. All Council general sessions, the first and third Monday of each month, are open to the public. Unless announced otherwise, the meetings are at 7:00 PM in Council Chambers at City Hall, 100 North Fifth Avenue. Council meetings are also broadcast on cable channel 16, CTN. In addition, targeted public meetings are periodically held to discuss improvements and to listen to our citizens' and customers' concerns.

Customer Service and Billing Information:
Customer Service Center
100 North Fifth Avenue
Ann Arbor, Michigan 48107
(734) 794-6320

Water Quality and Treatment:
Water Treatment Services
919 Sunset Road
Ann Arbor, Michigan 48103
(734) 794-6426

email: water@a2gov.org
http://www.a2gov.org/government/publicservices

AFTER HOURS EMERGENCY: (734) 994-2840

The Water Treatment Services Unit is staffed 24 hours per day. In the event of emergencies such as water main breaks, emergency water turn-offs and sanitary or storm sewer back-ups, please call the City of Ann Arbor Water Treatment Services Unit.

City of Ann Arbor
Water Treatment Services

919 Sunset Rd.
Ann Arbor, MI 48103
(734) 794-6426

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Exhibit 30

the ann arbor chronicle
it's like being there

Commission OKs FY 2013 Parks Budget

Also: Windemere tennis court problems; drain project at Veterans

BY MARY MORGAN APRIL 27, 2012 at 8 am

Ann Arbor park advisory commission meeting (April 17, 2012): The action items at this month's PAC meeting focused on the upcoming fiscal year, with parks-related budget recommendations for July 1, 2012 through June 30, 2013. Sam Offen, who chairs PAC's budget and finance committee, observed that the FY 2013 budget is in better shape than in recent years.

At left is city councilmember Christopher Taylor (Ward 3), who also serves as an ex officio member of the Ann Arbor park advisory commission. To the right is Sam Offen, chair of PAC's budget and finance committee. (Photos by the writer.)

This is the second year of a two-year budget cycle, and commissioners had recommended approval of budgets for both years at their April 2011 meeting. The recent recommendations for FY 2013 include: (1) increasing the frequency of the mowing cycle from every 19 days to every 14 days; (2) increasing seasonal staffing between April 15–October 15 to maintain active recreation areas better; (3) establishing three seasonal park steward/supervisor positions to improve park maintenance and enforcement; and (4) increasing seasonal staffing at the ice arenas to improve facility cleanliness.

Fee increases at several parks and rec facilities are also part of the budget recommendations, but most have already been implemented in the current fiscal year.

The April 17 meeting included a public hearing on the renewal of the city's park maintenance and capital improvements millage, which will likely be on the November 2012 ballot. No one spoke at the hearing. In general, "there seems to be a great deal of relative silence" about the millage, parks and rec manager Colin Smith told commissioners. Few people have attended the recent public forums held by parks staff. The final forum is set for Thursday, April 26 from 6:30-7:30 p.m. at the Ann Arbor District Library's Traverwood branch, 3333 Traverwood Drive.

Parks staff gave an update on deteriorating conditions at Windemere Park's two tennis courts, and provided an initial estimate on costs to replace one or both courts at that location. No formal recommendation has been made, but options include moving the courts to another park. Commissioners discussed the need to assess the distribution and conditions of all of the city's public courts – including ones in the public school system – as well as their overall usage, to get a better idea of where the greatest needs are.

Another update came from an engineer at the Washtenaw County water resources commissioner's office, who described a drain replacement project that will affect Veterans Memorial Park later this year. Also related to Veterans Memorial, the request for proposals (RFP) for a skatepark there has been issued. [.pdf of skatepark RFP] The goal is to solicit proposals for a consultant to handle design and oversee construction of the skatepark, which will be located on city-owned property.

During public commentary, commissioners were given an update on the nonprofit Project Grow, which has several gardens located in city parks and is celebrating its 40th anniversary this year. Another speaker urged commissioners to take control of the parking lots in city parks, and possibly increase revenues by installing metered parking.

Parks & Rec Budget Recommendation

Park commissioners considered two resolutions related to the city's fiscal year 2013 budget, for the year beginning July 1, 2012 through June 30, 2013. It's the second year of a two-year budget planning cycle. PAC had previously recommended approval of budgets for both years at its April 2011 meeting. The parks budget is part of the city's overall budget, which city administrator Steve Powers proposed at the April 16 meeting of the Ann Arbor city council.

Most of these changes have already been implemented, as part of the current year's budget. Colin Smith, the city's parks and rec manager, reminded commissioners that there will be no increase in budgeted expenses. These changes will be made within the budget plan that was discussed last year for FY 2013, when the FY 2012 budget was formally adopted. [.pdf of budget resolution adopted by council for FY 2012, including parks-related items]

The portion of the city budget relating to parks is separated into two parts: (1) park operations; and (2) parks and recreation.

Sam Offen, who chairs PAC's budget and finance committee, noted that the budget is in better shape than in recent years. He joked that it makes his job much easier.

Parks & Rec Budget Recommendation: Parks Operations Budget

PAC was asked to approve recommendations for the FY 2013 parks operations budget, which includes the following proposed changes: (1) increasing the frequency of the mowing cycle from every 19 days to every 14 days; (2) increasing seasonal staffing between April 15–October 15 to maintain active recreation areas better; (3) establishing three seasonal park steward/supervisor positions to improve park maintenance and enforcement; and (4) increasing seasonal staffing at the ice arenas to improve facility cleanliness. [.pdf of parks operations budget recommendation]

There was considerable discussion about whether to change the wording on the recommendation for the mowing cycle. Tim Doyle initially felt it sounded too much like a dictate rather than an objective, and preferred deferring to staff's judgement on the exact number of days in the cycle. After some wordsmithing on a possible amendment, Christopher Taylor – PAC's ex officio member who also serves on city council – was asked whether his council colleagues would understand the intent. "Contextually, it's plain enough," he said.

Ultimately, PAC reached a consensus not to change wording on the recommendation.

Outcome: Commissioners voted unanimously to recommend approval of the FY 2013 parks operations budget.

Parks & Rec Budget Recommendation: Parks & Rec Budget

In a separate resolution, PAC was asked to recommend approval of the FY 2013 parks and recreation budget. The resolution commended parks staff for its work, and made several general recommendations: (1) reduce energy expenses to reflect the benefit of infrastructure energy improvements at recreational facilities, including Cobblestone Farm and Mack Pool; (2) reduce materials and supplies used to maintain various facilities as a result of recent improvements; (3) reduce water usage expense to reflect actual usage better; (4) eliminate unnecessary software installations where appropriate; (5) increase revenue by initiating additional programming at the Argo Cascades; and (6) increase revenue by increasing fees for admission to swimming pools. [.pdf of parks & rec budget recommendation] [.pdf of fee increases]

Most of these items have been started in the current fiscal year, Offen noted, and will continue into FY 2013.

Outcome: Commissioners unanimously recommended approval of the FY 2013 parks and recreation budget.

Parks Millage Renewal: Public Hearing

No one spoke during a public hearing on the renewal of the city's park maintenance and capital improvements millage, which will likely be on the November ballot.

Park commissioners had been briefed by staff about the millage renewal at PAC's March 20, 2012 meeting.

John Lawter, PAC's vice chair who was presiding over the meeting in the absence of chair Julie Grand, noted that two of the four public informational forums regarding the millage had been held.

[The third forum took place on Monday, April 23. The final one is set for Thursday, April 26 from 6:30-7:30 p.m. at the Ann Arbor District Library's Traverwood branch, 3333 Traverwood Drive.]

Colin Smith, parks and rec manager, noted that Grand had wanted to schedule some of the public forums prior to the public hearing at PAC, and prior to a vote by PAC on whether to recommend millage renewal. That way, PAC could respond if any issues arose. However, Smith added, "there seems to be a great deal of relative silence," and nothing has come up to indicate that the city is on the wrong track in seeking renewal. [At an April 11 forum held at Cobblestone Farm, several city parks staff, PAC commissioners, city councilmember Jane Lumm, and two members of the media – from The Chronicle and WEMU – showed up. But only one member of the public came: Eric Meves, a board member at Project Grow who also spoke during public commentary at the April 17 PAC meeting (see below).]

From left: Greg McDonald, assistant manager of city operations for Community Television Network (CTN), explains a camera problem to Colin Smith, the city's parks and recreation manager. The controller that allows CTN staff technicians to remotely control cameras in city council chambers wasn't working during the April 17 park advisory commission meeting. CTN staff instead adjusted the cameras manually prior to the meeting, to capture wide angle views of the proceedings.

Gwen Nystuen observed that it's hard to get people excited now about a vote that won't happen until November. She said she hadn't heard anything unfavorable about the millage, and that people in Ann Arbor are very supportive of parks. "I'm optimistic," she said.

Sam Offen asked whether there were any significant comments or feedback from the first two forums. Lawter reported that the one person at the forum he attended was supportive. [That person was Meves.] Nystuen praised the staff – she said they had done a good job of answering questions at the first forum about how the budget was prepared.

Informational handouts are being distributed, and Smith pointed out that information about the millage renewal is also available on the city's website.

Windemere Park Tennis Courts

Parks planner Amy Kuras gave a presentation on the tennis courts at Windemere Park, a nearly four-acre parcel on the city's northeast side, north of Glazier Way between Green and Earhart roads. There was no action requested of PAC at this meeting – the staff just wanted to update commissioners on the situation.

The courts were initially built in 1986, then color coated in 2007. Repairs to cracks in the court were attempted in 2009, Kuras said, but failed because of poor soil conditions. The city also attempted to install new net posts in 2009, but that also failed.

In 2010, the city took soil borings in five parts of the park. The borings revealed saturated organic soil and fill, particularly in areas located near the tennis courts in the west part of the park.

Part of the problem is a high water table, Kuras said. In fact, the parks staff have noted higher water tables throughout the city, she added. The only hard data that the city has collected on the water table is at the municipal airport, and there the water table measures between 2-7 feet below the surface now, compared to 15 feet below the surface 50 years ago. Jen Lawson, the city's water quality manager, attributed the change to a variety of factors, Kuras reported, including climate change and more impervious surfaces in the city.

Kuras presented a chart showing cost estimates to replace either one or both courts at the current location. She based her estimates on work done for tennis courts at Veterans Memorial Park and West Park. The total would be $181,377 for two courts at Windemere, or $107,408 for one court. [Link to chart of itemized replacement costs.]

The options to consider, Kuras said, include: (1) replacing both tennis courts at the current location, (2) replacing the courts in another part of Windemere Park, (3) replacing only one court, (4) removing

the courts, or (5) possibly putting the courts in another park.

Matt Warba, the city's acting field operations manager, told commissioners that he's frustrated by the situation. The staff has attempted several repairs, but with water at just two feet below the surface, it's difficult. There's a likelihood that having tennis courts at that location isn't reasonable, he said. But he understands the value to the neighborhood, and the staff is still working on getting some firm numbers and options to consider. There's no easy or quick solution, he said, but they're working on it.

Cracked pavement at the Windemere Park tennis court. (Image provided by city staff in a slide presentation to PAC.)

Windemere Park Tennis Courts: Public Commentary

Jeff Alson told commissioners that he has lived near the park since the late 1970s. He bought his home there in part because of the park. There are a lot of tennis players in the neighborhood, and there are a lot of young children in the area so demand could grow. But because of water issues there's only one court that can be used. Last summer, he hardly played there at all. Alson said he understood that there are problems with water that make maintenance of the courts more expensive. But he emphasized that the courts have held up well for at least the last 10 years, and he would consider it a good investment. It would be disappointing to him if the courts were removed. Alson concluded by thanking commissioners for their service to the city.

Windemere Park Tennis Courts: Commission Discussion

David Barrett asked whether the water table is the same throughout the park. Yes, Kuras said, but the soil composition is different at certain locations in the park – that's a factor, too. She clarified that there are water table issues at other parks, but nothing to the degree they're seeing at Windemere.

Barrett recalled that when the city decided to put in rain gardens at Burns Park, they were slow to let the community know about it. He wondered what kind of outreach was happening for the tennis courts at Windemere. Colin Smith, parks and recreation manager, indicated that outreach would occur when the staff had more information to share. If it makes sense to move the tennis courts, the neighborhood would need to be engaged, he said.

Tim Doyle asked is there's evidence of this same kind of problem at other city tennis courts. He said he's encountered it on a similar project he's working on near Honey Creek, on the west side of town. Warba said that certainly there are areas in the parks that are wetter than they've been in the past. But the Windemere courts are the worst by far.

Sam Offen noted that there are a lot of city tennis courts on the west side of town, but he wondered how many there were on the northeast side. Kuras reported that there are three courts in Leslie Park and two in Sugarbush Park, and it might be possible to accommodate new tennis courts somewhere in Foxfire North Park. All of those parks are in northeast Ann Arbor.

Jeff Alston, a resident who'd spoken during public commentary, pointed out that the courts at Sugarbush are too short for adults to play – they hit the back fence with their rackets, he said.

Gwen Nystuen said she didn't know too much about tennis courts, but that it seemed like the city should assess the distribution and conditions of all of its courts, as well as their overall usage, to get a better idea of where the greatest needs are.

Commissioners and staff also discussed the availability of tennis courts at Ann Arbor public schools, noting that certain times of day and certain days of the week those courts are heavily used by students. Tim Berla noted that Ann Arbor Rec & Ed runs tennis leagues, as does the Ann Arbor Area Community Tennis Association. He pointed out that court conditions aren't just a concern for the city parks – a sinkhole developed at the relatively new tennis courts at Skyline High School, putting one of

the courts out of commission. Berla suggested looking at other materials, such as clay, which he said required more maintenance but wouldn't crack.

Assuming there's need for more tennis courts on the northeast side of town, Berla wondered whether the former Pfizer property – now owned by the University of Michigan – could be a possible location for new courts. He noted that there's a lot of unused land there, as well as available parking.

Drain Project at Veterans Memorial Park

Scott Miller, an engineer with the Washtenaw County water resources commissioner's office, was on hand to give a presentation about a drain project that would affect Veterans Memorial Park. He said the county had been petitioned by the city to do this project. It's referred to as the West Park Fairgrounds project, which is the name of the drain that runs through that section of town – on the west side of town, in the former fairgrounds area. Miller acknowledged that it was a bit confusing, given that a park in a different location is called West Park.

Scott Miller of the Washtenaw County water resources commissioner's office describes an upcoming drain project that will affect Veterans Memorial Park.

The upper end of the drain is located in the Maple Village Shopping Center, where Kmart and Plum Market are located. The drain starts out as a 30-inch pipe and quickly transitions to a 54-inch pipe and then a 66-inch corregated metal pipe as it runs toward town. The pipe runs through Veterans Memorial Park, crosses under Dexter Road and heads east, eventually connecting to a pipe that contains another branch of the Allen Creek.

The city conducted video inspection of the pipe and found several sections that are cracked and corroded, resulting in leaks. Portions of the pipe were clogged with debris. [The city council voted at its Sept. 20, 2010 meeting to petition the county water resources commissioner for this project, estimated to cost roughly $2 million. It will be repaid by the city in annual installments over 15 years.]

Miller said the county staff began work last fall, first clearing the debris and then conducting another video assessment. That revealed two sections of the pipe that have a significant sag, and result in water being held in those sections year-round. One sagging section is in the parking area in the shopping center. Another is in the north side of the park's parking lot that's accessed off of Dexter Road. The preliminary design is to dig up the two sections of sagging pipe and replace them. For the rest of the pipe, the plan calls for putting in a cast lining to reinforce the pipe structurally.

The project would cause minimal disruption, he said, but would include some impact to the parking lot and a small portion of the area west of one of the ballfields. The county is coordinating with the city, which is doing road work and water main replacement along Dexter Road, as well as upcoming work to renovate the ballfields in the park.

The project is in the design phase now, Miller said, with construction expected to begin in the fall.

Drain Project at Veterans Memorial Park: Commission Discussion

Gwen Nystuen asked for more details about how much land would be dug up for the project. Miller reported that in the Maple Village lot, a section about 15 feet wide and 150 feet long would be excavated. In Veterans Memorial Park, the work would be about 15 feet wide and 190 feet long.

Nystuen also commented on the confusing name of the project, and Miller agreed: "It's raised confusion at a lot of levels," he said, but they don't have much latitude to change it.

David Barrett pointed out that there's already disruption to the park – a big pile of dirt has been dumped by the ballfield. He wondered if the county had also coordinated with Ann Arbor Rec & Ed, which runs softball leagues in the park. Miller said the drain work hasn't yet started, so the excavated dirt isn't from their project. Matt Warba, the city's acting field operations manager, clarified that it was likely related to road construction there. Parks and rec manager Colin Smith said the parks staff has been coordinating with Rec & Ed since last year regarding work in the park.

Sam Offen asked about the project's timeframe. It will likely take about two months, Miller replied, but more if there's a lot of rain. In response to another query from Offen, Miller said the county is mindful of the potential flooding impact downstream, but noted that this project isn't intended to increase capacity dramatically. There will be more efficient flow, however.

Ann Arbor park advisory commissioner David Barrett.

Tim Berla clarified that Rec & Ed has cancelled its fall season, which starts in August, because of renovation work on the ballfields at three parks, including Veterans. [PAC had recommended those renovations at their February 2012 meeting.] He asked whether it would be possible to do the park portion of the drain project first, to ensure it would be finished by the spring season. Miller said it probably wouldn't matter – the entire project is expected to be done by the spring of 2013 – but he would look into it.

Berla also asked whether the proposed skatepark – to be located in another part of Veterans Memorial Park – would affect the drain project, in terms of adding runoff. Miller said that although the addition of any impervious surfaces would affect runoff, the pipe is underutilized and has the capacity to handle it.

Smith noted that one of the elements of the skatepark design, as reflected in the request for proposals, will be to include stormwater management that meets or exceeds city standards.

Communications & Commentary

Every meeting includes opportunities for public commentary and communications from commissioners and staff.

Comm/Comm: Public Commentary – Parking in Parks

During public commentary, **George Gaston** told commissioners that he recently visited the University of Michigan's Matthaei Botanical Gardens – it's a lovely place, he said. He had noticed that UM now has metered parking there at $1.20 per hour, between 8 a.m. and 8 p.m. Gaston noted that the city leases its Fuller Park parking lot to UM. It was supposed to be a temporary arrangement, but it's been going on for about 20 years. He wondered if the city has considered taking back control of that lot and and making it a metered lot, too. UM hospital employees use it 24/7, Gaston said, but only pay for part of that time. It could be a great revenue source for the city.

Gaston noted that people park their vehicles all day at Island Park and West Park, as two examples. And with UM planning to build a parking structure on Wall Street that would add another 500 spaces to that area, it might be possible to forego leasing the 18 spaces at Riverside Park to UM and adding metered spaces instead. "You might gain real money out of this," Gaston said. There's precedent in the city for 24-hour metered lots – at the Amtrak station on Depot Street, for example. Right now, it seems the city is undercharging the university for parking. With meters, the lots would be available to anyone if they paid. It might make sense to look into this, he concluded.

Comm/Comm: Project Grow – Public Commentary

Eric Meves, a board member of Project Grow, gave commissioners an overview of the nonprofit. He started by referring to Gaston's comments about parking, noting that Project Grow had to buy parking tags at Matthaei for its gardeners there this year. Meves told commissioners that Project Grow is celebrating its 40th anniversary this year, and he's gardened with the group for 39 of those years.

Several Project Grow gardens are in city parks, so he wanted PAC to become familiar with the organization. It's an educational organization, with assistance for low-income residents. Although the nonprofit has received city funding in the past, it no longer receives public money, he noted.

Project Grow doesn't own any land. About a third of the gardens are located in Washtenaw County parks, and a third on Ann Arbor public school property. The remaining third is evenly divided between

UM land, private property, and city of Ann Arbor parks. About 300-350 families have garden plots each year, Meves said. People do it to grow food, but also for outdoor exercise and to be in a pleasant environment, he said. There's also an element of community – being with your fellow gardeners.

Eric Meves, treasurer of the Project Grow board.

The nonprofit grosses about $40,000 to $50,000 annually, Meves said. About 60% of that comes from plot fees – it costs about $130 for a full plot. About 20% of revenues come from fundraising, primarily through an annual plant sale. The remaining 20% comes from an organic gardening class that Project Grow developed for Washtenaw Community College.

Roughly half of those revenues allow Project Grow to have one half-time employee who works out of his house, Meves said. The group relies on volunteers and a working board. The rest of the funds are used to pay for things like water, utilities, insurance and capital improvements. There are about 40 people on a waiting list for gardens now – demand for gardens is about two to three times what Project Grow can provide, he said.

Meves unfurled a map that he said was made with the help of Merle Johnson and Dan Rainey of the city's information technology department. It showed possible additional locations for gardens within the parks system.

Comm/Comm: Project Grow – Manager's Report

Later in the meeting, Colin Smith reported that parks planner Amy Kuras has been working with the Project Grow managing director [Kirk Jones] to draft an agreement that will outline the formal relationship between the city and the nonprofit. It's been a few years since the city funded Project Grow, he said, but because the group uses city parkland, there's still a relationship. The agreement will stipulate what the procedures are for putting gardens into parks. There have been varied reactions to having gardens in the parks, depending on the neighborhood, he noted. Parks staff will share the agreement with PAC when it's ready, he said.

Tim Berla asked if there's anything PAC or the city can do to help Project Grow identify potential locations for more gardens. Kuras said she works with the organization – sometimes she'll be contacted by someone in a neighborhood who's interested, and she'll in turn contact Project Grow, or sometimes Project Grow comes to her. There are certain requirements, she noted. The land needs to be in a sunny area, and have access to a water source. The city also needs to hold a public meeting if a park is being considered for gardens, and sometimes neighbors don't want it, she said.

From left: Park advisory commissioners Tim Berla and John Lawter. Lawter, who chaired the April 17 meeting in the absence of chair Julie Grand, was reviewing procedural rules with Berla before the meeting. Berla's advice: "No one ever did time" for flubbing Robert's Rules.

Smith noted that the agreement with Project Grow will include details about how PAC can be involved in the process of selecting new locations.

Gwen Nystuen said she appreciated that Eric Meves had spoken to PAC during public commentary. She hadn't realized how many people are involved, and how the city provides relatively little land for

the group. It's useful information, she said, especially given the growing interest in the local food movement.

Tim Doyle clarified with Smith that there is no relationship between Project Grow and the city's greenbelt program.

Comm/Comm: Skatepark RFP

Smith reported that the request for proposals (RFP) for a skatepark at Veterans Memorial Park would be issued the following day. [.pdf of skatepark RFP] The goal is to solicit proposals for a consultant to handle design and oversee construction of the skatepark, which will be located on city-owned property.

Tim Doyle asked how the project would be funded. Smith replied that there are three sources for the roughly $1 million cost of the project: (1) private donations – primarily solicited through the Friends of the Ann Arbor Skatepark; (2) a $300,000 state grant; and (3) up to $400,000 in matching funds from the Washtenaw County parks and recreation commission. The Ann Arbor Area Community Foundation is acting as fiduciary for the project.

The city's contribution will be the land and staff time to manage the process, Smith said, not money. It will be a city-owned asset, he said.

In terms of process, a selection committee – which will include members of the Friends of the Ann Arbor Skatepark, as well as city and county representatives – will be relied on to make a recommendation for the designer. That recommendation will be reviewed by PAC. PAC commissioner David Barrett will serve on the committee. Park planner Amy Kuras is the city's point person on the project.

Construction is expected to start in the spring of 2013.

Gwen Nystuen asked about the relocation of pathways that will be required because of the skatepark location. Kuras noted that some pathways in Veterans Memorial Park are being redone as part of the Dexter Avenue improvement project that's currently underway. Paths that connect to the skatepark will be designed as part of the overall skatepark design, she said.

Comm/Comm: Manager's Report – Market Manager

Smith reported that the field had been narrowed to two candidates to replace Molly Notarianni, who left the job of public market manager earlier this year. He said he hoped to have finalized a hire by PAC's May 15 meeting.

Comm/Comm: Manager's Report – Argo Cascades

The same day as the PAC meeting, the consultant who designed the new canoe/kayak bypass by Argo Dam – Gary Lacy of Boulder, Colo. – was testing the series of drop pools along with city staff. Smith said he had hoped that Lacy would have the time to give an update to PAC about the new Argo Cascades, but the morning had been chilly and Lacy had gotten a late start on the testing, so he wasn't able to attend the meeting.

A grand opening of the Argo Cascades is planned for June, but it will be open to the public before that. May 5 is the date for the first trips from the Argo Pond livery to Gallup Park, Smith said.

Present: David Barrett, Tim Berla, Doug Chapman, Tim Doyle, John Lawter, Karen Levin, Gwen Nystuen, Sam Offen, councilmember Christopher Taylor (ex-officio). Also Colin Smith, city parks and recreation manager.

Absent: Julie Grand, councilmember Mike Anglin (ex-officio).

Next meeting: PAC's meeting on Tuesday, May 15, 2012 begins at 4 p.m. in the city hall second-floor council chambers, 301 E. Huron St., Ann Arbor. [confirm date]

Section: Center Column, Govt., Meeting Watch

The following terms describe the content of this article. Click on a term to see all articles described with that term: **Ann Arbor Parks & Recreation**, **drains**, **park maintenance and capital improvements millage**, **parks budget**, **Project Grow**, **skatepark**, **tennis courts**

0

One Comment

1. BY TRACEY WENTZ & BLACKMER
   MAY 1, 2012 at 11:54 am | PERMALINK

   We encourage action, soon. This problem has existed for a long time without solution. Just listen to the nearby neighborhoods say the demand is there and fix a community resource. Seems like a sunk cost without adequate maintenance.

   Consider a local bond issue or ~ and do something.

Exhibit 31

JENNIFER M. GRANHOLM
GOVERNOR

STATE OF MICHIGAN
DEPARTMENT OF TRANSPORTATION
LANSING

KIRK T. STEUDLE
DIRECTOR

June 23, 2008

Mr. Matthew J. Kulhanek, Airport Manager
Ann Arbor Municipal Airport
801 Airport Road
Ann Arbor, Michigan 48104

Dear Mr. Kulhanek:

Subject: Ann Arbor Municipal Airport

Enclosed is a conditionally approved copy of the Ann Arbor Municipal Airport, Airport Layout Plan (ALP), dated April 2008. This letter cancels or supersedes all prior ALP approvals. The ALP approval is based on recognition of and adherence to the following:

1. The approval is not to be considered a commitment of Federal funding for the proposed development. The FAA has concurred with the proposed development for planning purposes only based on current safety, utility, and efficiency standards. Actual development should comply with approved standards applicable at the time of construction. The airport will need to provide the FAA justification of need before seeking FAA financial participation in the following projects;
   - Shift and extension of runway 6-24 with proposed approach improvements;
   - Associated parallel taxiway construction for the above referenced runway;
   - Identification of a future terminal development area;
   - Achieving the lowest possible minimums for the airport including the installation of additional NAVAIDs; and
   - Purchasing additional land and clearing all objects necessary to meet approach and Part 77 requirements necessary for development and protection of FAA design criteria.
2. No design standard modifications have been granted.
3. We note the following:
   a. If any runways are to be shifted or extended, the shift/extension must be designed such that Standard Runway Safety Areas and Object Free Areas are maintained.
   b. If any design critical aircraft or aircraft group changes for the runway identified, this ALP must be reevaluated by the FAA.
4. Our approval does not infer or imply that the land in the airport vicinity is considered compatible with airport operations. Federal requirements stipulate:
   a. All development programs should be reasonably consistent with the plans of local and state planning agencies for the development in the airport vicinity.
   b. That fair consideration has been given to the interest of communities in or near the airport.
   c. That development programs provide for the protection and enhancement of the environment.
5. The FAA offers no objections to the proposed ultimate airspace utilization as depicted on the ALP based on considerations of safe and efficient use of airspace. The ALP has the status of "Plan on File" for the purpose of 14 CFR 77, Obstruction Evaluations, and 14 CFR 152, Airport Aid Program. A review of the airside landing area development was conducted according to the following 14 CFR's: -77, -152, and -157, Notice of Construction, Alteration, Activation, and Deactivation of Airports (reference Aeronautical Study Number 2008-AGL-533-NRA). It should be noted that FAA cannot prevent erection of any structure near an airport. Airport environs can only be protected through state and local zoning ordinances, building regulations, and like requirements. Please refer to the FAA Airspace Approval letter dated June 8, 2008 for additional detailed information.
6. All development depicted on this ALP must comply with the National Environmental Policy Act (NEPA) of 1969. FAA environmental approval is required for all airport development actions depicted on this ALP. This would apply to development projects, even if there were no FAA funding involved in the project. Additional requirements concerning FAA NEPA approval can be found in FAA Order 5050.4B. *"National Environmental Policy Act (NERPA) Implementing Instruction for Airport Actions."*
7. To avoid conflicts with future development, we recommend you utilize the ALP when preparing leases. We further recommend you provide copies to the local and state planning zoning boards and county and city officials and encourage them to adopt compatible land use criteria in and around the airport. Copies should also be distributed to the Fixed Base Operators (FBO's) and airport users.
8. The Airport and Airway Improvement Act (49 USC 47107 (a) (16) (D)) requires the sponsor to eliminate any adverse effects on Federal facilities, or bear all costs to relocate those facilities, that are a result of an airport change. However, if AIP eligible construction/development items adversely affect FAA facilities, the cost of relocating the facilities may be eligible under AIP. If the proposed development requires any displaced or relocated FAA facility, the construction will have to be coordinated with the FAA in order to establish reimbursable funding for the engineering and relocation.
9. This approval does not include a detailed evaluation of actual construction. Prior to constructing any development on the airport, notice (FAA Form 7460-1) consistent with 14 CFR 77 must be filed with this office. This approval does not include approval for temporary construction equipment which may be used during actual construction, e.g., cranes, equipment staging areas, site access routes, etc. A separate construction safety/phasing plan for any project should be reviewed by the FAA no less than 60 days prior to beginning any project. The airport must take all measures necessary during construction to ensure there are no runway incursions.
10. If development is planned without aviation trust fund investments that will change the status or geometrics of runways, taxiways, aprons, or other operating airport surfaces, notice (FAA Form 7480-1) must be filed with this office consistent with 14 CFR 157.
11. The planned runway developments will require new FAA flight procedures. If the FAA concurs with these developments there will need to be close coordination with different FAA offices. Development on new approaches will not begin until environmental approvals have been given and the sponsor requests the FAA Flight Procedures Office to initiate design of new approaches. Publication of revised Instrument Approach Procedures (IAPs) could take from 18 months to two years, after runway data is submitted. Review of this ALP does not constitute an automatic request for amended procedures.

We trust this letter provides a clear explanation of the conditions and terms of our approval. If you desire further clarification, please contact John D. Pierce at 517-335-9857.

Sincerely,

David L. Baker, PE, Manager
AIP Programs
Airports Division
Bureau of Aeronautics and Freight Services

cc: FTW-FPO
AGL-AJW-C15A
AGL-520
DET-ADO
B. Malinowski, URS

STATE OF MICHIGAN

DEPARTMENT OF TRANSPORTATION

AIRPORTS DIVISION
LANSING, MICHIGAN

ANN ARBOR MUNICIPAL AIRPORT

WASHTENAW COUNTY
ANN ARBOR, MI

AIRPORT LAYOUT PLAN

ANN ARBOR AIRPORT
CITY OF ANN ARBOR

APPROVED ______ MATTHEW KULHANEK – AIRPORT MANAGER ______ DATE

APPROVED ______ JOHN HIEFTJE – MAYOR ______ DATE

MICHIGAN AERONAUTICS COMMISSION

APPROVED ______ RICK HAMMOND – AIRPORTS DIV. ADMINISTRATOR ______ DATE

APPROVED ______ DAVID L. BAKER P.E. NO. 40936 – CHIEF ENGINEER ______ DATE

AIRPORT TYPE – GENERAL AVIATION

REVISION BLOCK

DATE	MODIFICATIONS	INITIALS

DESIGNERS & CONSULTANTS
URS
GRAND RAPIDS, MI.
3950 SPARKS DR. S.E.
616 574-8500

APPROVED ______ WILLIAM M. MALINOWSKI, P.E. NO. 17808 ______ DATE

NOTE: SIGNATURE IN CONSULTANT BLOCK CERTIFIES ALP WAS PREPARED USING ALP CHECKLIST.

DATE	ISSUED FOR
06/27/08	ALP PUBLICATION
03/21/08	FAA AIRSPACE REVIEW
12/17/07	MDOT DRAFT REVIEW

D/E JVV
PM RJC
SQC DR
QC WMM
W. MALINOWSKI IN CHARGE

URS
GRAND RAPIDS, MI.
3950 SPARKS DR. S.E.
616 574-8500

ANN ARBOR MUNICIPAL AIRPORT
ANN ARBOR, MICHIGAN
AIRPORT LAYOUT PLAN
TITLE & SIGNATURE PAGE

SITE NO. 81-1

DRAWING 1 OF 10

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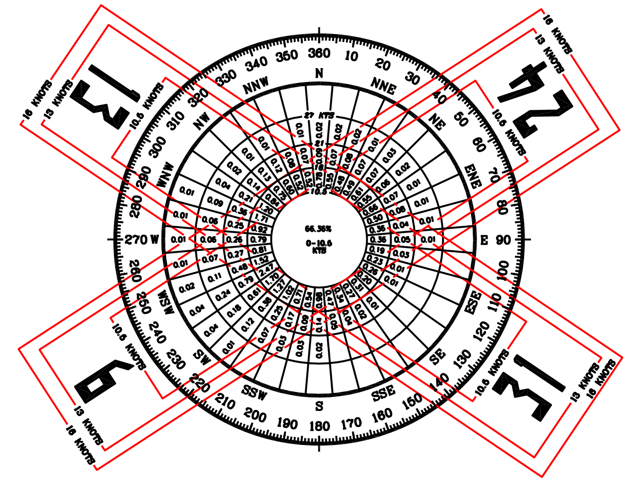
Image=P:\12940723\IMAGES\LETTER(3).tif

MODIFICATIONS TO FAA DESIGN STANDARDS

DATE OF FAA LETTER	DESCRIPTION
MARCH 27, 1995	CATEGORY C APPROACH MINIMA GRANDFATHERED FAA AIRSPACE NO. 92-AGL-698-NRA
	TAXIWAY WIDTH AT 30', NOT STANDARD 35'
	NORTHEAST FBO HANGAR ATCT LINE OF SITE TO END OF PARALLEL TAXIWAY
MARCH 27, 1995	TWO T-HANGARS IN NORTHEAST CORNER OF AIRPORT ATCT LINE OF SITE TO END OF PARALLEL TAXIWAY

AIRPORT DATA TABLE

COUNTY: WASHTENAW	TOWNSHIP: PITTSFIELD	TOWN: T 3 S
MEAN MAXIMUM TEMPERATURE:	83°F JULY	RANGE: R 6 E
AIRPORT REFERENCE POINT:	LAT: 42°13'20.67" N.	LONG: 83°44'47.82" W
AIRPORT REFERENCE CODE:	ARB	
	EXISTING	FUTURE
AIRPORT ELEVATION (MSL)	829	829
AIRPORT AND TERMINAL NAVAIDS	ROTATING BEACON VOR, ATCT, ASOS	ROTATING BEACON VOR, ATCT, ASOS
SERVICE LEVEL	GENERAL AVIATION	GENERAL AVIATION
AIRPORT ROLE	GENERAL UTILITY	GENERAL UTILITY
APPROACH CATEGORY	B	B
AIRPLANE DESIGN GROUP	II	II



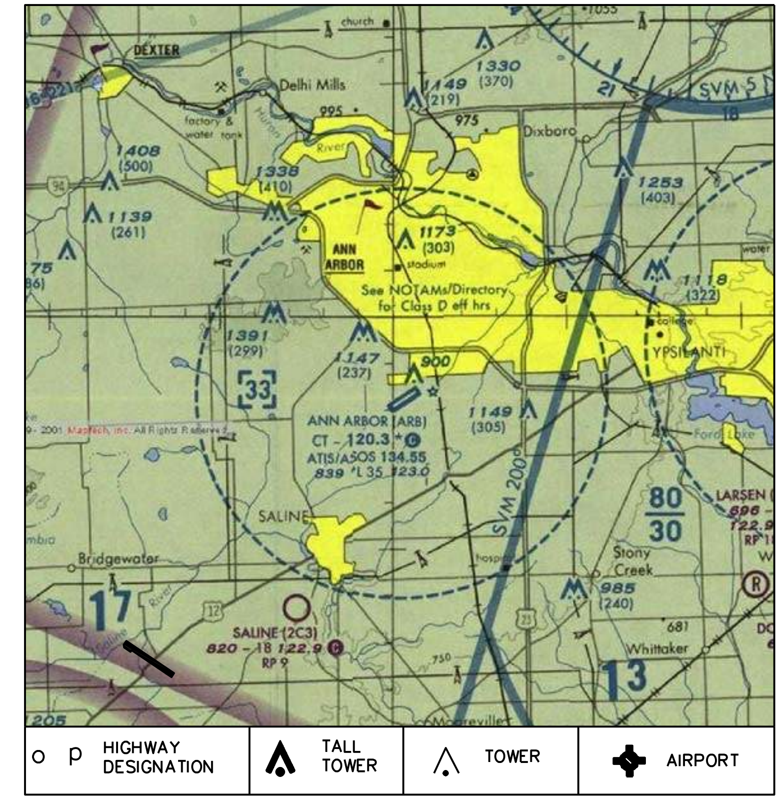
STATION : DETROIT METROPOLITAN AIRPORT
PERIOD : 1/82 TO 1/89
OBSERVATIONS: 94,847

WIND COVERAGE SUMMARY

	10.5 KNOTS	13 KNOTS	16 KNOTS
RUNWAY 6-24	88.30%	94.10%	98.50%
RUNWAY 13-31	81.80%	88.80%	--
COMBINED COVERAGE	96.90%	99.20%	--

N

MAG. DEC.= -6°28'N (2003)

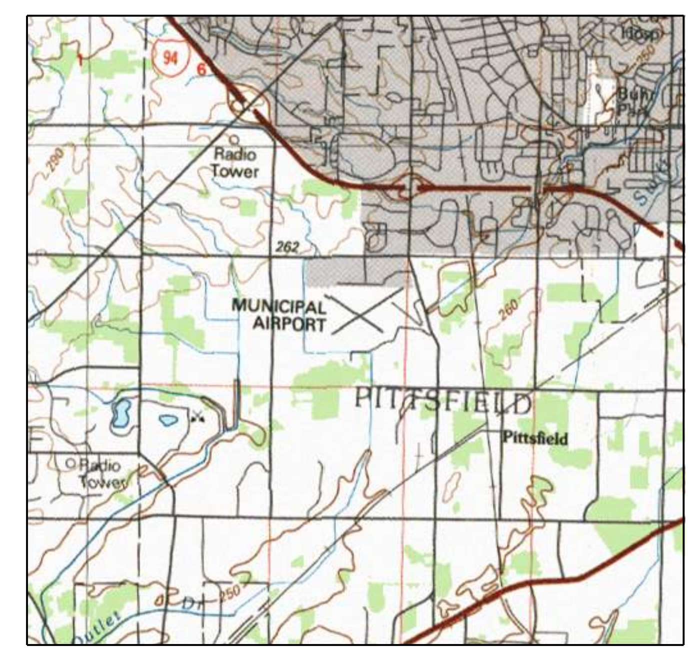


LOCATION MAP

SCALE: 1:500,000

NORTH

0 10 MILE



VICINITY MAP

SCALE: 1"=4000'

NORTH

0 4000' 8000'

RUNWAY AND APPROACH DATA

RUNWAY	6		24		12		30	
	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
RUNWAY LENGTH	3505'	4300'	3505'	4300'	2750'	2750'	2750'	2750'
RUNWAY WIDTH	75'	75'	75'	75'	110'	110'	110'	110'
DISPLACED THRESHOLD	--	--	--	--	--	--	--	--
EFFECTIVE LANDING LENGTH	3505'	4300'	3505'	4300'	2750'	2750'	2750'	2750'
EFFECTIVE TAKEOFF LENGTH	3505'	4300'	3505'	4300'	2750'	2750'	2750'	2750'
TORA	--	--	--	--	--	--	--	--
TODA	--	--	--	--	--	--	--	--
ASDA	--	--	--	--	--	--	--	--
LDA	--	--	--	--	--	--	--	--
STOPWAY	--	--	--	--	--	--	--	--
CLEARWAY	--	--	--	--	--	--	--	--
RUNWAY CATEGORY	NON-PRECISION	NON-PRECISION	NON-PRECISION	NON-PRECISION	UTILITY	UTILITY	UTILITY	UTILITY
RUNWAY GRADIENT	0.17%	0.17%	0.17%	0.17%	0.61%	0.61%	0.61%	0.61%
PAVEMENT TYPE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	TURF	TURF	TURF	TURF
PAVEMENT STRENGTH: GEAR/LOAD(X 1000)	SW 45 DW 70	SW 45 DW 70	SW 45 DW 70	SW 45 DW 70	NONE	NONE	NONE	NONE
RUNWAY LIGHTING	MIRL	MIRL	MIRL	MIRL	NONE	NONE	NONE	NONE
RUNWAY MARKING	N.P.I.	N.P.I.	N.P.I.	N.P.I.	NONE	NONE	NONE	NONE
NAVIGATIONAL AIDS	PAPI ROT. BEACON SEG. CIRCLE REIL	PAPI ROT. BEACON SEG. CIRCLE REIL	VASI ROT. BEACON SEG. CIRCLE	PAPI ROT. BEACON SEG. CIRCLE	ROT. BEACON SEG. CIRCLE	ROT. BEACON SEG. CIRCLE	ROT. BEACON SEG. CIRCLE	ROT. BEACON SEG. CIRCLE
APPROACH LIGHTING	-	-	ODALS	ODALS	NONE	NONE	NONE	NONE
AIRCRAFT APPROACH CATEGORY	B	B	B	B	B	B	B	B
AIRPLANE DESIGN GROUP	II	II	II	II	I	I	I	I
CRITICAL AIRCRAFT	BEECH KING AIR C90-1	CESSNA CITATION II	BEECH KING AIR C90-1	CESSNA CITATION II	CESSNA 172	CESSNA 172	CESSNA 172	CESSNA 172
APPROACH	NON-PRECISION RNAV(GPS)/VOR	NON-PRECISION RNAV(GPS)/VOR	NON-PRECISION RNAV(GPS)/VOR	NON-PRECISION RNAV(GPS)/VOR	VISUAL	VISUAL	VISUAL	VISUAL
RPZ	500'x 700' x 1000'	500'x 700' x 1000'	500'x 700' x 1000'	500'x 700' x 1000'	250'x 450' x 1000'	250'x 450' x 1000'	250'x 450' x 1000'	250'x 450' x 1000'
APPROACH RATIO FAR PART 77	20:1	34:1	20:1	34:1	20:1	20:1	20:1	20:1
APPROACH VISIBILITY MINIMUMS	1 MILE	1 MILE	1 MILE	1 MILE	VISUAL	VISUAL	VISUAL	VISUAL
RUNWAY END COORDINATE (NAD 83) LAT:	N 42°13'12.88"	N 42°13'07.46"	N 42°13'32.97"	N 42°13'32.11"	N 42°13'29.3"	N 42°13'29.3"	N 42°13'14.8"	N 42°13'14.8"
LONG:	W 83°45'00.38"	W 83°45'10.61"	W 83°44'22.45"	W 83°44'24.07"	W 83°45'04.0"	W 83°45'04.0"	W 83°44'33.1"	W 83°44'31.1"

EX. RUNWAY COORDINATES ARE FROM 2005 NOAA APPROACH SURVEY

ODALS - OMNI-DIRECTIONAL APPROACH LIGHTING SYSTEM

ISSUED FOR	DATE
ALP PUBLICATION	06/27/08
FAA AIRSPACE REVIEW	03/21/08
MDOT DRAFT REVIEW	12/17/07

IN CHARGE	
D/E JW	x
PM RJC	x
SQC DR	x
QC WMM	x
W. MALINOWSKI	

URS
GRAND RAPIDS, MI.,
3950 SPARKS DR. S.E.
616 574-8500

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN
AIRPORT DATA SUMMARY

SITE NO. 81-1

DRAWING 2 OF 10

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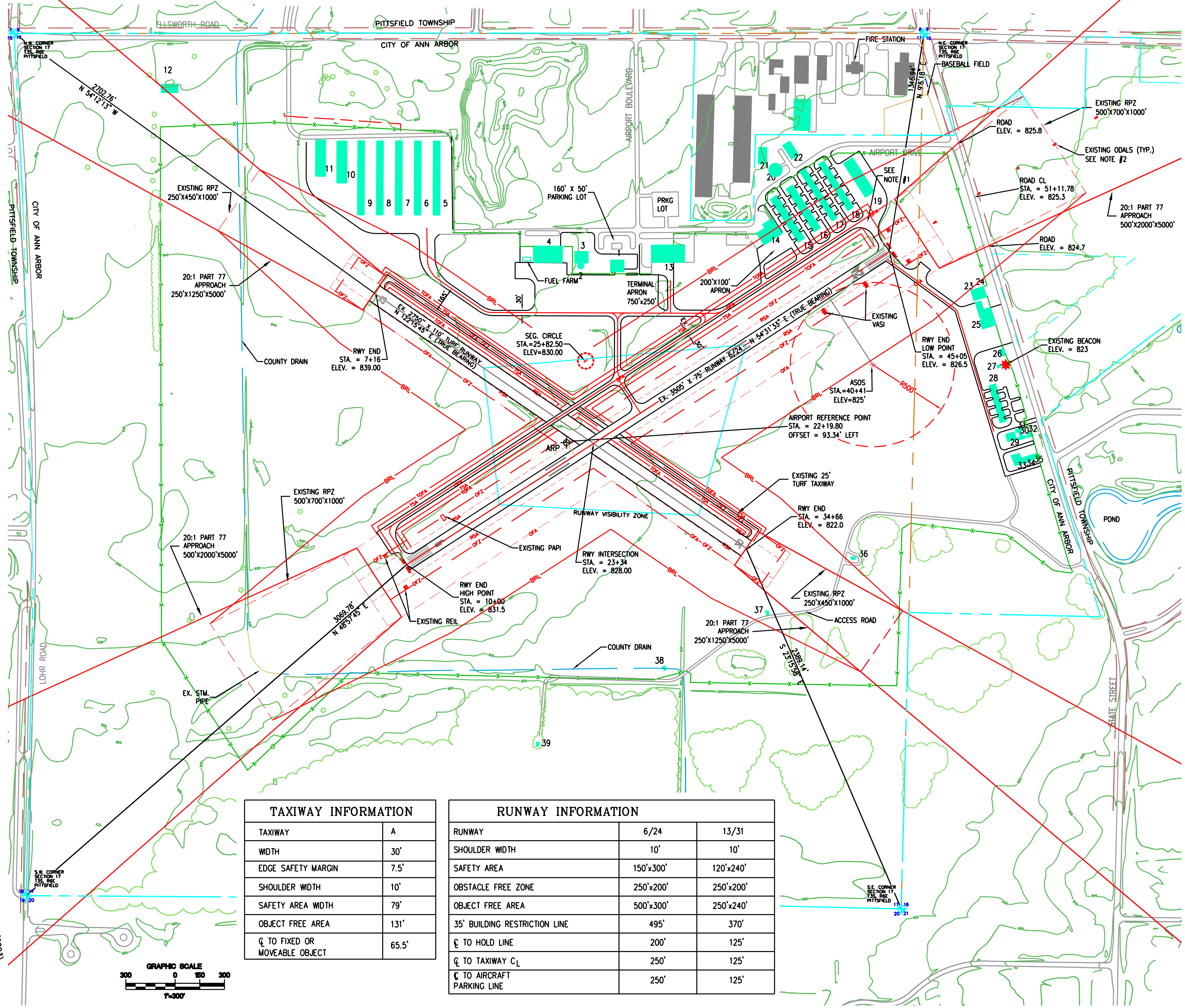
BUILDING ELEVATION TABLE

NO.	DESCRIPTION	ELEVATION
1	ADMINISTRATION/TERMINAL BUILDING	849.56
2	AIR TRAFFIC CONTROL TOWER (ATCT)	893.29
3	AIR TRAFFIC ADMINISTRATION BUILDING	864.52
4	CORPORATE HANGAR (AV. GAS CO.)	866.72
5	T-HANGAR	858.03
6	T-HANGAR	857.98
7	T-HANGAR	857.12
8	T-HANGAR	857.95
9	T-HANGAR	858.01
10	T-HANGAR (NESTED)	863.58
11	T-HANGAR (NESTED)	863.56
12	BARN	894.80
13	CORPORATE HANGAR (MICHIGAN UNIVERSITY)	861.57
14	FIXED BASE OPERATION HANGAR	862.57
15	T-HANGAR	846.73
16	T-HANGAR	846.47
17	T-HANGAR	843.65
18	T-HANGAR	846.30
19	T-HANGAR (NESTED)	849.13
20	ROTATING FLOOR HANGAR	850.89
21	CONVENTIONAL HANGAR	851.15
22	CONVENTIONAL HANGAR	847.51
23	CONVENTIONAL HANGAR	838.92
24	CONVENTIONAL HANGAR	838.87
25	FIXED BASE OPERATION HANGAR	846.03
26	OFFICE BUILDING	837.91
27	CITY WATER FACILITY	823.35
28	T-HANGAR	836.39
29	CONVENTIONAL HANGAR	842.77
30	T-HANGAR	834.98
31	T-HANGAR	835.85
32	T-HANGAR	836.80
33	CONVENTIONAL HANGAR	843.80
34	CONVENTIONAL HANGAR	842.34
35	CONVENTIONAL HANGAR	841.81
36	CITY WATER FACILITY	837.20
37	CITY WATER FACILITY	837.60
38	CITY WATER FACILITY	834.09
39	CITY WATER FACILITY	836.12

LEGEND

AIRPORT PROPERTY LINE	BM
EASEMENT	
SECTION LINES	CORNER
RUNWAYS, PARKING, TAXIWAYS	
FU. RUNWAYS, PARKING, TAXIWAYS	
RWY PROTECTION ZONES	
EXISTING BUILDINGS	EX-BUILD
FUTURE BUILDINGS	FU-BUILD
ROADS	
FUTURE AIRPORT PROPERTY LINE	
CENTERLINES	
EX. RUNWAY SAFETY AREA	RSA
EX. TAXIWAY SAFETY AREA	TSA
EX. OBJECT FREE AREA	OFA
EX. OBJECT FREE ZONE	OFZ
EX. TAXIWAY OBJECT FREE AREA	TOFA
EX. BUILDING RESTRICTION LINE	BRL
EXISTING TREES AND TREE LINES	TREE / TREELIN
EXISTING FENCE LINE	
EX. REIL	REIL
EX. VASI OR PAPI	VASI / PAPI
EX. SEGMENTED CIRCLE	SEG
EXISTING POWER & TELEPHONE LINE	PT / PP / F-PP
RUNWAY VISIBILITY ZONE	



TAXIWAY INFORMATION

TAXIWAY	A
WIDTH	30'
EDGE SAFETY MARGIN	7.5'
SHOULDER WIDTH	10'
SAFETY AREA WIDTH	79'
OBJECT FREE AREA	131'
℄ TO FIXED OR MOVEABLE OBJECT	65.5'

RUNWAY INFORMATION

RUNWAY	6/24	13/31
SHOULDER WIDTH	10'	10'
SAFETY AREA	150'x300'	120'x240'
OBSTACLE FREE ZONE	250'x200'	250'x200'
OBJECT FREE AREA	500'x300'	250'x240'
35' BUILDING RESTRICTION LINE	495'	370'
℄ TO HOLD LINE	200'	125'
℄ TO TAXIWAY C_L	250'	125'
℄ TO AIRCRAFT PARKING LINE	250'	125'

NOTE #1
TWO T-HANGARS IN NORTHEAST CORNER OF AIRPORT AND NORTHEAST FBO HANGAR OBSCURE LINE OF SITE TO END OF PARALLEL TAXIWAY

NOTE #2
OADLS - OMNIDIRECTIONAL APPROACH LIGHTING SYSTEM

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DATE	ISSUED FOR
06/27/08	ALP PUBLICATION
03/21/08	FAA AIRSPACE REVIEW
12/17/07	MDOT DRAFT REVIEW

D/E JVV · PM RJC · SQC DR · QC WMM · IN CHARGE W. MALINOWSKI

URS
GRAND RAPIDS, MI.

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN
AIRPORT LAYOUT PLAN (EXISTING)

SITE NO. 81-1

DRAWING 3 OF 10

12940723

BUILDING ELEVATION TABLE

NO.	DESCRIPTION	ELEVATION
1	ADMINISTRATION/TERMINAL BUILDING	849.56
2	AIR TRAFFIC CONTROL TOWER (ATCT)	893.29
3	AIR TRAFFIC ADMINISTRATION BUILDING	864.52
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7	T-HANGAR	857.12
8	T-HANGAR	857.95
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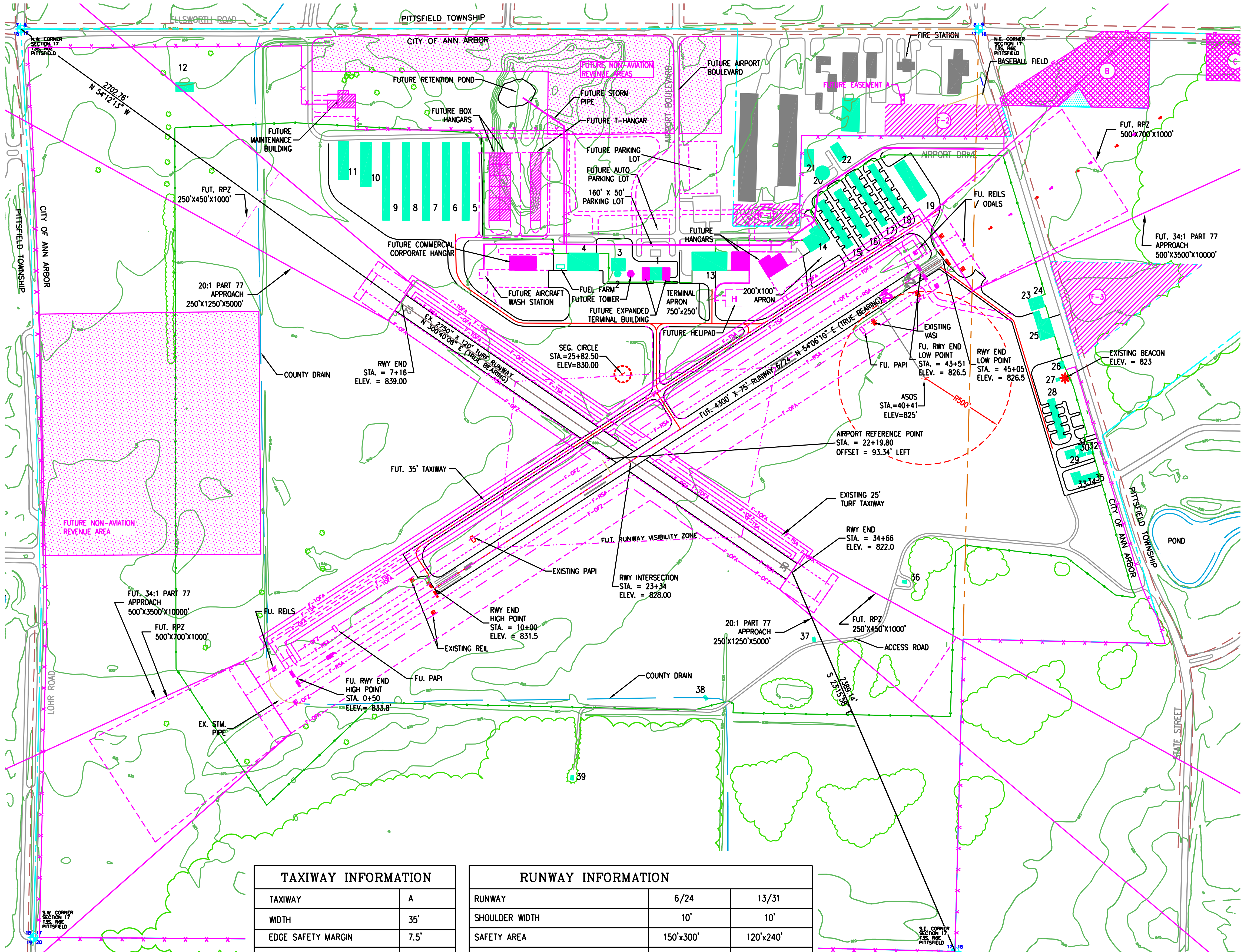
39	CITY WATER FACILITY	836.12



LEGEND

- AIRPORT PROPERTY LINE
- SECTION LINES — SW CORNER
- RUNWAYS, PARKING, TAXIWAYS
- FU. RUNWAYS, PARKING, TAXIWAYS
- RWY PROTECTION ZONES
- PROPERTY LIMITS — IRON
- AVIGATION EASEMENT — OR — E
- SPOT ELEVATIONS
- EXISTING BUILDINGS — EX-BUILD
- FUTURE BUILDINGS — FU-BUILD
- ROADS
- UTILITY EASEMENT
- FUTURE AIRPORT PROPERTY LINE
- FUTURE EASEMENT
- CENTERLINES
- EX. RUNWAY SAFETY AREA — RSA
- EX. TAXIWAY SAFETY AREA — TSA
- EX. OBJECT FREE AREA — OFA
- EX. TAXIWAY OBJECT FREE AREA — TOFA
- EX. BUILDING RESTRICTION LINE — BRL
- EXISTING TREES AND TREE LINES — TREE — TREELINE
- EXISTING FENCE LINE
- EX. REIL — REIL
- EX. VASI OR PAPI — VASI / PAPI
- EX. SEGMENTED CIRCLE — SEG
- FUTURE ROADS
- FUT. TAXIWAY SAFETY AREA — F-TSA
- FUT. TAXIWAY OBJECT FREE AREA — F-TOFA
- FUTURE RWY PROTECTION ZONES
- FUT. RUNWAY SAFETY AREA — F-RSA
- FUT. OBJECT FREE AREA — F-OFA
- FUTURE CENTERLINES
- EXISTING POWER & TELEPHONE LINE — PT — PP — F-PP
- FUT. FENCE

NOTE #3
RUNWAY 24 END TO BE SHORTENED BY 154 LFT TO PROVIDE 15' CLEARANCE FOR THE FUTURE 34:1 APPROACH OVER STATE STREET. EXISTING 154' OF RUNWAY PAVEMENT AND CONNECTORS TO BE REMOVED AND REPLACED WITH NEW CONNECTORS AT THE END OF THE SHORTENED RUNWAY. EXISTING ODALS WILL BE RELOCATED FOR NEW RUNWAY END.

GRAPHIC SCALE 300 0 150 300 1"=300'

TAXIWAY INFORMATION

TAXIWAY	A
WIDTH	35'
EDGE SAFETY MARGIN	7.5'
SHOULDER WIDTH	10'
SAFETY AREA WIDTH	79'
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℄ TO FIXED OR MOVEABLE OBJECT	65.5'

RUNWAY INFORMATION

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35' BUILDING RESTRICTION LINE	495'	370'
℄ TO HOLD LINE	200'	125'
℄ TO TAXIWAY C_L	250'	125'
℄ TO AIRCRAFT PARKING LINE	250'	125'

NOTE #4
EASEMENTS A, B, C, AND LAND ACQUISITION OF PARCELS F-2 AND F-3 ARE NEEDED FOR FUTURE APPROACH PROTECTION.

NOTE #5
EXISTING FENCE TO REMAIN ALONG WITH FUTURE FENCE.

06/27/08	ALP PUBLICATION	
03/21/08	FAA AIRSPACE REVIEW	
12/17/07	MDOT DRAFT REVIEW	
DATE	ISSUED FOR	

D/E JVV
PM RJC
SQC DR
QC WMM
W. MALINOWSKI IN CHARGE

URS
GRAND RAPIDS, MI.

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

AIRPORT LAYOUT PLAN (FUTURE)

SITE NO. 81-1

DRAWING 4 OF 10

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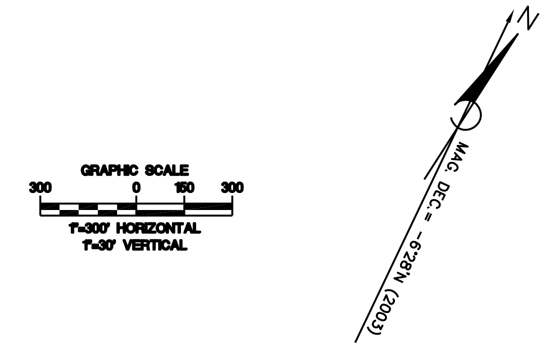
LEGEND

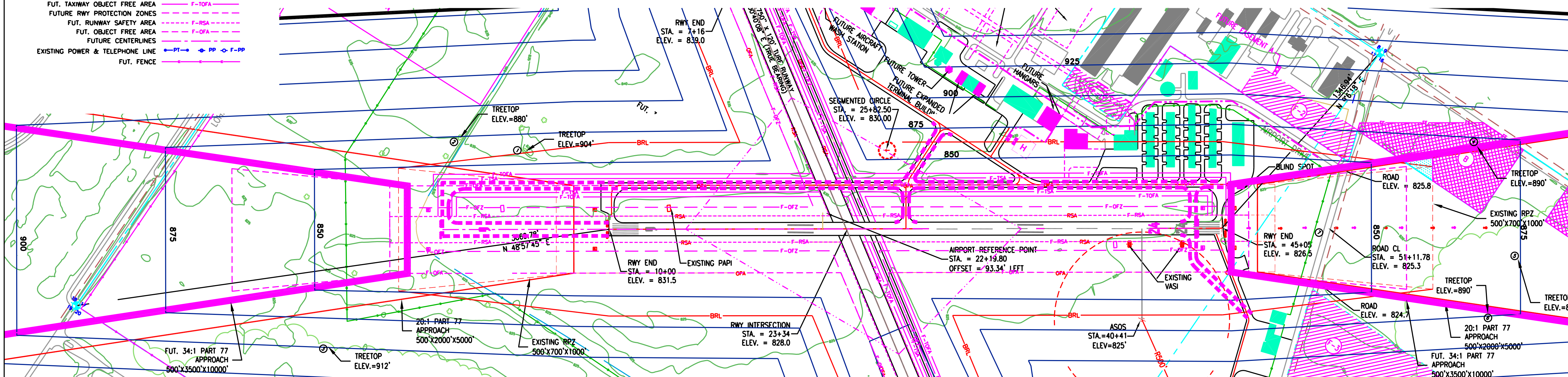
- AIRPORT PROPERTY LINE
- SECTION LINES (BM, CORNER)
- RUNWAYS, PARKING, TAXIWAYS
- FU. RUNWAYS, PARKING, TAXIWAYS
- RWY PROTECTION ZONES
- PROPERTY LIMITS (IRON)
- AVIGATION EASEMENT (OR — E)
- SPOT ELEVATIONS
- EXISTING BUILDINGS (EX-BUILD)
- FUTURE BUILDINGS (FU-BUILD)
- ROADS
- UTILITY EASEMENT
- FUTURE AIRPORT PROPERTY LINE
- FUTURE EASEMENT
- CENTERLINES
- EX. RUNWAY SAFETY AREA (RSA)
- EX. TAXIWAY SAFETY AREA (TSA)
- EX. OBJECT FREE AREA (OFA)
- EX. TAXIWAY OBJECT FREE AREA (TOFA)
- EX. BUILDING RESTRICTION LINE (BRL)
- EXISTING TREES AND TREE LINES (TREE, TREELINE)
- EXISTING FENCE LINE
- EX. REIL (REIL)
- EX. VASI OR PAPI (VASI / PAPI)
- EX. SEGMENTED CIRCLE (SEG)
- FUTURE ROADS
- FUT. TAXIWAY SAFETY AREA (F-TSA)
- FUT. TAXIWAY OBJECT FREE AREA (F-TOFA)
- FUTURE RWY PROTECTION ZONES
- FUT. RUNWAY SAFETY AREA (F-RSA)
- FUT. OBJECT FREE AREA (F-OFA)
- FUTURE CENTERLINES
- EXISTING POWER & TELEPHONE LINE (PT, PP, F-PP)
- FUT. FENCE

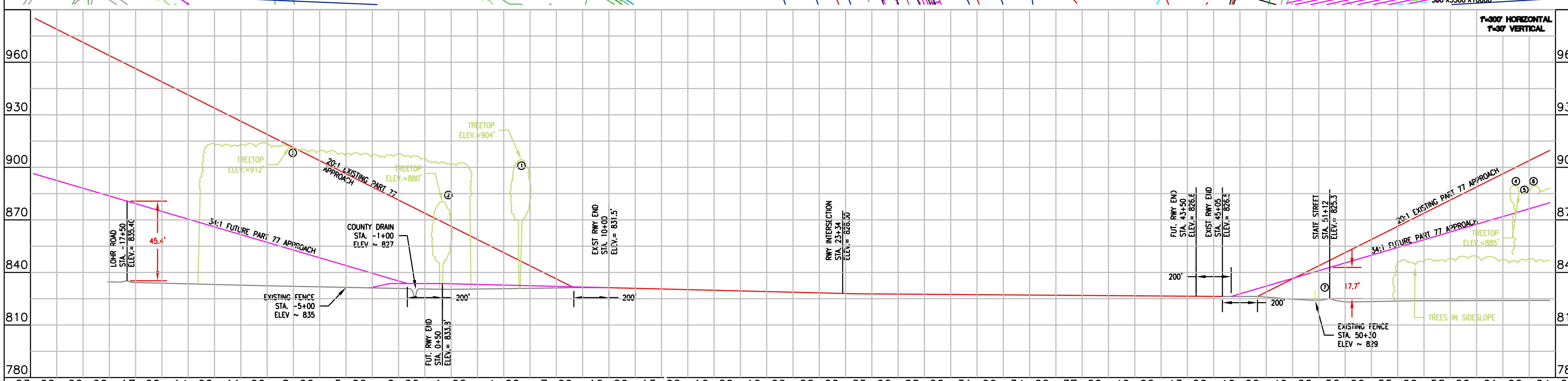
OBSTRUCTION TABLE

NO	TYPE	TOP ELEV	MAX. ELEV. EX.	MAX. ELEV. FUT.		PENETRATION EX.	PENETRATION FUT.		PROPOSED DISPOSITION
1	TREES	904'	882' **	862' **		22'	42'		REMOVE
2	TREES	880'	900' **	868' **			12'		REMOVE
3	TREES	912'	933' **	900' **			12'		REMOVE
4	TREES	890'	896' **	867' **			23'		REMOVE
5	TREES	885'	900'	874'			11'		REMOVE
6	TREES	890'	902' **	870' **			20'		REMOVE

** IN SIDE OR TRANSITIONAL SLOPE







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X	06/27/08	ALP PUBLICATION	
X	03/21/08	FAA AIRSPACE REVIEW	
X	12/17/07	MDOT DRAFT REVIEW	
	DATE	ISSUED FOR	

D/E	JVV	X
PM	RJC	X
SQC	DR	X
QC	WMM	X
W. MALINOWSKI		X
IN CHARGE		

URS

3950 SPARKS DR. S.E.
GRAND RAPIDS, MI.
616 574-8500

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

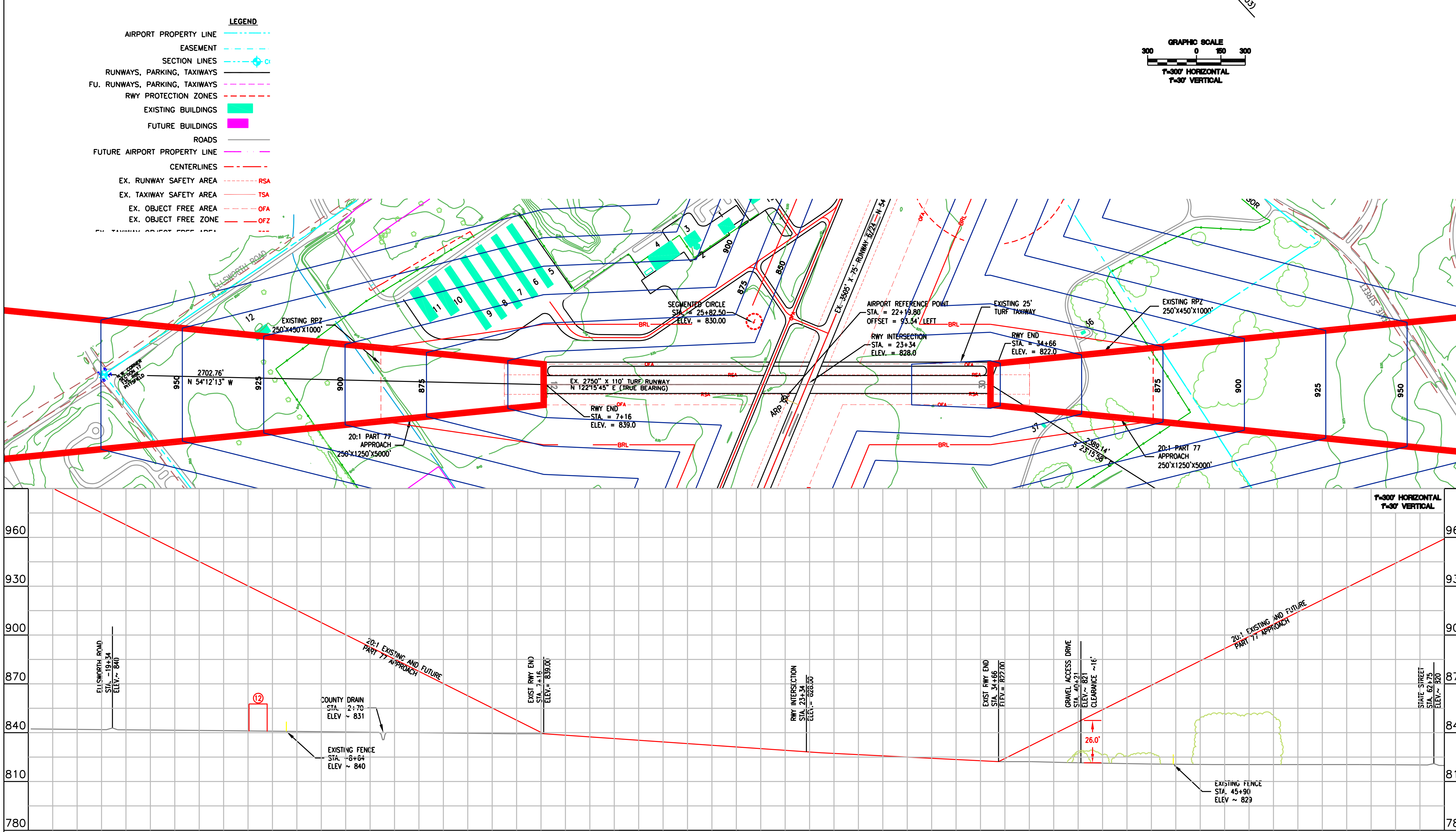
RUNWAY APPROACH ZONE DRAWING (RWY 6/24)

SITE NO.
81-1

DRAWING
6 OF 10

12940723

NOTE:
RWY 13/31 APPROACHES WERE SURVEYED IN 2003, NO OBSTRUCTIONS OBSERVED.



DATE	ISSUED FOR
06/27/08	ALP PUBLICATION
03/21/08	FAA AIRSPACE REVIEW
12/17/07	MDOT DRAFT REVIEW

D/E JVV · PM RJC · SQC DR · QC WMM · W. MALINOWSKI IN CHARGE

URS
GRAND RAPIDS, MI.

ANN ARBOR MUNICIPAL AIRPORT
ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN
RUNWAY APPROACH ZONE DRAWING (RWY 13/31)

SITE NO. 81-1

DRAWING 7 OF 10

12940723

BUILDING ELEVATION TABLE

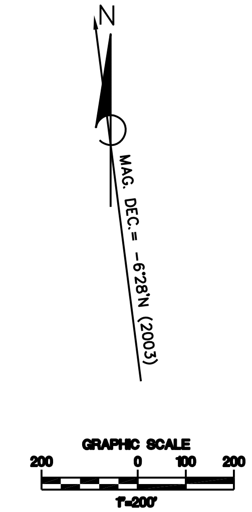
NO.	DESCRIPTION	ELEVATION
1	ADMINISTRATION/TERMINAL BUILDING	849.56
2	AIR TRAFFIC CONTROL TOWER (ATCT)	893.29
3	AIR TRAFFIC ADMINISTRATION BUILDING	864.52
4	CORPORATE HANGAR (AV. GAS CO.)	866.72
5	T-HANGAR	858.03
6	T-HANGAR	857.98
7	T-HANGAR	857.12
8	T-HANGAR	857.95
9	T-HANGAR	858.01
10	T-HANGAR (NESTED)	863.58
11	T-HANGAR (NESTED)	863.56
12	BARN	894.80
13	CORPORATE HANGAR (MICHIGAN UNIVERSITY)	861.57
14	FIXED BASE OPERATION HANGAR	862.57
15	T-HANGAR	846.73
16	T-HANGAR	846.47
17	T-HANGAR	843.65
18	T-HANGAR	846.30
19	T-HANGAR (NESTED)	849.13
20	ROTATING FLOOR HANGAR	850.89
21	CONVENTIONAL HANGAR	851.15
22	CONVENTIONAL HANGAR	847.51
23	CONVENTIONAL HANGAR	838.92
24	CONVENTIONAL HANGAR	838.87
25	FIXED BASE OPERATION HANGAR	846.03
26	OFFICE BUILDING	837.91
27	CITY WATER FACILITY	823.35
28	T-HANGAR	836.39
29	CONVENTIONAL HANGAR	842.77
30	T-HANGAR	834.98
31	T-HANGAR	835.85
32	T-HANGAR	836.80
33	CONVENTIONAL HANGAR	843.80
34	CONVENTIONAL HANGAR	842.34
35	CONVENTIONAL HANGAR	841.81
36	CITY WATER FACILITY	837.20
37	CITY WATER FACILITY	837.60
38	CITY WATER FACILITY	834.09
39	CITY WATER FACILITY	836.12

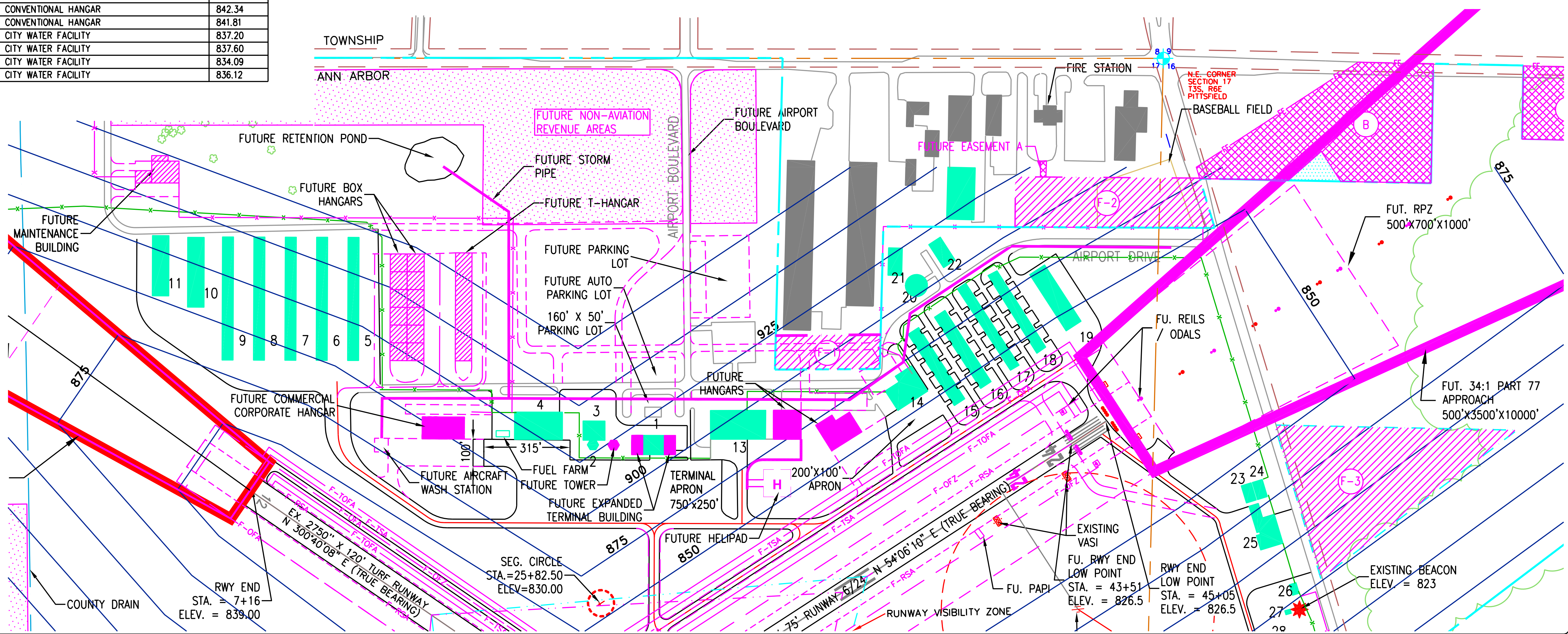
TAXIWAY INFORMATION

TAXIWAY	A
WIDTH	30'
EDGE SAFETY MARGIN	7.5'
SHOULDER WIDTH	10'
SAFETY AREA WIDTH	79'
OBJECT FREE AREA	131'
℄ TO FIXED OR MOVEABLE OBJECT	65.5'

RUNWAY INFORMATION

RUNWAY	6/24	13/31
SHOULDER WIDTH	10'	10'
SAFETY AREA	150'x300'	120'x240'
OBSTACLE FREE ZONE	250'x200'	250'x200'
OBJECT FREE AREA	500'x300'	250'x240'
35' BUILDING RESTRICTION LINE	495'	370'
℄ TO HOLD LINE	200'	125'
℄ TO TAXIWAY C_L	250'	125'
℄ TO AIRCRAFT PARKING LINE	250'	125'





URS
GRAND RAPIDS, MI.

D/E	JVV
PM	RJC
SQC	DR
QC	WMM
W. MALINOWSKI	IN CHARGE

DATE	ISSUED FOR
06/27/08	ALP PUBLICATION
03/21/08	FAA AIRSPACE REVIEW
12/17/07	MDOT DRAFT REVIEW

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

TERMINAL AREA PLAN

SITE NO. 81-1

DRAWING 8 OF 10

12940723

JVonDuin 1/10/2007 4:05 pm

FUTURE PARCEL ACQUISITIONS

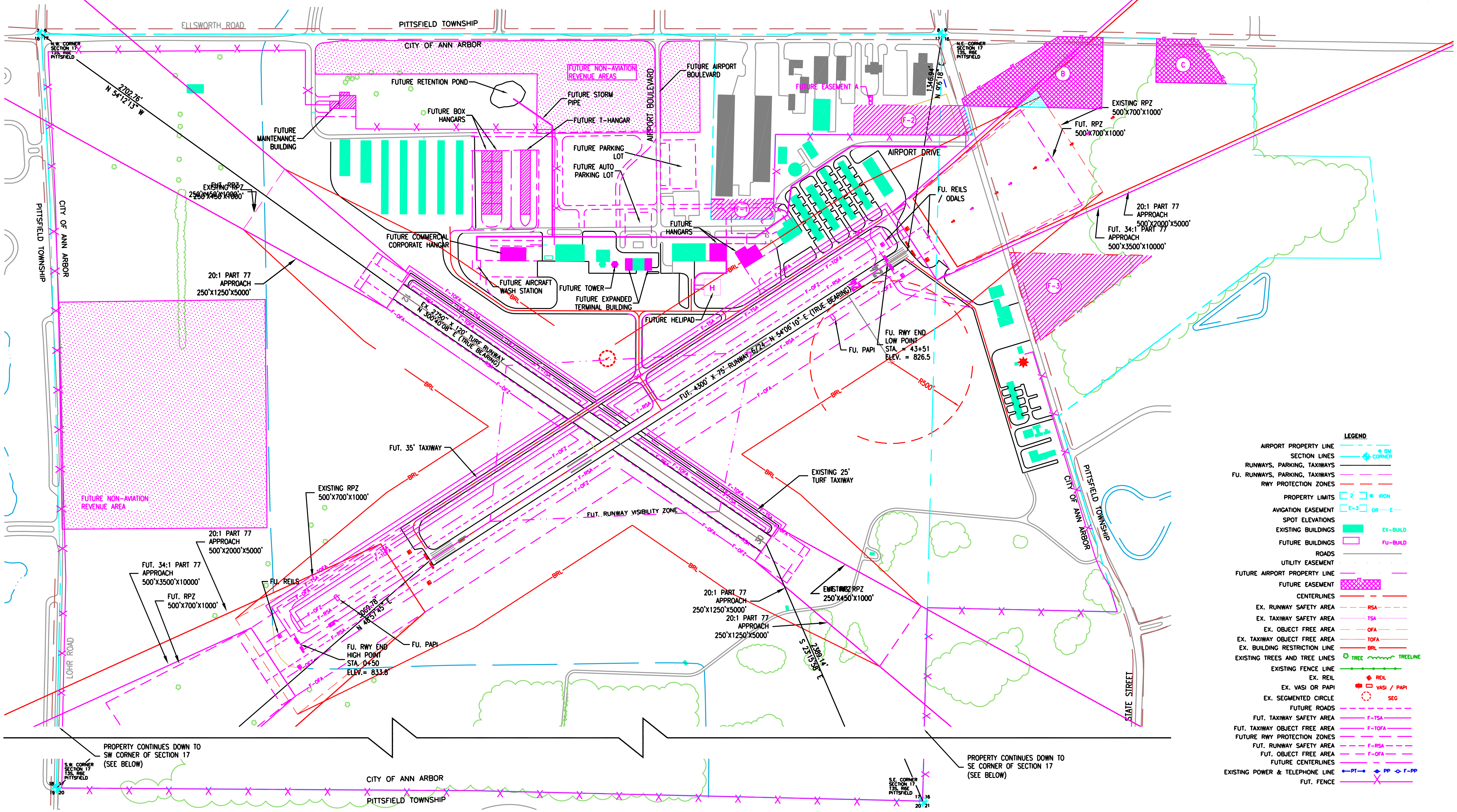
FEDERAL PROJECT NUMBER	PARCEL NUMBER	GRANTORS	DEED*	LIBER AND PAGE	RECORDED DATE	ACREAGE	NOTES *	CONTROLLING HEIGHT
-	F-1	DB WAREHOUSE LTD.	WD	00-00 00-00	00/00/00	1.09	-	-
-	F-2	PITTSFIELD TOWNSHIP	WD	00-00	00/00/00	2.94	-	-
-	F-3	CLARA SEYMOUR	WD	00-00	00/00/00	5.69	-	-
					FEE ACRES	9.72		

AE-AVIGATION EASEMENT
CJ-CONSENT JUDGMENT
E-EASEMENT
GD-GUARDIAN DEED
CE-CLEARING EASEMENT
LE-LIGHT EASEMENT
WD-WARRANTY DEED
QC-QUIT CLAIM DEED

FUTURE EASEMENT INTERESTS

NO.	PARCEL	TYPE	GRANTEE	ACREAGE	LIBER-PAGE	RECORDED DATE	NOTES
A	-	EE EASEMENT	PITTSFIELD TOWNSHIP	0.028	00-00	00/00/00	FIRE STATION ACCESS
B	-	AE EASEMENT	PITTSFIELD TOWNSHIP	5.98	00-00	00/00/00	34:1 APPROACH EASEMENT
C	-	AE EASEMENT	PITTSFIELD TOWNSHIP	2.12	00-00	00/00/00	34:1 APPROACH EASEMENT
				8.128	TOTAL ACREAGE		

DE - DRAINAGE EASEMENT
EE - ACCESS EASEMENT
AE - AVIGATION EASEMENT



ISSUED FOR	DATE
ALP PUBLICATION	06/27/08
FAA AIRSPACE REVIEW	03/21/08
MDOT DRAFT REVIEW	12/17/07

D/E JVV
PM RJC
SQC DR
QC WMM
IN CHARGE W. MALINOWSKI

URS
GRAND RAPIDS, MI.
3950 SPARKS DR. S.E.
616 574-8500

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

AIRPORT PROPERTY PLAN

SITE NO. 81-1

DRAWING 9 OF 10

12940723

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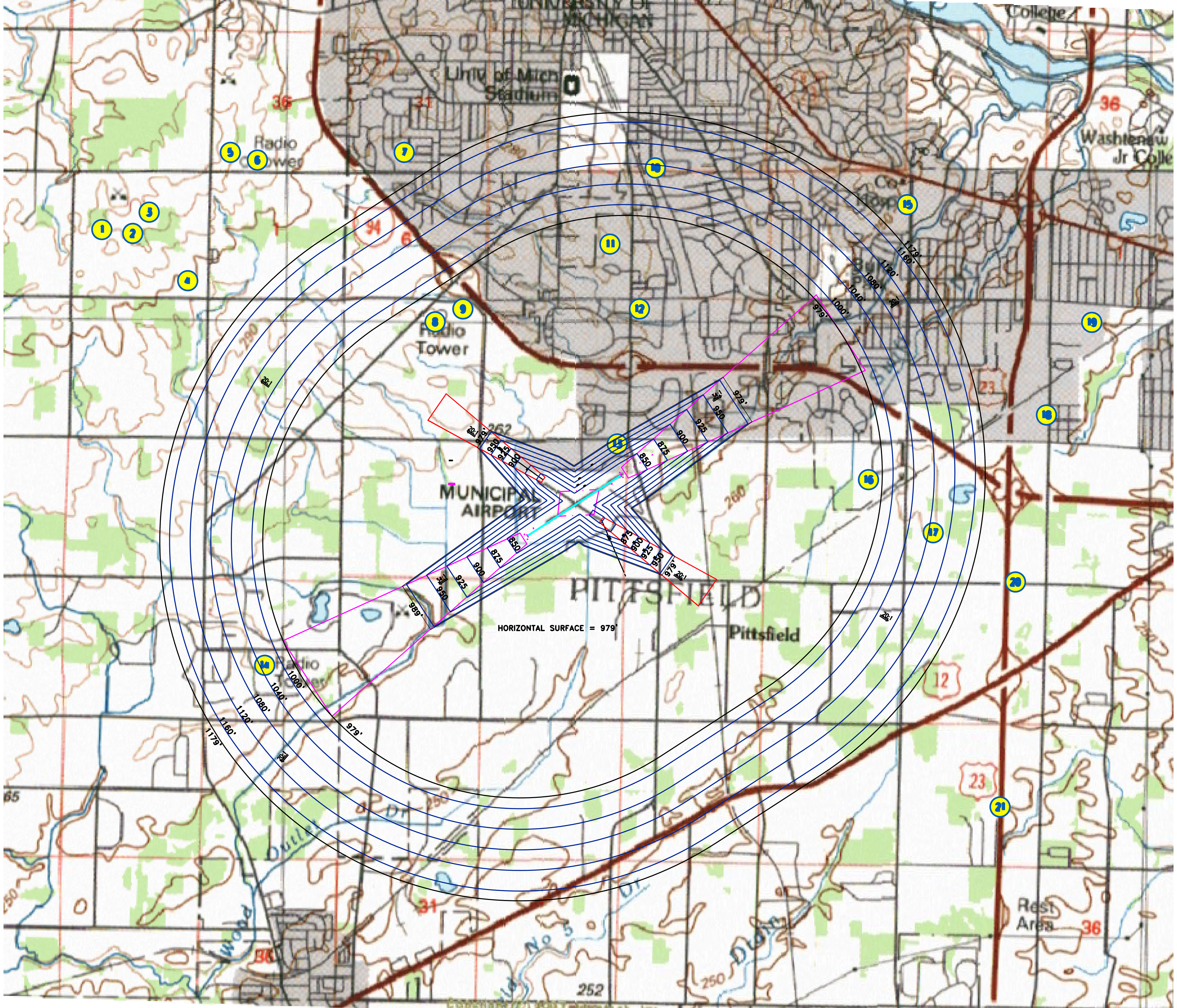
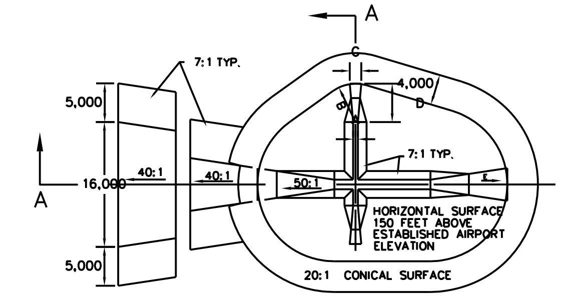
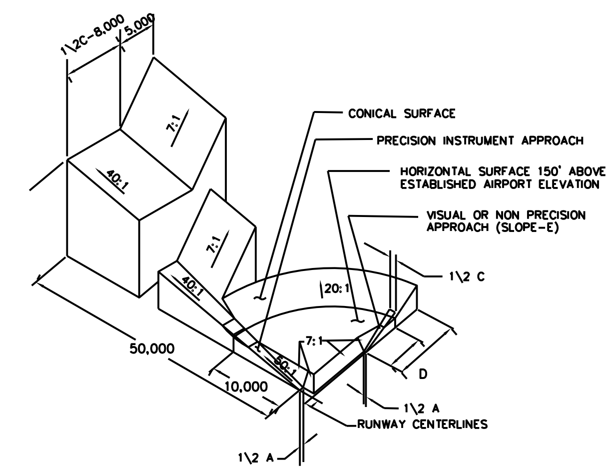




DIM	ITEM	DIMENSIONAL STANDARDS (FEET)					
		VISUAL RUNWAY		NON-PRECISION INSTRUMENT RUNWAY			PRECISION INSTRUMENT RUNWAY
		A	B	A	B: C	B: D	
A	WIDTH OF PRIMARY SURFACE AND APPROACH SURFACE WIDTH AT INNER END	250	500	500	500	1,000	1,000
B	RADIUS OF HORIZONTAL SURFACE	5,000	5,000	5,000	10,000	10,000	10,000
		VISUAL APPROACH		NON-PRECISION INSTRUMENT APPROACH			PRECISION INSTRUMENT APPROACH
		A	B		B: C	B: D	
C	APPROACH SURFACE WIDTH AT END	1,250	1,500	2,000	3,500	4,000	16,000
D	APPROACH SURFACE LENGTH	5,000	5,000	5,000	10,000	10,000	•
E	APPROACH SLOPE	20:1	20:1	20:1	34:1	34:1	•

A- UTILITY RUNWAYS
B- RUNWAYS LARGER THAN UTILITY
C- VISIBILITY MINIMUMS GREATER THAN 3\4 MILE
D- VISIBILITY MINIMUMS AS LOW AS 3\4 MILE
• PRECISION INSTRUMENT APPROACH SLOPE IS 50:1 FOR INNER 10,000 FEET AND 40:1 FOR AN ADDITIONAL 40,000 FEET



ESTABLISHED AIRPORT EL.= 829'

AIRPORT REFERENCE POINT

LAT: 42°13'20.67" N.
LONG: 83°44'47.82" W

TOWERS		
NO.	AGL	AMSL
1	210	1282
2	210	1282
3	299	1391
4	222	1222
5	118	1181
6	279	1319
7	274	1240
8	237	1147
9	185	1079
10	107	950
11	165	1062
12	100	939'
13	70	900
14	174	1029
15	100	930
16	240	1090
17	197	1047
18	250	1088
19	190	1015
20	305	1149
21	189	1021

N
MAG. DEC.= -6°28'N (2003)

GRAPHIC SCALE
1000 0 1000 2000
1"=2000'

06/27/08	ALP PUBLICATION	
03/21/08	FAA AIRSPACE REVIEW	
12/17/07	MDOT DRAFT REVIEW	
DATE	ISSUED FOR	

D/E JW x
PM RJC x
SQC DR x
QC WMM x
W. MALINOWSKI
IN CHARGE

URS
GRAND RAPIDS, MI., 3950 SPARKS DR. S.E. 616 574-8500

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN
FAR PART 77 APPROACH SURFACES DRAWING

SITE NO. 81-1

DRAWING 10 OF 10

12940723

P:\12940723\PDS\81-01-alp10-pt77.dgn
jon_van_duinen
3/26/2008 3:43 pm

LEGEND

- AIRPORT PROPERTY LINE — BM
- EASEMENT
- SECTION LINES — CORNER
- RUNWAYS, PARKING, TAXIWAYS
- FU. RUNWAYS, PARKING, TAXIWAYS
- RWY PROTECTION ZONES
- EXISTING BUILDINGS — EX-BUILD
- FUTURE BUILDINGS — FU-BUILD
- ROADS
- FUTURE AIRPORT PROPERTY LINE
- CENTERLINES
- EX. RUNWAY SAFETY AREA — RSA
- EX. TAXIWAY SAFETY AREA — TSA
- EX. OBJECT FREE AREA — OFA
- EX. OBJECT FREE ZONE — OFZ
- EX. TAXIWAY OBJECT FREE AREA — TOFA
- EX. BUILDING RESTRICTION LINE — BRL
- EXISTING TREES AND TREE LINES — TREE, TREELIN
- EXISTING FENCE LINE
- EX. REIL — REIL
- EX. VASI OR PAPI — VASI / PAPI
- EX. SEGMENTED CIRCLE — SEG
- FUTURE ROADS
- FUT. TAXIWAY SAFETY AREA — F-TSA
- FUT. TAXIWAY OBJECT FREE AREA — F-TOFA
- FUTURE RWY PROTECTION ZONES
- FUT. RUNWAY SAFETY AREA — F-RSA
- FUT. OBJECT FREE AREA — F-OFA
- FUTURE CENTERLINES
- FUTURE RWY PROTECTION ZONES
- EXISTING POWER & TELEPHONE LINE — PT, PP, F-PP

NOTE:
RWY 13/31 APPROACHES WERE SURVEYED IN 2003, NO OBSTRUCTIONS OBSERVED.

N
MAG. DEC. = -6°28' N (2003)

GRAPHIC SCALE
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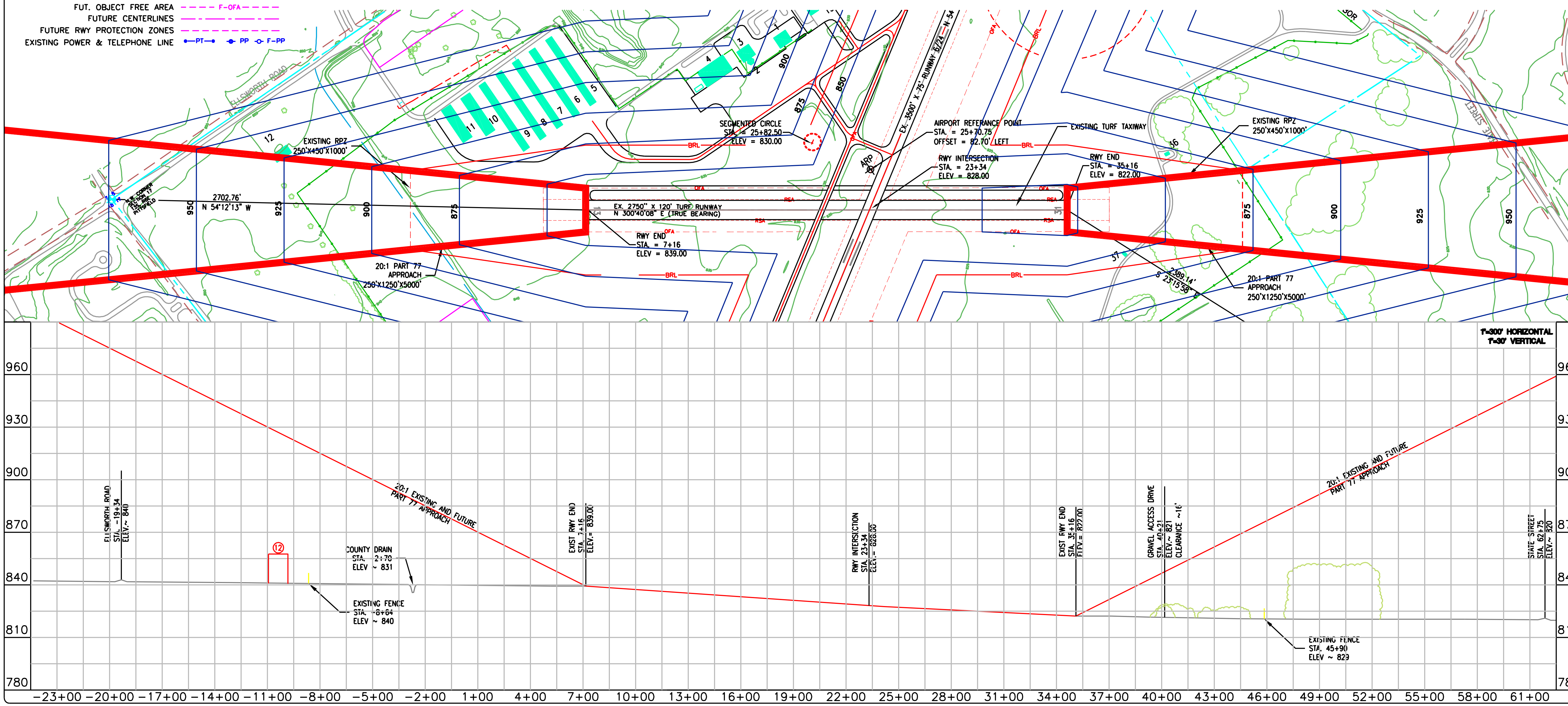
1"=300' HORIZONTAL
1"=30' VERTICAL



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DATE	ISSUED FOR
01/10/06	APPROVED ALP
01/10/06	FAA APPROVAL
11/08/05	MDOT FINAL DRAFT
10/14/04	MDOT REVIEW & APPROVAL

D/E JVV
PM RJC
SQC KAU
QC WAM
W. MALINOWSKI — IN CHARGE

URS
3950 SPARKS DR. S.E.
GRAND RAPIDS, MI.
616 574-8500

ANN ARBOR MUNICIPAL AIRPORT
ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN
RUNWAY APPROACH ZONE DRAWING (RWY 13/31)

SITE NO. 81-1

DRAWING 7 OF 10

12934808

BUILDING ELEVATION TABLE

NO.	DESCRIPTION	ELEVATION
1	ADMINISTRATION/TERMINAL BUILDING	849.56
2	AIR TRAFFIC CONTROL TOWER (ATCT)	893.29
3	AIR TRAFFIC ADMINISTRATION BUILDING	864.52
4	CORPORATE HANGAR (AV. GAS CO.)	866.72
5	T-HANGAR	858.03
6	T-HANGAR	857.98
7	T-HANGAR	857.12
8	T-HANGAR	857.95
9	T-HANGAR	858.01
10	T-HANGAR (NESTED)	863.58
11	T-HANGAR (NESTED)	863.56
12	BARN	894.80
13	CORPORATE HANGAR (MICHIGAN UNIVERSITY)	861.57
14	FIXED BASE OPERATION HANGAR	862.57
15	T-HANGAR	846.73
16	T-HANGAR	846.47
17	T-HANGAR	843.65
18	T-HANGAR	846.30
19	T-HANGAR (NESTED)	849.13
20	ROTATING FLOOR HANGAR	850.89
21	CONVENTIONAL HANGAR	851.15
22	CONVENTIONAL HANGAR	847.51
23	CONVENTIONAL HANGAR	838.92
24	CONVENTIONAL HANGAR	838.87
25	FIXED BASE OPERATION HANGAR	846.03
26	OFFICE BUILDING	837.91
27	CITY WATER FACILITY	823.35
28	T-HANGAR	836.39
29	CONVENTIONAL HANGAR	842.77
30	T-HANGAR	834.98
31	T-HANGAR	835.85
32	T-HANGAR	836.80
33	CONVENTIONAL HANGAR	843.80
34	CONVENTIONAL HANGAR	842.34
35	CONVENTIONAL HANGAR	841.81
36	CITY WATER FACILITY	837.20
37	CITY WATER FACILITY	837.60
38	CITY WATER FACILITY	834.09
39	CITY WATER FACILITY	836.12

TAXIWAY INFORMATION

TAXIWAY	A
WIDTH	30'
EDGE SAFETY MARGIN	7.5'
SHOULDER WIDTH	10'
SAFETY AREA WIDTH	79'
OBJECT FREE AREA	131'
℄ TO FIXED OR MOVEABLE OBJECT	65.5'

RUNWAY INFORMATION

RUNWAY	6/24	13/31
SHOULDER WIDTH	10'	10'
SAFETY AREA	150'x300'	120'x240'
OBSTACLE FREE ZONE	250'x200'	250'x200'
OBJECT FREE AREA	500'x300'	250'x240'
35' BUILDING RESTRICTION LINE	495'	370'
℄ TO HOLD LINE	200'	125'
℄ TO TAXIWAY ℄	250'	125'
℄ TO AIRCRAFT PARKING LINE	250'	125'

N

MAG. DEC. = -6°28'N (2003)

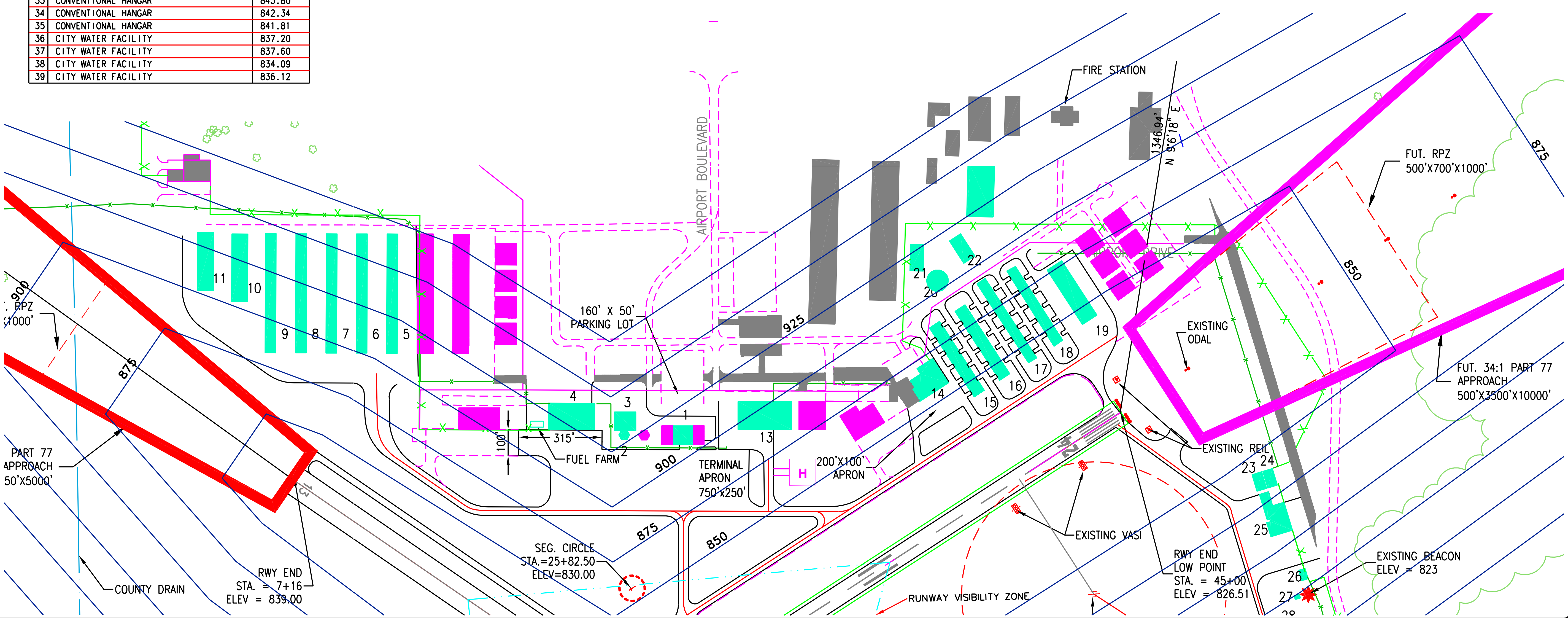
GRAPHIC SCALE

200 0 100 200

1"=200'

LEGEND

AIRPORT PROPERTY LINE
EASEMENT — BM
SECTION LINES — CORNER
RUNWAYS, PARKING, TAXIWAYS
FU. RUNWAYS, PARKING, TAXIWAYS
RWY PROTECTION ZONES
EXISTING BUILDINGS — EX-BUILD
FUTURE BUILDINGS — FU-BUILD
ROADS
FUTURE AIRPORT PROPERTY LINE
CENTERLINES
EX. RUNWAY SAFETY AREA — RSA
EX. TAXIWAY SAFETY AREA — TSA
EX. OBJECT FREE AREA — OFA
EX. OBJECT FREE ZONE — OFZ
EX. TAXIWAY OBJECT FREE AREA — TOFA
EX. BUILDING RESTRICTION LINE — BRL
EXISTING TREES AND TREE LINES — TREE, TREELIN
EXISTING FENCE LINE
EX. REIL — REIL
EX. VASI OR PAPI — VASI / PAPI
EX. SEGMENTED CIRCLE — SEG
FUTURE ROADS
FUT. TAXIWAY SAFETY AREA — F-TSA
FUT. TAXIWAY OBJECT FREE AREA — F-TOFA
FUTURE RWY PROTECTION ZONES
FUT. RUNWAY SAFETY AREA — F-RSA
FUT. OBJECT FREE AREA — F-OFA
FUTURE CENTERLINES
FUTURE RWY PROTECTION ZONES
EXISTING POWER & TELEPHONE LINE — PT, PP, F-PP
RUNWAY VISIBILITY ZONE



ISSUED FOR: APPROVED ALP 01/10/06; FAA APPROVAL 01/10/06; MDOT FINAL DRAFT 11/09/05; MDOT REVIEW & APPROVAL 10/14/04

D/E JVV; PM RJC; SOC KAU; QC WAM; IN CHARGE W. MALINOWSKI

GRAND RAPIDS, MI. 3950 SPARKS DR. S.E. 616 574-8500

URS

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

TERMINAL AREA PLAN

SITE NO. 81-1

DRAWING 8 OF 10

12934808

P:\41...\PDS\81-01-ALP08-TERM.dwg JVonDuin 12/8/2006 2:46 pm

FUTURE PARCEL ACQUISITIONS

FEDERAL PROJECT NUMBER	PARCEL NUMBER	GRANTORS	DEED*	LIBER AND PAGE	RECORDED DATE	ACREAGE	NOTES *	CONTROLLING HEIGHT
-	F-1	DB WAREHOUSE LTD.	WD	00-00 00-00	00/00/00	1.09	-	-
-	F-2	PITTSFIELD TOWNSHIP	WD	00-00	00/00/00	2.94	-	-
-	F-3	CLARA SEYMOUR	WD	00-00	00/00/00	5.69	-	-
					FEE ACRES	9.72		

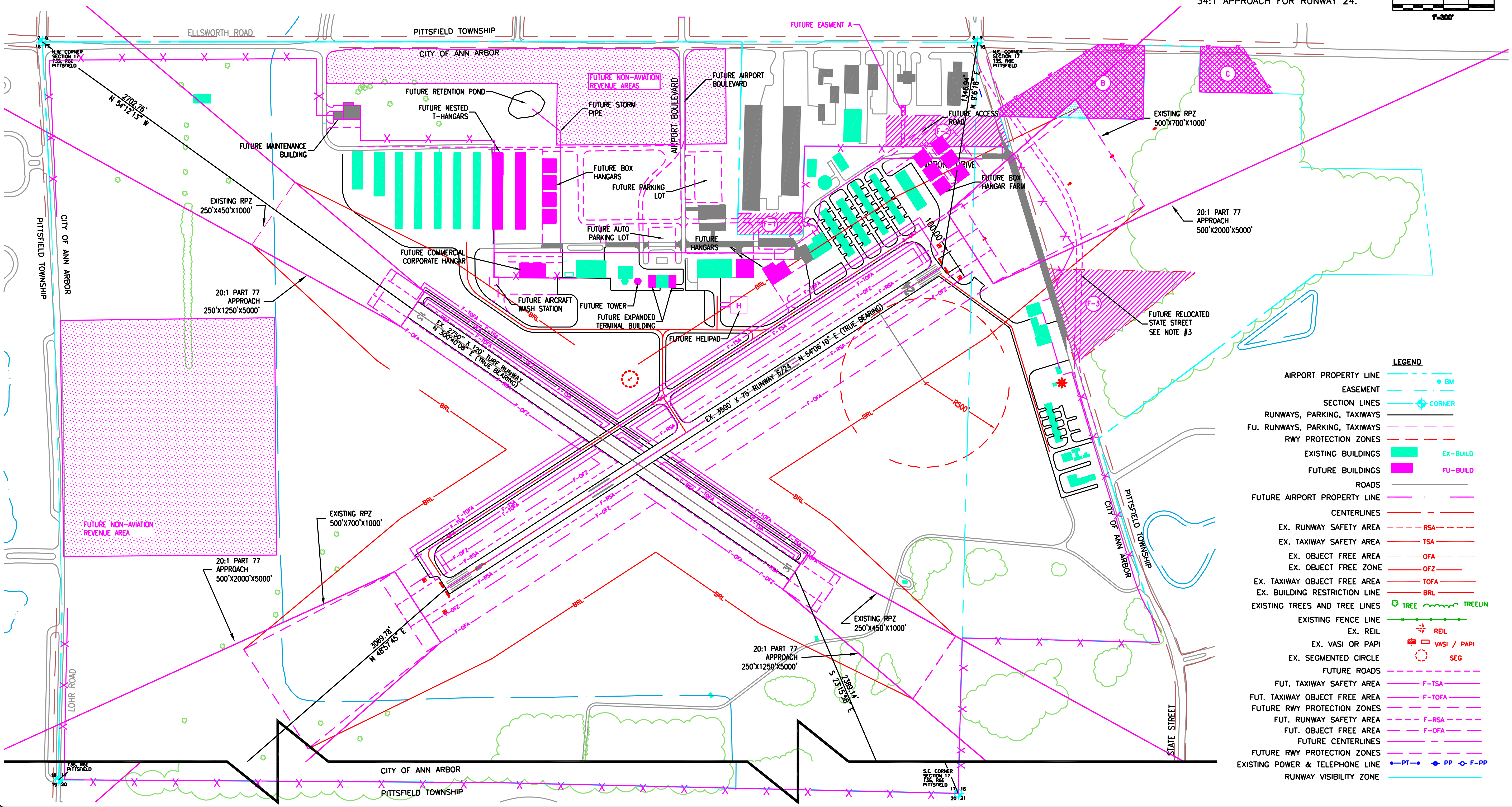
AE-AVIGATION EASEMENT
CJ-CONSENT JUDGMENT
E-EASEMENT
GD-GUARDIAN DEED
CE-CLEARING EASEMENT
LE-LIGHT EASEMENT
WD-WARRANTY DEED
QC-QUIT CLAIM DEED

FUTURE EASEMENT INTERESTS

NO.	PARCEL	TYPE	GRANTEE	ACREAGE	LIBER-PAGE	RECORDED DATE	NOTES
A	-	EE EASEMENT	PITTSFIELD TOWNSHIP	0.028	00-00	00/00/00	FIRE STATION ACCESS
B	-	AE EASEMENT	PITTSFIELD TOWNSHIP	5.98	00-00	00/00/00	34:1 APPROACH EASEMENT
C	-	AE EASEMENT	PITTSFIELD TOWNSHIP	2.12	00-00	00/00/00	34:1 APPROACH EASEMENT
				8.128	TOTAL ACREAGE		

DE - DRAINAGE EASEMENT
EE - ACCESS EASEMENT
AE - AVIGATION EASEMENT

NOTE #3
STATE STREET TO BE RELOCATED OR LOWERED TO PROVIDE 15' CLEARANCE FOR THE FUTURE 34:1 APPROACH FOR RUNWAY 24.



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01/10/06	FAA APPROVAL		
11/08/05	MDOT FINAL DRAFT		
10/14/04	MDOT REVIEW & APPROVAL		
DATE	ISSUED FOR		

D/E JVY
PM RJC
SOC KAU
QC WAM
W. MALINOWSKI
IN CHARGE

URS
3950 SPARKS DR. S.E.
GRAND RAPIDS, MI.
616 574-8500

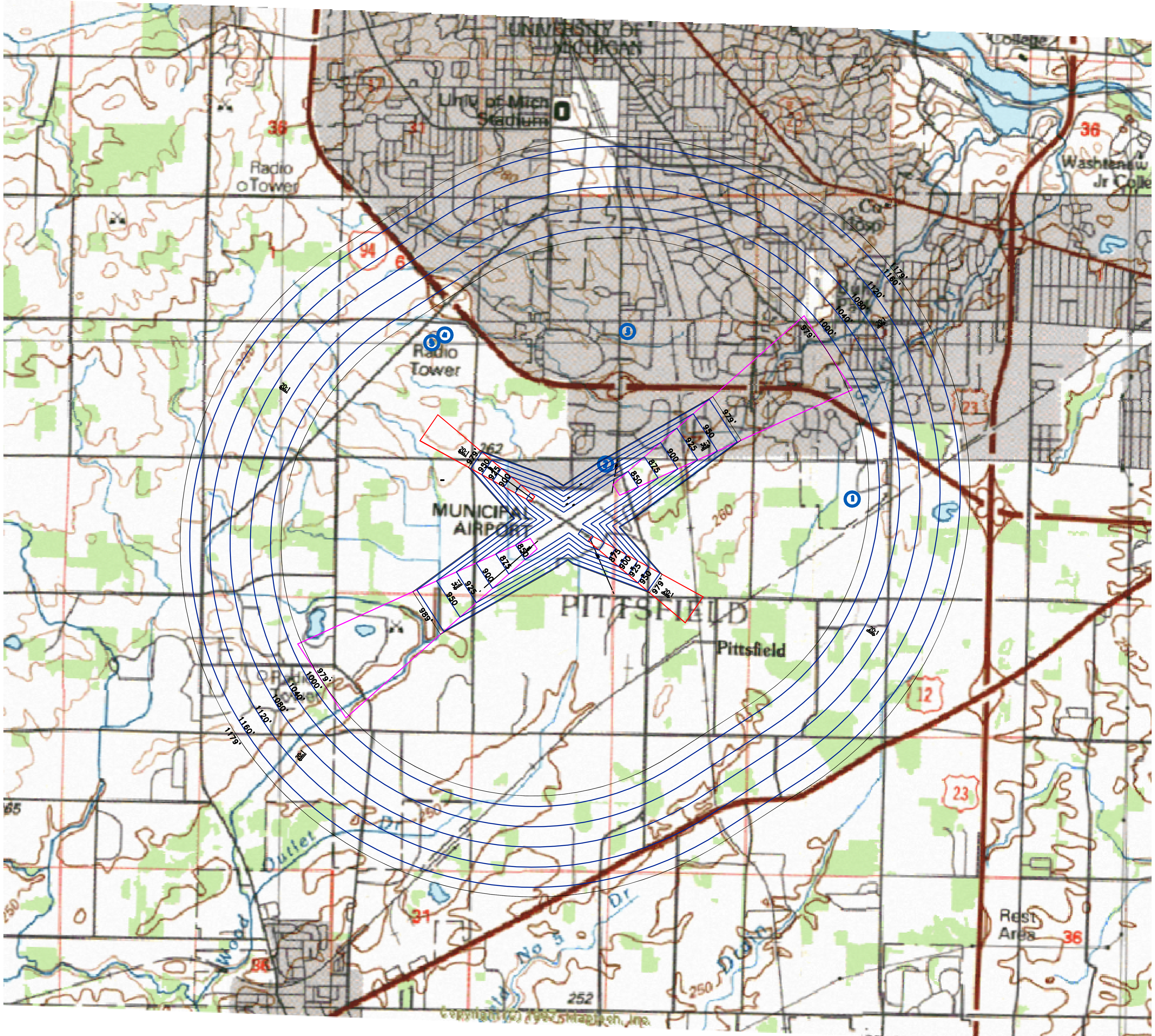
ANN ARBOR MUNICIPAL AIRPORT
ANN ARBOR, MICHIGAN

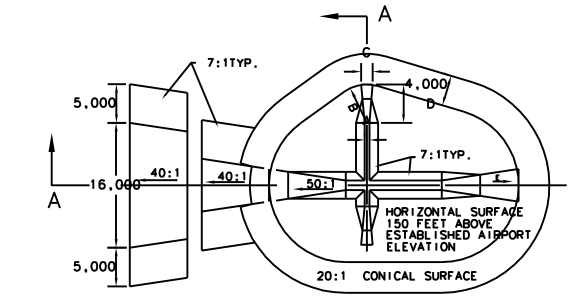
AIRPORT LAYOUT PLAN
AIRPORT PROPERTY PLAN

SITE NO.
81-1

DRAWING
9 OF 10

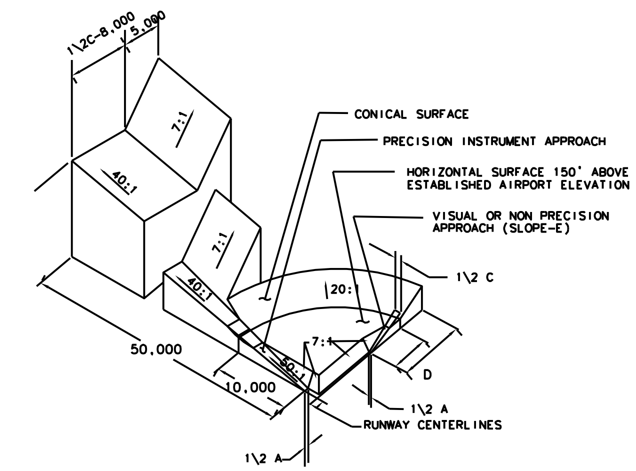
12934808





DIM	ITEM	DIMENSIONAL STANDARDS (FEET)					
		VISUAL RUNWAY		NON-PRECISION INSTRUMENT RUNWAY			PRECISION INSTRUMENT RUNWAY
		A	B	A	B		
					C	D	
A	WIDTH OF PRIMARY SURFACE AND APPROACH SURFACE WIDTH AT INNER END	250	500	500	500	1,000	1,000
B	RADIUS OF HORIZONTAL SURFACE	5,000	5,000	5,000	10,000	10,000	10,000
		VISUAL APPROACH		NON-PRECISION INSTRUMENT APPROACH			PRECISION INSTRUMENT APPROACH
					B		
		A	B		C	D	
C	APPROACH SURFACE WIDTH AT END	1,250	1,500	2,000	3,500	4,000	16,000
D	APPROACH SURFACE LENGTH	5,000	5,000	5,000	10,000	10,000	•
E	APPROACH SLOPE	20:1	20:1	20:1	34:1	34:1	•

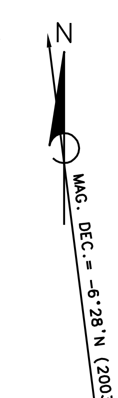
A- UTILITY RUNWAYS
B- RUNWAYS LARGER THAN UTILITY
C- VISIBILITY MINIMUMS GREATER THAN 3\4 MILE
D- VISIBILITY MINIMUMS AS LOW AS 3\4 MILE
• PRECISION INSTRUMENT APPROACH SLOPE IS 50:1 FOR INNER 10,000 FEET AND 40:1 FOR AN ADDITIONAL 40,000 FEET



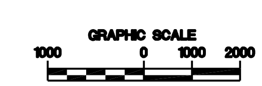
ESTABLISHED AIRPORT EL.= 829'

AIRPORT REFERENCE POINT

EXISTING
LAT. 42°13'22.14" N.
LONG. 83°44'39.79" W.



TOWERS		
	AGL	AMSL
1	240'	1090'
2	70'	900'
3	100'	939'
4	185'	1079'
5	237'	1147'



DATE	ISSUED FOR
10/14/04	MDOT REVIEW & APPROVAL
11/08/05	MDOT FINAL DRAFT
01/10/06	FAA APPROVAL
01/10/06	APPROVED ALP

D/E JVV ×
PM RJC ×
SQC KAU ×
QC WMM ×
W. MALINOWSKI
IN CHARGE

URS
GRAND RAPIDS, MI.,
3950 SPARKS DR. S.E.
616 574-8500

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

FAR PART 77 APPROACH SURFACES DRAWING

SITE NO. 81-1

DRAWING 10 OF 10

12934808

P:\MID4515\PDS\81-01-ALP05-AERIAL.dwg
Xref: ...\UTIL\UTIL.dwg
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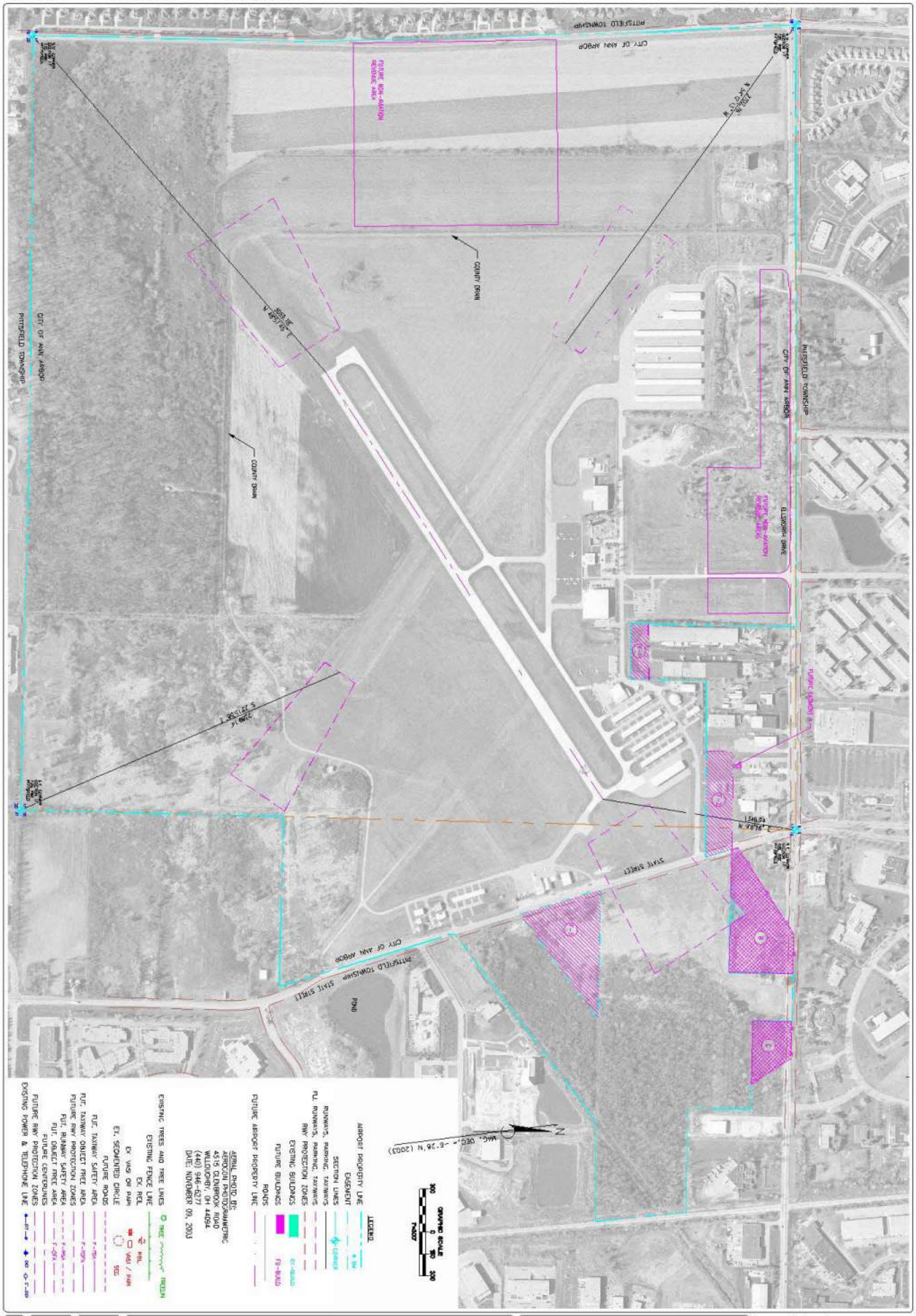


ANN ARBOR MUNICIPAL AIRPORT

AIRPORT LAYOUT PLAN — ANN ARBOR, MICHIGAN

AIRPORT LAYOUT AERIAL

SITE NO. 81-1

DRAWING 5 OF 10

12934808

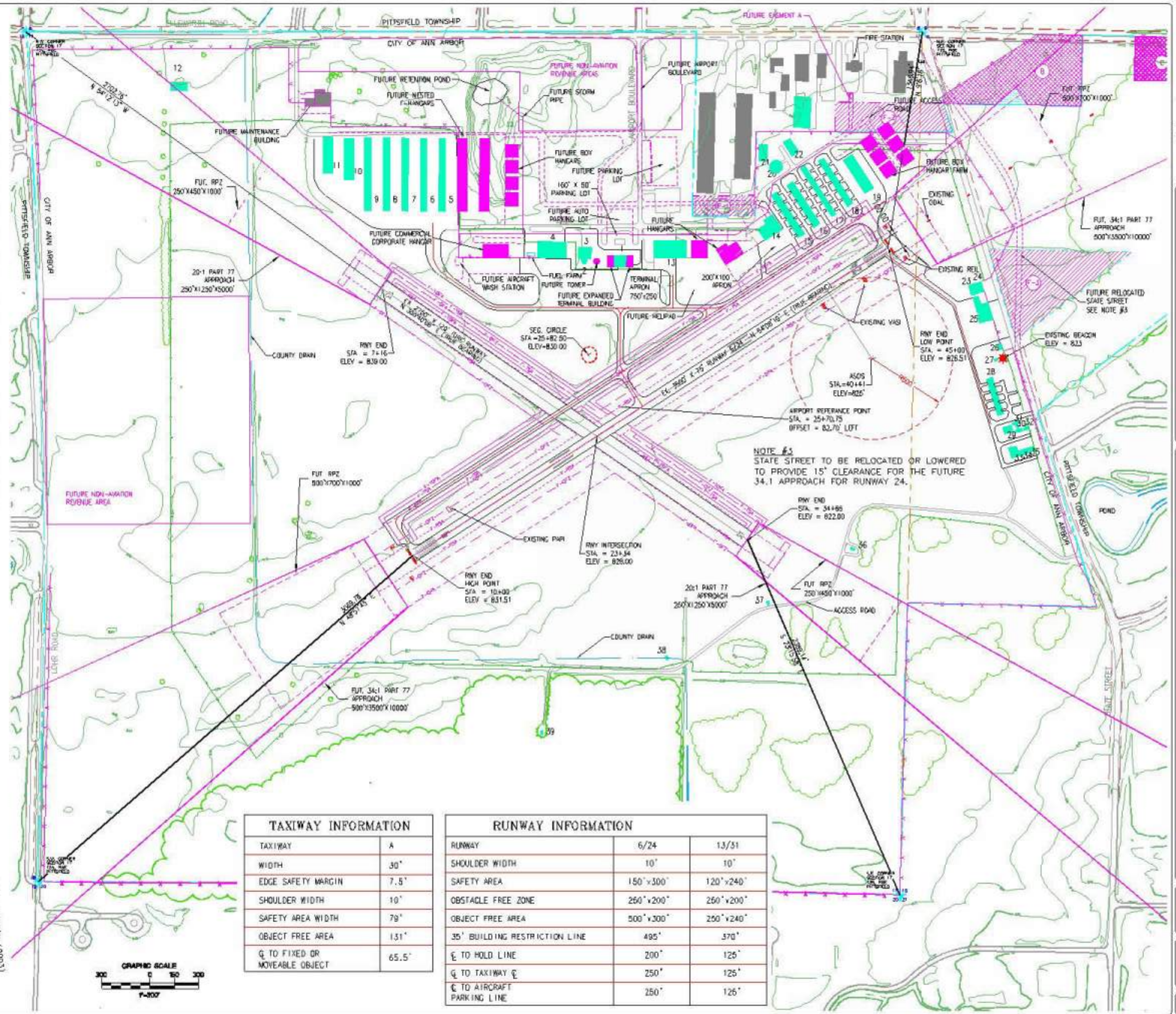
URS
GRAND RAPIDS, MI.
2600 DANTE DR. S.E.
616 574-8500

D/E	JVY
PM	RJC
SQC	KAU
QC	WMM
W. MALINOWSKI	IN CHARGE

DATE	ISSUED FOR
01/10/06	APPROVED ALP
01/10/06	FAA APPROVAL
11/08/05	MDOT FINAL DRAFT
10/14/04	MDOT REVIEW & APPROVAL

BUILDING ELEVATION TABLE

NO.	DESCRIPTION	ELEVATION
1	ADMINISTRATION/TERMINAL BUILDING	849.56
2	AIR TRAFFIC CONTROL TOWER (ATCT)	893.29
3	AIR TRAFFIC ADMINISTRATION BUILDING	864.52
4	CORPORATE HANGAR (AV. GAS CO.)	866.72
5	T-HANGAR	858.03
6	T-HANGAR	857.98
7	T-HANGAR	857.12
8	T-HANGAR	857.95
9	T-HANGAR	858.01
10	T-HANGAR (NESTED)	863.58
11	T-HANGAR (NESTED)	863.56
12	BARN	894.80
13	CORPORATE HANGAR (MICHIGAN UNIVERSITY)	861.57
14	FIXED BASE OPERATION HANGAR	862.57
15	T-HANGAR	846.73
16	T-HANGAR	846.47
17	T-HANGAR	843.65
18	T-HANGAR	846.30
19	T-HANGAR (NESTED)	849.13
20	ROTATING FLOOR HANGAR	850.89
21	CONVENTIONAL HANGAR	851.15
22	CONVENTIONAL HANGAR	847.51
23	CONVENTIONAL HANGAR	838.92
24	CONVENTIONAL HANGAR	838.87
25	FIXED BASE OPERATION HANGAR	846.03
26	OFFICE BUILDING	837.91
27	CITY WATER FACILITY	823.35
28	T-HANGAR	836.39
29	CONVENTIONAL HANGAR	842.77
30	T-HANGAR	834.98
31	T-HANGAR	835.85
32	T-HANGAR	836.80
33	CONVENTIONAL HANGAR	843.80
34	CONVENTIONAL HANGAR	842.34
35	CONVENTIONAL HANGAR	841.81
36	CITY WATER FACILITY	837.20
37	CITY WATER FACILITY	837.60
38	CITY WATER FACILITY	834.09
39	CITY WATER FACILITY	836.12



TAXIWAY INFORMATION

TAXIWAY	A
WIDTH	30'
EDGE SAFETY MARGIN	7.5'
SHOULDER WIDTH	10'
SAFETY AREA WIDTH	79'
OBJECT FREE AREA	131'
℄ TO FIXED OR MOVEABLE OBJECT	65.5'

RUNWAY INFORMATION

RUNWAY	6/24	13/31
SHOULDER WIDTH	10'	10'
SAFETY AREA	150'x300'	120'x240'
OBSTACLE FREE ZONE	250'x200'	250'x200'
OBJECT FREE AREA	500'x300'	250'x240'
35' BUILDING RESTRICTION LINE	495'	370'
℄ TO HOLD LINE	200'	125'
℄ TO TAXIWAY ℄	250'	125'
℄ TO AIRCRAFT PARKING LINE	250'	125'

URS

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

AIRPORT LAYOUT PLAN (FUTURE)

SITE NO. 81-1

DRAWING 4 OF 10

12934808

LEGEND

AIRPORT PROPERTY LINE	BM
EASEMENT	
SECTION LINES	CORNER
RUNWAYS, PARKING, TAXIWAYS	
FU. RUNWAYS, PARKING, TAXIWAYS	
RWY PROTECTION ZONES	
EXISTING BUILDINGS	EX-BUILD
FUTURE BUILDINGS	FU-BUILD
ROADS	
FUTURE AIRPORT PROPERTY LINE	
CENTERLINES	
EX. RUNWAY SAFETY AREA	RSA
EX. TAXIWAY SAFETY AREA	TSA
EX. OBJECT FREE AREA	OFA
EX. OBJECT FREE ZONE	OFZ
EX. TAXIWAY OBJECT FREE AREA	TOFA
EX. BUILDING RESTRICTION LINE	BRL
EXISTING TREES AND TREE LINES	TREE, TREELIN
EXISTING FENCE LINE	
EX. REIL	REIL
EX. VASI OR PAPI	VASI / PAPI
EX. SEGMENTED CIRCLE	SEG
FUTURE ROADS	
FUT. TAXIWAY SAFETY AREA	F-TSA
FUT. TAXIWAY OBJECT FREE AREA	F-TOFA
FUTURE RWY PROTECTION ZONES	
FUT. RUNWAY SAFETY AREA	F-RSA
FUT. OBJECT FREE AREA	F-OFA
FUTURE CENTERLINES	
FUTURE RWY PROTECTION ZONES	
EXISTING POWER & TELEPHONE LINE	PT, PP, F-PP

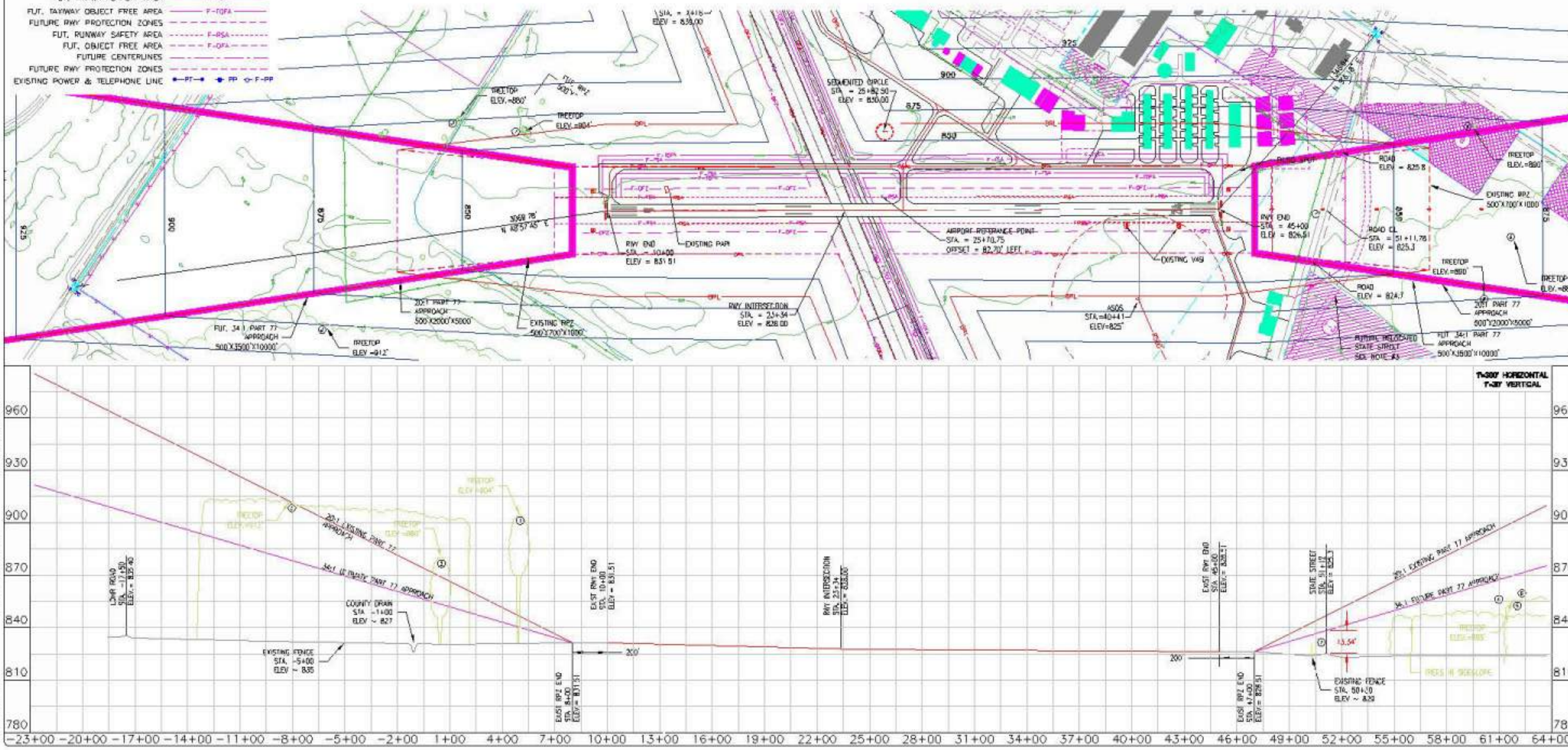
OBSTRUCTION TABLE							
		TOP	MAX. ELEV.		PENETRATION		PROPOSED
NO	TYPE	ELEV	EX.	FUT.	EX.	FUT.	DISPOSITION
1	TREES	904'	882' **	863' **	22'	41'	REMOVE
2	TREES	880'	900' **	875' **		5'	REMOVE
3	TREES	912'	933' **	902' **		10'	REMOVE
4	TREES	890'	886' **	868' **		22'	REMOVE
5	TREES	885'	900'	871'		14'	REMOVE
6	TREES	890'	902' **	875' **		15'	REMOVE
7	ROAD	825.3'	872'	823.6'		1.3'	RELOCATE

** IN SIDE OR TRANSITIONAL SLOPE

NOTE #1
STATE STREET TO BE RELOCATED OR LOWERED TO PROVIDE 15' CLEARANCE FOR THE FUTURE 34:1 APPROACH FOR RUNWAY 24.

MAG. DEC. = -6°28'N (2003)

GRAPHIC SCALE
300 0 150 300
1"=300' HORIZONTAL
1"=30' VERTICAL



D/E JVY	X	01/10/08	APPROVED ALP
PM RJC	X	01/10/08	FAA APPROVAL
SDO RAU	X	11/08/05	MDOT FINAL DRAFT
DC MHAM	X	10/14/04	MDOT REVIEW & APPROVAL
M. WALKINGSHAW		DATE	ISSUED FOR
IN CHARGE			

URS

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

RUNWAY APPROACH ZONE DRAWING (RWY 6/24)

SITE NO. 81-1

DRAWING 6 OF 10

12934808

STATE OF MICHIGAN
DEPARTMENT OF TRANSPORTATION
LANSING

JENNIFER M. GRANHOLM
GOVERNOR

KIRK T. STEUDLE
DIRECTOR

May 11, 2006

Mr. James R. Hawley, Manager
Ann Arbor Municipal Airport
801 Airport Road
Ann Arbor, Michigan 48104

Dear Mr. Hawley:

Subject: Ann Arbor Municipal Airport, Ann Arbor, Michigan
Airport Layout Plan (ALP) Airspace Approval
Airspace Case No. 06-AGL-0008-NRA

Enclosed is one approved copy of the Ann Arbor Municipal Airport Layout Plan (ALP), dated January 10, 2006. This ALP is being approved on behalf of the FAA under the authority of Section 534 of the Airport and Airways Improvement Act (AAIA) of 1982 as amended, pursuant to the State Block Grant program. This letter cancels or supersedes all prior ALP approvals. The ALP approval is based on recognition of and adherence to the following:

1. The approval is not to be considered a commitment of Federal funding for the proposed development. The FAA has concurred with the proposed development for planning purposes only based on current safety, utility, and efficiency standards. Actual development should comply with approved standards applicable at the time of construction. No design standard modifications have been granted.

   If any of the design critical aircraft or aircraft groups change, this ALP must be reevaluated by the FAA.

2. Our approval does not infer or imply that the land in the airport vicinity is considered compatible with airport operations. Federal requirements stipulate:

   a. All development programs should be reasonably consistent with the plans of local and state planning agencies for the development in the airport vicinity.

   b. That fair consideration has been given to the interest of communities in or near the airport.

   c. That development programs provide for the protection and enhancement of the environment.

3. The FAA offers no objections to the proposed ultimate airspace utilization as depicted on the ALP based on considerations of safe and efficient use of airspace. The ALP has the status of "Plan on File" for the purpose of 14 CFR 77, Obstruction Evaluations, and 14

CFR 152, Airport Aid Program. A review of the airside landing area development was conducted according to the following 14 CFR's: -77, -152, and -157, Notice of Construction, Alteration, Activation, and Deactivation of Airports (reference Aeronautical Study Number 05-AGL-942-NRA). It should be noted that FAA cannot prevent erection of any structure near an airport. Airport environs can only be protected through state and local zoning ordinances, building regulations, and like requirements.

4. Approval is given subject to the condition that any proposed airport development requiring environmental processing shall not be undertaken without prior written environmental approval by the FAA. Any airport development action that falls within the scope of Paragraph 24 of FAA Order 5050.4A, or which involves any of the following:

   a. Runway End 24 currently has a NPI approach 20:1 with a displaced threshold.

   b. Purchase additional land in fee and easements for the approach to Runway End 24 to provide for a 15' clearance over State Road for a future 34:1 NPI approach. State Road is proposed to be relocated or lowered to provide this 15' clearance.

   c. Proposed new Air Traffic Control Tower (ATCT).

   d. Proposed new access road to the administration building area.

   e. Proposed additional hangars.

   f. Proposed new drainage system.

   g. Clear, lower or remove obstructions (refer to the Obstruction Table on Sheet 6).

   h. Land acquisition associated with any of the above items plus land acquisition which results in relocation of residential units where there is evidence of insufficient comparable replacement dwellings, major disruption of business activities, or acquisition which involves land covered under Section 4(f) of the DOT Act (rectified 49 USC Subtitle I, Section 303, January 12, 1983).

   i. Any airport development action that falls within the scope of Paragraph 24 of FAA Order 5050.4A, or which involves any of the following:

      i. Use of Section 4(f) lands.
      ii. Effect on any properties included in or eligible for inclusion in the National Register of Historic Places or other property of state or local historical, architectural, archeological, or cultural significance.
      iii. Land acquisition for the conversion of farmland, which scores more than 160 on Form AD-1006 and is protected under the Farmland Protection Policy Act (FPPA), to nonagricultural use through federal financial assistance or through conveyance of government land.
      iv. Wetlands, coastal zones, or flood plains.
      v. Endangered or threatened species.

Any items not covered above in item 4 shall not take place until the environmental processing has been approved by the FAA. All development items must comply with the National Environmental Policy Act of 1969 (P.L. 91-190).

To avoid conflicts with future development, we recommend you utilize the ALP when preparing leases. We further recommend you provide copies to the local and state planning zoning boards and county and city officials and encourage them to adopt compatible land use criteria in and around the airport. Copies should also be distributed to the Fixed Base Operators (FBO's) and airport users.

The Airport and Airway Improvement Act (49 USC 47107(a)(16)(D)) requires the sponsor to eliminate any adverse effects on Federal facilities, or bear all costs to relocate those facilities that are a result of an airport change. However, if AIP eligible construction/development items adversely affect FAA facilities, the cost of relocating the facilities may be eligible under AIP.

This approval does not include a detailed evaluation of actual construction. Prior to constructing any development on the airport, notice (FAA Form 7460-1) consistent with 14 CFR 77 must be filed with this office. This approval does not include approval for temporary construction equipment which may be used during actual construction, e.g., cranes, equipment staging areas, site access routes, etc. A separate construction safety/phasing plan for any project should be reviewed by the FAA no less than 60 days prior to beginning any project.

If development is planned without aviation trust fund investments that will change the status or geometrics of runways, taxiways, aprons, or other operating airport surfaces, notice (FAA Form 7480-1) must be filed with this office consistent with 14 CFR 157.

We trust we have provided a clear explanation of the conditions and terms of our approval. If you need further clarification, please contact John D. Pierce at (517) 335-9857.

Sincerely,

David L. Baker, P.E., Manager
AIP Programs
Airports Division
Multi-Modal Transportation Services Bureau

Enclosure
cc: ASW-520 (w/ALP on PDF file); FTW-FPO (w/ALP on PDF file); FAA-ADO (w/ALP); Superior SMO (w/ALP on PDF file); AGL-470 (w/ALP on PDF file); and B. Malinowski, URS Corp, Inc.

STATE OF MICHIGAN
DEPARTMENT OF TRANSPORTATION
AIRPORTS DIVISION
LANSING, MICHIGAN

ANN ARBOR MUNICIPAL AIRPORT
WASHTENAW COUNTY
ANN ARBOR, MI
AIRPORT LAYOUT PLAN

ANN ARBOR AIRPORT
CITY OF ANN ARBOR

APPROVED ______ MATTHEW KULHANEK - AIRPORT MANAGER ______ DATE

APPROVED ______ JOHN HIEFTJE - MAYOR ______ DATE

MICHIGAN AERONAUTICS COMMISSION

APPROVED ______ RICK HAMMOND - AIRPORTS DIV. ADMINISTRATOR ______ DATE

APPROVED ______ DAVID L. BAKER P.E. NO. 40936 - CHIEF ENGINEER ______ DATE

REVISION BLOCK

DATE	MODIFICATIONS	INITIALS

DESIGNERS & CONSULTANTS

URS
GRAND RAPIDS, MI.
3950 SPARKS DR. S.E.
616 574-8500

APPROVED ______ WILLIAM M. MALINOWSKI, P.E. NO. 17808 ______ DATE

NOTE: SIGNATURE IN CONSULTANT BLOCK CERTIFIES ALP WAS PREPARED USING ALP CHECKLIST.

AIRPORT TYPE - GENERAL AVIATION | SITE NO. - 81-1

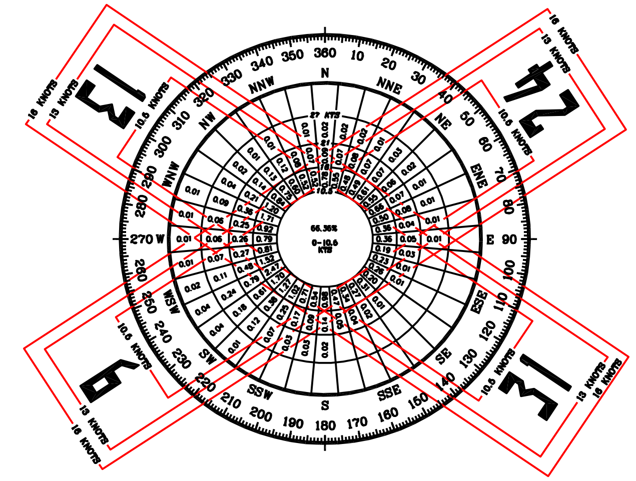
\M104333\PDS\01-TITLE.dwg
JVandyin
8:20 am on Mar 1, 01

MODIFICATIONS TO FAA DESIGN STANDARDS

DATE OF FAA LETTER	DESCRIPTION
	CATEGORY C APPROACH MINIMA GRANDFATHERED FAA AIRSPACE NO. 92-AGL-698-NRA
	TAXIWAY WIDTH AT 30', NOT STANDARD 35'
	NORTHEAST FBO HANGAR ATCT LINE OF SITE TO END OF PARALLEL TAXIWAY
	TWO T-HANGARS IN NORTHEAST CORNER OF AIRPORT ATCT LINE OF SITE TO END OF PARALLEL TAXIWAY

AIRPORT DATA TABLE

COUNTY: WASHTENAW	TOWNSHIP: PITTSFIELD	TOWN: T 3 S
MEAN MAXIMUM TEMPERATURE:	83°F JULY	RANGE: R 6 E
AIRPORT REFERENCE POINT:	LAT: 42°13'22.14" N.	LONG: 83°44'39.79" W
AIRPORT REFERENCE CODE:	ARB	
	EXISTING	FUTURE
AIRPORT ELEVATION (MSL)	829	829
AIRPORT AND TERMINAL NAVAIDS	ROTATING BEACON VOR, ATCT	ROTATING BEACON VOR, ATCT
SERVICE LEVEL	GENERAL AVIATION	GENERAL AVIATION
AIRPORT ROLE	GENERAL UTILITY	GENERAL UTILITY
APPROACH CATEGORY	B	B
AIRPLANE DESIGN GROUP	II	II

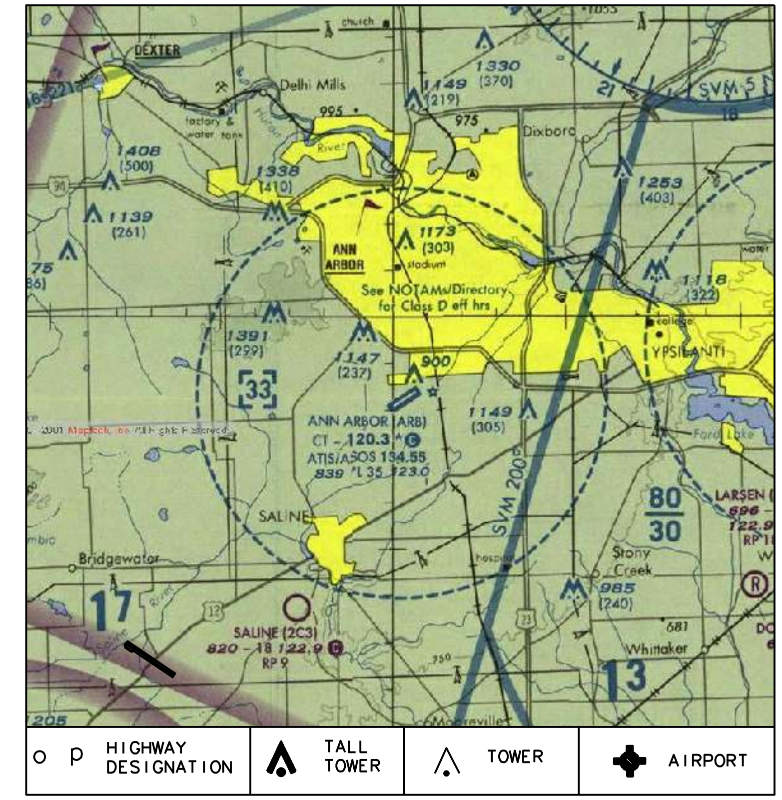


STATION : DETROIT METROPOLITAN AIRPORT
PERIOD : 1/82 TO 1/89
OBSERVATIONS: 94,847

WIND COVERAGE SUMMARY

	10.5 KNOTS	13 KNOTS	16 KNOTS
RUNWAY 6-24	88.30%	94.10%	98.50%
RUNWAY 13-31	81.80%	88.80%	--
COMBINED COVERAGE	96.90%	99.20%	--

N
MAG. DEC. = -6°28'N (2003)



LOCATION MAP

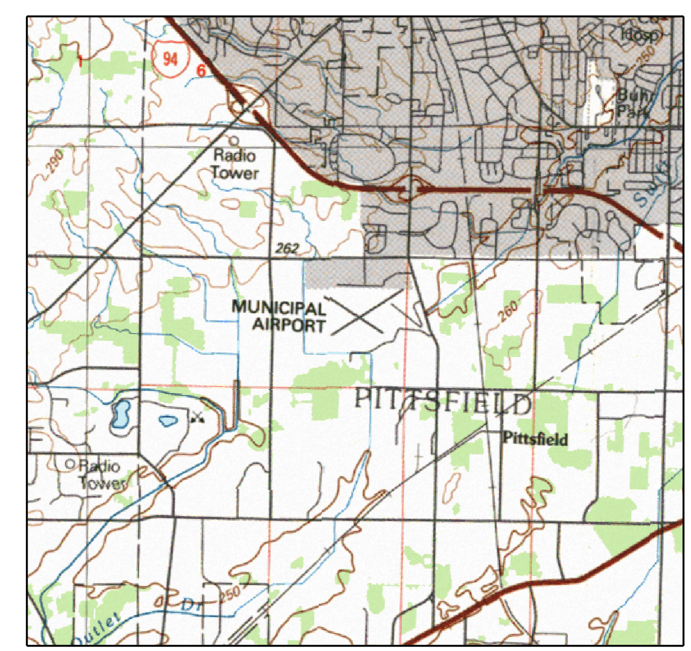
SCALE: 1:500,000

NORTH
0 10 MILE

RUNWAY AND APPROACH DATA

RUNWAY	6		24		13		31	
	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
RUNWAY LENGTH	3500'	3500'	3500'	3500'	2750'	2750'	2750'	2750'
RUNWAY WIDTH	75'	75'	75'	75'	110'	110'	110'	110'
DISPLACED THRESHOLD	--	--	--	--	--	--	--	--
EFFECTIVE LANDING LENGTH	3500'	3500'	3500'	3500'	2750'	2750'	2750'	2750'
EFFECTIVE TAKEOFF LENGTH	3500'	3500'	3500'	3500'	2750'	2750'	2750'	2750'
TORA	--	--	--	--	--	--	--	--
TODA	--	--	--	--	--	--	--	--
ASDA	--	--	--	--	--	--	--	--
LDA	--	--	--	--	--	--	--	--
STOPWAY	--	--	--	--	--	--	--	--
CLEARWAY	--	--	--	--	--	--	--	--
RUNWAY CATEGORY	NON-PRECISION	NON-PRECISION	NON-PRECISION	NON-PRECISION	UTILITY	UTILITY	UTILITY	UTILITY
RUNWAY GRADIENT	0.17%	0.17%	0.17%	0.17%	0.61%	0.61%	0.61%	0.61%
PAVEMENT TYPE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	TURF	TURF	TURF	TURF
PAVEMENT STRENGTH: GEAR/LOAD(X 1000)	SW 45 DW 70	SW 45 DW 70	SW 45 DW 70	SW 45 DW 70	NONE	NONE	NONE	NONE
RUNWAY LIGHTING	MIRL	MIRL	MIRL	MIRL	NONE	NONE	NONE	NONE
RUNWAY MARKING	N.P.I.	N.P.I.	N.P.I.	N.P.I.	NONE	NONE	NONE	NONE
NAVIGATIONAL AIDS	VOR, PAPI ROT. BEACON SEG. CIRCLE REIL, RNAV	VOR, PAPI ROT. BEACON SEG. CIRCLE REIL, RNAV	GPS, VOR, PAPI ROT. BEACON SEG. CIRCLE ODALS, RNAV	GPS, VOR, PAPI ROT. BEACON SEG. CIRCLE ODALS, RNAV	ROT. BEACON SEG. CIRCLE	ROT. BEACON SEG. CIRCLE	ROT. BEACON SEG. CIRCLE	ROT. BEACON SEG. CIRCLE
APPROACH LIGHTING	PAPI	PAPI	VASI	PAPI	NONE	NONE	NONE	NONE
AIRCRAFT APPROACH CATEGORY	B	B	B	B	B	B	B	B
AIRPLANE DESIGN GROUP	II	II	II	II	I	I	I	I
CRITICAL AIRCRAFT	BEECH KING AIR C90-1	CESSNA CITATION II	BEECH KING AIR C90-1	CESSNA CITATION II	CESSNA 172	CESSNA 172	CESSNA 172	CESSNA 172
APPROACH	NON-PRECISION	NON-PRECISION	NON-PRECISION	NON-PRECISION	VISUAL	VISUAL	VISUAL	VISUAL
RPZ	500'x 700' x 1000'	500'x 700' x 1000'	500'x 700' x 1000'	500'x 700' x 1000'	250'x 450' x 1000'	250'x 450' x 1000'	250'x 450' x 1000'	250'x 450' x 1000'
APPROACH RATIO FAR PART 77	20:1	34:1	20:1	34:1	20:1	20:1	20:1	20:1
APPROACH VISIBILITY MINIMUMS	> 1 MILE	> 1 MILE	> 1 MILE	> 1 MILE	> 1 MILE	> 1 MILE	> 1 MILE	> 1 MILE
RUNWAY END COORDINATE (NAD 83) LAT: LONG:	N 42°13'12.88" W 83°45'00.38"	N 42°13'12.88" W 83°45'00.38"	N 42°13'32.97" W 83°44'22.45"	N 42°13'32.97" W 83°44'22.45"	N 42°13'29.3" W 83°45'04.0"	N 42°13'29.3" W 83°45'04.0"	N 42°13'14.8" W 83°44'33.1"	N 42°13'14.8" W 83°44'31.1"

RUNWAY 13/31 COORDINATES ARE FROM 2004 GPS SURVEY
RUNWAY 6/24 COORDINATES ARE FROM PREVIOUS ALP



VICINITY MAP

SCALE: 1"=4000'

NORTH
0 4000' 8000'

P:\M104513\PDS\81-01-ALP02-DATA.dwg
ADrouin
4/30/2004 9:26 am

D/E JVV	01/10/06	APPROVED ALP
PM RJC	01/10/06	FAA APPROVAL
SOC KAU	11/08/05	MDOT FINAL DRAFT
QC WMM	10/14/04	MDOT REVIEW & APPROVAL
W. MALINOWSKI		
IN CHARGE	DATE	ISSUED FOR

URS
GRAND RAPIDS, MI.
3950 SPARKS DR. S.E.
616 574-8500

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN
AIRPORT DATA SUMMARY

SITE NO. 81-1

DRAWING 2 OF 10

12934808

BUILDING ELEVATION TABLE

NO.	DESCRIPTION	ELEVATION
1	ADMINISTRATION/TERMINAL BUILDING	849.56
2	AIR TRAFFIC CONTROL TOWER (ATCT)	893.29
3	AIR TRAFFIC ADMINISTRATION BUILDING	864.52
4	CORPORATE HANGAR (AV. GAS CO.)	866.72
5	T-HANGAR	858.03
6	T-HANGAR	857.98
7	T-HANGAR	857.12
8	T-HANGAR	857.95
9	T-HANGAR	858.01
10	T-HANGAR (NESTED)	863.58
11	T-HANGAR (NESTED)	863.56
12	BARN	894.80
13	CORPORATE HANGAR (MICHIGAN UNIVERSITY)	861.57
14	FIXED BASE OPERATION HANGAR	862.57
15	T-HANGAR	846.73
16	T-HANGAR	846.47
17	T-HANGAR	843.65
18	T-HANGAR	846.30
19	T-HANGAR (NESTED)	849.13
20	ROTATING FLOOR HANGAR	850.89
21	CONVENTIONAL HANGAR	851.15
22	CONVENTIONAL HANGAR	847.51
23	CONVENTIONAL HANGAR	838.92
24	CONVENTIONAL HANGAR	838.87
25	FIXED BASE OPERATION HANGAR	846.03
26	OFFICE BUILDING	837.91
27	CITY WATER FACILITY	823.35
28	T-HANGAR	836.39
29	CONVENTIONAL HANGAR	842.77
30	T-HANGAR	834.98
31	T-HANGAR	835.85
32	T-HANGAR	836.80
33	CONVENTIONAL HANGAR	843.80
34	CONVENTIONAL HANGAR	842.34
35	CONVENTIONAL HANGAR	841.81
36	CITY WATER FACILITY	837.20
37	CITY WATER FACILITY	837.60
38	CITY WATER FACILITY	834.09
39	CITY WATER FACILITY	836.12

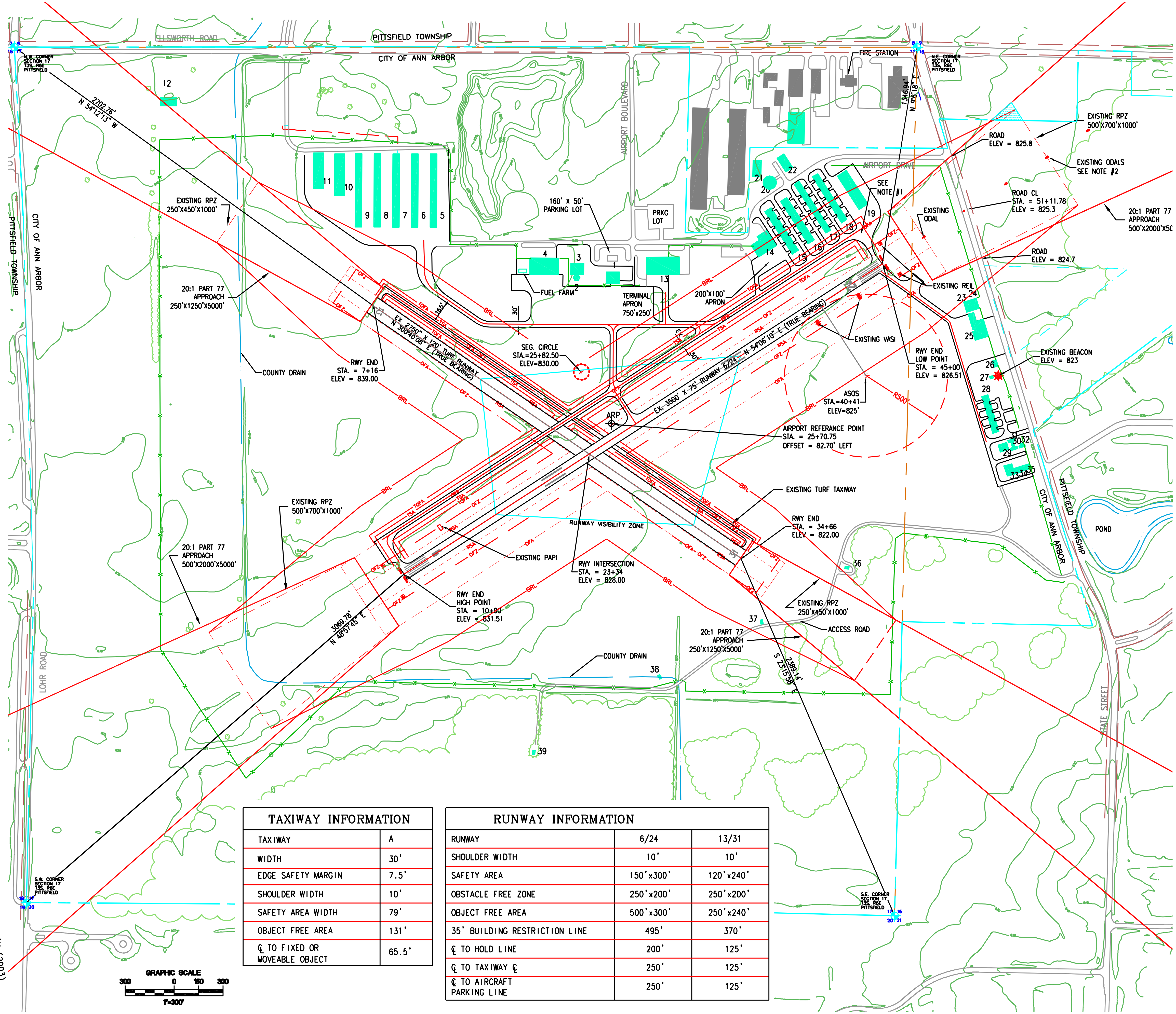
LEGEND

AIRPORT PROPERTY LINE
EASEMENT — BM
SECTION LINES — CORNER
RUNWAYS, PARKING, TAXIWAYS
FU. RUNWAYS, PARKING, TAXIWAYS
RWY PROTECTION ZONES
EXISTING BUILDINGS — EX-BUILD
FUTURE BUILDINGS — FU-BUILD
ROADS
FUTURE AIRPORT PROPERTY LINE
CENTERLINES
EX. RUNWAY SAFETY AREA — RSA
EX. TAXIWAY SAFETY AREA — TSA
EX. OBJECT FREE AREA — OFA
EX. OBJECT FREE ZONE — OFZ
EX. TAXIWAY OBJECT FREE AREA — TOFA
EX. BUILDING RESTRICTION LINE — BRL
EXISTING TREES AND TREE LINES — TREE — TREELIN
EXISTING FENCE LINE
EX. REIL — REIL
EX. VASI OR PAPI — VASI / PAPI
EX. SEGMENTED CIRCLE — SEG
FUTURE ROADS
FUT. TAXIWAY SAFETY AREA — F-TSA
FUT. TAXIWAY OBJECT FREE AREA — F-TOFA
FUTURE RWY PROTECTION ZONES
FUT. RUNWAY SAFETY AREA — F-RSA
FUT. OBJECT FREE AREA — F-OFA
FUTURE CENTERLINES
FUTURE RWY PROTECTION ZONES
EXISTING POWER & TELEPHONE LINE — PT — PP — F-PP
RUNWAY VISIBILITY ZONE

NOTE #1
TWO T-HANGARS IN NORTHEAST CORNER OF AIRPORT AND NORTHEAST FBO HANGAR OBSCURE LINE OF SITE TO END OF PARALLEL TAXIWAY

NOTE #2
OADLS – OMNIDIRECTIONAL APPROACH LIGHTING SYSTEM

N
MAG. DEC. = -6°28'N (2003)



TAXIWAY INFORMATION

TAXIWAY	A
WIDTH	30'
EDGE SAFETY MARGIN	7.5'
SHOULDER WIDTH	10'
SAFETY AREA WIDTH	79'
OBJECT FREE AREA	131'
℄ TO FIXED OR MOVEABLE OBJECT	65.5'

RUNWAY INFORMATION

RUNWAY	6/24	13/31
SHOULDER WIDTH	10'	10'
SAFETY AREA	150'x300'	120'x240'
OBSTACLE FREE ZONE	250'x200'	250'x200'
OBJECT FREE AREA	500'x300'	250'x240'
35' BUILDING RESTRICTION LINE	495'	370'
℄ TO HOLD LINE	200'	125'
℄ TO TAXIWAY ℄	250'	125'
℄ TO AIRCRAFT PARKING LINE	250'	125'

DATE	ISSUED FOR
10/14/04	MDOT REVIEW & APPROVAL
11/08/05	MDOT FINAL DRAFT
01/10/06	FAA APPROVAL
01/10/06	APPROVED ALP

D/E JVV
PM RJC
SOC KAU
QC WAM
W. MALINOWSKI IN CHARGE

URS
GRAND RAPIDS, MI.

ANN ARBOR MUNICIPAL AIRPORT

ANN ARBOR, MICHIGAN

AIRPORT LAYOUT PLAN

AIRPORT LAYOUT PLAN (EXISTING)

SITE NO. 81-1

DRAWING 3 OF 10

12934808

BASE=..\CIVIL\BASE.dwg
info1=..\CDET\info1.dwg
info2=..\CDET\info2.dwg
EXIST=..\CIVIL\EXIST.dwg
PROP=..\CIVIL\PROP.dwg
P:\M10413\PDS\81-01-ALP03-EXIST.dwg
JVanDuin
3/13/2006 11:54 am

Pittsfield Charter Township

6201 West Michigan Avenue, Ann Arbor, MI 48108
Phone: (734) 822-3135 • Fax: (734) 944-6103
Website: www.pittsfield-mi.gov

Office of the Supervisor

May 30, 2019

MEAD & HUNT, Inc.
c/o William Ballard, AICP
2605 Port Lansing Road
Lansing, Michigan 48906

Re: Response to Your April 15, 2019, Letter Requesting Pittsfield Township's Input regarding Ann Arbor Municipal Airport's Proposed 800' Extension of the Runway.

Dear Mr. Ballard,

As you are no doubt aware, Pittsfield Township has been opposed to lengthening the runway at Ann Arbor Municipal Airport (ARB or the "Airport") for social, economic and environmental reasons since the Airport first announced its intention to extend the runway in 2007. Extending the runway defies Pittsfield Township's Resolution opposing such an expansion. It will cause issues with the Township's noise ordinance. And the Township will lose millions of dollars in tax revenues. However, the Airport and MDOT believe that they can ignore Pittsfield Township's wishes and take on a project within its governmental jurisdiction despite the Township's adamant opposition. What makes this situation worse is that the runway extension is not needed. Pittsfield Township has been ignored and marginalized by the Airport and MDOT for 12 years. After 12 years of discussions, which have negatively affected the Township and its residents, this project needs to be set aside for good.

Since a new environmental assessment will be drafted about the extension of the runway, you have asked that the Township address specific issues. What follows is Pittsfield Township's responses to each category you mentioned in your April 15, 2019, letter.

I. Specific Areas of Concern/Regulatory Jurisdiction.

A. There Is No "Purpose" or "Need" for Lengthening the Runway at ARB.

In your April 15, 2019, letter you state that MDOT will be conducting an environmental assessment of the proposed project. Because this Project will be financed with federal funds through the FAA's Block Grant program, MDOT must comply with the federal National Environmental Policy Act (NEPA). This includes a full evaluation of the "Purpose and Need" for extending the runway. Pittsfield Township's primary concern is there is no purpose or need for extending the runway at ARB. An environmental assessment (EA) must include a discussion of the purpose and need for the proposed action which must "specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action." 40 C.F.R. § 1502.13. In addressing the Purpose and Need section of an EA, FAA Order 1050.1F provides that the Purpose and Need section "presents the problem being addressed and describes what the FAA is trying to achieve with the proposed action. The purpose and need for the proposed action must be clearly explained and stated in terms that are understandable to individuals who are not familiar with aviation or commercial aerospace activities. To provide context while keeping this section of the EA brief, the FAA may incorporate by reference any supporting data, inventories, assessments, analyses, or studies." FAA Order 1050.1F, ¶ 6-2.1c. As it exists, there is no problem at ARB for which an extended runway is the best answer.

1. Use of the lengthened runway would rarely be required but would pose substantial risks to the surrounding community every day.

The Airport has long claimed that an extended runway is needed because the B-II aircraft operating out of ARB "suffer" weight penalties due to the "short" runway. If this is still the case, then the environmental assessment must include any data on B-II operational usage in terms of the number of days or operations when aircraft suffered actual weight penalties, number of aircraft involved, or the actual penalties suffered on the runway. It is only then that a true analysis as to whether the extension is needed can be drafted.

However, it is possible to provide a rough statistical analysis based on usage data of how frequently the expanded runway might be necessary. FAA Advisory Circular 150/5325-4B *Runway Length Requirements for Airport Design* aids an airport in determining the recommended runway length. AC 150/5325-4B, contains a runway length curve utilized with temperatures at 83 degrees Fahrenheit or above, and an ARB elevation of 839 feet, criteria to which MDOT has stipulated, to meet the mean daily temperature during the hottest month at ARB. ARB had 63,107 total operations in 2018, of which, the FAA claims 697 were category B-II operations. An analysis of data from the National Oceanic and Atmospheric Administration Weather Station at ARB shows that in 2015 there were 42 days in which the temperature was 83 degrees Fahrenheit or above. ARB has a based population of 164 aircraft, of which 14 are category B-II aircraft. These data are based on the most current publicly available information at the time of drafting this letter.

With these data, a calculation of potential need of an expanded runway based on maximum potential need can be made. If, on every day on which the temperature reached or exceeded 83 degrees, every aircraft in the B-II fleet operated at its maximum take-off weight – a highly unlikely possibility – and required the expanded runway to take-off, based on the ARB fleet population the need for the expanded runway would be 0.00848, or 8.5 in 1,000 (42/365 x 14/164). This is based on the number of days with temperatures exceeding 83 degrees and the proportion of the total ARB fleet that is Category B-II. However, if this calculation were based on the more realistic actual usage in the most recent operational year (2018), on every day the temperature reached 83 degrees or above, the actual need for an expanded runway would be 0.00127 – or about 1.25 in 1,000 (42/365 x 697/63107) – the number of B-II operations relative to the total operations in the most recent year of 2018.

Thus, operational need for an expanded runway would be rare. Based on statistical analysis the expanded runway would be necessary for approximately 50 operations per year, at most. Yet, it would place citizens in the surrounding community at risk hundreds of times more frequently because aircraft would be taking off and landing 950 feet closer to residential areas, and larger and heavier aircraft will be attracted to ARB by the expanded runway. The area to the west and south of the Airport – just off the most frequently used end of the runway – is heavily residential. The Airport is not in a rural setting and more homes are being constructed close to the Airport. These risks are exacerbated because of the potential dangers posed by aircraft that would be landing just 93 feet over homes in an area heavily populated with Canada geese just west of the airport, and by the reduced margins of safety if an aircraft suffers an engine failure on or just after takeoff. Such aircraft can lose their climbing power with an engine loss and could crash into the heavily-populated neighborhood. The risk of – and liability from – such a potential accident has not been studied and should be as part of any assessment about the purpose and need of extending the runway at the Airport.

2. The "problem" that the Airport claims needs fixing is overstated.

In the April 15, 2019, letter to Pittsfield Township, MDOT stated that the document would be developed under FAA Order 1050.1F, "Environmental Impact: Policies and Procedures." Section 6-2.1(c) of Order 1050.1F defines "need" as the problem and "purpose" as the proposed solution to the problem. The Purpose (*i.e.,* the Project) is supposed to resolve the Need (*i.e.,* the problem). Here it is the opposite, one large tenant's desire (AvFuel Corp.) to extend the runway is driving the proposed action. This is a case of a Purpose looking for a Need. It is a project looking for a problem to justify its existence.

The claimed Need mentioned in the April 15, 2019, letter that an extended runway is needed "to meet the current and future fleet mix needs of the Airport" lacks substantive evidence. The Airport has previously defined the Need as "[n]eed of the proposed actions is to allow the critical aircraft to safely operate at their optimum capabilities without weight restrictions (i.e. reductions in passengers, cargo, and fuel associated with cargo range) due to suitable runway length." But that statement (and the statement in the April 15, 2019, letter) presumes that such critical aircraft cannot already operate at such capabilities regularly. There has been no evidence this is the case.

On the few occasions that a longer runway is needed, Willow Run Airport (YIP) is a short 12 miles from ARB (approximately 15 minutes by car). YIP has three runways (7500, 7300 and 6000) and robust general aviation and business aviation facilities. Thus, the Airport's argument is that the runway needs to be lengthened so a handful of aircraft pilots and passengers need not drive an extra 12 miles to get to/from the airport on the few days that a weight restriction would be required.

This issue of justification of the need to lengthen the runway has been problematic since the idea was first raised in 2007. Even the FAA has questioned the need for an extended runway. In May 2010 comments on the 2010 Draft Environmental Assessment (DEA), the FAA asked, "[h]as it been documented that the current B-II 'small' users operate with load restrictions? If so, how often does this occur and what are the quantifiable impacts to their operations?" The Airport failed to answer the FAA's question. In addition, in a separate question, the FAA asked, "the conclusion for the implementation for the preferred alternative states that a positive result of improvements is the ability of business owners to achieve improved fleet efficiency for critical aircraft by maximizing their passenger and/or cargo loads. How has this statement been substantiated? What records exist that current users at ARB are not operating at maximum passenger and/or cargo loads? What has been the economic impact of the reduction of loads if they are occurring?" To paraphrase the FAA's questions, if there is no established, substantiated loss of passenger or cargo load opportunities, or established current negative economic impact, there is no Need. These questions must be answered before any project to lengthen the runway is even considered by MDOT.

It is also worth noting that MDOT's federal block grant status could be at risk if it does not enforce the requirements under FAA Order 1050.1F in terms of requiring applicants to provide supporting data, inventories, assessments, analyses, or studies to support its proposed expansions, even though MDOT has not traditionally done so.

3. Not all reasonable alternatives have been considered.

The National Environmental Policy Act ("NEPA") (42 U.S.C. §§ 4321 *et seq.*) requires that federal agencies examine all reasonable alternatives in preparing environmental documents. 42 U.S.C. § 4332(c)(iii). An agency preparing an EA should develop a range of alternatives that could reasonably achieve the need that the proposed action should address.

In the past, MDOT has ignored the possibility of using Willow Run Airport (YIP) as an alternative to the proposed project because it was determined that using YIP is not "desirable based on proximity to corporate offices or business needs." This is not a valid reason to not consider an alternative in an Environmental Assessment and in violation of NEPA, NEPA regulations, and FAA Order 1050.1F.

Using YIP instead of ARB meets the purpose and need of the project making it a reasonable alternative that must be considered in the Environmental Assessment. YIP has the runway length and facilities to accommodate the aircraft that may be weight-restricted from using ARB. The only reason given to dismiss it from further consideration is that it is located 12 miles from ARB and that it is a slight "inconvenience" to the corporations who want to use ARB instead of YIP. Even if lengthening the runway would benefit more than one or two aircraft, this is not an appropriate reason to dismiss an alternative from further consideration in an Environmental Assessment. If an alternative is "reasonable" (*i.e.,* it meets the purpose and need) then it must be considered in the Environmental Assessment alongside the preferred alternative and the no action alternative. *Friends of Southeast's Future v. Morrison*, 153 F.3d 1059, 1065 (9th Cir. 1998). Since using YIP instead of ARB would achieve the purpose and need of allowing "critical aircraft" to take-off and land without weight restrictions, it is a reasonable alternative and must be fully analyzed as part of the Environmental Assessment process.

B. Expanding the Runway Will Result in an Increase in Violations of Pittsfield Township's Ordinances and Planning Procedures

1. Noise Ordinance

Pittsfield Township, within which ARB is wholly located, has a long-standing noise ordinance making it unlawful for "any person to create, assist in creating, permit, continue, or permit the continuance of any unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace, or safety of others within the limits of the township." Pittsfield Township has a duty to protect its citizens' health, safety and property from "unreasonably loud, disturbing, unusual or unnecessary noise."[1]

How the lengthening of the runway will affect the enforcement of this ordinance has not been examined, as required by NEPA, NEPA Regulations and FAA Order 1050.1F. If the ARB runway was expanded to the west, as proposed, and the noise impacts on Pittsfield residents were to change, this ordinance would face demands from citizens for more strenuous enforcement.

Therefore, all aircraft flying in and out of ARB are subject to Pittsfield's noise ordinance and fines can be levied on the aircraft owners for operating their aircraft if they create an "unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace, or safety of others within the limits of the township."

[1] See attached Exhibit A.

2. Violation of Agreements between the City of Ann Arbor and Pittsfield Township.

The Airport and Pittsfield Township have a long and contentious history. In 1979 Pittsfield Township and the City of Ann Arbor, the owner of ARB, reached an agreement intended to resolve issues at the Airport.[2] In 2009, a new agreement was reached that incorporated the 1979 Agreement and sought to instill a sense of cooperation between the City of Ann Arbor and Pittsfield Township on issues regarding the Airport.[3] The 2009 Agreement is up for renewal this year.

It is Pittsfield Township's position that extending the runway at ARB is a violation of the 2009 Agreement, if not to the letter of the agreement, at least to the spirit of the agreement. The 2009 Agreement was meant to foster cooperation between the City of Ann Arbor and Pittsfield Township on issues related to the Airport. However, the Airport's insistence on extending the runway over the strong opposition of Pittsfield Township is not being "cooperative." Since the 2009 Agreement is set for renewal on October 1, 2019, Pittsfield Township is considering not renewing the agreement. Pittsfield Township would then require that ARB comply with Pittsfield Township's ordinances, planning procedures and construction codes. Pittsfield Township will also consider passing an ordinance requiring all airports within its jurisdiction to receive approval from the Township Board of Trustees before extending any runway at an airport in Pittsfield Township.

C. "Safety" Issues Do not Justify Runway Expansion and Increase dangers to surrounding Communities.

One of the primary issues facing this project is that when the FAA and MDOT emphasize "safety," they are talking about safety regarding the airport, its airplanes, and their fliers. None of the environmental documents drafted have mentioned a concern for the safety or well-being of citizens in the communities surrounding the airport. This is especially troublesome given that two small jets crashed nearby – one on a runway comparable to that proposed for an expanded ARB, a crash which could have been catastrophic had it occurred at ARB.

Historically, MDOT has claimed that a goal of the Project is to prevent overruns. MDOT has concluded "[t]here is no evidence in the incident reports that any of the aircraft which overran the end of the existing 3,505-foot runway exceeded the limits of the 300-foot-long turf Runway Safety Area (RSA). Therefore, in each of these cases, the proposed 4,300-foot runway would have provided sufficient length for the small category A-1 aircraft to safely come to a stop while still on the runway pavement, without running off the runway end." Revised Draft Environmental Assessment (RDEA), p.25. However, our review of the 11 runway overrun incidents shows they were all the result of pilot error or mechanical problems – one as careless as the lack of marking construction areas on the

[2] See attached Exhibit B.
[3] See attached Exhibit C.

runway itself by the airport operator, so the pilot was unaware of a construction berm. The FAA agreed these incidents did not support runway expansion, concluding in its comments to the 2010 DEA, "…[t]he local objective of reducing runway overrun incidents appears to conclude that if the added runway length were present, all the incidents would have been avoided. Based on the information presented, the FAA does not necessarily come to the same conclusion. There are many factors that go into any overrun incident and if additional runway length were present this may have only prolonged the overrun incident. The A-1 category of aircraft involved with the overrun incidents do not appear to have needed any length beyond the existing runway length to operate at full capacity and in a safe manner." RDEA, Appendix J, FAA letter dated 5-13-10, pp. 5-6, ¶¶ 7 (p.5) and (p.6).

But there is evidence that expanding the runway could lead to *additional* runway excursions. This results from the potential dangers created by attracting more business jets because of the extended runway length. On February 11, 2016, the National Business Aviation Association reported that runway excursions by business jets on landings cause about one-third of all runway excursions, making them the most common business aviation accident, about twice weekly somewhere in the world for about $900 million annually. These incidents are frequently caused by not aborting landings when pilots should, landing at unfamiliar airports, and landing too fast and too far down the runway. The added risk for ARB is these larger jet aircraft, with larger fuel payloads, could pose added challenges to firefighters if an emergency occurs. Those firefighters are not based on the ARB airport, which does not actually provide on-site fire and rescue services – and are provided by Pittsfield Township.

One such excursion occurred nearby – just 20 miles northwest of Ann Arbor on January 16, 2017, at the Livingston County Spencer J. Hardy Airport (OZW) in Howell, when just such an unfamiliar pilot attempted to land his Cessna Citation 525 CJ4, but crashed on landing, destroying the aircraft and injuring the pilot. The pilot, who was the only one aboard the 10-passenger, twin-engine jet, apparently lost control on landing, skidding off the end of the runway, through a fence, across a road, and striking a clump of trees, tearing the wings from the fuselage, and causing a fire. Witnesses helped the pilot from the wreckage before emergency crews could arrive (L.T. Hansen, "Report: Plane with single occupant crash-lands at Livingston County Airport," *MLive.com*). The distance from the end of the runway to the trees is about 1,800 feet.

This is important because while the Livingston County airport runway is 5,000-feet long – 700 feet longer than the proposed ARB extended runway – the aircraft would have been more than capable of landing on an expanded ARB runway of 4,300-feet. And, the Runway Safety Zones (RSZs) and Runway Protection Zones (RPZs) frequently mentioned by MDOT as protecting neighborhoods surrounding airports from the effects from potential aircraft accidents, afforded no such benefits. If a similar incident were to have occurred at an expanded ARB, with a high-speed jet crashing, skidding not just 1,800 feet, but 2,500 feet – because the Livingston County airport runway was longer – beyond the end of an expanded 4,300-foot ARB runway, and burning, it could have ended up in homes across Lohr Road from the end of the runway, which could have been deadly!

The NTSB has reported on the significant danger of crashes in private and charter airplanes vs. commercial aircraft, the aircraft likely to be attracted to an expanded ARB. Between 2000 and 2015, the NTSB found there were five times fatal accidents in the U.S. involving private and chartered corporate planes than airlines. Investigators cited pilot error in 88 percent of the crashes, noting crews skipping safety checks, working long days, missing rest periods, overlooking ice on wings, or trying to land when they could not see the runway as among the causes of crashes ("Private Jets Have More Fatal Accidents than Commercial Planes," A. Levin, May 15, 2015, *Bloomberg News*).

The best way for an ARB surrounded by population centers to avoid such potential tragic problems is to not expand the existing airport and invite such larger and heavier jet aircraft to impose such dangers and risks given the small benefit any expansion would provide. The airport is safe and presents no such dangers.

II. Specific benefits and detriments of the project for your organization or to the public.

The project has no benefits to Pittsfield Township, only detriments and costs. The project will substantially harm Pittsfield Township and its neighbors. Specifically, Pittsfield Township and the surrounding communities will lose needed tax revenue because of diminished property valuations. In addition, the surrounding communities have specifically told the Airport they are opposed to lengthening the runway.

A. Runway expansion could cause Pittsfield Township to lose millions of dollars from reduced taxes.

There is extensive research to suggest an extension of the runway could cause severe economic losses to several communities surrounding the airport, including Pittsfield Township, in reduced real estate values and, reduced property and school taxes based on assessed property values. Extensive research based on other communities in which airport runways have been extended – Atlanta, Reno-Tahoe, Chicago O'Hare, the Greensboro-High Point-Winston Salem metroplex, 23 cities in Canada, among others – show property values decline as runways are expanded. The most respected such study. *The Announcement Effect of an Airport Expansion on Housing Prices*, G.D. Jud & D.T. Winker, (2006), JOURNAL OF REAL ESTATE FINANCE AND ECONOMICS, 33, 2, 91-103, suggests house prices decline by about 9.2 percent within a 2.5-mile band of the airport, and, beyond that, in the next 1.5-mile band, prices decline another percent once an announcement – without extraneous influences – was made.

The lengthy hold up of the proposed ARB expansion has represented an extraneous influence since the initial announcement in 2007, but that if approved, these effects would occur at ARB. To further support this claim, a literature search could find no published, peer-reviewed research study where residential real estate values continued to rise in areas immediately surrounding an airport after runways were expanded. A decrease in property values in the areas surrounding ARB would have important consequences for the governmental bodies that benefit from property tax collections. In the corridors referenced in the Jud & Winker study noted above, there are:

- 6,239 Pittsfield Township parcels of land within the 2.5-mile area surrounding the airport; and
- 4,168 parcels within the 2.5-mile to 4-mile area.

These parcels will be subjected to a decline in real estate values of 9.2 percent and 5.7 per cent, respectively due to the expanded runway. Using those facts, the following is the estimated value of what the potential **annual** losses in property tax revenue would be for various governmental bodies based on their tax collections in the year following the extension of the runway:

- $1.5 million less for the Ann Arbor School District;
- $1.4 million less for the Saline School District;
- $850,000 less for Pittsfield Charter Township; and,
- $810,000 less for Washtenaw County.

This estimate is only for property in Pittsfield Township. These numbers understate the decline in tax revenues, because they do not consider the potential effects of property in Lodi Township, the City of Saline, (both of which could affect the Saline School District's revenues), or property in the City of Ann Arbor. Thus, governmental bodies could stand to lose millions of dollars in operating funds annually from a runway expansion project that has yet to demonstrate any real economic benefit.

B. The Airport must consider the interests of local communities.

Both Pittsfield Township, where ARB is located, and neighboring Lodi Township have passed Resolutions, (March 24, 2009,[4] and May 12, 2009,[5] respectively) opposing an expansion of the runway at ARB. The Resolutions oppose the expansion because of the risks from Canada geese in areas surrounding the airport, low-flying aircraft on the approaching newly expanding runway, and that 99 percent of the based aircraft can operate at their full weight capacity on the existing runway. More important, though, the Resolutions seek to protect the health and property rights of their citizens.

The Airport has ignored these Resolutions in the past and will do so again unless FAA or MDOT take them seriously when conducting an environmental assessment. Ignoring the resolutions violates NEPA, NEPA Regulations and FAA Order 1050.1F, it is also a violation of Ann Arbor's federal grant assurances, exposing the Ann Arbor to

[4] See attached Exhibit D.
[5] See attached Exhibit E.

litigation liability and potential loss of all federal funding for ARB. If the runway is necessary, the ARB should meet with the Township and explain why the Resolutions should be rescinded. Going forward with the project without the sign-off of the Township is not being a good neighbor or keeping with the spirit of cooperation regarding Airport issues.

Given Pittsfield and Lodi's resolutions of opposition, the expansion of the runway contradicts the will of those governing bodies. The expansion would benefit a minute number of airport users – while placing at risk thousands of members of the Pittsfield and Lodi communities with added larger and heavier aircraft, flying much closer to their homes, at lower altitudes, in an area heavily populated by Canada geese, and in an increasingly dense residential area.

The consideration of the wishes of these local communities must be weighed and evaluated and given "fair consideration" as required by the FAA's grant agreement with Ann Arbor. In the ten years since the proposed expansion has been pending, for example, not even one study on the potential safety effects of the expansion on the residents of Pittsfield has been conducted. ARB and MDOT have consistently ignored the interests of communities surrounding ARB.

C. Any Environmental Assessment Must Properly Consider the Intensity of the Impacts on the Surrounding Community.

NEPA Regulation 40 C.F.R. § 1508.27 requires that the Project be placed in context with the surrounding society so the Project's impact on the affected region, the affected interests, and the locality can be properly evaluated. Any environmental document undertaken by MDOT must adequately address this aspect before the Project can be approved. This aspect of the environmental assessment process is often called "Intensity," and it requires consideration of:

> (1) Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that the effect will be beneficial.
> (2) The degree to which the proposed action affects public health or safety.
> (4) How much the effects on the quality of the human environment are likely to be highly controversial.
> (5) How much the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
> ….
> (10) Whether the action threatens a violation of Federal, State, or **local law** or requirements imposed for protecting the environment."

40 C.F.R. § 1508.27 (emphasis added). *See also* FAA Order 1050.1F, § 4-3.2, p.4-3.

This proposed project has a statistically small benefit (.00175), and yet would attract larger and heavier jet aircraft in closer proximity to homes in areas heavily populated with Canada geese, potentially jeopardizing residents if an accident occurs – accidents that the FAA contends are the third most frequent that occur in terms of incidents with hazardous wildlife in aviation. The risk to public safety may far outweigh any established benefit, which has not been substantiated. Added risks in terms of additional noise and night flights have not been established, but with arrival traffic traveling just 93 feet over rooftops on an expanded runway, it could have a controversial and negative impact on the human environment of citizens in Pittsfield Township, in violation of that township's noise ordinance and resolution, and in violation of federal law.

III. Any Available Technical Information/Data for the Project Site

A. ISO 1996-1:2016 Must Be Used in Assessing Noise Impact to the Community Surrounding ARB.

ISO 1996-1:2016, entitled "Acoustics -- Description, measurement and assessment of environmental noise -- Part 1: Basic quantities and assessment procedures," which was published in March 2016, defines the basic qualities to be used for the description of noise in community environments and describes basic assessment procedures. ISO 1996-1:2016 predicts the potential annoyance response of a community to long-term exposure to noise based on characteristics of the community rather than based on the noise created. As a product of the International Organization for Standardization, ISO 1996-1:2016 represents the best science for assessing the impact of noise on affected communities. The FAA requires that the best scientific methods be used in technical matters to comply with the Data Quality Act (also called the Information Quality Act). Therefore ISO 1996-1:2016 must be used to avoid a violation of the Data Quality Act.

B. The Project Does Not Account for the Noise Impact of the Project on the Surrounding Community.

1. MDOT and ARB must protect the surrounding community from aviation noise.

It is "the policy of the United States - - that aviation facilities be constructed and operated to minimize current and projected noise impact on nearby communities." 49 U.S.C. § 47101(a)(2). Part of the FAA's mission, and therefore MDOT's mission, is to ensure that the communities surrounding airports are not hurt by noise from aircraft at airports. This mission is expressed in 49 U.S.C. § 47101(c), which states that "[i]t is in the public interest to recognize the effects of airport capacity expansion projects on aircraft noise. Efforts to increase capacity through any means can have an impact on surrounding communities. Noncompatible land uses around airports must be reduced and efforts to mitigate noise must be given a high priority." Thus, if noncompatible land uses around airports cannot be reduced, then the capacity of nearby airports should not be increased or else the FAA and the airport sponsor would violate federal law. ARB and MDOT seem aware that increases in capacity at the airport will affect the noise levels in Pittsfield, because they studiously have avoided the topic.

MDOT, as the agent of the FAA, must protect residents and property owners from the deleterious effects of aircraft noise. Federal law establishes the absolute duty of the government to protect both people and property from aircraft noise. "[T]he Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare." 42 USC § 4901(b). MDOT's statutory duty to protect people and property on the ground from the deleterious effects of aircraft noise goes beyond its duty under NEPA to determine what it believes to be "significant" or "reportable" under FAA Order 1050.1F. Legally speaking, the MDOT cannot conclude that a proposed MDOT action purportedly not "reportable" under 1050.1F, § 14.5e[6] or that purportedly does not have a "significant impact" under 1050.1F, § 14.3[7], is not subject to review and regulation under 42 USC § 4901(b), 49 U.S.C. § 40103(b)(2) and 49 U.S.C. § 44715(a)(1)(A). Those statutory obligations require that the lead agency address aircraft noise separate from its duties under NEPA because the lead agency's proposed action will create aircraft noise that will have a deleterious effect on the public health and welfare.

2. ARB and MDOT incorrectly assume that extending the runway will not increase the number of air operations, the fleet mix or other growth-inducing effects of the Project.

When considering an airport project for federal funding, the FAA must evaluate not merely the direct impacts of a project, but also its indirect impacts, including those "caused by the action and later in time but still reasonably foreseeable." 40 C.F.R. § 1508.8(b). Indirect impacts include a project's growth-inducing effects, such as changes in patterns of land use and population distribution associated with the project (40 C.F.R. § 1508.8(b)). It is reasonably foreseeable that the fleet mix at ARB will change for a higher percentage of jet operations as compared to the current level of light single and multi-engine propeller driven aircraft operations. The smaller Category A-I/II and B-I aircraft account for most of ARB operations. B-II and larger category aircraft account for a low percentage of ARB operations. If a longer runway became available, it is reasonably foreseeable that the number of night operations will increase as the number of arrivals of longer-haul business jets often occur in the evening hours due to the longer time duration

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[6] *See also* 1050.1F B-1.4, p.B-4.

[7] *See also* 1050.1F, Table 4-1, p.4-8 well as increased population, increased traffic, and increased demand for services. *City of Davis v. Coleman*, 521 F.2d 661, 675 (9th Cir. 1975). The "growth-inducing effects of [an] airport project appear to be its *raison d'etre*." *California v. U.S. D.O.T.*, 260 F.Supp.2d at 978, citing *City of Davis, supra*, 521 F.2d at 675. Even though the Project is virtually defined by its growth- inducing impacts, ARB and MDOT have ignored this requirement completely not only in the draft EA, but in the public participation aspects of the Project as well.

of their trips. This is not merely an indirect, but also a direct effect, that the Project will have on the surrounding community. This will also affect the fleet mix of night operations to reflect a higher percentage of jet operations than exist under current conditions.

The runway need not be extended for most of ARB's "critical aircraft" to operate at the airport without weight restrictions. For example, the "load restrictions" will apply to the higher category aircraft (jets in the C-I and C-II categories). Operationally, weight is reduced by carrying fewer passengers, less baggage and/or less fuel, which discourage these aircraft from conducting operations at ARB. A Cessna Citation II (Category B-II), for example, requires 2,990 feet for takeoff at maximum certificated gross weight on a standard day, and, most days, can operate at unrestricted weight from ARB's existing 3,505-foot runway. A Lear 35 (Category C-I), requires 5,000 feet for takeoff at maximum certificated gross weight on a standard day. While extending the runway to 4,300 feet would not facilitate unrestricted operations by the Lear 35, the required weight reduction would be less than is currently required. Therefore, the runway extension to 4,300 feet would operationally benefit the Category C-I Lear 35, but would provide little or no operational benefit to the Category B-II Citation jet. Thus, while the runway extension makes ARB no more attractive to the operator of the Citation II, ARB becomes more attractive to the operator of the Lear 35, causing an increase in usage of ARB by the Lear 35, but the same usage by the Citation II. If the runway is extended there will be an increase in operations. Because there is a potential of an increase in the number of operations, it must be analyzed thoroughly.

The evidence is clear that the Project will cause an increase in both jet and night operations. It is also reasonably foreseeable these added high-performance jet aircraft operations and night operations will come with significant noise and air quality impacts. These reasonably foreseeable impacts must be analyzed in any future environmental assessment.

IV. Potential Mitigation/Permitting Requirements for Project Implementation.

A. Extending the Runway may require permitting from Pittsfield Township

As explained above, Pittsfield Township is considering not renewing the agreement between itself and the City of Ann Arbor that mandates the use of Ann Arbor's construction and electrical codes at the Airport. If the Airport moves forward with the extension of the runway, Pittsfield Township will consider not renewing the Agreement, which would terminate the Agreement on October 1, 2019. After that date, the Airport becomes subject to all of Pittsfield's ordinances, codes and planning requirements. In addition, Pittsfield Township is considering an ordinance that would require airports within its jurisdiction to receive approval of the Township Board before extending any runway at the airport.

B. The Environmental Assessment Must Account for the Effect the Project Will Have on Water Resources in the Surrounding Communities.

The Airport is the location of a porous sand/gravel formation that yields much water for pumping. Historically, the land where the airport is located was originally acquired by the City of Ann Arbor for water rights in 1921. Until recently, 15% of Ann Arbor's water supply came from the three wells on Airport property. The paving that the Project will require increases not only the impervious area on top of the aquifer, but also increases the risk of contamination. This reduces the infiltration of water that feeds the aquifer/City water supply. Adding 950 feet to the end of the runway adds another 71,250 square feet of impervious area over an aquifer vital to the City.

So critical is drinking water from the airport wells to the city that de-icing is prohibited on the airport. Due to the 'unmaintained nature' of the airport vegetation, it is acting as a buffer around the wellheads," the water faces many potential threats from a lengthened runway. Those threats become more critical because of the potential for lead to contaminate Ann Arbor's water supply. Most of the fuel utilized at ARB is consumed by piston-driven aircraft, which mostly use leaded AvGas. Any risk to the aquifer underlying the airport could pose a threat of lead contamination. With Ann Arbor's other water resources affected by dioxane risks caused by the "Gelman spill," the Airport well-field has taken on a much more significant role.

As FAA Order 1050.1F points out "[i]f there is the potential for contamination of an aquifer designated by the [EPA] as a *sole or principal drinking water resource* for the area, the responsible FAA official needs to consult with the EPA regional office, as required by section 1424(e) of the Safe Drinking Water Act, as amended." FAA Order 1050.1F, p.4-12 (emphasis added). Likewise, "[w]hen the thresholds indicate that the potential exists for significant water quality impacts, additional analysis in consultation with State or Federal agencies responsible for protecting water quality will be necessary. *Id.*, pp. A-75, A-76, & 17.4a. Finally, in situations such as this, "[i]f the EA and early consultation [with the EPA] show that there is a potential for exceeding water quality standards [or] identify water quality problems that cannot be avoided or mitigated . . . an EIS may be required." *Id.*, pp. A-75, & 17.3.

Because the wells on ARB property are a principal source of Ann Arbor's water supply, the Washtenaw County Water Resources Commissioner – another entity with whom ARB and MDOT should have been consulting from the very beginning – raised serious issues about the Project. In response to the draft EA, the Washtenaw County Water Resources Commissioner pointed out that:

> The amount of impervious surface on site would increase slightly due to the extension of the runway and taxiway from the existing 7 percent of the 837 acres to 7.4 percent. This slight increase noted equates to an additional 3.348 acres or

> 145,839 square feet. This increase in impervious surface this office considers significant and not slight knowing that the additional runoff from this area will discharge to the Wood Outlet Drain.

Besides the dioxane contamination, water resources issues at the Airport have become even more important after it was reported in May 2012, that the water table in the Ann Arbor area, has risen substantially. In the Ann Arbor Chronicle, "[t]he only hard data that the city has collected on the water table is at the municipal airport, and there the water table measures between 2-7 feet below the surface now, compared to 15 feet below the surface 50 years ago." This is not an insubstantial problem. With the water table at the airport now being 2-7 feet below the ground surface instead of 15 feet, when the drinking water wells were first dug, the groundwater is even more vulnerable to contamination because there is much less soil for any surface pollution to filter through or attach to soil particles before it reaches the water table. This dramatic change in the water table may also alter ground water data from the past. The rise in the water table may have altered the direction of groundwater flow, or there may now be some barrier blocking the traditional pathway for the water to flow, which would cause Ann Arbor's principal drinking water supply to be contaminated.

ARB has a responsibility under the law to ensure the safety of the water in Ann Arbor's wells. Further, although Pittsfield Township does not receive its drinking water from these wells, water from the same aquifer filling these wells is the source of water for numerous Pittsfield Township waterways, including the several ponds in the Stonebridge Community. Thus, beyond ensuring the Airport's compliance with the law, Pittsfield Township and its citizens have a vested interest in ensuring the water in the aquifer be maintained to the highest possible quality level. The EA must contain a comprehensive analysis of the water quality issues, and close participation of the various water quality agencies at the local, state and federal levels.

C. Air Quality Laws and Regulations Must Be Followed.

United States federal law states at 49 U.S.C. § 47101(a)(6) that it is "the policy of the United States - - that airport development under this subchapter provide for the protection and enhancement of natural resources and the quality of the environment of the United States." The Project will have a significant impact on the environment not only on the airport, but throughout the surrounding community. Since it is Pittsfield Township's duty and responsibility to protect the environment within its boundaries and protect its citizens from significant environmental impacts, it has serious concerns about the environmental impact the Project will have on the community.

Section 7506 of the Federal Clean Air Act (42 U.S.C. § 7401 et seq.) mandates that "[n]o department, agency, or instrumentality of the Federal Government shall engage in, support in any way or provide financial assistance for, license or permit, or approve, any activity which does not conform to [a State Implementation Plan] after it has been approved or promulgated under [42 U.S.C. §7410].” The Environmental Protection Agency (EPA) has promulgated regulations implementing § 7506 (the “Conformity Provision”) in 40 C.F.R. § 93.150 *et seq*. (“General Conformity Rule”). The General Conformity Rule requires, in part, that federal agencies first determine if a project is exempt from conformity analysis or presumed to conform. If it is neither, the agency must conduct a conformity applicability analysis to determine if a full conformity determination is required. *See Air Quality Procedures for Civilian Airports and Air Force Bases*, p. 13.

The project area, *i.e.*, Washtenaw County, is in attainment for five of the eight criteria pollutants, and maintenance for Ozone, PM_{10} and $PM_{2.5}$. A conformity determination is required for criteria pollutants in maintenance areas. 40 C.F.R. § 93.153(b). Therefore, the EA must show that one of the following applies: (1) the project is exempt from conformity; (2) the project is presumed to conform; or (3) the agency must conduct a conformity applicability analysis to determine if a conformity determination for Ozone, PM10 and $PM_{2.5}$ is required.

D. Risk of Canada Geese strikes requires Wildlife Hazard Assessment be drafted.

The risks to the Airport because of large numbers of Canada geese surrounding ARB, would become an even greater risk given the larger number of jets attracted to a lengthened runway. Our comments to the 2010 DEA raised the risk of the large number of Canada geese and provided photographic evidence to support the claim. FAA Advisory Circular 150/5200-33B discusses Hazardous and Protected Wildlife Attractants on or Near Airports and ranks geese as No. 3 in causing damage to aircraft. It discusses how golf courses, such as the one within 1,500 feet of the proposed expanded runway end, are attractive to Canada geese. This alone, with the two large ponds at Stonebridge, is one reason for the continued sightings of large numbers of Canada geese on the flightpaths of ARB. And the potential risks these Canada geese could cause, especially if many jets are attracted to a lengthened runway at ARB, underscore the urgency of conducting such a Wildlife Hazard Assessment as part of any environmental assessment. A lengthened runway will put the aircraft lower and closer to the areas where Canada geese congregate.

Further, the Migratory Bird Act of 1918 (16 U.S.C. § 703-712) makes it illegal to kill a Canada goose or harm their nests or eggs. So, Canada geese not only pose a potential risk of causing an aviation accident, but they are also protected, causing a dual concern to the Airport. This is compounded by the fact that mute swans, a species even larger than Canada geese, also inhabit the Stonebridge area just west of ARB, and could pose a further accident risk. A Wildlife Hazard Assessment must be completed before the proposed runway expansion project can move forward.

The documented risk from Canada geese and mute Swans requires a Wildlife Hazard Management Assessment. 14 C.F.R. § 139.337(b)(4) specifies that such an assessment must be conducted *immediately* when these events occurs on or near the airport:

> (4) Wildlife of a size, or in numbers, capable of causing an event described in paragraphs (b)(1), (b)(2), or (b)(3) of this section is observed to have access to any airport flight pattern or aircraft flight pattern or aircraft movement area.

14 C.F.R. § 139.337(b)(4). The "events described in paragraphs (b)(1) – (3)" are wildlife strikes, engine ingestion of wildlife, and/or substantial damage to aircraft from striking wildlife. Further, that completed Wildlife Hazard Management Assessment must be submitted to, evaluated, and approved by the FAA administrator before any further action on the proposed project can proceed. 14 C.F.R. § 139.337(e)(2).

V. CONCLUSION

There is no purpose or need for an extension of the runway at Ann Arbor Municipal Airport. Moreover, with residential neighborhoods to the south and west of the Airport, it would seem that extending a runway *toward* a heavily residential neighborhood makes little sense. It makes even less sense when one considers the fact that an airport capable of handling the larger, faster aircraft that ARB seeks to attract is a short 12 miles away. And then if one adds the fact that the surrounding communities have been, and continue to be, opposed to the extension of the runway for social, economic and environmental reasons, only then can one begin to grasp the hubris of the Airport to propose, yet again, the extension of the runway at ARB. When the environmental assessment is drafted, these issues must be addressed, or the environmental assessment will be incomplete. Pittsfield Township's position has not changed – the runway should not be extended at Ann Arbor Municipal Airport.

Sincerely,

Mandy Grewal, Ph.D.
Supervisor of Pittsfield Charter Township

Exhibit A

Chapter 14 **Offenses and Miscellaneous Provisions**

Article VIII **Noise Offenses**

[Adopted 2-25-2015 by Ord. No. 317 as Ch. 14, Art. VIII, of the 2015 Pittsfield Charter Township Code]

§ 14-34 **Noise general prohibition.**

It shall be unlawful for any person to create, assist in creating, permit, continue, or permit the continuance of any unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace or safety of others within the limits of the Township.

§ 14-35 **Specific acts prohibited.**

The following acts are declared unreasonably loud, disturbing, or unnecessary noises and are unlawful and prohibited, but this enumeration shall not be deemed to be exclusive:

A. The playing of any radio, phonograph, tape recorder, stereo, musical instrument or any sound amplification device of any character in such a manner or with such volume, at any time or place as to annoy or disturb the quiet, comfort or repose of persons in any office, dwelling, hotel or other type of residence or of any person in the vicinity.

B. The discharge into the open air of exhaust of any steam engine, compressed air machine, stationary internal combustion engine, motor vehicle, or any other machine, except through a muffler or other device that will effectively prevent loud or explosive or disturbing noises.

C. The creation of a loud unnecessary noise in connection with the loading or unloading of any vehicle or the opening and closing or destruction of bales, boxes, crates or their containers.

D. Yelling, shouting, whistling, loud talking or singing on the public streets, particularly between the hours of 10:00 p.m. and 7:00 a.m., or at any other time or place as to annoy or disturb the quiet comfort or repose of persons in any office, dwelling, hotel or any other type of residence or of any persons in the vicinity.

E. The use of any drums, loudspeakers, musical devices, or other instruments or devices for the purpose of attracting attention by the creation of noise to any performance, show or sale or display of merchandise.

F. The use of mechanical loudspeakers, on or from motor vehicles in a manner that causes the sound emitted from the vehicle to be heard on private property, except when a specific permit is first granted by the Township Board of Trustees. The Township Board of Trustees shall cause such a permit be issued when it finds the following:

- **(1)** The applicant has a noncommercial message that cannot be effectively communicated to the public by any other means of communication available.
- **(2)** The applicant will limit the use of the loudspeakers to times, locations and sound levels that will not unreasonably disturb the public peace.
- **(3)** The applicant will not use such equipment in residential areas between 6:00 p.m. and 9:00 a.m.

G. Construction, repair, erection, excavation, demolition, alteration or remodeling at any time on Sunday and between 8:00 p.m. and 7:00 a.m., Monday through Saturday, except in case of urgent necessity in the interest of public safety and then only upon permission having been first obtained from the Department of Building Services or the Department of Utilities and Municipal Services.

H. The firing of firearms, air guns, or other combustible substances for the purpose of making a noise or disturbance.

I. The practicing and training of any drum corps, band, orchestra or other musical organization, or the practice by individuals on the various musical instruments, that produce a noise or disturbance, and which annoy the peace, repose and comfort of the residents in the vicinity.

J. The excessive sounding of any horn or signal device, emanating from a motor vehicle, so as to create any loud or harsh sound plainly audible within any dwelling unit or residence, except as a warning of danger signal or an alert. As used in this subsection, "motor vehicle" means any vehicle that is self-propelled.

K. The playing or operation of any device designed for sound reproduction, including, but not limited to, any radio, television set, musical instrument, audio system, including cassette tape players, compact disc players, MP3 players, and speakers, or loud speaker in such a manner or with such volume as to be plainly audible in any dwelling unit or residence which is not the source of the sound, or to operate any such device on public property or on a public right-of-way so as to be plainly audible 50 feet or more from such device.

§ 14-36 **Registered owner of motor vehicle responsible for noise violations.**

In a prosecution for a violation of this article, proof that the particular motor vehicle described in the citation, complaint, or warrant was used in the violation, together with proof that the defendant named in the citation, complaint or warrant was the registered owner of the motor vehicle at the time of the violation, constitutes in evidence a presumption that the registered owner of the motor vehicle was the person who operated or controlled the motor vehicle when the noise violation occurred. The person in whose name the motor vehicle is registered with the Secretary of State is presumed to be the registered owner of the motor vehicle.

Exhibit B

Council unanimously agreed with Councilmember Morris to amend Paragraph A of Section I (Annexation - General) of the policy agreement as follows:

A. All land areas in The Township lying west of U.S. 23 Expressway and north of the ~~centerline~~ SOUTH LINE of Ellsworth Road from U.S. 23 to the west line of ~~Platt~~ STATE Road, ~~thence southerly to the Railroad right-of-way adjacent to the City Landfill; thence westerly along the landfill line extended to Stone School Road, thence northerly along the east line of Stone School Road to the south line of Ellsworth Road; thence westerly to the west line of State Street,~~ thence northerly to the south line of I-94,...

The question being the Resolution with the amended Policy Agreement.

On a voice vote, Chair declared the motion carried unanimously.

The Resolution as adopted reads as follows:

R-280-7-78

RESOLUTION TO APPROVE CITY OF ANN ARBOR AND PITTSFIELD TOWNSHIP AGREEMENT

WHEREAS, the City of Ann Arbor officials and Pittsfield Township officials have spent many months negotiating an agreement of understanding; and,

WHEREAS, both governments agree to the principle of cooperation and not confrontation; and,

WHEREAS, the agreement is deemed in the best interests of the citizens of both units of government;

NOW, THEREFORE, BE IT RESOLVED that the following agreement of understanding be approved.

CITY OF ANN ARBOR–CHARTER TOWNSHIP OF PITTSFIELD POSITION PAPER ON PROMULGATION OF POLICIES

Promulgation of Policies

The CITY OF ANN ARBOR "The City", and the CHARTER TOWNSHIP OF PITTSFIELD, "The Township", by their respective governing bodies, for the purpose of furthering their common welfare, do hereby promulgate certain policies, and declare their intentions to abide the same in their exercise of governmental authority so far as practical and not in conflict with law.

I–ANNEXATION–GENERAL

A. All land areas in The Township lying west of U.S. 23 Expressway and north of the south line of Ellsworth Road from U.S. 23 to the west line of State Road, thence

northerly to the south line of I-94, thence westerly to the western boundary of The Township, shall be designated as "The Territory" and shall be eventually annexed to the City in an orderly manner.

B. It shall be understood that this aforementioned line is the unofficial boundary line until such times it can be so officially designated.

C. Inasmuch as the Township and the City have an existing contract for sewer service for portions of the Township, the Township shall not make plans to provide municipal sewer and/or water service to any properties within said Territory, however the Township shall maintain all other legal authority and responsibility for Township lands and residents in the Territory until such time as they do become annexed to the City.

D. Notwithstanding previous policies, decisions and procedures, the City and Township hereby agree that individual properties in the designated area may be annexed to the City even where such annexation may create new islands. Neither the City nor the Township shall interpose in any judicial or other proceeding pertaining to the annexation of any portion of the said Territory an objection to such annexation by reason that the same would create an enclave of Township land within the City.

E. Neither the City nor the Township shall seek to require annexation to the City of any such enclave of Township land lying within the Territory, solely because of its constituting an enclave, whether now existing or hereafter created through the annexation of a portion of the Territory. Nevertheless, upon request to the City by the owner of a property within any said enclave for City water and/or sewer service to such property, the City may require such property to become annexed to the City as a condition of granting such service.

F. The Township agrees that rather than furthering litigation in the case of the Pittsfield Islands, it will agree to the Boundary Commission decision of 1973 (File No. 8322) if the individual review procedure as set forth in paragraph I-H is applied.

G. Through joint resolutions of the City and Township governing bodies any portion of the Territory within the designated area may be annexed to the City upon the petition therefor signed by the petitioners as provided by MCLA 117.9(8) in the case of such alternate method of annexation.

H. Upon annexation to the City of properties within said Territory the City "deferred charges" thereon, for benefits conferred by capital improvements made prior to the annexation shall be payable at the property owners option, either in full, or in not

less than six (6) equal annual installments, provided that the same shall be payable in up to twelve (12) equal annual installments in cases of a property being, and continuing to be, the homestead of an owner occupant who has special hardship problems or is otherwise adjudged in need of special consideration. Hardship and special considerations may be conferred upon the single owner occupant at time of annexation. A transition appeals committee shall be established for the purpose of determining such need. It shall be authorized to make recommendations to City Council for special consideration and shall be comprised of two (2) members appointed from the City and one (1) member appointed from the Township.

II–MUNICIPAL AIRPORT

A. The City agrees that the pending appeal of the decision of the Washtenaw Circuit Court in the suit of the Township vs. the City (Docket No. 77-12619) respecting the City's proceedings to annex Territories in and about the Municipal Airport and a portion of Eisenhower Boulevard shall be dismissed.

B. The Township agrees to cooperate with the City in the establishment of an Airport Land Use Plan which recognizes the compatibility of light industrial, warehousing, gravel mining and other uses on airport lands. The Township will review and comment on the plan before City adoption. It is further understood that any private construction on Airport lands will require approval under Township zoning and site plan requirements, as well as Township Building and Safety Department permit requirements. Plans for municipal construction on Airport lands must be submitted to the Township for review and comment.

C. The Township agrees to establish a land use plan for the environs of the Airport which recognizes only land uses which are compatible to airport operations from a safety and environmental point of view. The City will review and comment on the plan before adoption by the Township.

D. It is further agreed that gravel mining may take place only for use on City of Ann Arbor roads and public works projects and for use on Pittsfield Township roads, and public works projects. In addition, that a gravel processing plan, a restoration plan and a soil erosion plan be filed and reviewed by the Township.

E. Excepting as exempt by law, the Township shall assess for taxes the real and personal properties of and upon the airport lands.

F. The Township agrees to provide right-of-way for City sanitary sewage mains to the Airport to serve Airport properties uses only.

III–LANDFILL

A. The City desires to expand its Landfill operations to the west on property known as the Derck, Nielsen, and McCalla parcels.

B. The Township agrees to actively support and assist in acquisition negotiations such expansion on the conditions that:

1. A land use and restoration plan be developed for long range use of the landfill area.

2. That a reasonable strip of land immediately east of Stone School Road, as well as along Ellsworth Road, as well as along the northern edge of what is known as the Morgan properties is excluded for environmental purposes.

C. A Landfill Expansion Advisory Committee composed of four (4) persons appointed by the City and three (3) persons appointed by the Township shall be created to advise the City on environmental and operational plans.

D. The Township desires that it be given preferred customer consideration by the City in the use of the Landfill or offered an opportunity for proportionate investment equity if the Landfill is to be expanded in this location.

E. The Township shall not adopt any ordinance, rule or regulation which regulates or attempts to regulate the City's use of the landfill property so long as that property is used for disposal of refuse materials or for park purposes.

IV–SEWER/WATER SERVICEES

A. Upon acceptance and execution of this position paper, the City agrees to immediately approve the Township's request for sewer service limited to the Township Hall and the State Road frontage of a proposed commercial development at Ellsworth and State Roads in accordance with procedures established in Paragraph I-A of the Ann Arbor Pittsfield Sewer Service Agreement dated September 30, 1975. It is understood State Department of Natural Resources approval will be sought eagerly by the City.

B. The sewer service will be provided at 103% of City rates in accordance with the aforementioned agreement.

C. The City will agree to consider additional requests for service prior to the completion of the new "area wide treatment plant" on a case by case basis.

COMMUNICATIONS FROM THE MAYOR

Mayor Louis D. Belcher informed Councilmembers that he will be communicating with Mr. Robert Lillie, Pittsfield Township Supervisor, to advise him of the changes made tonight in the Pittsfield Township Agreement.

* *

Mayor Belcher alerted Council that there are several major Planning matters comming up for consideration, such as the eighty acres of land to be developed in the Briarwood area and a proposal for downtown housing.

* *

Mayor Belcher recommended the appointment of Hugh M. Wanty, 2061 Pauline Boulevard, to the Housing Board of Appeals to replace James J. O'Kane for an indefinite term.

Moved by Councilmember Trowbridge that Council concur in the recommendation of the Mayor.

On roll call the vote was as follows: Yeas, Councilmembers Latta, Greenberg, Morris, Senunas, Sheldon, Trowbridge, Cmejrek, Mayor Belcher, 8

Nays, 0

Councilmember Bell was absent from the Council Chamber at the time the vote was taken.

Chair declared the motion carried.

* *

Mayor Belcher recommended the appointment of Roberta Lea Shrope, 321 South Revena Boulevard, to the Planning Commission, effective July 1, 1978 for a three year term ending June 30, 1981.

Moved by Councilmember Cmejrek that Council concur in the recommendation of the Mayor.

On roll call the vote was as follows: Yeas, Councilmembers Senunas, Sheldon, Trowbridge, Cmejrek, Bell, Mayor Belcher, 6

Nays, Councilmembers Latta, Greenberg, Morris, 3

Chair declared the motion carried.

* *

Mayor Belcher laid the nomination on the table of Charles T. Wagner, 3425 Brentwood Court, to the Planning Commission to be confirmed at the next session of Council.

COMMUNICATIONS FROM COUNCIL COMMITTEES

None.

Exhibit C

AGREEMENT SUPPLEMENTING 1979 POLICY STATEMENT RELATIVE TO AIRPORT LAYOUT PLANS, AERONAUTICAL FACILITIES AND NON-AERONAUTICAL FACILITIES AT THE ANN ARBOR AIRPORT

This agreement ("Agreement") is between the City of Ann Arbor ("Ann Arbor"), a Michigan Municipal Corporation and Pittsfield Charter Township ("Pittsfield"), a Michigan Municipal Corporation.

RECITALS:

Ann Arbor owns and operates the Ann Arbor Airport ("Airport"), which is located in Pittsfield Charter Township.

In 1979 Pittsfield and Ann Arbor entered into an agreement entitled "Policy Statement," a portion of which has addressed certain aspects of the operation of the Ann Arbor Airport.

This Agreement is not intended to replace the Policy Statement. However, in the event of any conflict with the Policy Statement, this agreement shall apply.

Under the Michigan Aeronautics Code, MCL 259.1 et seq., Ann Arbor has jurisdictional control for the management, governance and use of the Airport, including application of its police powers, rules, regulations and ordinances, and including the zoning and planning of aeronautical facilities on the Airport property.

The City of Ann Arbor has adopted its construction code, including the building code, electrical code and mechanical code components thereof, in accordance with the Stille-DeRossett-Hale Single State Construction Code Act (MCL 125.1501 et seq.) ("construction code"). The City and the Township do not agree as to the authority granted to the City by the Michigan Aeronautics Code to extend and enforce its construction code at the Airport relative to aeronautical facilities. However, without deciding the extent of the City's authority under the Michigan Aeronautics Code, the City and the Township agree that to the extent it may be necessary, this agreement is an agreement between two public agencies that constitutes an interlocal agreement for purposes of Sections 4 and 5 of the Urban Cooperation Act (MCL 124.504 and 124.505) and Subsection 8b(2) of the Stille-DeRossett-Hale Single State Construction Code Act (MCL 125.1508b(2)) by which the City and the Township agree that the City shall extend and enforce its construction code to all aeronautical facilities constructed on Airport property, including issuing permits, inspections and enforcement of violations.

The Airport is serviced in whole by Pittsfield sanitary sewer service and is serviced in part by Pittsfield water service.

Unless and until Ann Arbor or the Airport qualifies as an authorized public agency for the Airport under Section 9110 of Part 91, Soil Erosion and Sedimentation Control, of

the Natural Resources and Environmental Protection Act, MCL 324.9110, Pittsfield has jurisdiction over the Airport for soil erosion and sedimentation control.

Wherefore, the parties agree as follows:

1. "Aeronautical facilities" means Airport buildings, landing fields and other facilities that are used for and serve aeronautical or aeronautically related operations and purposes. Aeronautical facilities include both facilities constructed by Ann Arbor and facilities that are privately constructed.

2. "Non-aeronautical facilities" means facilities whose use is unrelated to aeronautical operations or purposes.

3. A modification of the Airport Layout Plan is a land use plan as used in Section II.B. of the Policy Statement.

4. If a modification of the Airport Layout Plan is proposed, Ann Arbor will give notice to Pittsfield's Building Official or such other person as Pittsfield designates in writing, of the intent to modify the Airport layout plan at least 30 days before authorizing a professional services agreement for the modification. At least 30 days before submitting a modification of the Airport Layout Plan for approval by the Michigan Aeronautics Commission or the Federal Aviation Administration, Ann Arbor will provide Pittsfield's Building Official with copies of the documents to be submitted to those bodies. After approval of a modified Airport Layout Plan by the Michigan Aeronautics Commission or the Federal Aviation Administration, Ann Arbor will provide Pittsfield's Building Official with a copy of the proposed modification at least 30 days before the Ann Arbor City Council meeting at which it is to be submitted for approval.

5. Annually Ann Arbor will provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with a copy of the five year Airport Improvement Plan for the Airport.

6. If Ann Arbor applies for grant funds for new or expanded facilities shown or listed on the Airport Layout Plan or Airport Improvement Plan it will notify Pittsfield's Building Official, or such other person as Pittsfield designates in writing, of the application.

7. Aeronautical facilities being constructed at the Ann Arbor Airport are not required to go through the Pittsfield site plan review and approval process. However, when civil construction drawings for a project have been completed, but prior to bid for construction of the facilities, Ann Arbor will submit copies of the civil construction drawings to Pittsfield's Building Official, or such other person as Pittsfield designates in writing, for review and comment. The plans submitted to Pittsfield shall consist of four (4) sets of full sized drawings and a description of

the type of project, the general scope and the time frame. All proposed utilities associated with civil construction drawings for a project shall meet all current Township Land Development Standards.

8. Typical administrative fees will not be charged for the review of the plans submitted pursuant to paragraph 7, but the City will be responsible for establishing an Airport Plan (AP) escrow account for costs, which Pittsfield agrees shall be limited to its actual costs for plan review and comment.

9. Pittsfield will provide a written evaluation of the plans specified in paragraph 7 based on the Pittsfield Zoning Ordinance and Land Development Standards to Ann Arbor's Fleet & Facilities Manager, or such other person as Ann Arbor designates in writing, within two (2) weeks of the submittal in order to permit Ann Arbor staff to consider its comments.

10. Ann Arbor will consider and endeavor to incorporate reasonable recommendations provided by Pittsfield.

11. Ann Arbor will obtain soil erosion and sedimentation control permits for the Airport from Pittsfield until such time as Ann Arbor or the Airport qualifies as an authorized public agency for the Airport under Section 9110 of Part 91, Soil Erosion and Sedimentation Control, of the Natural Resources and Environmental Protection Act, MCL 324.9110.

12. Ann Arbor will obtain Pittsfield utility permits as required by Pittsfield ordinance for connections to Pittsfield sanitary sewer or water lines.

13. Ann Arbor shall extend and enforce its construction code, including the building code, electrical code and mechanical code components thereof, to all aeronautical facilities constructed on Airport property and provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with copies of all construction permit documents including the application, the permit, inspection reports and any certificate of occupancy within thirty days of being issued or received.

14. Non-aeronautical facilities at the Airport will be required to comply with Pittsfield planning and zoning requirements and the Pittsfield construction code ordinance.

15. Nothing contained in this agreement shall be construed as limiting Pittsfield's authority to enforce the State Construction Code regarding any violations of that code for non-aeronautical facilities.

16. Nothing contained in this agreement shall exempt aeronautical facilities from being in compliance with the State Construction Code unless said facilities are under the jurisdiction of the Federal Aviation Administration.

17. Ann Arbor shall extend and enforce its fire prevention code to all aeronautical facilities located on Airport property and provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with copies of all fire inspection documents including fire alarm and detection systems and fire extinguishing system certification and test reports, and all required operational permits within thirty days of being issued or received.

18. This agreement shall be approved by the concurrent resolutions of the Ann Arbor City Council and Pittsfield Charter Township Board of Trustees.

19. This agreement shall take effect October 1, 2009 or after a copy has been filed with both the Washtenaw County Clerk and the Michigan Secretary of State, whichever is later.

20. This agreement shall have a term of 5 years beginning on October 1, 2009. It shall automatically renew for successive 5 year periods unless either party provides the other with written notice of non-renewal at least 60 days before the end of a term.

Dated: ________________________
City of Ann Arbor

By____________________________
John Hieftje, Mayor

By____________________________
Jacqueline Beaudry, City Clerk

Approved as to form:

____
Stephen K. Postema, City Attorney

Dated: ________________________
Pittsfield Charter Township

By____________________________
Mandy Grewal, Township Supervisor

By____________________________
Allen Israel, Township Clerk

Approved as to form:

____
R. Bruce Laidlaw, Township Attorney

Exhibit D

PITTSFIELD CHARTER TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RES #09-23
RESOLUTION OPPOSING PROPOSED EXPANSION OF THE ANN ARBOR MUNICIPAL AIRPORT RUNWAY

MARCH 24, 2009

Minutes of a Regular Meeting of the Township Board of Pittsfield Charter Township, Washtenaw County, Michigan, held at the Township Administration Building located at 6201 W. Michigan Avenue, in said Township, on the 24th day of March, at 6:30 p.m.

Members Present: Grewal, Israel, Scribner, Ferguson, Hunt, Krone, Yi.
Members Absent: None.

The following preamble and resolution were offered by Member Scribner and supported by Member Ferguson.

WHEREAS, the Ann Arbor airport is under the jurisdiction of the City of Ann Arbor and operated by an independent Authority and the land is located within Pittsfield Charter Township immediately adjacent to a residential area; and

WHEREAS, the existing width and length has not posed any substantial safety concerns in the past with only five incidents of landing mishaps out of a total of 600,000 landings in the past eight years; and

WHEREAS, the proposed changes and expansion would shift the runway dangerously close to a busy township roadway (Lohr Road) and closer to dense residential subdivisions; and

WHEREAS, such a runway expansion will significantly increase air traffic volumes and noise pollution experienced by residential subdivisions in the vicinity of the Ann Arbor airport, thereby resulting in a decline of residential home property values; and

WHEREAS, the City of Ann Arbor has not fully demonstrated the economic and safety justifications for undertaking the proposed runway expansion; and

WHEREAS, the City of Ann Arbor appears to have not taken into consideration the negative safety implications such a runway expansion may impose on the surrounding residential subdivisions by expanding a runway closer to residential subdivisions

NOW THEREFORE BE IT RESOLVED, the Pittsfield Charter Township Board of Trustees urges the City of Ann Arbor to reconsider the merits of expanding the Ann Arbor Airport runway in light of the negative implications such an expansion would impose on the residents of Pittsfield Charter Township.

AYES: Grewal, Israel, Scribner, Ferguson, Hunt, Krone, Yi.
NAYS: None.
ABSENT: None.
ABSTAIN: None.

RESOLUTION DECLARED ADOPTED.

Alan Israel, Clerk
Pittsfield Charter Township

DATED: March 24, 2009.

CERTIFICATE

I, Alan Israel hereby certify that the foregoing is a true and complete copy of a resolution adopted by the Township Board of Pittsfield Charter Township, County of Washtenaw, State of Michigan, at a Regular Meeting held on March 24, 2009, and that said meeting was conducted and public notice of said meeting was given pursuant to and in full compliance with the Open Meetings Act, being Act 267, Public Acts of Michigan, 1976, and that the minutes of said meeting were kept and will be or have been made available as required by said Act.

Alan Israel

Alan Israel, Clerk
Pittsfield Charter Township

DATED: March 24, 2009.

Exhibit E

LODI TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RESOLUTION # 2009-009
A RESOLUTION OPPOSING PROPOSED RUNWAY EXPANSION OF THE ANN ARBOR MUNICIPAL AIRPORT

WHEREAS, the Ann Arbor airport is under the jurisdiction of the City of Ann Arbor and operated by an independent Authority and the land is located within Pittsfield Charter Township immediately adjacent to residential areas, including Lodi Township;

WHEREAS, the existing width and length of Runway 6-24 has not be posed any substantial safety concerns in the past with only five incidents of landing mishaps out of a total of 600,000 landings in the past eight years; and

WHEREAS, the proposed changes and expansion would shift the runway so that it ends a mere 700 yards from a busy roadway (Lohr Road) and closer to dense residential subdivisions; and

WHEREAS, such a runway will significantly accommodate larger and heavier aircraft, increase air traffic volumes, and increase noise pollution experienced by residential subdivisions in the vicinity of the Ann Arbor airport, thereby resulting in a decline in residential home property values; and

WHEREAS, the City of Ann Arbor has not fully demonstrated the economic and safety justifications for undertaking the proposed runway expansion; and

WHEREAS, the City of Ann Arbor appears to have not taken into consideration the negative safety implications such a runway expansion may impose on the surrounding residential subdivisions by expanding a runway closer to residential subdivisions;

NOW, THEREFORE BE IT RESOLVED, the Lodi Township Board of Trustees urge the City of Ann Arbor to reconsider the merits of expanding the Ann Arbor Airport runway in light of the negative implications such an expansion would impose on the residents of Lodi Township.

ROLL CALL VOTE:
Ayes: Masters, Staebler, Lindemann, Canham, Foley, and Godek.
Nays: Rentschler.
Absent: None.
Abstain: None.

RESOLUTION DECLARED ADOPTED

____
Elaine Masters, Clerk, Lodi Township
DATED: May 12, 2009

State Block Grant Program
Memorandum of Agreement
Between
The Federal Aviation Administration
Detroit Airports District Office
And
State of Michigan, Department of Transportation
Bureau of Aeronautics and Freight Services

A Memorandum of Agreement (hereinafter referred to as "MOA") by and between the Bureau of Aeronautics and Freight Services, representing the Michigan Department of Transportation (hereinafter referred to as "BAFS" and "MDOT") and the Detroit Airports District Office, representing the Federal Aviation Administration (hereinafter referred to as "DET-ADO" and "FAA") to implement FAA's State Block Grant Program (hereinafter referred to as "SBGP") to improve general aviation airports in Michigan.

WHEREAS, Title 49 USC §47128, authorizes the Federal Aviation Administration's (FAA's) current SBGP; FAA regulation 14 CFR, Part 156 discusses how FAA carries out the SBGP. FAA Order 5100.38, *Airport Improvement Program Handbook, paragraphs 1090-1099*, provides guidance for "...administering a block grant made under this section" (49 USC §47128(b) (1)), and

WHEREAS, MDOT was selected by the Federal Aviation Administration to manage federal airport aid funds for nonprimary airports included under the FAA SBGP, and

WHEREAS, This Memorandum of Agreement (MOA) effective as of the date signed by both parties will replace the previous agreement dated March 16, 1993, and

WHEREAS, in mutual agreement, MDOT and FAA document and execute these understandings and commitments in written form by representatives of each party.

NOW, THEREFORE, MDOT and FAA do attest to the following understandings and commitments with respect to the FAA SBGP:

1. **Term of this Agreement**

   Unless otherwise stipulated, the responsibility of MDOT in carrying out the terms of this agreement and the SBGP will begin with acceptance of this agreement and run concurrently with current funding authorization or 5 years, whichever occurs first.

   The FAA will issue MDOT a Block Grant yearly for each of the five fiscal years beginning the fiscal year following the execution of this agreement. The DET-ADO may issue additional Block Grants if circumstances require. Block Grant issuance will occur as soon as practicable after the FAA has received its budget authorization to issue AIP grants. Non-primary entitlement funds must be obligated within three (3) years and expended within four (4) years. No construction to be funded with AIP Discretionary funds can start prior to the FAA awarding the SBG containing those funds.

The DET-ADO and MDOT will perform a review of this SBG agreement, within ninety (90) calendar days of any applicable legislative provision becoming law or regulatory provision taking effect, to determine the need for a new SBG agreement or amendment.

MDOT or FAA may elect to amend or terminate this agreement at the start of a new fiscal year with ninety (90) days prior written notice. MDOT also agrees that it will continue to administer SBGP projects placed under grant even though the final phases of administration and closeout of such projects may continue beyond the date MDOT no longer participates in the program.

2. **Airports Included**

The State will be responsible for monitoring project accomplishments at all airports covered by the SBGP to assure that all agreements and assurances with airport sponsors are met during the program, except that Part 139 requirements will continue to be FAA responsibilities where applicable.

Commercial service airports that change from primary to non-primary status will continue to be the responsibility of the FAA for three years. After three years, the airport will be included in the SBG and oversight transferred to MDOT. The DET-ADO will retain responsibility for administering and closing grants that were issued by the FAA. Airports within the SBG that change from non-primary to primary will be removed from subsequent SBG in the first fiscal year primary entitlements are available. MDOT will retain responsibility for administering grants issued while the subject airport was within the SBG. See Attachment A.

3. **Review**

Ongoing review of the Program by FAA is required by Title 49 USC § 47128. An advisory team comprised of DET-ADO representatives will conduct evaluations which may include visits to project sites and the MDOT offices. This review will include a yearly program evaluation, random periodic project reviews and general program administrative review. A summary report from MDOT may be required.

4. **Personnel**

MDOT shall maintain sufficiently qualified personnel to fulfill all of its professional, technical and administrative obligations under this MOA.

5. **Federal Regulations**

In carrying out this program, MDOT will comply with all Federal laws, regulations and executive orders set forth in Attachment B. MDOT also acknowledges awareness of FAA policy and guidance in the form of Orders which have applicability to the state block grant program and are set forth in Attachment B. The DET-ADO will provide advice, interpretation and guidance on any documents referenced in Attachments B and C.

6. **FAA Relationship to Block Grant sponsors and consultants**

The FAA will refer sponsors/consultants to MDOT to answer project specific questions on active and proposed block grant projects. In the event there is a dispute between the sponsor/consultant and MDOT, the parties may contact the FAA for advice. However, MDOT is ultimately responsible for project administration.

7. **Role of FAA**

DET-ADO shall serve as primary contact for MDOT on questions regarding policy, eligibility, and overall guidance.

8. **Land Use Zoning**

MDOT will assist airports in their efforts to protect against encroachment of incompatible land use. The State will assume a high-level of responsibility for helping airport sponsors establish zoning protection to safeguard the Federal investment in an airport.

9. **Runway Safety Area Determinations**

A runway safety area determination must be made prior to issuance of any subgrant under the SBGP for any project of runway construction, reconstruction, or significant expansion in accordance with FAA Order 5200.8, *Runway Safety Area Program*, current edition. Preferably, the RSA determination should be completed prior to the project being included in the CIP and ideally as part of the ALP approval process. The RSA determination should follow the format previously provided to MDOT by the DET-ADO. MDOT will prepare and sign those RSA determinations where the determination is that a) the existing RSA meets the current standards contained in FAA Advisory Circular 150/5300-13, *Airport Design*, or b) the existing RSA does not meet the current standards but it is practicable to improve the RSA so that it will meet current standards. Should the ADO disagree with any RSA determination prepared and signed by MDOT, the DET-ADO will discuss with MDOT the area(s) of disagreement and request that MDOT revise the determination. The DET-ADO retains the authority to modify and reissue any MDOT RSA determination. A copy of the RSA determinations issued by MDOT will be provided to the DET-ADO for database entry.

MDOT will provide a draft RSA determination to the DET-ADO where the proposed determination is that (1) the existing RSA can be improved to enhance safety, but the RSA will still not meet current standards, or (2) the existing RSA does not meet current standards, and it is not practicable to improve the RSA. The latter RSA determinations must be signed by the FAA Great Lakes Region's Airports Division Manager, therefore, the draft RSA determination should be provided to the DET-ADO at least 60 days prior to issuance of the applicable subgrant.

10. **Program Responsibilities**

Airport actions under the AIP that would normally be under FAA's scope become State actions under the SBGP. Attachment D contains a list of roles and associated responsibilities which serves as a nonexclusive guide of tasks to be performed under the SBGP. Revisions to this list will require agreement between the State and DET-ADO, as witnessed by the signature of their authorized representatives.

11. **Funds Control**

MDOT will establish rules to govern the co-mingling of AIP funds from multiple appropriation years, including both use and reporting of funds, as well as close-out process. Non-primary entitlement funds must be obligated within three (3) years and expended within four (4) years. MDOT will report to the DET-ADO on how the specified entitlement amounts were used at the end of four years after such block grant has been issued. If a subgrant for the non-primary entitlements is not issued within the four-year period, the funds will be considered excess and recovered by the DET-ADO.

12. **Capital Improvement Plan**

FAA Order 5100.39, *Airports Capital Improvement Plan (ACIP)*, outlines requirements to establish a capital improvement plan (CIP) as a rolling three-year planning document.

MDOT will work with the DET-ADO to update the CIP as required to accomplish SBGP programming. MDOT will use its own priority rating system for administration of apportionment and non-primary airport entitlement funds under the SBGP. If MDOT is pursuing discretionary funding for a project, MDOT will be required to clearly identify all phases of the project, proposed funding sources and types of funds. Discretionary fund planning ceilings for the SBG will be distributed to MDOT as soon as available to DET-ADO. MDOT will provide a current CIP, based on a three year rolling plan that is within the discretionary fund planning ceiling limitations established by DET-ADO for the associated funding years. Priority ranking of projects for each airport receiving funding will be included to assist FAA with overall planning and programming decisions related to the State of Michigan.

The updated CIP will be submitted to the DET-ADO by **December 15** of each calendar year, unless requested earlier. In the event that an alternative date is requested by the FAA for the CIP update, the DET-ADO will inform MDOT as soon as new deadlines are identified and become available to the DET-ADO. MDOT agrees to make every reasonable effort to meet an alternative date that is requested by the FAA.

A planning and financial plan will be required for any project that will depend on more than $5 million in Discretionary funds (in aggregate). This plan shall be submitted to the DET-ADO with the Discretionary request. MDOT will also prepare Benefit/Cost Analyses (BCAs) as required consistent with FAA policy.

13. **Reporting**

MDOT will provide quarterly status reports to the DET-ADO covering:

a) MDOT's current plan for spending Airport Improvement Program (AIP) state apportionment funds for past, current and future years (electronic spreadsheet format);
b) Grants received under the SBGP and subgrants awarded, clearly delineating funding sources by project, location, and funding year, and identifying any subsequent reimbursements planned (electronic spreadsheet format); and
c) Standard Form 272, Federal Cash Transactions Report.

14. **Limitations**

MDOT may not use SBGP funds to accomplish projects, which are not eligible under Title 49 USC, Chapter 471, as interpreted by the FAA, nor at airports, which are not eligible for grants under Title 49 USC, Chapter 471.

The SBG will include all non-primary airports within the State of Michigan, with the exception of Detroit-Willow Run Airport.

15. **Airport Sponsor Adherence to Standard Assurances**

Each recipient of federal funds under this program shall be required to adhere to the standard airport sponsors assurances as provided by FAA and such assurances shall be incorporated into the terms and conditions of the subgrant agreement issued to the sponsor by MDOT.

16. **Project Completion**

All projects funded with AIP funds, particularly Discretionary funds, are expected to be completed expeditiously and properly phased to use the funds in a reasonable timeframe. Each project should result in usable units of work.

17. **Accounting and Audits**

MDOT must have an accounting method that accurately reflects expenditures of SBGP funds. All SBGP projects are subject to the same audit requirements as any other grant and must comply with Order 5100.38, as amended. These reporting and auditing requirements may be supplemented from time to time by FAA Headquarters or Regional policies in order to comply with new statutory requirements, including the Federal Financial Accountability and Transparency Act (FFATA).

18. **Construction Specifications**

The construction specifications used for projects under this program shall be those promulgated by FAA in the Advisory Circulars or such MDOT construction specification as pre-approved by FAA. Any project complying with either FAA or FAA-approved MDOT standards shall be deemed to meet federal standards for the purpose of future federally funded projects.

19. **Records Retention/Availability**

MDOT will provide status reports when sought by the FAA. MDOT will maintain files on the status and history of each project. These files will be available to the FAA at any reasonable time for their review. In addition, MDOT will provide DET-ADO with copies of each subgrant agreement when it is executed. MDOT will retain sub-grant project files with a process and time frame that meets or exceeds FAA requirements as outlined in FAA Order 1350.15, *Records Transfer and Destruction Standards.* MDOT will also make historical project documentation accessible to airport sponsors and consultants for use in subsequent planning and environmental processes.

20. **Site Selection**

MDOT will provide to the FAA, through the DET-ADO, a review and recommendation for approval of any site selection where federal funds or future inclusion in the NPIAS is anticipated.

21. **Airport Sponsor Required to have Approved Airport Layout Plan (ALP)**

No development project grant will be issued under this program unless the Sponsor has an approved Airport Layout Plan (ALP) depicting the proposed work.

Under the SBGP, MDOT must coordinate an ALP with all interested parties, including the FAA, and approve it. The ALP will be in accordance with the Great Lakes Region PPM 5310.1, FAA Advisory Circular 150/5070, *Airport Master Plans* and requirements promulgated by the DET ADO. MDOT will provide the DET ADO with one copy of the final approved ALP.

22. <u>Design Criteria</u>

The geometric and design standards used for projects under this program will be those promulgated by the FAA in the Advisory Circulars. Any request for a modification to standards must come to the DET ADO through MDOT with their review and recommendation for approval. Any request sent directly to the FAA by a sponsor or sponsor's consultant to modify standards for a state block grant project will be immediately referred to MDOT for their action.

23. <u>Environmental Responsibilities</u>

SBGP Projects

The DET-ADO reserves the right to review and comment, at its discretion, on any environmental document prepared for projects funded under the SBGP. MDOT agrees to consider and reconcile such comments.

Federal Actions Connected to SBGP Projects

When airport development actions are to be conducted outside the purview of the SBGP such projects are considered "Federal actions" and are subject to relevant FAA environmental analysis per requirements of FAA Orders 5050.4 and 1050.1. The actions listed below are not authorized under the SBGP and occur clearly outside of its scope. FAA organizations retain NEPA review responsibility for the following:

a) SBGP airport actions for which MDOT requests AIP discretionary funds to supplement SBGP funding for a specific airport project at a specific location and FAA anticipates providing those funds,
b) Airport noise compatibility planning, including approval of airport noise compatibility programs under 14 CFR Part 150,
c) Airport land releases, including approval of such releases,
d) Approval of an airport location (new airport),
e) Installing or moving FAA-owned navigational equipment,
f) Establishing or revising air traffic and flight procedures.

Environmental Document Preparation

Paragraph 23, items a-f, above, list those Federal actions that may be connected to airport actions that are funded under the SBGP. Because those connected Federal actions fall outside the SBGP they remain under the purview of an FAA organization and are subject to NEPA. In preparing environmental documents for SBGP projects and for those projects considered Federally-connected actions, MDOT shall cooperate with the responsible FAA organization as it prepares the necessary environmental document to address both the State "NEPA-like" requirements, as well as the Federal NEPA responsibilities. Environmental document processing for SBGP and Federal actions is explained in FAA Order 5050.4, Paragraph 214.

24. <u>Wildlife Management</u>

MDOT agrees to address hazardous wildlife attractant issues on or near airports, in accordance with Advisory Circular 150/5200-33, as follows:

a) On landfill proposals, the MDOT shall evaluate the proposal and forward its draft determination to the DET-ADO for concurrence. Following receipt of FAA concurrence, the MDOT shall send a letter to the proponent with the final determination.
b) On other proposals with land use practices that could potentially attract wildlife hazards, the MDOT shall evaluate the proposal and issue the determination to the proponent with a copy to the DET-ADO.

25. <u>Congressional Inquires</u>

Congressional inquiries about all matters concerning the SBGP will be referred to DET-ADO. MDOT will provide assistance as requested. The DET-ADO will respond to the congressional office. DET-ADO will copy MDOT on all congressional responses.

26. <u>Request for Release of Land</u>

MDOT shall be responsible for review of requests for release of airport land made by sponsors. Once MDOT has reviewed the land release requests, they will be submitted, along with MDOT's recommendation, to the DET-ADO for coordination and final approval. DET-ADO will consider MDOT's recommendation before making land release decisions.

27. **Letter of Credit Drawdowns**

Drawdown of federal funds will be by letter of credit referencing Block Grant number.

FORM APPROVED 3/23/10 ASSISTANT ATTORNEY GENERAL

AGREED AS WRITTEN:

Director, Michigan Department of Transportation — Date: 3-25-10

Manager, Detroit Airports District Office
Federal Aviation Administration — Date: 3-25-10

DIRECTOR AGENDA 3-23-10

Reviewed Contract Admin.

Attachment A
Airports Not Included in the State Block Grant Program

Airport Name	Identifier	Previous Hub Size	Current Hub Size	Year Changed	Comments
Alpena County Regional	APN	PR - Non Hub	NP - CS	2007	Add to SBG 2011
Charlevoix Municipal	CVX	PR - Non Hub	NC	N/A	
Detroit Metro	DTW	PR - Large	NC	N/A	
Escanaba - Delta County	ESC	PR - Non Hub	NP - CS	2009	Add to SBG 2012
Flint - Bishop International	FNT	PR - Small	NC	N/A	
Grand Rapids - Gerald R. Ford International	GRR	PR - Small	NC	N/A	
Houghton County Memorial	CMX	PR - Non Hub	NC	N/A	
Kalamazoo/Battle Creek International	AZO	PR - Non Hub	NC	N/A	
Lansing - Capital Area Regional International	LAN	PR - Non Hub	NC	N/A	
Marquette - Sawyer International	SAW	PR - Non Hub/Special	NC	N/A	
Muskegon County	MKG	PR - Non Hub	NC	N/A	
Pellston Regional of Emmet County	PLN	PR - Non Hub	NC	N/A	
Saginaw - MBS International	MBS	PR - Non Hub	NC	N/A	
Sault Ste. Marie - Chippewa County International	CIU	PR - Non Hub	NC	N/A	
Traverse City - Cherry Capital	TVC	PR - Non Hub	NC	N/A	
Detroit - Willow Run	YIP	NP - RL	NC	N/A	

CS - Commercial Service
GA - General Aviation
PR - Primary
RL - Reliever

NP - Non Primary
NC - No Change
N/A - Not Applicable

Signed:

[signature]

Director, Michigan Department of Transportation

3-25-10
Date

[signature]

Manager, Detroit Airports District Office
Federal Aviation Administration

3-25-10
Date

Attachment B

Required Statutory and Regulatory References[1]

1. Title 49, U.S.C., subtitle VII, as amended.
2. Davis-Bacon Act - 40 U.S.C. 276(a), et seq. [2]
3. Federal Fair Labor Standards Act - 29 U.S.C. 201, et seq.
4. Hatch Act - 5 U.S.C. 1501, et seq. [2]
5. Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 Title 42 U.S.C. 4601, et seq. [2,3]
6. National Historic Preservation Act of 1966 - Section 106 - 16 U.S.C. 470(f). [2]
7. Archeological and Historic Preservation Act of 1974 - 16 U.S.C. 469 through 469c. [2]
8. Native Americans Grave Repatriation Act - 25 U.S.C. Section 3001, et seq.
9. Clean Air Act, P.L. 90-148, as amended.
10. Coastal Zone Management Act, P.L. 93-205, as amended.
11. Flood Disaster Protection Act of 1973 - Section 102(a) - 42 U.S.C. 4012a. [2]
12. Title 49 ,U.S.C., Section 303, (formerly known as Section 4(f))
13. Rehabilitation Act of 1973 - 29 U.S.C. 794.
14. Civil Rights Act of 1964 - Title VI - 42 U.S.C. 2000d through d-4.
15. Age Discrimination Act of 1975 - 42 U.S.C. 6101, et seq.
16. American Indian Religious Freedom Act, P.L. 95-341, as amended.
17. Architectural Barriers Act of 1968 -42 U.S.C. 4151, et seq. [2]
18. Power plant and Industrial Fuel Use Act of 1978 - Section 403- 2 U.S.C. 8373. [2]
19. Contract Work Hours and Safety Standards Act - 40 U.S.C. 327, et seq. [2]
20. Copeland Antikickback Act - 18 U.S.C. 874. [2]
21. National Environmental Policy Act of 1969 – U.S.C. 4321 et seq. [2]
22. Wild and Scenic Rivers Act, P.L. 90-542, as amended.
23. Single Audit Act of 1984 - 31 U.S.C. 7501, et seq. [3]
24. Drug-Free Workplace Act of 1988 - 41 U.S.C. 702 through 706.

Executive Orders

25. Executive Order 11246 - Equal Employment Opportunity [2]
26. Executive Order 11990 - Protection of Wetlands
27. Executive Order 11998 – Flood Plain Management
28. Executive Order 12372 - Intergovernmental Review of Federal Programs.
29. Executive Order 12699 - Seismic Safety of Federal and Federally Assisted New Building Construction [2]
30. Executive Order 12898 - Environmental Justice

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[1] Corresponds to references included in "Terms and Conditions of Accepting Airport Improvement Program Grants" (revised June 2005).

[2] These do not apply to airport planning sponsors.

3 These do not apply to private sponsors.

Federal Regulations

31. 14 CFR Part 13 - Investigative and Enforcement Procedures.
32. 14 CFR Part 16 - Rules of Practice For Federally Assisted Airport Enforcement Proceedings.
33. 14 CFR Part 150 - Airport noise compatibility planning.
34. 29 CFR Part 1 - Procedures for predetermination of wage rates. [2]
35. 29 CFR Part 3 - Contractors and subcontractors on public building or public work financed in whole or part by loans or grants from the United States. [2]
36. 29 CFR Part 5 - Labor standards provisions applicable to contracts covering federally financed and assisted construction (also labor standards provisions applicable to non-construction contracts subject to the Contract Work Hours and Safety Standards Act). [2]
37. 41 CFR Part 60 - Office of Federal Contract Compliance Programs, Equal Employment Opportunity, Department of Labor (Federal and federally assisted contracting requirements). [2]
38. 49 CFR Part 18 - Uniform administrative requirements for grants and cooperative agreements to state and local governments. [3]
39. 49 CFR Part 20 - New restrictions on lobbying.
40. 49 CFR Part 21 - Nondiscrimination in federally-assisted programs of the Department of Transportation - effectuation of Title VI of the Civil Rights Act of 1964.
41. 49 CFR Part 23 - Participation by Disadvantage Business Enterprise in Airport Concessions.
42. 49 CFR Part 24 - Uniform relocation assistance and real property acquisition for Federal and federally assisted programs.[2,3]
43. 49 CFR Part 26 – Participation By Disadvantaged Business Enterprises in Department of Transportation Programs.
44. 49 CFR Part 27 - Nondiscrimination on the basis of handicap in programs and activities receiving or benefiting from Federal financial assistance. [2]
45. 49 CFR Part 29 – Government wide debarment and suspension (non-procurement) and government wide requirements for drug-free workplace (grants).
46. 49 CFR Part 30 - Denial of public works contracts to suppliers of goods and services of countries that deny procurement market access to U.S. contractors.
47. 49 CFR Part 41 - Seismic safety of Federal and federally assisted or regulated new building construction. [2]

Office of Management and Budget Circulars

48. A-87 - Cost Principles Applicable to Grants and Contracts with State and Local Governments.
49. A-133 - Audits of States, Local Governments, and Non-Profit Organizations.

ATTACHMENT C

This attachment lists key provisions of applicable FAA Orders that should be incorporated by specific reference in the sate block grant agreement. The purpose is to ensure that block-grant states fully understand their legal obligations under the SBG program, and the FAA's oversight responsibilities in the various program areas.

1. FAA Order 5050.4B ("National Environmental Policy Act Implementing Instructions for Airport Projects"), with particular reference on Paragraph 210 ("The State Block Grant Program"). However, this paragraph includes references to the applicability of other requirements throughout the Order, based on Federal laws including but not limited to NEPA.

2. FAA Order 5100.38C ("Airport Improvement Program Handbook"), with particular reference to:

   - Chapter 1, Sections 1-3 which provide general background on the statutory provisions governing the Airport Improvement Program.
   - Chapter 10, Section 9 ("Block Grant Procedures"), with particular focus on Paragraphs 1090-1097.

3. FAA Order 5100.39A ("Airport Capital Improvement Plan"), particularly Paragraph 10 ("Use of Other Priority Systems").

4. FAA Order 5190.6A ("Airport Compliance Requirements"), particularly Chapter 3 ("Exclusive Rights") and Chapter 4 ("Obligations of Airport Owners").

ATTACHMENT D: PROGRAM RESPONSIBILITIES

Airport actions under the AIP that would normally be under FAA's scope become State actions under the SBGP. MDOT and FAA have program responsibility for airport actions, as described in the following Tables.

ADMINISTRATIVE RESPONSIBILIITES			
TASK/FUNCTION	STATE	FAA	COMMENTS
Airport (Non-primary Commercial Service)	X		
Airport (Reliever GA)	X		
Airport (Non-Reliever GA)	X		
Funding Privately Owned Airports-Approval	X		
Sponsor Eligibility	X		
Approve SBGP Funds for Airport Action	X		
Records Retention	X		3 years beyond financial completion of block grant
Facilities & Equipment (F&E) Budget Requests	X	X	Coordinate with ATO
Funds Control/Obligation Goals	X		
Congressional Inquiries	X		Copy of reply to DET-ADO
Civil Rights	X		Per Agreement with FAA Civil Rights Office

LAND RESPONSIBILITIES			
TASK/FUNCTION	STATE	FAA	COMMENTS
Appraisals	X		
Relocation	X		
Title Opinion	X		
Donated Land Value	X	X	Coordinate with DET-ADO
Property Interest Prior to Construction	X		
Exhibit A, Property Map Revision/ Update	X		

CONSTRUCTION RESPONSIBILITIES			
TASK/FUNCTION	STATE	FAA	COMMENTS
FAA Reimbursable Agreement	X	X	Coordinate with DET-ADO
Review Safety and Phasing Plan	X		

Construction Inspection –Interim	X		
Construction Inspection – Final	X		
Pre-Construction Conference	X		
User Coordination	X		
Change Orders	X		
Update FAA Form 5010	X		
Data for Approach Procedures	X	X	Submission in accordance with established timelines
As-Built Record Drawings	X		
Advertising for Bids	X		
Award to Low Bidder	X		
Reasonableness of Cost	X		
Non-AIP Separate Records	X		
Wage Rates	X		
EEO & Wage Rate Posters	X		
Bond Payment/Performance	X		
Construction Contracts	X		
Shutdown Schedule Coordination	X		
Contract for Utility Relocation	X		
Force Account Work Approval		X	Coordinate with DET-ADO for State Force Account Work
Debarment List	X		
No Work Prior to Federal Grant Execution	X		
Comply with Airspace	X		
Notice to Proceed	X		
Material Testing	X		
Construction Inspection Report	X		

PAYMENT RESPONSIBILITIES			
TASK/FUNCTION	**STATE**	**FAA**	**COMMENTS**
Payment via Letter of Credit	X		
Final Payments	X		
Partial Payments	X		No advance payments
Obligation Schedule	X		Submit to DET-ADO quarterly
Tracking Expenditures of Federal Funds	X		Submit to DET-ADO quarterly

AIRSPACE RESPONSIBILITIES			
TASK/FUNCTION	**STATE**	**FAA**	**COMMENTS**
Changes to Airport Layout Plan	X	X	Coordinated with DET-ADO, approved by MDOT.
Construction Equipment	X	X	Coordinated with DET-ADO,

			approved by MDOT.
Safety/Phasing Plan	X	X	Coordinated with DET-ADO, approved by MDOT.
Non-rule Making Actions (NRA) Studies	X	X	Coordinated with DET-ADO, approved by MDOT.
Local Airport Events	X	X	Coordinated with DET-ADO, approved by MDOT.

DESIGN RESPONSIBILITIES			
TASK/FUNCTION	STATE	FAA	COMMENTS
Pre-Design Meeting	X		
Plans/Spec. Review	X		
Plans/Spec. Certification	X		
Plans/Spec. Approval	X		
Relocation of NAVAIDs	X	X	Coordinate with DET-ADO to facilitate coordination with FAA ATO
Design Variance Approval/ Modification to Standards	X	X	MDOT submit request and recommendations to DET-ADO
Coordinate with State and Federal Highway Office	X		
Pavement Design/Materials	X		
Consultant Selection	X		
ARFF & Snow Removal Equipment Specs	X		Comply with Advisory Circular, no modifications

COMPLIANCE RESPONSIBILITIES			
TASK/FUNCTION	STATE	FAA	COMMENTS
Land Release	X	X	MDOT reviews proposal and requests FAA concurrence. FAA must approve.
Surplus Property Program		X	
Surplus Property Release	X	X	MDOT reviews proposal and request FAA concurrence. FAA must approve.
Sub-Grant Special Conditions	X		
Clear Approaches	X		
Compatible Land Use	X		
Landfills	X	X	Review proposal, FAA concurrence
GA Safety Inspections	X	X	FAA responsible for GA Part 139 airports.
Informal Complaints	X	X	MDOT responsible for

			investigation and resolution of informal complaints. If resolution unsuccessful, DET-ADO will assist and/or resolve.
Formal Complaints		X	
Compliance Determination FAA Order 5190.6A	X	X	Coordinate the DET-ADO

PLANNING RESPONSIBILITIES			
TASK/FUNCTION	**STATE**	**FAA**	**COMMENTS**
State System Plan update	X		Once every 5 years, at a minimum.
Determining Eligibility & Timing of Airport Actions	X		
National Environmental Policy Act (NEPA)	X	X	State – State Apportionment and Non-Primary Entitlement projects FAA – Discretionary projects
Public Coordination	X		
Planning Grants	X		
NPIAS Updates	X	X	Coordinate with DET-ADO
New NPIAS Site	X	X	MDOT request & provide rationale
Airport Layout Plan Approval	X		
Instrument Approach Procedures	X	X	Submission in accordance with established timelines
TASK/FUNCTION	**STATE**	**FAA**	**COMMENTS**
iOE/AAA Airport Data Base	X	X	MDOT inputs runway data.
Part 150		X	FAA – Part 150 Studies & Technical Assistance
Congressionally Mandated Projects	X	X	Projects must be funded or justification provided for not funding projects.
Executive Order 12372, Intergovernmental Review	X		
Zoning Ordinances	X		
Coordination with Local Councils of Governments or Other Appropriate Local Agencies	X		
Priority System	X	X	In conjunction with Regional guidance

ADDITIONAL RESPONSIBILITIES

The following reports/information is to be submitted to the DET-ADO by MDOT:

Reports/Submittals	Timing
Master Airport Sponsor Certification	Included in grant application
Grant expenditures & summary report	Quarterly & as requested
Copy of sub-grants	As issued
Copy of approved ALP's	Continuous
Copy of Congressional replies	Continuous
Compliance findings	Continuous
Summary reports	At Grant Closeout
NPIAS update	Continuous
Civil Rights report to AGL-9	If requested (State must have on file)
Terminal Area Forecast update	When requested

Chapter 14. Offenses and Miscellaneous Provisions

Article VIII. Noise Offenses

§ 14-34. Noise general prohibition.

It shall be unlawful for any person to create, assist in creating, permit, continue, or permit the continuance of any unreasonably loud, disturbing, unusual or unnecessary noise that either annoys, disturbs, injures or endangers the comfort, repose, health, peace or safety of others within the limits of the Township.

§ 14-35. Specific acts prohibited.

The following acts are declared unreasonably loud, disturbing, or unnecessary noises and are unlawful and prohibited, but this enumeration shall not be deemed to be exclusive:

A. The playing of any radio, phonograph, tape recorder, stereo, musical instrument or any sound amplification device of any character in such a manner or with such volume, at any time or place as to annoy or disturb the quiet, comfort or repose of persons in any office, dwelling, hotel or other type of residence or of any person in the vicinity.

B. The discharge into the open air of exhaust of any steam engine, compressed air machine, stationary internal combustion engine, motor vehicle, or any other machine, except through a muffler or other device that will effectively prevent loud or explosive or disturbing noises.

C. The creation of a loud unnecessary noise in connection with the loading or unloading of any vehicle or the opening and closing or destruction of bales, boxes, crates or their containers.

D. Yelling, shouting, whistling, loud talking or singing on the public streets, particularly between the hours of 10:00 p.m. and 7:00 a.m., or at any other time or place as to annoy or disturb the quiet comfort or repose of persons in any office, dwelling, hotel or any other type of residence or of any persons in the vicinity.

E. The use of any drums, loudspeakers, musical devices, or other instruments or devices for the purpose of attracting attention by the creation of noise to any performance, show or sale or display of merchandise.

F. The use of mechanical loudspeakers, on or from motor vehicles in a manner that causes the sound emitted from the vehicle to be heard on private property, except when a specific permit is first granted by the Township Board of Trustees. The Township Board of Trustees shall cause such a permit be issued when it finds the following:

   (1) The applicant has a noncommercial message that cannot be effectively communicated to the public by any other means of communication available.

   (2) The applicant will limit the use of the loudspeakers to times, locations and sound levels that will not unreasonably disturb the public peace.

(3) The applicant will not use such equipment in residential areas between 6:00 p.m. and 9:00 a.m.

G. Construction, repair, erection, excavation, demolition, alteration or remodeling at any time on Sunday and between 8:00 p.m. and 7:00 a.m., Monday through Saturday, except in case of urgent necessity in the interest of public safety and then only upon permission having been first obtained from the Department of Building Services or the Department of Utilities and Municipal Services.

H. The firing of firearms, air guns, or other combustible substances for the purpose of making a noise or disturbance.

I. The practicing and training of any drum corps, band, orchestra or other musical organization, or the practice by individuals on the various musical instruments, that produce a noise or disturbance, and which annoy the peace, repose and comfort of the residents in the vicinity.

J. The excessive sounding of any horn or signal device, emanating from a motor vehicle, so as to create any loud or harsh sound plainly audible within any dwelling unit or residence, except as a warning of danger signal or an alert. As used in this subsection, "motor vehicle" means any vehicle that is self-propelled.

K. The playing or operation of any device designed for sound reproduction, including, but not limited to, any radio, television set, musical instrument, audio system, including cassette tape players, compact disc players, MP3 players, and speakers, or loud speaker in such a manner or with such volume as to be plainly audible in any dwelling unit or residence which is not the source of the sound, or to operate any such device on public property or on a public right-of-way so as to be plainly audible 50 feet or more from such device.

Council unanimously agreed with Councilmember Morris to amend Paragraph A of Section I (Annexation - General) of the policy agreement as follows:

A. All land areas in The Township lying west of U.S. 23 Expressway and north of the ~~centerline~~ SOUTH LINE of Ellsworth Road from U.S. 23 to the west line of ~~Platt~~ STATE Road, ~~thence southerly to the Railroad right-of-way adjacent to the City Landfill; thence westerly along the landfill line extended to Stone School Road, thence northerly along the east line of Stone School Road to the south line of Ellsworth Road; thence westerly to the west line of State Street,~~ thence northerly to the south line of I-94,...

The question being the Resolution with the amended Policy Agreement.

On a voice vote, Chair declared the motion carried unanimously.

The Resolution as adopted reads as follows:

R-280-7-78

RESOLUTION TO APPROVE CITY OF ANN ARBOR AND PITTSFIELD TOWNSHIP AGREEMENT

WHEREAS, the City of Ann Arbor officials and Pittsfield Township officials have spent many months negotiating an agreement of understanding; and,

WHEREAS, both governments agree to the principle of cooperation and not confrontation; and,

WHEREAS, the agreement is deemed in the best interests of the citizens of both units of government;

NOW, THEREFORE, BE IT RESOLVED that the following agreement of understanding be approved.

CITY OF ANN ARBOR–CHARTER TOWNSHIP OF PITTSFIELD POSITION PAPER ON PROMULGATION OF POLICIES

Promulgation of Policies

The CITY OF ANN ARBOR "The City", and the CHARTER TOWNSHIP OF PITTSFIELD, "The Township", by their respective governing bodies, for the purpose of furthering their common welfare, do hereby promulgate certain policies, and declare their intentions to abide the same in their exercise of governmental authority so far as practical and not in conflict with law.

I–ANNEXATION–GENERAL

A. All land areas in The Township lying west of U.S. 23 Expressway and north of the south line of Ellsworth Road from U.S. 23 to the west line of State Road, thence

northerly to the south line of I-94, thence westerly to the western boundary of The Township, shall be designated as "The Territory" and shall be eventually annexed to the City in an orderly manner.

B. It shall be understood that this aforementioned line is the unofficial boundary line until such times it can be so officially designated.

C. Inasmuch as the Township and the City have an existing contract for sewer service for portions of the Township, the Township shall not make plans to provide municipal sewer and/or water service to any properties within said Territory, however the Township shall maintain all other legal authority and responsibility for Township lands and residents in the Territory until such time as they do become annexed to the City.

D. Notwithstanding previous policies, decisions and procedures, the City and Township hereby agree that individual properties in the designated area may be annexed to the City even where such annexation may create new islands. Neither the City nor the Township shall interpose in any judicial or other proceeding pertaining to the annexation of any portion of the said Territory an objection to such annexation by reason that the same would create an enclave of Township land within the City.

E. Neither the City nor the Township shall seek to require annexation to the City of any such enclave of Township land lying within the Territory, solely because of its constituting an enclave, whether now existing or hereafter created through the annexation of a portion of the Territory. Nevertheless, upon request to the City by the owner of a property within any said enclave for City water and/or sewer service to such property, the City may require such property to become annexed to the City as a condition of granting such service.

F. The Township agrees that rather than furthering litigation in the case of the Pittsfield Islands, it will agree to the Boundary Commission decision of 1973 (File No. 8322) if the individual review procedure as set forth in paragraph I-H is applied.

G. Through joint resolutions of the City and Township governing bodies any portion of the Territory within the designated area may be annexed to the City upon the petition therefor signed by the petitioners as provided by MCLA 117.9(8) in the case of such alternate method of annexation.

H. Upon annexation to the City of properties within said Territory the City "deferred charges" thereon, for benefits conferred by capital improvements made prior to the annexation shall be payable at the property owners option, either in full, or in not

less than six (6) equal annual installments, provided that the same shall be payable in up to twelve (12) equal annual installments in cases of a property being, and continuing to be, the homestead of an owner occupant who has special hardship problems or is otherwise adjudged in need of special consideration. Hardship and special considerations may be conferred upon the single owner occupant at time of annexation. A transition appeals committee shall be established for the purpose of determining such need. It shall be authorized to make recommendations to City Council for special consideration and shall be comprised of two (2) members appointed from the City and one (1) member appointed from the Township.

II–MUNICIPAL AIRPORT

A. The City agrees that the pending appeal of the decision of the Washtenaw Circuit Court in the suit of the Township vs. the City (Docket No. 77-12619) respecting the City's proceedings to annex Territories in and about the Municipal Airport and a portion of Eisenhower Boulevard shall be dismissed.

B. The Township agrees to cooperate with the City in the establishment of an Airport Land Use Plan which recognizes the compatibility of light industrial, warehousing, gravel mining and other uses on airport lands. The Township will review and comment on the plan before City adoption. It is further understood that any private construction on Airport lands will require approval under Township zoning and site plan requirements, as well as Township Building and Safety Department permit requirements. Plans for municipal construction on Airport lands must be submitted to the Township for review and comment.

C. The Township agrees to establish a land use plan for the environs of the Airport which recognizes only land uses which are compatible to airport operations from a safety and environmental point of view. The City will review and comment on the plan before adoption by the Township.

D. It is further agreed that gravel mining may take place only for use on City of Ann Arbor roads and public works projects and for use on Pittsfield Township roads, and public works projects. In addition, that a gravel processing plan, a restoration plan and a soil erosion plan be filed and reviewed by the Township.

E. Excepting as exempt by law, the Township shall assess for taxes the real and personal properties of and upon the airport lands.

F. The Township agrees to provide right-of-way for City sanitary sewage mains to the Airport to serve Airport properties uses only.

III–LANDFILL

A. The City desires to expand its Landfill operations to the west on property known as the Derck, Nielsen, and McCalla parcels.

B. The Township agrees to actively support and assist in acquisition negotiations such expansion on the conditions that:

1. A land use and restoration plan be developed for long range use of the landfill area.

2. That a reasonable strip of land immediately east of Stone School Road, as well as along Ellsworth Road, as well as along the northern edge of what is known as the Morgan properties is excluded for environmental purposes.

C. A Landfill Expansion Advisory Committee composed of four (4) persons appointed by the City and three (3) persons appointed by the Township shall be created to advise the City on environmental and operational plans.

D. The Township desires that it be given preferred customer consideration by the City in the use of the Landfill or offered an opportunity for proportionate investment equity if the Landfill is to be expanded in this location.

E. The Township shall not adopt any ordinance, rule or regulation which regulates or attempts to regulate the City's use of the landfill property so long as that property is used for disposal of refuse materials or for park purposes.

IV–SEWER/WATER SERVICEES

A. Upon acceptance and execution of this position paper, the City agrees to immediately approve the Township's request for sewer service limited to the Township Hall and the State Road frontage of a proposed commercial development at Ellsworth and State Roads in accordance with procedures established in Paragraph I-A of the Ann Arbor Pittsfield Sewer Service Agreement dated September 30, 1975. It is understood State Department of Natural Resources approval will be sought eagerly by the City.

B. The sewer service will be provided at 103% of City rates in accordance with the aforementioned agreement.

C. The City will agree to consider additional requests for service prior to the completion of the new "area wide treatment plant" on a case by case basis.

COMMUNICATIONS FROM THE MAYOR

Mayor Louis D. Belcher informed Councilmembers that he will be communicating with Mr. Robert Lillie, Pittsfield Township Supervisor, to advise him of the changes made tonight in the Pittsfield Township Agreement.

* *

Mayor Belcher alerted Council that there are several major Planning matters comming up for consideration, such as the eighty acres of land to be developed in the Briarwood area and a proposal for downtown housing.

* *

Mayor Belcher recommended the appointment of Hugh M. Wanty, 2061 Pauline Boulevard, to the Housing Board of Appeals to replace James J. O'Kane for an indefinite term.

Moved by Councilmember Trowbridge that Council concur in the recommendation of the Mayor.

On roll call the vote was as follows: Yeas, Councilmembers Latta, Greenberg, Morris, Senunas, Sheldon, Trowbridge, Cmejrek, Mayor Belcher, 8

Nays, 0

Councilmember Bell was absent from the Council Chamber at the time the vote was taken.

Chair declared the motion carried.

* *

Mayor Belcher recommended the appointment of Roberta Lea Shrope, 321 South Revena Boulevard, to the Planning Commission, effective July 1, 1978 for a three year term ending June 30, 1981.

Moved by Councilmember Cmejrek that Council concur in the recommendation of the Mayor.

On roll call the vote was as follows: Yeas, Councilmembers Senunas, Sheldon, Trowbridge, Cmejrek, Bell, Mayor Belcher, 6

Nays, Councilmembers Latta, Greenberg, Morris, 3

Chair declared the motion carried.

* *

Mayor Belcher laid the nomination on the table of Charles T. Wagner, 3425 Brentwood Court, to the Planning Commission to be confirmed at the next session of Council.

COMMUNICATIONS FROM COUNCIL COMMITTEES

None.

AGREEMENT SUPPLEMENTING 1979 POLICY STATEMENT RELATIVE TO AIRPORT LAYOUT PLANS, AERONAUTICAL FACILITIES AND NON-AERONAUTICAL FACILITIES AT THE ANN ARBOR AIRPORT

This agreement ("Agreement") is between the City of Ann Arbor ("Ann Arbor"), a Michigan Municipal Corporation and Pittsfield Charter Township ("Pittsfield"), a Michigan Municipal Corporation.

RECITALS:

Ann Arbor owns and operates the Ann Arbor Airport ("Airport"), which is located in Pittsfield Charter Township.

In 1979 Pittsfield and Ann Arbor entered into an agreement entitled "Policy Statement," a portion of which has addressed certain aspects of the operation of the Ann Arbor Airport.

This Agreement is not intended to replace the Policy Statement. However, in the event of any conflict with the Policy Statement, this agreement shall apply.

Under the Michigan Aeronautics Code, MCL 259.1 et seq., Ann Arbor has jurisdictional control for the management, governance and use of the Airport, including application of its police powers, rules, regulations and ordinances, and including the zoning and planning of aeronautical facilities on the Airport property.

The City of Ann Arbor has adopted its construction code, including the building code, electrical code and mechanical code components thereof, in accordance with the Stille-DeRossett-Hale Single State Construction Code Act (MCL 125.1501 et seq.) ("construction code"). The City and the Township do not agree as to the authority granted to the City by the Michigan Aeronautics Code to extend and enforce its construction code at the Airport relative to aeronautical facilities. However, without deciding the extent of the City's authority under the Michigan Aeronautics Code, the City and the Township agree that to the extent it may be necessary, this agreement is an agreement between two public agencies that constitutes an interlocal agreement for purposes of Sections 4 and 5 of the Urban Cooperation Act (MCL 124.504 and 124.505) and Subsection 8b(2) of the Stille-DeRossett-Hale Single State Construction Code Act (MCL 125.1508b(2)) by which the City and the Township agree that the City shall extend and enforce its construction code to all aeronautical facilities constructed on Airport property, including issuing permits, inspections and enforcement of violations.

The Airport is serviced in whole by Pittsfield sanitary sewer service and is serviced in part by Pittsfield water service.

Unless and until Ann Arbor or the Airport qualifies as an authorized public agency for the Airport under Section 9110 of Part 91, Soil Erosion and Sedimentation Control, of

the Natural Resources and Environmental Protection Act, MCL 324.9110, Pittsfield has jurisdiction over the Airport for soil erosion and sedimentation control.

Wherefore, the parties agree as follows:

1. "Aeronautical facilities" means Airport buildings, landing fields and other facilities that are used for and serve aeronautical or aeronautically related operations and purposes. Aeronautical facilities include both facilities constructed by Ann Arbor and facilities that are privately constructed.

2. "Non-aeronautical facilities" means facilities whose use is unrelated to aeronautical operations or purposes.

3. A modification of the Airport Layout Plan is a land use plan as used in Section II.B. of the Policy Statement.

4. If a modification of the Airport Layout Plan is proposed, Ann Arbor will give notice to Pittsfield's Building Official or such other person as Pittsfield designates in writing, of the intent to modify the Airport layout plan at least 30 days before authorizing a professional services agreement for the modification. At least 30 days before submitting a modification of the Airport Layout Plan for approval by the Michigan Aeronautics Commission or the Federal Aviation Administration, Ann Arbor will provide Pittsfield's Building Official with copies of the documents to be submitted to those bodies. After approval of a modified Airport Layout Plan by the Michigan Aeronautics Commission or the Federal Aviation Administration, Ann Arbor will provide Pittsfield's Building Official with a copy of the proposed modification at least 30 days before the Ann Arbor City Council meeting at which it is to be submitted for approval.

5. Annually Ann Arbor will provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with a copy of the five year Airport Improvement Plan for the Airport.

6. If Ann Arbor applies for grant funds for new or expanded facilities shown or listed on the Airport Layout Plan or Airport Improvement Plan it will notify Pittsfield's Building Official, or such other person as Pittsfield designates in writing, of the application.

7. Aeronautical facilities being constructed at the Ann Arbor Airport are not required to go through the Pittsfield site plan review and approval process. However, when civil construction drawings for a project have been completed, but prior to bid for construction of the facilities, Ann Arbor will submit copies of the civil construction drawings to Pittsfield's Building Official, or such other person as Pittsfield designates in writing, for review and comment. The plans submitted to Pittsfield shall consist of four (4) sets of full sized drawings and a description of

the type of project, the general scope and the time frame. All proposed utilities associated with civil construction drawings for a project shall meet all current Township Land Development Standards.

8. Typical administrative fees will not be charged for the review of the plans submitted pursuant to paragraph 7, but the City will be responsible for establishing an Airport Plan (AP) escrow account for costs, which Pittsfield agrees shall be limited to its actual costs for plan review and comment.

9. Pittsfield will provide a written evaluation of the plans specified in paragraph 7 based on the Pittsfield Zoning Ordinance and Land Development Standards to Ann Arbor's Fleet & Facilities Manager, or such other person as Ann Arbor designates in writing, within two (2) weeks of the submittal in order to permit Ann Arbor staff to consider its comments.

10. Ann Arbor will consider and endeavor to incorporate reasonable recommendations provided by Pittsfield.

11. Ann Arbor will obtain soil erosion and sedimentation control permits for the Airport from Pittsfield until such time as Ann Arbor or the Airport qualifies as an authorized public agency for the Airport under Section 9110 of Part 91, Soil Erosion and Sedimentation Control, of the Natural Resources and Environmental Protection Act, MCL 324.9110.

12. Ann Arbor will obtain Pittsfield utility permits as required by Pittsfield ordinance for connections to Pittsfield sanitary sewer or water lines.

13. Ann Arbor shall extend and enforce its construction code, including the building code, electrical code and mechanical code components thereof, to all aeronautical facilities constructed on Airport property and provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with copies of all construction permit documents including the application, the permit, inspection reports and any certificate of occupancy within thirty days of being issued or received.

14. Non-aeronautical facilities at the Airport will be required to comply with Pittsfield planning and zoning requirements and the Pittsfield construction code ordinance.

15. Nothing contained in this agreement shall be construed as limiting Pittsfield's authority to enforce the State Construction Code regarding any violations of that code for non-aeronautical facilities.

16. Nothing contained in this agreement shall exempt aeronautical facilities from being in compliance with the State Construction Code unless said facilities are under the jurisdiction of the Federal Aviation Administration.

17. Ann Arbor shall extend and enforce its fire prevention code to all aeronautical facilities located on Airport property and provide Pittsfield's Building Official, or such other person as Pittsfield designates in writing, with copies of all fire inspection documents including fire alarm and detection systems and fire extinguishing system certification and test reports, and all required operational permits within thirty days of being issued or received.

18. This agreement shall be approved by the concurrent resolutions of the Ann Arbor City Council and Pittsfield Charter Township Board of Trustees.

19. This agreement shall take effect October 1, 2009 or after a copy has been filed with both the Washtenaw County Clerk and the Michigan Secretary of State, whichever is later.

20. This agreement shall have a term of 5 years beginning on October 1, 2009. It shall automatically renew for successive 5 year periods unless either party provides the other with written notice of non-renewal at least 60 days before the end of a term.

Dated: ______________________
City of Ann Arbor

By______________________
John Hieftje, Mayor

By______________________
Jacqueline Beaudry, City Clerk

Approved as to form:

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Stephen K. Postema, City Attorney

Dated: ______________________
Pittsfield Charter Township

By______________________
Mandy Grewal, Township Supervisor

By______________________
Allen Israel, Township Clerk

Approved as to form:

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R. Bruce Laidlaw, Township Attorney

Ann Arbor Municipal Airport (ARB), Ann Arbor Michigan - Draft Environmental Assessment FAA Combined Comment Matrix

--May thru October 2016--

Comment Number	Page Number	Section Number	Paragraph	FAA Comment	MDOT Comment Resolution
1	1	title page	n/a	Need statement that "This Environmental Assessment becomes a *Federal* document…" before the FAA signature block, per FAA Order 1050.1F paragraph 6-2.1(a).	Revised draft EA
2	1	title page	n/a	Federal signature block should read "Responsible FAA Official"	Revised draft EA
3	9, 10 & 12	1.3 & 1.4	all	The Intro and background sections are discussing the State Standards. What are the Federal Requirements, in addition to the State reqmts? Critical Aircraft (1.5.1) & use of runway, Aircraft Activity (1.5.2) and Characteristics /Recommendations (1.5.3) all need to be in the background section before purpose and need section. Info in P & N needs to be in the background section.	On April, 21 2015 the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft. AERO put significant effort into modeling this draft after the Bolingbrook example and believes the content is consistent. The draft EA was revised to try and clarify the issue raised here, yet remain consistent with the example previously provided.
4	10	1.3	6	Need a discussion of the SBGP so that the reader is better able to understand the division of porposed actions between state and Federal	Revised draft EA
5	10	1.3	6	The paragraph is implying that the ALP is "fully approved".. If this were the case, it would have been unconditionally approved rather than conditionally approved. - Remove, "…it is in fact a fully approved ALP" - Add "conditional" to the last sentence, "...prior to AERO signing the conditional approval letter."	Revised draft EA
6	12	1.3	2	Please explain why the comments from the ADO were not addressed.	Revised draft EA
7	12	1.4	3	Is the purpose to meet the "FAA design objectives" or to accommodate the runway length needed by critical aircraft? This is implying that FAA is forcing the runway extension. Recommend changing the wording to clarify that aircraft are currently impacted by the shorter runway length. Is "increasing the line of sight for ATCT personnel" (presumably to improve a hotspot) more of a Need than a purpose?	Revised draft EA

8	12	1.4	4	States that the Need is to allow aircraft to operate at "Optimum Capabilities", should this include why there's a need to operate at "optimum capabilities"? Where are aircraft going, how often is the runway length affecting users?	In response to FAA's question regarding the need to allow the majority of critical aircraft to safely operate at their optimum capabilities without weight restrictions, we reference Paragraph 103 of FAA Advisory Circular 150/5325-4B, *Runway Length Requirements for Airport Design* . This paragraph states "The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions". The term "regularly use it" is further identified by the FAA as being the volume of usage provided by the runway's particular critical aircraft category (a minimum of 500 Annual Itinerant Operations). As far as FAA questions related to where the aircraft are going, an Origin-Destination Analysis was conducted using records obtained from the FlightAware Instrument Flight Rules (IFR) flight plan database associated with ARB. Flight operations were verified between ARB and at least 31 other states (approximately 63% of the continental U.S.). A list of all of the states involved is included in User Survey Supplemental Report No. 2, which is included in Appendix A-2 of the Draft EA. Additional information related to both of the above paragraphs is included in Sections 1.5.1, 1.5.2, and 1.5.3 of the Draft EA. Revised draft EA where appropriate.
9	12	1.4	3	Another sentence should be added after the first sentence of the paragraph to explain that the Purpose includes lengthening and shifting the runway. The second sentence is a Need and should be placed in the following paragraph.	Revised draft EA
10	12	1.4	all	Use of the term "Safely" implies the airport is not safe currently.	Revised draft EA
11	12	1.4	all	The purpose and needs statement should be complete and concise. This would include stating the problem that is looking to be addressed. A statement of overall safe and efficient and usable is a general statement and should be tightened up to reflect the discussion that follows. It is confusing on why the line of sight issue is singled out in the statement. Consider revising this statement.	On April, 21 2015 the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft. AERO put significant effort into modeling this draft after the Bolingbrook example and believes the content is consistent. The draft EA was revised to try and clarify the issue raised here, yet remain consistent with the example previously provided.
12	12	1.4	4	Clarify why the statement regarding aircraft says majority and not "all' aircraft?	Revised draft EA

13	13	1.5.1	2	Clarify whether the critical aircraft is properly grouped; is it okay to use the category B-II Small Aircraft? Cross reference B-II Large in the document.	The critical aircraft category of "B-II Small Aircraft" is properly grouped. In conducting the analysis of the critical aircraft, the distinction between Small versus Large category aircraft was considered in order to determine which Runway Length Curves in FAA Advisory Circular 150/5325-4B would be applicable to ARB. The curves in Chapter 2 are applicable to Small category aircraft, and the curves in Chapter 3 are applicable to Large category aircraft. The FAA recommended runway length of 4,200' was obtained from Figure 2-2 of Chapter 2. Had the critical aircraft at ARB been determined to be of the Large category, Tables 3-1 and 3-2 of Chapter 3 show that a much longer runway length would have been recommended by the FAA Advisory Circular. As far as FAA's request to cross reference the B-II Large category in the EA document, it is clearly referenced in section 1.5.3.
14	13	1.5.1	5	This paragraph is general in nature. A runway of 4,300 feet would allow without load restrictions… why 4,300's, why not 4,500, 5,000, or 10,000. The paragraph should instead define the runway length needs of the aircraft regularly using the runway, including haul lengths and loads rather than suddenly put out that 4,300 ft. would satisfy it.	As explained in Section 1.5.3, The FAA recommended runway length of 4,200 feet at ARB was obtained by calculation following the methodology referenced in Chapter 2 of FAA Advisory Circular 150/5325-4B, "Runway Length Requirements for Airport Design," a publication that is used nationally by the agency. The methodology and figures referenced in this section of the AC result in recommended runway lengths that are airport-specific, and they can vary by hundreds of feet from site to site, depending on the specific airport elevations and mean daily maximum temperatures used in the calculations. For example, if a representative higher-elevation airport in the Denver area had an elevation of 5,000 feet MSL, interpolation of Figure 2-2 of Chapter 2 of the AC shows that a runway length of approximately 5,000 feet in length would be recommended for the same B-II Small category of critical aircraft. In Michigan, airport elevations at our public-use airports only range from 578 feet to 1,622 feet MSL. The AERO runway length recommendation of 4,300 feet is a statewide standard for all airports in the state with category B-II critical aircraft classifications, as identified in Table 40 of the Michigan Airport System Plan (MASP). Since airport elevations and mean maximum temperatures do not vary significantly from airport to airport in Michigan, as opposed to many other states, AERO uses a single runway length recommendation for all airports of the same critical aircraft classification.
14 Cont.	13	1.5.1	5		The reason that the preferred alternative in the draft EA references a runway length of 4,300 feet is that this length meets both FAA and AERO runway length recommendations for critical aircraft in the B-II Small category.

15	13	1.5.1	6	The example seems to be an extreme case, how often does this user use the airport and what type of B-II aircraft is it? Why do they base at ARB instead of another close airport if they cannot use the aircraft to it's max capability above 40 degree F?	This user flies approximately 200 operations from ARB annually in Cessna 560 Excel jet. The user's business is based in Ann Arbor and the proximity to the airport provides convenience and a significant time savings over other local airports.
16	14	1.5.1	1	"Part 135 operators must reduce the useable length of the runway by anywhere from 20-35% based on runway conditions" has this quote been verified through citation to the actual Part 135?	The corporate pilot quotation regarding Part 135 operators has been verified to 14 CFR 135.385 paragraphs (b) and (f).
17	14	1.5.2	2	"Also, approximately 67% of the IFR flight plan records examined were between ARB and out-of-state locations." It's not clear how far of a distance these itinerant operations are going.. Are they all to surrounding States or are the haul length further?	The first sentence of Section 1.5.2 of the draft EA refers the reader to User Survey Supplemental Report No. 2 in Appendix A-2 for full details regarding the Origin-Destination Analysis. Exhibit No. 2 in the User Survey Supplemental Report lists the names of all 31 states (and Washington DC) that were associated with flights to and from ARB, as obtained from just the IFR Flight Plan database of FlightAware. Potentially, there are even more states associated with ARB flights than those confirmed by the referenced FlightAware records. Nonetheless, the records reviewed confirm that direct flights were conducted from ARB to other airports located in states as far away as Arizona, Texas, Florida, and Maine, just to name a few. The confirmation of flight operations between ARB and at least 31 other states verifies that operations are not confined to the few states surrounding Michigan, and that flights with long distance stage lengths are being conducted.
18	14	1.5.2	2	Second half of paragraph: Why are NetJets and AvFuel further called out in the two final sentences? What about the other six companies?	While many of the large corporations listed as users of ARB are commonly known, NetJets and AvFuel were lesser known entities that are active at the airport. NetJets because of the variety of businesses they serve and AvFuel because they are a local business.
19	16	1.5.3	FAA	Clarify why 4,200' (AC 150/5325-4B) would not support the Purpose and Need (P& N) as opposed to the requested 4,300.'	As explained in section 1.5.3 of the draft EA, utilization of current FAA runway design standards results in a recommended runway length of 4,200 feet at ARB. Utilization of current AERO runway design standards results in a recommended runway length of 4,300 feet. Although the recommendations are very similar, the reason that 4,300 feet was referenced in the draft EA in meeting the purpose and need is that it meets both the FAA and AERO current standards for runway length recommendations based on the critical aircraft category of aircraft.
20	16	1.5.3	FAA	Why isn't 4,200' listed as an alternative?	As explained in Comment 19 shown above, the reason that a runway length of 4,200 feet was not included as an alternative is that it is very similar in length to the 4,300 foot long alternative, and it does not meet current AERO runway design standards.
21	16	1.5.3	3	"The AERO recommendation of 4,300 feet is a statewide standard…" Recommend including how AERO developed their standard. What is this length based on, is it a random length they chose or does it meet the requirements identified in the P&N (optimum capabilities of the critical aircraft at ARB)?	Revised draft EA

22	16	1.5.3	4	Clarify whether the category B-II Small Aircraft requires a runway length of up to 4,300, or do the larger B-II airplanes require this length? The Small B-II may be on the lower end of the spectrum?	Revised draft EA
23	16/17	1.5.4	8 (last)/several	Clarify why User-Survey Reports were heavily relied upon? Why not TAF and Tower Counts? TAF was very close to accurate, however it is not logical to conclude (quantitative to qualitative) that ops will increase, because TAF may not always support constant increase. (Justify, e.g. is there a new coach that may boost attendance for Michigan games which will increase probability of increased attendance/travel?)	The reason that User Survey Reports were relied upon in this study is that they distinguish between the various aircraft makes and models, while the TAF and Tower Counts do not. From the various make and model information, aircraft approach categories, design groups, weight classifications (large vs. small), and critical aircraft categories can be determined. The TAF shows total numbers of forecasted operations, but no distinction of aircraft makes or models. The Tower Counts show historical numbers of total operations, but no distinction of aircraft makes or models. All three data sources (user surveys, TAF reports, and Tower Count reports) are useful for different aspects of analysis and forecasting, and all of these sources were used appropriately in this study. As stated in paragraph 1.5.4, the current TAF (which is prepared by FAA personnel and updated annually) forecasts continually increasing operations at ARB from year 2014 through year 2040, and the current MASP (which is prepared by MDOT personnel and updated periodically) also forecasts similar numbers of continually increasing operations through year 2030.
24	17	1.5.4	4	The paragraph indicates that the TAF is used to project forecasted operations to 2040. Does the airport have a locally developed forecast to compare this to? Does the airport understand how the TAF was developed and if it's really a good indicator of B-II itinerant ops?	While the airport does not have a locally developed forecast, the current FAA-developed TAF as well as the current MDOT-developed MASP both show continually increasing operations at ARB from present date at least through the year 2030. It is logical to conclude that all categories of aircraft that use the airport would show some increase in their annual operational numbers as part of the overall increase in activity. But even if category B-II operations remained at the level of the 538 annual operations that were documented in year 2014, and the entire increase in operations was attributed solely to increased activity by the smaller categories of aircraft (highly unlikely – especially if the runway is extended to 4,300 feet in length as proposed), the justification for the proposed project would still be substantiated both presently and through future years.
25	17	1.5.4	5	"…it is logical to conclude that operations by B-II category aircraft and larger will also increase beyond the 551 that were documented in 2014." Table 1-1 indicates that the 5-year trend from 2010 to 2014 is a steady or downward trend in B-II ops. Why is it logical to believe B-II ops will increase given the history of ops at the airport? - does the 551 include just B-II aircraft or B-II and larger as indicated in the paragraph? - How many of the 551 ops by B-II aircraft are by the representative King Air 200 or aircraft with 10 or more passenger seats?	Changes made and clarification added to Section 1.5.4 as requested. A table has also been added to User Survey Report No. 4 (Exhibit 1 of Appendix A-4 of the draft EA) which clarifies the number of annual operations conducted in 2014 by specific aircraft models and groupings (B-II, B-III, and C-III). As a result of preparing the table and analyzing and categorizing the operations by specific aircraft models, the operations performed exclusively by category B-II aircraft have been revised to 538 instead of the 551 that were mentioned in the previous draft of the EA. A total of 544 annual operations were performed by the combined B-II and Larger categories of aircraft. The text in Section 1.5.4 as well as numbers shown in Table 1-1 have been revised accordingly.

25 Cont.	17	1.5.4	5		In answer to FAA's question regarding a "steady or downward trend in B-II ops" from year 2010 to 2014: Table 1-1 of the draft EA does show minor fluctuations in the levels of estimated annual B-II operations during this time frame, from a low of 537 to a high of 600. These numbers were based on the minor fluctuations in total operations that occurred during the same time frame. The trend is not a steady downward trend as FAA suggests, but rather the numbers fluctuate both downwards and upwards. The numbers are also relatively close to each other, as opposed to being drastically different. The severe and multi-year economic recession that originated in 2009 likely played a role in the minor fluctuations of the total operations at ARB during the time frame in question, and as a result the minor fluctuations in the number of estimated B-II operations. Since the TAF (which is prepared by FAA personnel) shows that Total Annual Operations at ARB are forecasted to increase every year beyond year 2014, it is logical to conclude that operations by B-II category aircraft will also increase beyond the 538 that were documented in 2014. As noted in the text of revised Section 1.5.4 of the draft EA, even if B-II category operations do not increase in the future, but remain the same as in year 2014 (very unlikely if total operations are increasing), justification for the proposed runway extension would still be substantiated through the year 2040.
25 Cont.	17	1.5.4	5		In answer to FAA's questions regarding more details of operations performed by "B-II" versus "B-II and Larger" categories of aircraft, as well as more specifics regarding individual aircraft types, the information is shown in Exhibit 1 of User Survey Report No. 4 (see Appendix A-4 of the draft EA).
26	17	1.5.4	6	"These numbers have been calculated based on the percentage of actual B-II operations to actual Total Operations…" Why wasn't flight aware and FAA data used to determine actual usage by B-II aircraft over more years? Was FAA or Flight Aware data compared to the Airport User Survey data used for 2007, 2009, and 2014?	Changes made and clarification added to Section 1.5.4 as requested. In answer to FAA's questions, FlightAware data was used in the determination of B-II operations for survey data years 2007 and 2009, and FAA's Traffic Flow Management System Counts (TFMSC) data was used in the determination of B-II operations for survey data year 2014. This is clearly explained in User Survey Report Nos. 2, 3, and 4 (see Appendices A-2, A-3, and A-4 of the draft EA). Also, Exhibit 1 in each of these three reports shows a listing of the specific B-II category aircraft that were included in these records. Operational data obtained from both the FlightAware and the TFMSC sources is considered the most accurate available, as it is based on actual documented operations obtained from Flight Plans filed by pilots, over an entire calendar year of time. None of the data is based on estimates of annual operations generated by pilots, or proration of partial year survey data, as is common in conducting many other operational surveys.
27	20	1.6	first	First sentence should read: "The City of Ann Arbor proposes to extend and shift 160' the existing…"	Revised draft EA

28	20	1.6	2	"…as it does not currently meet the FAA design objectives" Recommend that all references to "FAA design objectives" be removed… the purpose should not be to meet FAA design objectives or put the onus on the FAA causing the runway length, but their user need for the longer runway	Excerpt directly from Purpose and Need...The **Purpose** of the proposed actions is to provide facilities at ARB that fully accommodate the operational requirements of critical aircraft currently using the airport, while at the same time enhancing safety. Revised draft EA as appropriate.
29	20	1.6	3	First sentence should read: "The existing runway approach light system pilots use to identify…"	Revised draft EA
30	20	1.6	3	After the second sentence, the remainder of the paragraph should read: "Due to difficulty in maintaing the system, the ODALS are currently temporarily out of service. Due to the fact that the Runway 24 end is proposed to be relocated, the FAA is proposing to permanenty decommission and remove the ODALS according to an FAA airspace letter signed on May 13, 2015, Airspace Case Number 15-AGL-14NR (Appendix H). A new runway approach lighting system will not be constructed as part of the proposed action."	Revised draft EA
31	20	1.6	4	Clarify throughout the document the direction of rw/taxi shifting and extension - either west or southwest	Revised draft EA where appropriate.
32	20	1.6	4	The Shift and Extension of the existing runway should be clarified, is the physical pavement going to be shifted and extended or is the pavement just going to be extended and the Runway 24 threshold moved 150 ft. If the remaining 150 ft pavement remains, is it usable? How will the existing taxiway across the threshold be handled (to the southeast)?	Revised draft EA to clarify, details contained in "proposed action" bulleted list.
33	20	1.6	5	delete entire paragraph, as this is not the appropriate section for this discussion.	Revised draft EA
34	20	1.6	6	Paragraph should read: "Implementation of the Preferred Alternative would meet the Purpose and Need by adequately addressing the needs of the…"	Revised draft EA
35	21	1.6	first bullet	To clarify the meaning, please reword this bullet	Revised draft EA
36	21	1.6	second bullet	specify that the parallel taxiway is designated Alpha	Revised draft EA
37	21	1.6	bullets 1, 2, 3	Clarify that 150' is being removed from the northeast end of the runway and added to the southwest end. Runway is being extended by 795'; please label the taxiway and rw; delineate why it is being extended by 945' if the new runway portion will be 795' once the 150' is newly constructed.	Revised draft EA (addressed by Comment #35)
38	21	1.6	bullets 1, 2, 3 & 4	Clarify whether entire runway is being reconstructed, or just portions to determine impacts.	There are no proposed actions to reconstruct the entire runway and the draft EA is clear that the proposed actions only impact the proposed 795' extension and the proposed 150' shift.
39	21	1.6	bullet 5	Reiterate throughout the document direction of the shift/extension	Revised draft EA where appropriate.
40	21	1.6	seventh bullet	Should read: "Relocate airport-owned Precision Approach…"	Revised draft EA
41	21	1.6	tenth bullet	Should read: "Relocate/reconstruct FAA-owned Ruwnay 6 Runway End Identifier…"	Revised draft EA
42	22	1.7.1	after first bullet	add new second bullet: "FAA acceptance of relocated NAVAIDs (REIL)	Revised draft EA

43	22	1.7.1	third bullet	I was unaware that this project would use AIP funds. If this is not the case, reword with the correct funding source or delete	In a December 2013 email between the FAA-Region and MDOT-AERO, the funding sources intended for the project were clarified and remain the same, State Apportionment, Non-primary Entitlements and State/Local Shares will be used.
44	22	1.7.1	3	This bullet needs to be removed. There are no AIP funds being sought or provided for this proposed action.	State Apportionment and Non-primary Entitlements are AIP funds.
45	22	1.8	all	The section labeled, "Other considerations" should be included in the purpose and needs section. These issues kept separate from the statement objectives makes it difficult to have a clear purpose and need statement and to recognize these as part of the project.	On April, 21 2015 the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft. AERO put significant effort into modeling this draft after the Bolingbrook example and believes the content is consistent. The draft EA was revised to try and clarify the issue raised here, yet remain consistent with the example previously provided.
46	22	1.8.1	1	"The proposed shift would enahance operatinal safety, and possibly prevent a runway incursion, by expanding the view of the hold area and paralle taxiway to ATCT personnel." Therefore, please clarify, does this this shift cause other operational issues with the existing Northeasternmost hangar apron view still blocked from ATCT line of sight? How will aircraft taxi to the Southeast hangar section? - Is 150 ft enough of a shift to remove the hot spot?	With the proposed shift of the A1 connector from Alpha Taxiway to Runway 06/24 to the southwest, the Line of Sight issue will be significantly improved. Aircraft entering the Movement Area from Echo, Delta and Charlie (east facing hangars only) will still have limited visual oversight by controllers. This will be a significant improvement over current conditions where all aircraft using the taxiway hold area of Runway 24 are in a restricted visibility area. The existing Delta taxiway from the southeast hangars will be shifted to the southwest as well under the proposed project. This will allow them full access from Runway 06/24 to the southeast hangar area with full visual access from the control tower. The proposed 150' shift will significantly improve the safety of ground operations of taxiing aircraft. While some visual restrictions for aircraft originating from the northeastern most T hangars will remain, it will be up the FAA to determine if this area should still be designated as a "hot spot."
47	23	1.8.1	second on page	In response to the first sentence, clarify what type of "more negative impacts" would there be?	Revised draft EA
48	23	1.8.1	2	"…than with the runway theshold shift alternative"… is the preferred alternative to shift the threshold only and leave the pavement, or to shift and remove the 150 ft of pavement?	Revised draft EA to clarify, details contained in "proposed action" bulleted list. (Section 1.6)
49	23	1.8.1	3	"…raising the tower in its existing location would very likely result in the tower penetrating the 7:1 transitional surfaces…" Has an airspace study been completed to determine if this is a hazard?	Changes made and clarification added to Section 1.8.1. In answer to FAA's question, yes an airspace study was completed to determine if a raised tower would become a hazard. See revised Section 1.8.1 for details.
50	23	1.8.1	4	How old is the ATCT? Is it due for a modernization or rehab that might cause it to be beneficial to move it?	The ATCT was constructed in the mid-1970's and the attached office structure was constructed around 2003. The ATCT exterior was rehabbed within the last 5 years. The Airport is unaware of any pending plans for additional modernization or rehab.
51	23	1.8.1	4	Delete "disruption of Airport Traffic Control operations"	Revised draft EA
52	23	1.8.2	1	"The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach slope…" Why are they protecting for a 34:1 approach slope when the minimums for existing approaches are 1 mile? 34:1 is typically required for minimums below 3/4 mile. If the 34:1 doesn't apply, why would this be a "concern"?	The 34:1 approach slope is planned for future developments at ARB on the current ALP. (Sheet 4 - "Airport Layout Plan (Future)") Plus, any lowering of obstacles in the approach to a runway is an improvement and should always be attempted to improve the safety of the flying public.

53	23	1.8.2	5	Justify the slope gradient based on page 2 of the AC 150/5325 (10) Effective Runway Gradient	The justification of the slope gradient based on page 2 of the AC 150/5325 (10) Effective Runway Gradient will be accomplished once detailed design is performed on the preferred alternative.
54	24	1.8.3	1	Regarding 150/5235 4-B, Figures AC 2-1 and 2-2, an engineer from ARPs stated that the charts support the runway being extended to 4,150 when the temperature is higher than 82.5◦. But if the sponsor believes the longer runway is necessary please justify.	The mean daily maximum temperature of the hottest month of the year at ARB is 83.0 degrees F (July). The airport elevation is 839' MSL. When these numbers are factored into Figure 2-2 of FAA AC 150/5325-4B, the resulting recommended runway length is 4,200'. See the draft EA for additional information regarding the FAA recommendation of 4,200' versus the MDOT recommendation of 4,300'. (Section 1.5.3)
55	24	1.8.3	3	Please explain what is meant by a "local objective"	A "local objective" is a goal set by Ann Arbor Municipal Airport leadership that would be obtained by the implementation of the proposed airfield improvements.
56	24	1.8.3	3	several comments. How many overruns occurred? This objective should not be labeled as a local. The runway design criteria accounts for RSAs an RPZ for the critical aircraft.	Eleven overruns have been documented. If additional overruns occurred, the Airport has been unable to find verifiable documentation for them. As overruns are not officially recognized by the FAA or AERO as justification for extending a runway, the objective of keeping aircraft on the pavement is a local one. While the existing RSA and RPZ meet the design criteria for critical aircraft, the Airport believes that keeping aircraft on pavement instead of transitioning to an RSA or RPZ reduces the hazard to aircraft, their occupants and the airport facilities.
57	24	1.8.4	1	This section is being viewed as part of the justification for the statement. Commerce can not be of the P/N. Otherwise, other commerce alternatives will have to be included. Suggest that this section be removed.	On April, 21 2015 the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft. AERO put significant effort into modeling this draft after the Bolingbrook example and believes the content is consistent. The items included as "Other Considerations" are not items to justify the proposed project but are other items that will be impacted if the proposed project is constructed. These items are of significant interest or impact that they warrant explanation.
58	25	1.9	third bullet	How would the project "enhance operational safety in low-visibility conditions" without installing an ILS? Would providing a 34:1 approach really be enough to make this claim?	In answer to FAA's question, the project would enhance operational safety in low visibility conditions by providing a greater margin of safety between the approaching aircraft and the obstacles on the ground in the Runway 24 approach area. Since the 34:1 approach surface provided by the proposed project is flatter than the existing 20:1 approach surface, obstacles with heights just below the 34:1 surface would be farther away (vertically) from overflying aircraft than obstacles with heights just below the 20:1 surface. The greater vertical distance of object-free airspace would obviously increase the margin of safety in low visibility conditions.
59	25	1.9	last bullet	explain "local objective"	(Addressed by Comment #55)
60	25	1.9	all	The summary should be moved up and be made part of the P/N statement and renamed objectives. The document to this point uses safely through out. Either remove the language or change to enhanced safety.	MDOT-Aero and the FAA-Region have had previous discussion regarding the summary, the summary will be left in place. Revised draft EA to address safely/enhanced safety where appropriate.

61	26	2	1	include the number of alternatives at the beginning of the sentence. Drop the rest of the sentence after "project"	Revised draft EA
62	26	2.1.1	3	In regards to the second and third sentences of the paragraph: Does the fact that B-II aircraft still land at ARB instead of nearby YIP demonstrate that the restrictions put on those aircraft by the short runway are not significant, otherwise these users would land at YIP instead? For clarity, this should be rebutted in order to strengthen the Purpose and Need	The Ann Arbor Municipal Airport cannot dictate which airfield a pilot uses. Many factors go into that aircraft operator's decision on where to operate from. B-II aircraft are a regular user of the Airport and the existing runway configuration does not satisfy the FAA design objective of providing sufficient runway length to allow airplanes that regularly use it to operate without weight restrictions. The proposed project would also result in ARB achieving full compliance with all AERO basic development standards outlined in the MASP 2008 for category B-II airports.
63	26-28	2.1	all	What were the criteria used to dismiss these alternatives. For example, there is no mention of environmental impacts etc. in the purpose and needs statement	As is consistent with the standard EA process, alternatives are most commonly dismissed because they failed to meet the Purpose and Need or other alternatives had less harmful impacts on the environment.
64	28	2.2	1	how were these alternatives deemed feasible?	As is consistent with the standard EA process, alternatives are typically only carried forward if they meet the Purpose and Need and avoid, minimize, and/or appropriately mitigate impacts on the environment.
65	29	2.2	3	Build Alt 3 - label the parallel taxiway that will be extended; will a portion of the taxiway or all be demolished and reconstructed? Or new construction to southwest?	Existing taxiway connector Alpha1 will be demolished on the northeast end of the runway and reconstructed 150' to the southwest. The parallel taxiway will be extended with new construction to the southwest. Revised draft EA.
66	33	Figure 3.4	map	For clarity please label the taxiway and runway and the lengths, on the same map	Revised draft EA
67	34	2.3.1	2	The airport is currently safe. This section implies the airport is unsafe.	Revised draft EA
68	35	2.3.3	1	Line of sight is not listed as an objective. Need to make sure the P/N statement is concise, clearly stated, focus, with justification and objectives. Please provide better clarity/flow when tracking the P/N section.	Line of Sight is shown as a "Need" in the revised Purpose & Need section and is consistently addressed in each of the alternative evaluations.
69	35	2.4	1	Clarify that the preferred ALT 3 is to remove 150' from the east end of the runway, (adding back 150' on the west end) plus the adding the 795' and shifting to the southwest	Revised draft EA
70	35	2.4	2	Add on to end of first sentence: "except for the ODALS."	Revised draft EA
71	35	2.4	2	Third sentence should read: "FAA approval for the relocation of the REILS will be required as part of the proposed action."	Revised draft EA
72	35	2.4	2	Fifth sentence should read: "If the decommissioning proposal is finalized, the approach lighting system will be removed and no relocation will occur."	Revised draft EA

73	36-68	3	all	This section needs to use the environmental impact categories specified in FAA Order 1050.1F, paragraph 4-1	The draft EA has been in process continually since 2009 and significant effort has gone into preparing it in accordance with FAA Orders 1050.1E and 5050.4B. Also, as previously mentioned in this comment matrix the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft, it was also prepared in accordance with 1050.1E. Because this change would result in no change to content and the regulatory agencies, tribes and public have previously reviewed the draft EA as is, MDOT-AERO proposes to leave the draft EA unchanged.
74	36	3.1	1	What about the other noise impacts, such as from construction activities?	Noise associated with construction activities is covered in Construction Impacts category not the Noise category. (Section 3.15) Revised draft EA to clarify.
75	36	3.1	all	What about evaluation of the no action alternative for noise impacts?	Included in Section 3.1.2
76	36	3.1.1	1	The title of the methodologies need to be included in the paragraph	They are described in the same section.
77	37	3.1.1	last four bullets on page	Update these sources with more recent versions	These are the original sources used for the 2009 Noise Impact Analysis and should remain for consistency. MDOT-Aero reevaluated the 2009 study in 2015 and found it to be substantially valid. (Section 3.1.3)
78	39	3.1.3	all	Why not just redo the noise analysis with 2015 data?	The effort, timing and cost associated with redoing the noise analysis does not seem prudent, especially for little anticipated change in fleet mix and night operations, and a forecasted decrease in annual operations from the level analyzed in the original 2009 noise analysis. MDOT-Aero reevaluated the 2009 study in 2015 and found it to be substantially valid. (Section 3.1.3)
79	41	4.1	map	Noise Contour - Existing Conditions, please clarify the year.	Revised draft EA
80	42	4.2	map	No build - are the existing conditions still the same? Reasonable representation?	Revised draft EA. MDOT-Aero reevaluated the 2009 study in 2015 and found it to be substantially valid. (Section 3.1.3)
81	43	4.3	map	Preferred Alternative - Please delineate the projection out for the next five years	Revised draft EA. MDOT-Aero reevaluated the 2009 study in 2015 and found it to be substantially valid. (Section 3.1.3)
82	46	Figure 4.4		Is a newer source available than June 2011?	No
83	49	Figure 4.7		Is a newer source available than June 2011?	No
84	50	3.3.2	4	Update U.S. Census data with more recent source	Revised draft EA
85	51	3.3.2	1	Update U.S. Census data with more recent source	Revised draft EA
86	51	3.3.2	2	Update U.S. Census data with more recent source	Revised draft EA
87	52	3.3.4	4	Update U.S. Census data with more recent source	Revised draft EA
88	53	Table 3-2		Update U.S. Census data with more recent source	Revised draft EA

89	55	3.4	1	According to the Federal Register EPA 40 CFR Part 81 which was published in January of 2015, using the latest information from 2012 Annual Fine Particulate Matter NAAQS, Washtenaw (Livingston, Macomb etc.) County; PM 2.5 is Unclassified attainment. Clarify that the data submitted is correct.	The following is an excerpt directly from the 2014 Michigan Annual Air Quality Report published in June 2015 - All Michigan counties from 2010-2014 met the 1997 annual PM2.5 standard of 15 μg/m3 and the 2006 24-hour PM2.5 standard of 35 μg/m3. The EPA designated Michigan in attainment of these standards in August 2013. In December 2012, the EPA revised the annual primary standard to12 μg/m3 while the annual secondary standard remained at 15 μg/m3. The primary and secondary 24-hour standard remained as 35 μg/m3. The EPA has not made designations for the 2012 NAAQS revisions; however, PM2.5 concentrations are below 12 μg/m3 throughout Michigan. (DEQ 2016 Attainment Map Appendix C)
90	55	3.4	3	In regard to air quality, please provide the data from MDEQ (Do not see in Appendix D - there is a Land and Water Management and Wetlands letter)	Appendix D is specifically for "Early Agency Coordination" documentation, Appendix H is for "Additional Agency Correspondence" and includes the letter from MDEQ to EPA.
91	55	3.4	4 thru 7	The discussion does not quite fit affected environment. In terms of air quality what is the baseline conditions.	This language was not included in the first draft EA, however during discussions with the FAA-Region during review of this draft EA, this language was specifically recommended and later provided by the FAA-Region for inclusion into this draft.
92	56	3.4	3	Is there are more recent study than the L&B study from 1996?	No
93	56	3.4	3	Fourth sentence: which standards is this referring to?	NAAQS as referenced in the following sentence.
94	56	3.4	3	Last sentence: The reference to "proposed projects at general aviation airports" is very broad. How could the report know the extent of future projects at all GA airports in MI, especially if the report in 20 years old?	It is assumed that the report considered past GA airport projects and their typical scope and impacts when referencing proposed projects and made the general assertion that those projects are typically not of the scale to contribute to any NAAQS exceedances.
95	56	3.4	4	Please reword paragraph, as it is very confusing	Revised draft EA
96	56	3.4	4	It is not clear if this area is in a nonattainment area or maintenance area. Also not how this estimate was achieved. What calculations, models and sources were used. The citing of the court case should be removed and CAA regulations should be cited.	Based on the 2014 Annual Air Quality Report all of Michigan is in attainment. The following is an excerpt directly from the 2014 Michigan Annual Air Quality Report published in June 2015 - "Michigan ambient NO2 levels have always been well below the NAAQS. Since March 3, 1978, all areas in Michigan have been in attainment for the annual NO2 NAAQS...all monitoring sites have had an annual NO2 concentration at less than half of the 0.053 ppm NAAQS. As such, the DEQ requested a designation of unclassifiable/attainment for the entire state. Unclassifiable/attainment means that there are no air quality measurements that would justify classifying these attainment areas as either serious or moderate nonattainment areas." (DEQ 2016 Attainment Map Appendix C)
97	56	3.4	5	First sentence referenres NOX - what about the other NAAQS?	Revised draft EA.
98	56	3.4	5	Last sentence: replace "should" with "would"	Revised draft EA
99	57	3.5	1	How was it determined that the water quality is degraded. Was MDEQ contacted? With out some reliable way of establishing this the baseline for environmental conditions is not met.	There was no formal determination that it is degraded, only as it states, that it is "likely degraded", based on the existing conditions, observations and characteristics provided. Given that this is primarily a storm water dominated system, as described, it doesn't seem unreasonable to conclude that it is likely degraded, as it is common thought that many storm water dominated systems are.

100	57	3.5.1	4	Please clarify the status of the NPDES permit, as mentioned in secton 4.2.2? The reason for the permit should also be stated.	There are two distinctly different NPDES Storm Water Discharge Permits at ARB, one permanent for municipal storm water discharges and the other temporary for storm water discharges associated with construction activity. Revised draft EA to clarify.
101	57	3.5.2	2	Did not find a map that shows the 14 soil units and how their location to the proposed action site	Revised draft EA
102	58	3.5.2	1	Did not find a map that shows the wellhead area in relationship to the proposed action site.	A map of the City of Ann Arbor's Wellhead Protection Areas is now included. (Appendix H) The airport is located within the Steere Farm Wellhead Protection Area.
103	58	3.5.2	4	What about soils? The paragraph also mentions a new water line. Please provide more info on the water line.	The City replaced an existing raw (untreated) water line with a new 30" raw water line in 2010 along the east side of the airport. (Appendix H)
104	61	3.7	1	What were the results of the survey?	Revised draft EA
105	61	3.7	3	Did SHPO/THPO provide concurrence? If so, please state so.	Yes. Revised draft EA
106	61	3.8	2	Fourth sentence: be more location-specific, as the way the sentence is worded makes it sound the grassy meadows are within the RSA.	Revised draft EA
107	61	3.8	2	Last sentence: This discussion should be expanded. What does the agreement call for? Why does it exist?	This discussion is already included in Section 3.9 Threatened & Endangered Species and Section 4.2 Mitigation Measures.
108	62	3.8	4	Third sentence: What does the Audubon society think of this? Were they contacted as part of the EA public outreach process?	Revised draft EA
109	63	3.9	1	Update June 2009 survey, as this is already seven years old.	Revised draft EA
110	63	3.9	3	Last sentence: Did Audubon agree with this as well?	Revised draft EA
111	63	3.9	3	Update letters from 2009 for preferred alternative (Department of Natural Resources have instructions that may have changed)	As soon as this draft EA is finalized, the regulatory agencies will be contacted in writing and given the opportunity to review, comment and/or update their instructions.
112	63	3.1O	1	Update June 2009 survey. As part of the wetlands analysis, was USACE contacted? If so, did they make a jurisdictional determination? Are there any wetlands on the Rwy 06 approach, as the USFWS map depicts a wetland area. What about the removal of the ODALS - will this action impact the wetlands?	Review of available data sources was completed in 2015 and appear largely consistent with what was found in 2009. MDOT-AERO will complete a real-time field review of project areas to confirm the presence of wetlands, or lack thereof, during project design to ensure proper permitting requirements are met, if necessary. In Michigan, the USACE only retains authority over certain wetlands, the USEPA has agreed that MDEQ has compliance responsibilities over all the rest. Both MDOT-AERO and MDEQ have concluded that the wetlands at ARB are not regulated by USACE.
113	64	3.11	3 and 4	Was the floodplain analysis and conclusion confirmed with the local Floodplain Administrator?	The floodplain impacts were discussed at a meeting of MDOT Statewide Environmental Permit Coordinators and Resource Specialists. This level of analysis is adequate for draft EA purposes and the regulatory agency will be involved, as necessary, prior to the project being finalized.
114	64	3.11	3	Agencies should be changed to Agency. A flood plain map that shows the flood plain and the floodway with the proposed action should be included to support the discussion.	Revised draft EA (Appendix H)

115	64	3.12	1	See US Department of Agriculture NRSC letter, dated September 3, 2009, signed by Steve Olds. Update needed since this Agency requested follow up. See Appendix D-7	The following is an excerpt directly from the September 2009 NRCS Letter - "Some prime and farmland of local importance would be impacted by the project. <u>If the project proceeds</u>, I would urge you to utilize NRCS standards and specifications for conservation practices..." The draft EA is still in process and cannot proceed until that process is completed. Revised draft EA to clarify. As soon as this draft EA is finalized, the regulatory agencies will be contacted in writing and given the opportunity to review, comment and/or update their instructions.
116	66	3.14	1	Last sentence: delete "within the light lane"	Revised draft EA
117	66	3.14	2	Second sentence: Wouldn't these impacts be noted here? Where else would they be noted?	Revised draft EA
118	67	3.17		Why is this a separate section, as it is not an impact category?	Hazardous Waste Sites are an impact category under 1050.1E. (Addressed by Comment No. 73.)
119	67	3.18	1	Change to ASTM International Standard 1527-13	Revised draft EA
120	68	3.18	2	Last sentence: Add that any contamination encountered would be characterized and handled in accordance with state regulations	This language is already included later in the "Consequences of the Preferred Alternative" paragraph of Section 3.18 as appropriate.
121	69	4		The title of this section sounds like Section 3. What is the purpose of this section? Recommend changing the title to mitigation.	Revised draft EA
122	69	4	-	Title should be changed to Mitigation. EC was included in the previous section	Revised draft EA
123	-	-	-	In regard to the comment concerning Wildlife Hazards. The existence of the various nature features and species of concern should be assessed and part of the EA. FAA does not agree with the position that changing the profile of the airport will not change the relationship to the wildlife and their use of attractants. Only a certified Airport Wildlife Biologist is qualified to make that determination. The response to previous comment did not cite the participation of a certified Airport Wildlife Biologist.	This comment was not included in the revised draft EA, however it was included in the Response to Comments (Appendix K) . MDOT-AERO did consult with a certified Airport Wildlife Biologist from USDA when preparing the Response to Comments.
124	69	4.2.1	1	Last sentence: Does Audubon agree with this?	Revised draft EA
125	70	4.2.2	1	What about BMPs for air and water quality?	Addressed in Consequences of Preferred Alternative Sections of their respective impact categories.
126	71	5	1	The last public meeting was held six years ago; a new meeting will be needed.	This language is already included later in Section 5.2.2 Public Hearing.
127	71	5.1	1	What were the agencies' comments, at least in summary? What was MDOT's response?	Agency comments are provided in Appendix D and MDOT Responses are provided in Appendix K.
128	71	5.1	3	What did the local tribes say? Provide a summary.	Agency comments are provided in Appendix D and MDOT Responses are provided in Appendix K.
129	72	5.2.2	4	Add that another public meeting will be held.	This language was already included in the last paragraph of Section 5.2.2. Revised draft EA to clarify.

U.S. Department of Transportation
Federal Aviation Administration

MDOT AERONAUTICS
MAY 17 2010
AIRPORTS DIVISION

Detroit Airports District Office
Metro Airport Center
11677 S. Wayne Road, Ste. 107
Romulus, MI 48174

May 13, 2010

Michigan Department of Transportation
Bureau of Aeronautics and Freight Services
c/o Ms. Molly Lamrouex
2700 Port Lansing Road
Lansing, MI 48906

Subject: Draft Environmental Assessment for Ann Arbor Municipal Airport
Federal Aviation Administration Review Comments

Dear Ms. Lamrouex:

We have completed a review of the draft Environmental Assessment (EA) submitted to the Federal Aviation Administration (FAA) Detroit Airports District Office (ADO). Based on our review the FAA offers the following.

Air Traffic offers the following comments:

No comments.

Tech Ops offers the following comments:

Cover sheet. If the document is to be accepted as a federal document the coversheet will need to reflect this.

Section 2.1. Second bullet states "Shift and extend the parallel taxiway to coincide with the revised Runway 6/24". We recommend *revised* be changed to *extended*.

Section 2.2. This section does not appear to clearly state the need for the proposed action. Are the bulleted "objectives of the proposed project" actually proposed actions? The last bullet states "Relocate and potentially upgrade the Runway 24 Approach Light System". When will it be known if the approach light system will be replaced or upgraded? What is this dependent on? The remainder of the document deals with the impact of the runway extension, but does not address impacts related to the relocation of the existing light system or an upgrade to a new system. Also, action associated with Runway End Identifier Lights (REIL) is mentioned later in Section 4.17 and should be listed here as a proposed action. Are there any other NAVAIDs moving or being established?

Section 2.2.1. This section states that the Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF) would serve the same function as the Omni-Directional Approach Lighting System (ODALS) and is structurally very similar. How would the footprint of the MALSF structures compare to the ODALS? What environmental impacts would installation of a MALSF create?

Section 3.1.2. We suggest adding a qualifier in the second paragraph to state the following: "...would be greater than those expected with the *proposed* expansion of ARB in its current location."

Section 4.4. The Consequences of the Preferred Alternative section states: "Comparisons of existing conditions at various airports with future build out conditions indicate that the net change in air emission is still below standards." Do these *conditions* include runway extension projects similar to the proposed action at ARB?

This section additionally states: "Consequently, the air model results for the Preferred Alternative would be identical to those for the No Build Condition." This statement implies that no air emissions would result from the proposed action. Is this accurate?

Section 4.5.1. Would the existing Storm Water Pollution Prevention Program cover the additional impervious surface area?

Section 4.5.2. We would recommend rewording the first sentence of the Consequences of the Preferred Alternative section to the following (if true and appropriate): *Surface and subsurface geological conditions would not be impacted by the Preferred Alternative.*

<u>Flight Procedures offers the following comments;</u>

No comments were provided by Flight Procedures Office (FPO).

However, it should be noted that the FPO must be notified by formal letter to request the development of future approach procedures for the relocated runway end coordinates. Information needed includes identification of when construction will start, finish, when the equipment will be relocated, etc. This information is critical for developing/amending approach procedures. The FPO must know the project phasing in order to have procedures ready when construction is complete. (Equipment relocation, threshold displacements, etc). Changes in runway pavement length will result in survey data. Please note that survey data must meet the specifications outlined in Advisory Circulars 150/5300-16, 17, and 18. Third party surveys must be coordinated with the FPO. The proponent must submit Proposed Equipment Relocation Data along with information related to any equipment that will be relocated or added to AVN-210 and ATA-110. 7. Publication of new/amended Approach Procedures could take from 18 months to 2 years after runway data is submitted to AVN-210 and ATA-110. NOTE: Development of Approach Procedures will not begin until an official letter of request for development of procedures is received by FPO and the proposed runway data and equipment data provided to AVN-210 and ATA-110. Proponent must update the airport FAA Form 5010-1 to reflect new runway data and updated runway changes.

<u>Airports Division offers the following comments;</u>

The report is not clear if there is a federal action being requested.

Based on the information contained within the draft EA it appears that at least two federal actions are being requested. These actions include the relocation or replacement of the current approach lighting system as well as the development for future approach procedures for the new runway end locations. The FAA recommends that these actions be clearly identified throughout the document. The first page of the document states that this draft EA will become a State of Michigan document when signed by the State Official and does not include similar language for the Federal Aviation Administration although there is a signature line included for a federal official. Please refer to FAA Order 5050.4B section 707(f).

Section 1 page 1-1. The draft EA states that the projects under consideration are those shown on the FAA approved Airport Layout Plan (ALP). This statement should be clarified as to the role of Michigan Department of Transportation (MDOT) in conditionally approving the ALP set on behalf of the FAA under the authority of the State Block Grant Program. When referencing the ALP throughout the document, additional emphasis should be made to the June 23, 2008 ALP approval letter that clearly states that the approval is conditional. Several conditions were placed on the approval letter including the requirements that the projects contained within the ALP set must comply with the National Environmental Policy Act (NEPA). The FAA recommends inclusion of the conditional ALP approval letter in the draft EA for disclosure purposes.

We also suggest the executive summary clearly outline who will be responsible for actions associated with the proposed project (i.e. local sponsor, local unit of government, State of Michigan, Federal Government). For the FAA to co-sign the document, the requested Federal Actions must be clearly identified within the executive summary and throughout the document where appropriate.

Section 2 page 2-1. References to the ALP set need to clarify that MDOT has only conditionally approved the ALP.

Section 2.2 page 2-4. The classification of a B-II Small Aircraft has been determined with a reference to MDOT 2009. Is the B-II "Small Aircraft" a designation that is contained within MDOT planning guidance? The FAA is not familiar with the classification of "small" when identifying the critical design aircraft for an airport. Please clarify how this distinction was derived.

Section 2.2 page 2-4. The paragraph discussing Origin-Destination Analysis should be expanded (or references made where information can be reviewed) to provide clarification to the general statements that are made. Specifically, is there a list of destinations that can be provided that will substantiate the need for a runway extension? A listing of destinations may aid the reader in putting the proposed project into perspective and may further substantiate the need for a runway extension. The report states that a significant number of operations occur between ARB and distant locations without quantifying the number and types of operations that are being referenced. The FAA recommends this be clarified in the report or referenced to the appropriate appendices.

Section 2.2 page 2-5. Are the bulleted items for the objectives of the proposed project presented in order of relative importance?

The statement that the project will enhance interstate commerce does not appear to be substantiated by supporting documentation here or elsewhere in the document. How has this been verified? What are the enhancements? Is this a need for the project? The FAA recommends referring to FAA Orders and Advisory Circulars that address runway length, operational capacity of the aircraft utilizing ARB, and any deficiencies that currently exist at ARB that are a function of the current runway length. Without a detailed discussion and explanation of what the interstate commerce enhancement is and how this has been quantified as a current need, the FAA does not recognize this as a need for the project based on the information provided.

If enhancing interstate commerce is a stated need for the project then the report should be expanded to include a full range of alternatives that can address this need including alternative modes of transportation as an example.

The last bulleted objective in this section is for the relocation and potential upgrade of the Runway 24 approach lighting system. The report does not appear to document why this is a need for the project or if the approach lighting system is currently required or needed in the future.

What benefit does the current approach lighting system provide the airport? There does not appear to be a credit for a reduction in minimums at the airport as a result of having the ODALS. Has a Benefit Cost Analysis (BCA) been completed or requested of the FAA substantiating the need for relocating or replacing the ODALS? Depending on the results of the BCA and associated justification for relocating the existing or installing a replacement light lane at ARB, the potential exists that the Federal Action may be limited to abandoning the existing ODALS and no relocation or replacement would occur with federal funds.

Section 2.2.1 page 2-5. The first paragraph implies that runway incursions have been occurring at ARB as a result of issues with the current line of sight between the ATCT and a portion of the taxiway system and taxiway hold area. The report further indicates that the proposed project will possibly prevent incursions from occurring. Are there any documented runway incursions resulting from the current line of sight issue that can be included in the report to substantiate this claim? The FAA supports safety enhancement projects and would consider this a measure to improve the line of sight from the ATCT to parallel taxiway and the hold area if it can be demonstrated that the existing condition contributes to runway incursions. While a goal of the FAA is to reduce the number of runway incursions at airports nationwide, the FAA can not definitively conclude that this proposed safety enhancement at ARB will potentially *prevent* runway incursions but rather if the line of sight issue is improved this may *reduce the possibility* of runway incursions.

This section includes discussion of the potential to achieve a clear 34:1 approach and reduce minimums at the airport. The ADO previously requested clarification on this issue in an e-mail dated March 4, 2010 (attached for reference). Based on the e-mail exchange, the FAA understands there is no anticipation of a reducing of minimums at this airport for the foreseeable planning future.

Since minimums will not be reduced as a result of the project, the FAA is unclear on the need for a 34:1 approach or how it enhances safety of the approach procedures currently published for the airport based on the existing 20:1 approaches. The document should better explain how providing a 34:1 approach enhances safety for the existing and future users at the airport or how this also may impact interstate commerce. Has the current 20:1 clear approach resulted in missed approaches that have been documented? If so how often does this condition occur?

Is providing clear 34:1 approaches a project need or a benefit that may result from the relocation of the runway? Earlier in the report it was identified as a stated objective, however, the discussion in the report does not appear to substantiate the need for this when combined with the e-mail exchange of March 4, 2010 and conditionally approved ALP dated June 23, 2008.

While the future 34:1 approaches are identified on the conditionally approved ALP, it should be noted that this would result in an expansion of the approach surface from the existing 500'x2,000'x5,000' to 500'x3,500'x10,000'. The EA needs to fully disclose the increase in the approach surface if a 34:1 approach is achieved and document any environmental impacts that result from the larger approach surface.

Section 2.2.2 page 2-6. It is not clear to the FAA why there is a summary of Wings of Mercy operations since 1992 including 51 flights reported in 2009. This data appears to be in addition to what was collected as part of the user survey report that relied predominately on information from calendar year 2007. What is the relevance of including the 2009 data or specifically identifying the Wings of Mercy flight operations? Are there a range of aircraft types that fly for Wings of Mercy? Does the proposed runway extension impact their operational capacity?

Section 2.2.2 page 2-7. Discussion on the Michigan State System Plan (MASP) identifies the airport reference code (ARC) as B-II. Does the MASP differentiate between B-II small and B-II large? In absence of a clearly defined category of B-II "small aircraft", the FAA would suggest simply referring to the airport with a B-II ARC.

Section 2.2.3 pages 2-7 and 2-8. This section most clearly identifies why a runway extension is being proposed in accordance with FAA advisory circulars and State standards outlined in the 2008 MASP. This section, in combination with section 2.2.4 that documents substantial use (i.e. over 500 annual operations) by the B-II critical design family of aircraft appears to substantiate the justification for the runway extension based on the 2007 operational data.

Section 2.2.4 page 2-9. Detailed operational information is presented for calendar year 2007. Subsequent years are generalized based on trend analysis and overall decrease in operations as reported in the FAA Terminal Area Forecast (TAF). There does not appear to be an evaluation to account for the 21.8% decrease in operations between 2007 and 2009. Would it be prudent to verify if the operational decrease impacted one user group more than other user groups? Are the numbers of local and itinerant operations decreasing at the same rate or is one segment impacted to a greater extent? This evaluation may be accomplished through additional user survey data collection or potentially from the ATCT located at ARB for subsequent years since 2007. Additionally, the FAA recommends that the year of the TAF being utilized for this report be identified.

Section 2.2.4 page 2-11. Specific information for AvFuel Corporation is presented to validate assumptions for the continued classification of the airport as B-II. It should be noted that AvFuel bases a Citation 560 Excel jet at ARB and is designated in the report as a B-II "*Large*" aircraft. The discussion further indicates that the Chief Pilot submitted written documentation regarding potential future operational levels at ARB. The written documentation does not appear to be included within the report or appendices. However, according to the text in the report, the Chief Pilot anticipates future operational levels increasing to 350-450 annual operations. This level of use, in combination with a limited number of additional similar B-II aircraft would appear to classify the airport as a B-II "*Large*" designation. The FAA reiterates the hesitation on identification of either a "small" or "large" within an airport reference code and recommends that any qualifier to the size of the B-II critical design aircraft be removed from the report. The number of operations forecasted to occur by AvFuel Corporation would further support the elimination of the qualifier as "small" to the ARC.

Section 2.2.6 page 2-12. The local objective of reducing runway overrun incidents appears to conclude that if the added runway length were present, all the incidents would have been avoided. Based on information presented, the FAA does not necessarily come to the same conclusion. There are many factors that go into any overrun incident and if additional runway length were present this may have only prolonged the overrun incident. The A-I category of aircraft involved with overrun incidents do not appear to have needed any length beyond the existing runway length to operate at full capacity and in a safe manner.

The paragraph that references Accelerated Stop Distance Available (ASDA) requirements appear to include fleet mixes other than A-I and implies that aircraft can accommodate their operational requirements with a reduced load capacity. The ADO is not aware of any A-I aircraft operating at ARB that would need to operate at a reduced load capacity to adequately satisfy their calculations for safely operating at ARB.

It is not clear when the 11 overrun incidents occurred, their cause, or conclusions that support that runway length was a factor in the overrun incidents. Can additional information be provided to support this position? If additional information is not available the FAA recommends removing this section from the document.

The FAA recognizes that this section of the report was included as a local objective and it is clearly and appropriately stated that the FAA does not recognize this as a need for extending the runway at ARB.

Section 2.2.7 page 2-12. The first bullet point indicates that additional runway length will allow for the majority of B-II "small" aircraft to operate without load restrictions. Has it been documented that the current B-II "small" users operate with load restrictions? If so, how often does this occur and what are the quantifiable impacts to their operations?

The third bullet implies that operational safety will be improved with a clear 34:1 approach. Currently the airport has LPV approaches with minimums of 300' and 1 mile. The ADO questions if a flatter approach is warranted in absence of reducing minimums as indicated in the March 4, 2010 e-mail correspondence. The discussion on the 34:1 approach should be re-evaluated and its need clearly identified. Currently the report does not seem to substantiate a need for a 34:1 approach if minimums are not anticipated to be lowered.

Section 3 page 3-1. The report indicates that alternatives were developed to meet the goals of ARB. These goals are to improve safety and efficiency and serve current users. These goals do not appear to be consistent with those previously outlined in the bullet points of section 2.2 (purpose and need). This section should refer to the stated needs and evaluate the alternatives ability to meet those needs.

Section 3.1.3 pages 3-3 and 3-4. There is discussion on extending the runway to the east and a listing of items impacted by pursuing this alternative. There is, however, no conclusion or statement that this option either should be, or was, eliminated. It can be inferred later in the report by the absence of this alternative that it was eliminated but the conclusion as to why it has been eliminated has not been stated.

When addressing the FAA's comments (included within this letter) associated with the stated needs for the project earlier in the report, the responses to these comments may influence the conclusions on why some of the alternatives carried forward have been eliminated. Specifically, if needs stated in section 2.2 are not further substantiated, or it is concluded that one or more of the needs do not exist, additional alternatives may need to be carried forward if they adequately address the needs for the project. The FAA will re-evaluate the conclusions of the alternatives section once the FAA's comments on the purpose and need section are addressed.

Section 3.3 page 3-8. Based on the Information presented in the draft EA, the FAA has not reached the same conclusion that alternatives 1 and 2 do not meet the stated needs for the project. An apparent evaluation parameter for alternative 2 included in section 3.3.3 discusses the tower line of sight. This evaluation matrix does not appear to be consistent with those goals stated in Section 3 on page 3-1. The previous comment on the apparent disconnect between the different sections of the report also applies to the specific alternative evaluation. The FAA recommends that the decision matrix for which alternatives were eliminated be clarified in the EA.

Table 3-1 page 3-8. The table appears to incorrectly dismiss alternative 1 because it does not meet purpose and need. .The discussion in 3.3.2 does not support that conclusion. Additionally, there is reference to a future expansion of State Road. This appears to be the first reference to this issue. Is this a need for the State Road expansion project? In what time frame is the State Road expansion project expected to occur? Should there be expanded discussion on other regional planning projects in this EA so the public can better understand the different parameters that ARB is confined to or bound by?

Additional alternatives that may be considered for evaluation to address the need statements could include a combination of items such as: alternative modes of transportation to address enhancing interstate commerce, removal or relocation of obstructions that limit the ATCT line of sight issues, and raising or constructing a new ATCT to address the line of sight issues. Have any previous discussion on additional alternatives been eliminated prior to, or as part of the planning and environmental assessment process for ARB?

Section 3.4 page 3-9. This section contains a brief summary of environmental resources that will not be impacted by build alternative 3. Would it be advantageous to also summarize environmental impacts associated with the other build alternatives? There is a general statement regarding noise impact analysis in this section that identifies that the 65 DNL contour is not within 1,000 feet of any residential structure. What is the purpose for this statement? The FAA is not aware of an environmental impact decision matrix associated with the distance between residential structures and the 65 DNL.contour.

Section 4.3.5 page 4-17. The conclusion for the implementation of the preferred alternative states that a positive result of improvements is the ability of business owners to achieve improved fleet efficiency for critical aircraft by maximizing their passenger and/or cargo loads. How has this statement been substantiated? What records exist that current users at ARB are not operating at maximum passenger and/or cargo loads? What has been the economic impact of the reduction of loads if they are occurring?

Section 4.9 pages 4-22 and 4-23. State endangered and special concern species were identified at ARB. The sponsor appears to be proposing a mitigation effort to limit grading for the project to avoid breeding seasons for the specific species. Has this proposed mitigation plan been found to be acceptable by the resource agencies? There is reference to an Audubon Society agreement regarding mowing boundaries. Who is the agreement between? Has this agreement been reviewed by the environmental assessment preparation team? Are there limitations or restrictions for use of airport land as a result of this agreement? Has the Audubon Society been included or have they provided input to this draft EA?

Section 4-15 pages 4-24 and 4-25. The FAA recommends that the score from the USDA form AD 1006 be disclosed in this section and explain what the score means. The consequences identify that some prime and unique farmland of local importance are impacted by this project. The amount of prime and unique farmland should be quantified. Are there any mitigation requirements for this change in use?

Section 4-16 page 4-25. The report identified a decrease in facility energy usage with the installation of LED taxiway lights. Is this net decrease in energy usage compared to baseline or existing conditions?

Section 4.17 page 4-25. There is no discussion on potential relocation of the ODALS or replacement with upgraded equipment. Would there be impacts with either scenario (relocation or replacement)? It should also be noted that the potential exists for the current ODALS to be abandoned if a relocation or upgrade is not justified with a BCA.

Section 4.20 page 4-26. The evaluation regarding construction impacts in the draft EA do not appear to address staging areas during project implementation. The FAA recommends the report verify that staging areas will not impact environmental resources; and as necessary, outline any required mitigation measures for staging area impacts.

Section 4.21 page 4-26. Should the reference to ASTM Standard E1527-94 be updated to E1527-05? The EA should also state if the review was done in accordance with FAA Order 1050.19B, *"Environmental Due Diligence Audits"*.

Section 5 page 5-1. The FAA suggests that this section be titled *Mitigation* rather than *Environmental Consequences – Other Considerations*. We also question if it is prudent to discuss noise, social impacts and community disruption, wetland impacts, and threatened and endangered species in this section since there appear to be no mitigation requirements associated with any of these categories. The FAA suggests either listing all environmental categories reviewed that do not require mitigation or not list any of the categories that do not have required mitigation. Is it a true statement that there are no mitigation measures for threatened and endangered species? Section 4.9 appears to indicate there are seasonal limitations on when grading will occur.

Would it be better to outline required permits for the project in this section, best management practices, construction requirements, etc. rather than having a discussion on what mitigation measures are not required?

Section 6.2.1 pages 6-1 and 6-2. This section includes a summary of when Citizen's Advisory Committee (CAC) meetings were held and the overall agenda for each meeting. The EA does not document either in the text or in an appendix what issues may have been raised and how they were addressed in the CAC meetings. The FAA suggests additional information from the CAC meetings be included in the EA.

Section 6.2.2, page 6-2. The last sentence of this section should indicate that comments received will be reviewed, summarized, and addressed.

Section 7 page 7-3. This section identifies a request that the state and federal agencies approve a Finding of No Significant Impact. This is the first location in the document that specifically requests a federal action. As discussed previously, the FAA requests that earlier in the document the specific actions being requested of each agency be outlined. Based on the review of this document the FAA anticipates that the FAA will be requested to evaluate, and as appropriate, abandon/relocate/replace the existing approach lighting system and develop new flight procedures for the new runway end locations.

Next steps.

The draft EA appears to be intended to be a jointly executed document by both MDOT and the FAA. Since there are several updates/clarifications requested by the FAA contained in this letter and the sponsor's responses may be substantial, it would be prudent to afford the public an additional opportunity to review and comment on the changes that are anticipated to be made for the final draft publication. Most specifically, the document will need to clearly outline the requested local, state and federal actions. Since this was not clearly presented in the initial draft EA, the FAA may consider these changes and clarifications as a material change to the document that should result in solicitation of additional public comment. This may be accomplished by an additional public information meeting or public hearing.

Once the FAA receives confirmation that the above comments have been addressed in the form of an updated draft EA, the FAA requests that we be allotted sufficient time to review, comment, and potentially concur with the updates prior to making the document available to the public for further comment.

If you desire further clarification of these comments, please contact me at (734) 229-2916.

Sincerely,

Brad N. Davidson, P.E.
Community Planner/Environmental Protection Specialist
Detroit Airports District Office

Encl: E-mail correspondence dated March 4, 2010 between the ADO and MDOT

U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: RUNWAY LENGTH REQUIREMENTS FOR AIRPORT DESIGN	**Date:** 7/1/2005 **Initiated by:** AAS-100	**AC No:** 150/5325-4B **Change:**

1. PURPOSE. This Advisory Circular (AC) provides guidelines for airport designers and planners to determine recommended runway lengths for new runways or extensions to existing runways.

2. CANCELLATION. This AC cancels AC 150/5325-4A.

3. APPLICATION. The standards and guidelines contained in this AC are recommended by the Federal Aviation Administration strictly for use in the design of civil airports. The guidelines, the airplane performance data curves and tables, and the referenced airplane manufacturer manuals *are not to be used* as a substitute for flight planning calculations as required by airplane operating rules. For airport projects receiving Federal funding, the use of this AC is mandatory.

David L. Bennett
Director, Office of Airport Safety and Standards

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CHAPTER 1. INTRODUCTION

101. BACKGROUND. Airplanes today operate on a wide range of *available* runway lengths. Various factors, in turn, govern the *suitability* of those available runway lengths, most notably airport elevation above mean sea level, temperature, wind velocity, airplane operating weights, takeoff and landing flap settings, runway surface condition (dry or wet), effective runway gradient, presence of obstructions in the vicinity of the airport, and, if any, locally imposed noise abatement restrictions or other prohibitions. Of these factors, certain ones have an operational impact on available runway lengths. That is, for a given runway the usable length made available by the airport authority may not be entirely *suitable* for all types of airplane operations. Fortunately, airport authorities, airport designers, and planners are able to mitigate some of these factors. For example, runways designed with longitudinal profiles equaling zero slope avoid required runway length adjustments. Independently, airport authorities working with their local lawmakers can establish zoning laws to prohibit the introduction of natural growth and man-made structural obstructions that penetrate existing or planned runway approach and departure surfaces. Effective zoning laws avoid the displacement of runway thresholds or reduction of takeoff runway lengths thereby providing airplanes with sufficient clearances over obstructions during climb outs. Airport authorities working with airport designers and planners should validate future runway demand by identifying the critical design airplanes. In particular, it is recommended that the evaluation process assess and verify the airport's ultimate development plan for realistic changes that could result in future operational limitations to customers. In summary, the goal is to construct an available runway length for new runways or extensions to existing runways that is suitable for the forecasted critical design airplanes.

102. DETERMINING RECOMMENDED RUNWAY LENGTHS.

a. Assumptions and Definitions.

(1) Design Assumptions. The assumptions used by this AC are approaches and departures with no obstructions, zero wind, dry runway surfaces, and zero effective runway gradient. Assumptions relative to airplane characteristics are described within the applicable chapter of this AC.

(2) Critical Design Airplanes. The listing of airplanes (or a single airplane) that results in the longest recommended runway length. The listed airplanes will be evaluated either individually or as a single family grouping to obtain a recommended runway length.

(3) Small Airplane. An airplane of 12,500 pounds (5,670 kg) or less maximum certificated takeoff weight.

(4) Large Airplane. An airplane of more than 12,500 pounds (5,670 kg) maximum certificated takeoff weight.

(5) Maximum Certificated Takeoff Weight (MTOW). The maximum certificated weight for the airplane at takeoff, i.e., the airplane's weight at the start of the takeoff run.

(6) Regional Jets. Although there is no regulatory definition for a regional jet (RJ), an RJ for this advisory circular is a commercial jet airplane that carries fewer than 100 passengers.

(7) Crosswind Runway. An additional runway built to compensate primary runways that provide less than the recommended 95 percent wind coverage for the airplanes forecasted to use the airport.

(8) Substantial Use Threshold. Federally funded projects require that critical design airplanes have at least 500 or more annual itinerant operations at the airport (landings and takeoffs are considered as separate operations) for an individual airplane or a family grouping of airplanes. Under unusual circumstances, adjustments may be made to the 500 total annual itinerant operations threshold after considering the circumstances of a particular airport. Two examples are airports with demonstrated seasonal traffic variations, or airports situated in isolated or remote areas that have special needs.

(9) Itinerant Operation. Takeoff or landing operations of airplanes going from one airport to another airport that involves a trip of at least 20 miles. Local operations are excluded.

(10) Effective Runway Gradient. The difference between the highest and lowest elevations of the runway centerline divided by the runway length.

b. Procedure and Rationale for Determining Recommended Runway Lengths. This AC uses a five-step procedure to determine recommended runway lengths for a selected list of critical design airplanes. As previously stated, the information derived from this five-step procedure is for airport design and is not to be used for flight operations. Flight operations must be conducted per the applicable flight manual. The five steps and their rationale are as follows:

(1) Step #1. Identify the list of critical design airplanes that will make regular use of the proposed runway for an established planning period of at least five years. For Federally funded projects, the definition of the term "*substantial use*" quantifies the term "regular use" (see paragraph 102a(8).)

(2) Step #2. Identify the airplanes that will require the longest runway lengths at maximum certificated takeoff weight (MTOW). This will be used to determine the method for establishing the recommended runway length. Except for regional jets, when the MTOW of listed airplanes is 60,000 pounds (27,200 kg) or less, the recommended runway length is determined according to a *family grouping of airplanes* having similar performance characteristics and operating weights. Although a number of regional jets have an MTOW less than 60,000 pounds (27,200 kg), the exception acknowledges the long range capability of the regional jets and the necessity to offer regional jet operators the flexibility to interchange regional jet models according to passenger demand without suffering operating weight restrictions. When the MTOW of listed airplanes is over 60,000 pounds (27,200 kg), the recommended runway length is determined according to *individual airplanes*. The recommended runway length in the latter case is a function of the most critical individual airplane's takeoff and landing operating weights, which depend on wing flap settings, airport elevation and temperature, runway surface conditions (dry or wet), and effective runway gradient. The procedure assumes that there are no obstructions that would preclude the use of the full length of the runway.

(3) Step #3. Use table 1-1 and the airplanes identified in step #2 to determine the method that will be used for establishing the recommended runway length. Table 1-1 categorizes *potential design airplanes* according to their MTOWs. MTOW is used because of the significant role played by airplane operating weights in determining runway lengths. As seen from table 1-1, the first column separates the various airplanes into one of three weight categories. Small airplanes, defined as airplanes with MTOW of 12,500 pounds (5,670 kg) or less, are further subdivided according to approach speeds and passenger seating as explained in chapter 2. Regional jets are assigned to the same category as airplanes with a MTOW over 60,000 pounds (27,200 kg). The second column identifies the applicable airport design approach (by airplane family group or by individual airplanes) as noted previously in step #2. The third column directs the airport designer to the appropriate chapter for design guidelines and whether to use the referenced tables contained in the AC or to obtain airplane manufacturers' airport planning manuals (APM) for each individual airplane under evaluation. In the later case, APMs provide the takeoff and landing runway lengths that an airport designer will in turn apply to the associated guidelines set forth by this AC to obtain runway lengths. The airport designer should be aware that APMs go by a variety of names. For example, Airbus, the Boeing Company, and Bombardier respectively title their APMs as "Airplane Characteristics for Airport Planning," "Airplane Characteristics for Airport Planning," and "Airport Planning Manuals." For the purpose of this AC, the variously titled documents will be referred to as APM. Appendix 1 lists the websites of the various airplane manufacturers to provide individuals a starting point to retrieve an APM or a point of contact for further consultation.

(4) Step #4. Select the recommended runway length from among the various runway lengths generated by step #3 per the process identified in chapters 2, 3, or 4, as applicable.

(5) Step #5. Apply any necessary adjustment to the obtained runway length, when instructed by the applicable chapter of this AC, to the runway length generated by step #4 to obtain a final recommended runway length. For instance, an adjustment to the length may be necessary for runways with non-zero effective gradients. Chapter 5 provides the rationale for these length adjustments.

Table 1-1. Airplane Weight Categorization for Runway Length Requirements

Airplane Weight Category Maximum Certificated Takeoff Weight (MTOW)			Design Approach	Location of Design Guidelines
12,500 pounds (5,670 kg) or less	Approach Speeds less than 30 knots		Family grouping of small airplanes	Chapter 2; Paragraph 203
	Approach Speeds of at least 30 knots but less than 50 knots		Family grouping of small airplanes	Chapter 2; Paragraph 204
	Approach Speeds of 50 knots or more	With Less than 10 Passengers	Family grouping of small airplanes	Chapter 2; Paragraph 205 Figure 2-1
		With 10 or more Passengers	Family grouping of small airplanes	Chapter 2; Paragraph 205 Figure 2-2
Over 12,500 pounds (5,670 kg) but less than 60,000 pounds (27,200 kg)			Family grouping of large airplanes	Chapter 3; Figures 3-1 or 3-2 [1] and Tables 3-1 or 3-2
60,000 pounds (27,200 kg) or more or Regional Jets [2]			Individual large airplane	Chapter 4; Airplane Manufacturer Websites (Appendix 1)

Note [1]: When the design airplane's APM shows a longer runway length than what is shown in figure 3-2, use the airplane manufacturer's APM. However, users of an APM are to adhere to the design guidelines found in Chapter 4.

Note [2]: All regional jets regardless of their MTOW are assigned to the 60,000 pounds (27,200 kg) or more weight category.

103. PRIMARY RUNWAYS. The majority of airports provide a single primary runway. Airport authorities, in certain cases, require two or more primary runways as a means of achieving specific airport operational objectives. The most common operational objectives are to (1) better manage the existing traffic volume that exceed the capacity capabilities of the existing primary runway, (2) accommodate forecasted growth that will exceed the current capacity capabilities of the existing primary runway, and (3) mitigate noise impacts associated with the existing primary runway. Additional primary runways for capacity justification are parallel to and equal in length to the existing primary runway, unless they are intended for smaller airplanes. Refer to AC 150/5060-5, *Airport Capacity and Delay,* for additional discussion on runway usage for capacity gains. Another common practice is to assign individual primary runways to different airplane classes, such as, separating general aviation from non-general aviation customers, as a means to increase the airport's efficiency. The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions. For Federally funded projects, the criterion for substantial use applies (see paragraph 102a(8).) The design objective for additional primary runways is shown in table 1-2. The table takes into account the separation of airplane classes into distinct airplane groups to achieve greater airport utilization. Procedurally, follow the guidelines found in subparagraph 102(b) for determining recommended runway lengths for primary runways, and, for additional primary runways, apply table 1-2.

104. CROSSWIND RUNWAYS. The design objective to orient primary runways to capture 95 percent of the crosswind component perpendicular to the runway centerline for any airplane forecast to use the airport is not always achievable. In cases where this cannot be done, a crosswind runway is recommended to achieve the design standard provided in AC 150/5300-13, *Airport Design,* for allowable crosswind components according to airplane design groups. Even when the 95-percentage crosswind coverage standard is achieved for the design airplane or airplane design group, cases arise where certain airplanes with lower crosswind capabilities are unable to utilize the primary runway. For airplanes with lesser crosswind capabilities, a crosswind runway may be built, provided there is regular usage. For Federally funded projects, the criterion for substantial use applies to the airplane used as the design airplane needing the crosswind runway (see paragraph 102a(8).) The design objective for the length of crosswind runways is shown in table 1-3. Procedurally, follow the guidelines found in subparagraph 102(b) for determining recommended runway lengths for crosswind runways, and, for additional crosswind runways, apply table 1-3.

Table 1-2. Runway Length for Additional Primary Runways

Runway Service Type, User	Runway Length for Additional Primary Runway Equals
Capacity Justification, Noise Mitigation, Regional Jet Service	100 % of the primary runway
Separating Airplane Classes - Commuter, Turboprop, General Aviation, Air Taxis	Recommended runway length for the less demanding airplane design group or individual design airplane

Table 1-3. Runway Length for Crosswind Runway

Runway Service	Runway Length for Crosswind Runway Equals
Scheduled [1] Such as Commercial Service Airports	100 % of primary runway length when built for the same individual design airplane or airplane design group that uses the primary runway
	100% of the recommended runway length determined for the lower crosswind capable airplanes using the primary runway
Non-Scheduled [2] Such as General Aviation Airports	100% of the recommended runway length determined for the lower crosswind capable airplanes using the primary runway

Note [1]: Transport service operated over routes pursuant to published flight schedules that are openly advertised with dates or times (or both) or otherwise made readily available to the general public or pursuant to mail contracts with the U.S. Postal Service (Bureau of Transportation Statistics, Department of Transportation (DOT)).

Note [2]: Revenue flights, such as charter flights that are not operated in regular scheduled service, and all non-revenue flights incident to such flights (Bureau of Transportation Statistics, DOT). For Federally funded programs, such as AIP, there must be at least 500 annual itinerant operations and 100% of the class.

105. RUNWAY LENGTH BASED ON DECLARED DISTANCES CONCEPT. The application of the declared distances concept to overcome safety deficiencies is not intended for new runways. New runways must meet design standards when constructed. See AC 150/5300-13, appendix 14, for information related to declared distances.

106. COMPUTER PROGRAM. The airport design software cited in Appendix 11 of AC 150/5300-13, Airport Design for Microcomputers (AD42D.EXE), was developed for airport planners to facilitate in the planning of airport layouts. The computer program only provides estimates instead of actual length requirements. The design software is available at http://www.faa.gov/airports_airtraffic/airports/construction/.

107. SELECTED 14 CODE OF FEDERAL REGULATIONS CONCERNING RUNWAY LENGTH REQUIREMENTS. Appendix 2 provides a list of selected 14 Code of Federal Regulations that address the airworthiness certification and operational requirements of airplanes associated with runway length.

CHAPTER 2. RUNWAY LENGTHS FOR SMALL AIRPLANES WITH MAXIMUM CERTIFICATED TAKEOFF WEIGHT OF 12,500 POUNDS (5,670 KG) OR LESS

201. DESIGN GUIDELINES. The design procedure for small airplanes requires the following information: the critical design airplanes under evaluation, approach speed in knots (1.3 x stall speed), number of passenger seats, airport elevation above mean sea level, and the mean daily maximum temperature of the hottest month at the airport. Once obtained, apply the guidance from the appropriate paragraph below to obtain the recommended runway length. For this airplane weight category, no further adjustment to the obtained length from the figures 2.1 or 2.2 is necessary. For example, there is no operational requirement to take into account the effect of effective runway gradient for takeoff or landing performance.

202. DESIGN APPROACH. For purposes of design, this AC provides a design concept for airports that serve only airplanes with a maximum certificated takeoff weight of 12,500 pounds (5,670 kg) or less. The design concept starts by grouping all small airplanes, that is, the critical design airplanes, according to approach speed. The highest approach speed group is divided on the basis of passenger seats, namely, “airplanes having fewer than 10 passenger seats” as compared to “airplanes having 10 or more passenger seats.” The less than 10 passenger seats category is further based on two percentages of fleet, namely, “95 percent of the fleet” or “100 percent of the fleet” categories, as explained in paragraph 205. For these airplanes, figures 2-1 and 2-2 show only a single curve that takes into account the most demanding operations to obtain the recommended runway length. Although both figures pertain mainly to small propeller driven airplanes, figure 2-2 does include small turbo-powered airplanes. Airport designers can, instead of applying the small airplane design concept, determine the recommended runway length from airplane flight manuals for the airplanes to be accommodated by the airport in lieu of the runway length curves depicted in figures 2-1 or 2-2. For example, owners of multi-engine airplanes may require that their pilots use the airplane’s accelerate-stop distance in determining the length of runway available for takeoff.

203. SMALL AIRPLANES WITH APPROACH SPEEDS OF LESS THAN 30 KNOTS. Airplanes with approach speeds of less than 30 knots are considered to be short takeoff and landing or ultra light airplanes. Their recommended runway length is 300 feet (92 meters) at mean sea level. Runways located above mean sea level should be increased at the rate of 0.03 x airport elevation above mean sea level to obtain the recommended runway length at that elevation.

204. SMALL AIRPLANES WITH APPROACH SPEEDS OF 30 KNOTS OR MORE BUT LESS THAN 50 KNOTS. The recommended runway length is 800 feet (244 meters) at mean sea level. Runway lengths above mean sea level should be increased at the rate of 0.08 x airport elevation above mean sea level to obtain the recommended runway length at that elevation.

205. SMALL AIRPLANES WITH APPROACH SPEEDS OF 50 KNOTS OR MORE WITH MAXIMUM CERTIFICATED TAKEOFF WEIGHT OF 12,500 POUNDS (5,670 KG) OR LESS. Figures 2-1 and 2-2 provide the recommended runway lengths based on the seating capacity and the mean daily maximum temperature of the hottest month of the year at the airport. The fleet used in the development of the figures consisted of small airplanes certificated in the United States. Figure 2-1 categorizes small airplanes with less than 10 passenger seats (excludes pilot and co-pilot) into two family groupings according to “percent of fleet,” namely, 95 and 100 percent of the fleet. Figure 2-2 categorizes all small airplanes with 10 or more passenger seats into one family grouping. Figure 2-2 further alerts the airport designer that for airport elevations above 3,000 feet (914 m), that the airport designer must use the 100 percent of fleet chart of figure 2-1 instead of using figure 2-2. As shown, both figures provide examples that start with the horizontal temperature axis then, proceed vertically to the applicable airport elevation curve, followed by proceeding horizontally to the vertical axis to read the recommended runway length.

a. Selecting Percentage of Fleet for Figure 2-1. The differences between the two percentage categories are based on the airport’s location and the amount of existing or planned aviation activities. The airport designer should make the selection based on the following criteria.

(1) 95 Percent of Fleet. This category applies to airports that are primarily intended to serve medium size population communities with a diversity of usage and a greater potential for increased aviation activities. Also included in this category are those airports that are primarily intended to serve low-activity locations, small population communities, and remote recreational areas. Their inclusion recognizes that these airports in many cases develop into airports with higher levels of aviation activities.

(2) 100 Percent of Fleet. This type of airport is primarily intended to serve communities located on the fringe of a metropolitan area or a relatively large population remote from a metropolitan area.

b. Future Airport Expansion Considerations. Airports serving small airplanes remain fairly constant in terms of the types of small airplane using the airport and their associated operational requirements. However, it is recommended that the airport designer assess and verify the airport's ultimate development plan for realistic changes that, if overlooked, could result in future operational limitations to customers. The airport designer should at least assess and verify the impacts of:

(1) Expansions to accommodate airplanes of more than 12,500 pounds (5,670 kg). Failure to consider this change during an initial development phase may lead to the additional expense of reconstructing or relocating facilities in the future.

(2) Requirements to operate the runway during periods of Instrument Meteorological Conditions (IMC). The requirement for this capability is highest among airplanes used for business and air taxi purposes.

206. DEVELOPMENT OF THE RUNWAY LENGTH CURVES. 14 Code of Federal Regulations Part 23, *Airworthiness Standards: Normal, Utility, and Acrobatic Category Airplanes*, prescribes airworthiness standards for the issuance of small airplane type certificates. The performance information for each airplane (for example, as defined in *Section 23.51, Takeoff; Section 23.75, Landing; and Section 2.1587, Performance Information*) is contained in the individual airplane flight manual. This information is provided to assist the airplane operator in determining the runway length necessary to operate safely. Performance information from those manuals was selectively grouped and used to develop the runway length curves in figures 2-1 and 2-2. The major parameters utilized for the development of theses curves were the takeoff and landing distances for figure 2-1 and the takeoff, landing, and accelerate-stop distances for figure 2-2. The following conditions were used in developing the curves:

Zero headwind component.

Maximum certificated takeoff and landing weights.

Optimum flap setting for the shortest runway length (normal operation).

Airport elevation and temperature were left variable (values need to be obtained).

Other factors, such as relative humidity and effective runway gradient, also have a variable effect on runway length but are not accounted for in certification. However, these other factors were accounted for in the runway length curves by increasing the takeoff or landing distance (whichever was longer) of the group's most demanding airplane by 10 percent for the various combinations of elevation and temperature.

14 Code of Federal Regulations Part 135, *Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons on Board such Aircraft*, imposes the operational requirements on those airplanes having a seating configuration of 10 passenger seats or more to include the accelerate-stop distance parameter in computing the required takeoff runway length. As previously mentioned, figure 2-2 includes the accelerate-stop distance parameter.

Figure 2-1. Small Airplanes with Fewer than 10 Passenger Seats
(Excludes Pilot and Co-pilot)

Example:

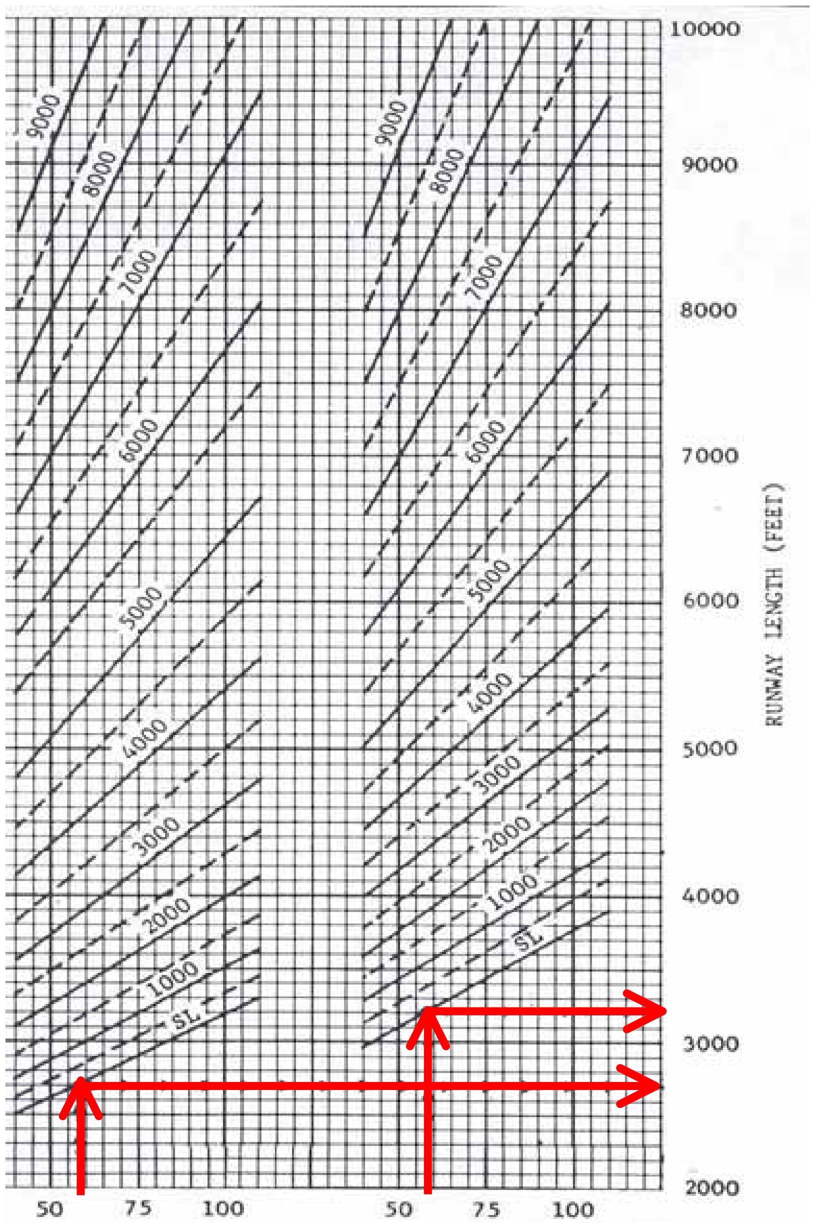
Temperature (mean day max hot month): 59° F (15° C)
Airport Elevation: Mean Sea Level

Note: Dashed lines shown in the table are mid values of adjacent solid lines.

Recommended Runway Length:

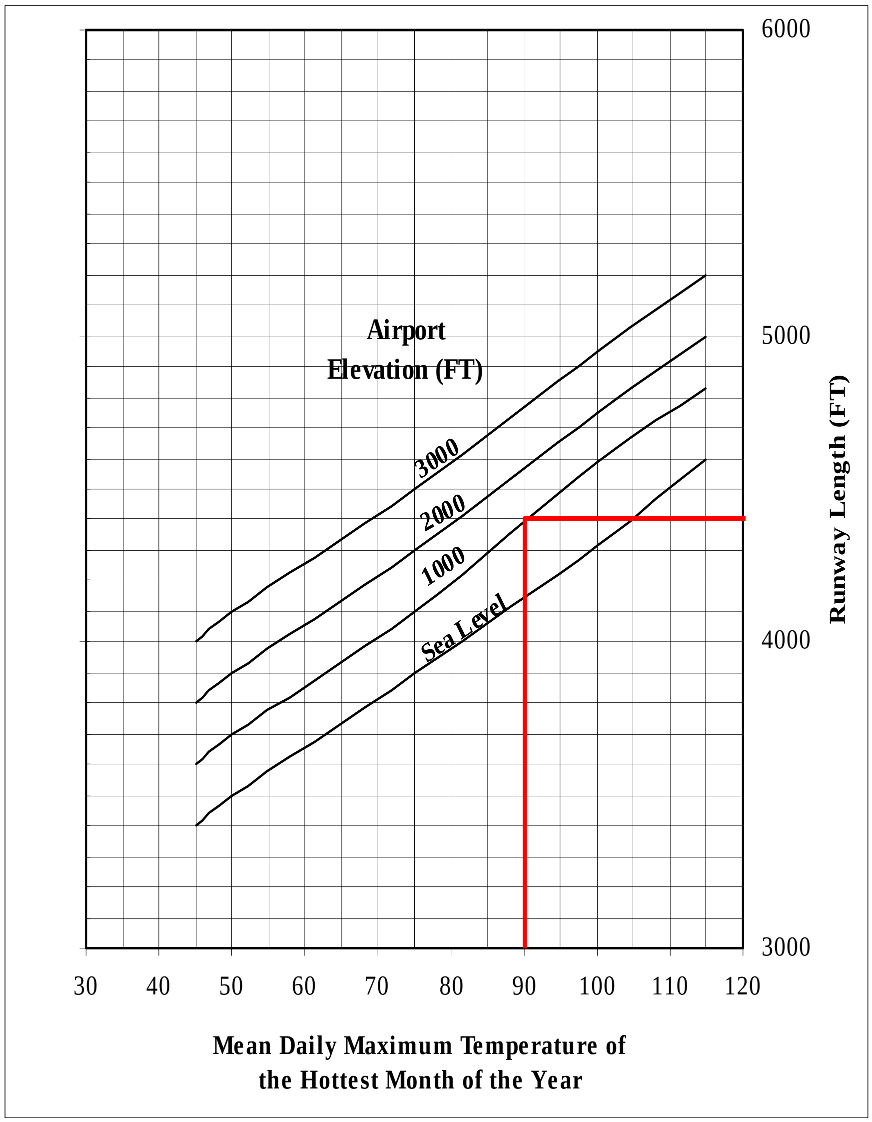
For 95% = 2,700 feet (823 m)
For 100% = 3,200 feet (975 m)

Airport Elevation
(feet)
95 Percent of Fleet 100 Percent of Fleet



Mean Daily Maximum Temperature of the Hottest Month of Year
(Degrees F)

Figure 2-2. Small Airplanes Having 10 or More Passenger Seats
(Excludes Pilot and Co-pilot)

Representative Airplanes	Runway Length Curves
Raytheon B80 Queen Air **Raytheon** E90 King Air **Raytheon** B99 Airliner **Raytheon** A100 King Air (Raytheon formerly Beech Aircraft) **Britten-Norman** Mark III-I Trilander **Mitsubishi** MU-2L **Swearigen** Merlin III-A **Swearigen** Merlin IV-A **Swearigen** Metro II	**Example:** Temperature (mean day max hot month) 90° F (32° C) Airport Elevation (msl) 1,000 feet (328 m) Recommended Runway Length 4,400 feet (1,341 m) **Note:** For airport elevations above 3,000 feet (915 m), use the 100 percent of fleet grouping in figure 2-1.  **(Degrees F)**

CHAPTER 3. RUNWAY LENGTHS FOR AIRPLANES WITHIN A MAXIMUM CERTIFICATED TAKEOFF WEIGHT OF MORE THAN 12,500 POUNDS (5,670 KG) UP TO AND INCLUDING 60,000 POUNDS (27,200 KG)

301. DESIGN GUIDELINES. The design procedure for this airplane weight category requires the following information: airport elevation above mean sea level, mean daily maximum temperature of the hottest month at the airport, the critical design airplanes under evaluation with their respective useful loads. Once obtained, apply either figure 3-1 or figure 3-2 to obtain a single runway length for the entire group of airplanes under evaluation. Finally, apply any landing or takeoff length adjustments, if necessary, to the resulting runway length to obtain the recommended runway length.

302. DESIGN APPROACH. The recommended runway length for this weight category of airplanes is based on performance curves (figures 3-1 and 3-2) developed from FAA-approved airplane flight manuals in accordance with the provisions of 14 Code of Federal Regulations Part 25, *Airworthiness Standards: Transport Category Airplanes,* and Part 91, *General Operating and Flight Rules*. If the airport is planned for operations that will include only turbojet-powered airplanes weighing under 60,000 pounds (27,200 kg) maximum certificated takeoff weight (MTOW) in conjunction with other small airplanes of 12,500 pounds (5,670 kg) or less, use the curves shown in either figures 3-1 or 3-2. To determine which of the two figures to apply, first use tables 3-1 and 3-2 to determine which one of the two “percentage of fleet” categories represents the critical design airplanes under evaluation. With that determination, then select either the “60 percent useful load” curves or the “90 percent useful load” curves on the basis of the haul lengths and service needs of the critical design airplanes. **Note:** at elevations over 5,000 feet (1,524 m) above mean sea level, the recommended runway length obtained for small airplanes from chapter 2 may be greater than those obtained by these figures. In this case, the requirements for the small airplanes govern. Finally, the curves of figures 3-1 and 3-2 apply to airport elevations up to 8,000 feet (2,439 m) above mean sea level. For higher elevations, consult the airplane manufacturer(s) for their recommendations.

303. PERCENTAGE OF FLEET AND USEFUL LOAD FACTOR. The curves in figure 3-1 and 3-2 are based on a grouping of only the turbojet-powered fleet (and business jets) according to performance capability as contained in the FAA-approved airplane manuals under an assumed loading condition. Interpolation is allowed only within *a single set of curves* (e.g., an elevation at 2,500 feet within the “75 percent of the fleet at 60 percent useful load” set of curves) but not valid *between sets of curves* (e.g., an 85 percent useful load between the set of curves “75 percent of the fleet at 60 percent useful load” and “75 percent of the fleet at 90 percent useful load.”) The restriction is because each set assumed a specific, non-variable loading condition. Figures 3-1 and 3-2 contain a set of two curves based upon the percentage of the fleet and the percentage of useful load that can be accommodated by the runway lengths obtained from the curves. For example, the “75 percent fleet at 60 percent useful load” curve provides a runway length *sufficient to satisfy the operational requirements* of approximately 75 percent of the fleet at 60 percent useful load. This figure is to be used for those airplanes operating with no more than a 60 percent useful load factor. Both figures 3-1 and 3-2 provide examples that start with the horizontal temperature axis, then proceed vertically to the airport elevation curve, and finally proceed horizontally to the vertical axis to obtain the runway length. The final step is to apply any necessary length adjustments to the obtained length in accordance with paragraph 304 to determine the recommended runway length.

a. Percentage of Fleet.

(1) Tables 3-1 and 3-2. Table 3-1 provides the list of those airplanes that comprise the “75 percent of fleet” category and therefore can be accommodated by the runway lengths resulting from figure 3-1. Table 3-2, provides the remaining airplanes beyond that of table 3-1 that comprise the “100 percent of fleet” category and therefore can be accommodated by the resulting runway lengths from figure 3-2. The distinction between the tables is that airplanes listed in table 3-2 require at least 5,000-foot (1,524 m) runways at mean sea level and at the standard day temperature of 59° F (15° C) (see paragraph 403 and table 4-1 for an explanation of the concept.). Airplanes listed in table 3-1 require less than 5,000 feet (1,524 m) for the same conditions.

(2) Selecting Figures 3-1 or 3-2. The airport designer must determine from which list the airplanes under evaluation are found. Use figure 3-1 when the airplanes under evaluation are not listed in table 3-2. If a relatively few airplanes under evaluation are listed in table 3-2, then figure 3-2 should be used to determine the runway length. If no adjustments to this length are necessary as outlined above, then this becomes the recommended runway length.

b. Useful Load Factor.

(1) The term *useful load factor* of an airplane for this AC is considered to be the difference between the maximum allowable structural gross weight and the operating empty weight. A typical operating empty weight includes the airplane's empty weight, crew, baggage, other crew supplies, removable passenger service equipment, removable emergency equipment, engine oil, and unusable fuel. In other words, the useful load then consists of passengers, cargo, and usable fuel. It is noted that although o*perating empty weight* varies considerably with individual airplanes, the curves used in the figures were based on the average operating empty weights of numerous business jets.

(2) Figures 3-1 and 3-2 provide only two useful load percentages, namely "60 percent useful load" and "90 percent useful load." Curves are not developed for operations at "100 percent useful load" because many of the airplanes used to develop the curves in figures 3-1 and 3-2 were operationally limited in the second segment of climb. That is, the allowable gross takeoff weight is often limited by ambient conditions of temperature and elevation to an operating weight that is less than their maximum structural gross weight. Therefore, APMs contain climb limitations when required. Because of the climb limitation, the runway length resulting from the "90 percent useful load" curves are considered by this AC to approximate the limit of beneficial returns for the runway. A specific list of business jets were used to obtain an average operating empty weight, which in turn, was used to develop the curves.

c. Privately Owned Business Jets. Business jets that are privately owned are included in their respective 75 percent and 100 percent of fleet categories.

d. Air Carrier Regional Jets. As previously mentioned, the recommended runway lengths for regional jets for air carrier service are addressed in chapter 4.

304. RUNWAY LENGTH ADJUSTMENTS. The runway lengths obtained from figures 3-1 and 3-2 are based on no wind, a dry runway surface, and zero *effective runway gradient*. Effective runway gradient is defined as the difference between the highest and lowest elevations of the runway centerline divided by the runway length. Therefore, increase the obtained runway lengths from the figures to account for (1) takeoff operations when the effective runway gradient is other than zero and (2) landing operations of turbojet-powered airplanes under wet and slippery runway surface conditions. These increases are not cumulative since the first length adjustment applies to takeoffs and the latter to landings. After both adjustments have been independently applied, the larger resulting runway length becomes the recommended runway length. The procedures for length adjustments are as follows:

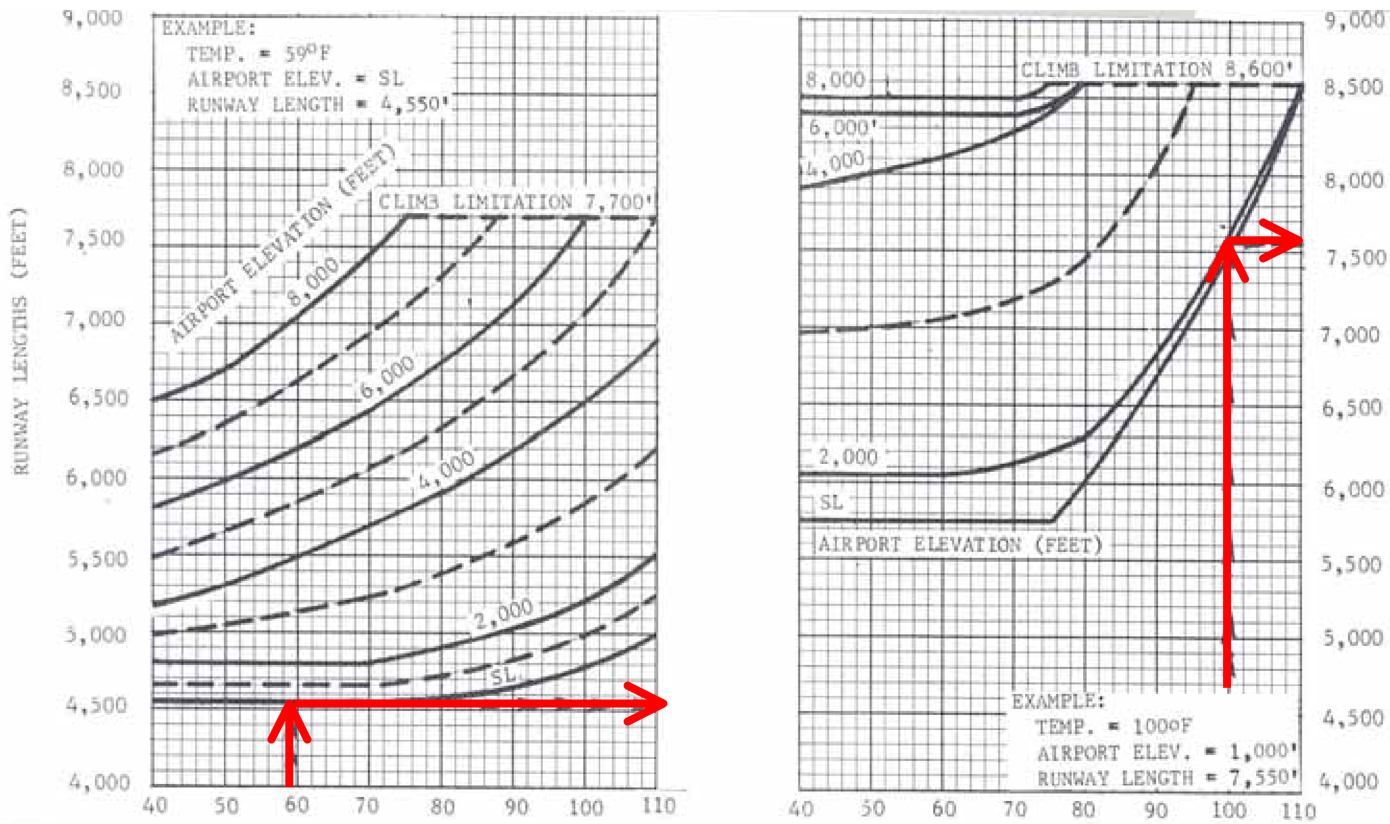
a. Effective Runway Gradient (Takeoff Only). The runway lengths obtained from figures 3-1 or 3-2 are increased at the rate of 10 feet (3 meters) for each foot (0.3 meters) of elevation difference between the high and low points of the runway centerline.

b. Wet and Slippery Runways (Applicable Only to Landing Operations of Turbojet-Powered Airplanes). By regulation, the runway length for turbojet-powered airplanes obtained from the "60 percent useful load" curves are increased by 15 percent or up to 5,500 feet (1,676 meters), whichever is less. By regulation, the runway lengths for turbojet powered airplanes obtained from the "90 percent useful load" curves are also increased by 15 percent or up to 7,000 feet (2,133 meters), whichever is less. No adjustment is necessary by regulation for turboprop-powered airplanes.

305. PRECAUTION FOR AIRPORTS LOCATED AT HIGH ALTITUDES. At elevations above 5,000 feet (1,524 m) mean sea level, the recommended runway length for *propeller* driven airplanes of 12,500 pounds (5,670 kg) MTOW or less found in chapter 2 may be *greater* than those determined in this chapter for turbojet-powered airplanes. In this case, the longer recommended runway length of the small airplane weight category must be provided.

306. GENERAL AVIATION AIRPORTS. General aviation (GA) airports have witnessed an increase use of their primary runway by scheduled airline service and privately owned business jets. Over the years business jets have proved themselves to be a tremendous asset to corporations by satisfying their executive needs for flexibility in scheduling, speed, and privacy. In response to these types of needs, GA airports that receive regular usage by large airplanes over 12,500 pounds (5,670 kg) MTOW, in addition to business jets, should provide a runway length comparable to non-GA airports. That is, the extension of an existing runway can be justified at an existing GA airport that has a need to accommodate heavier airplanes on a frequent basis.

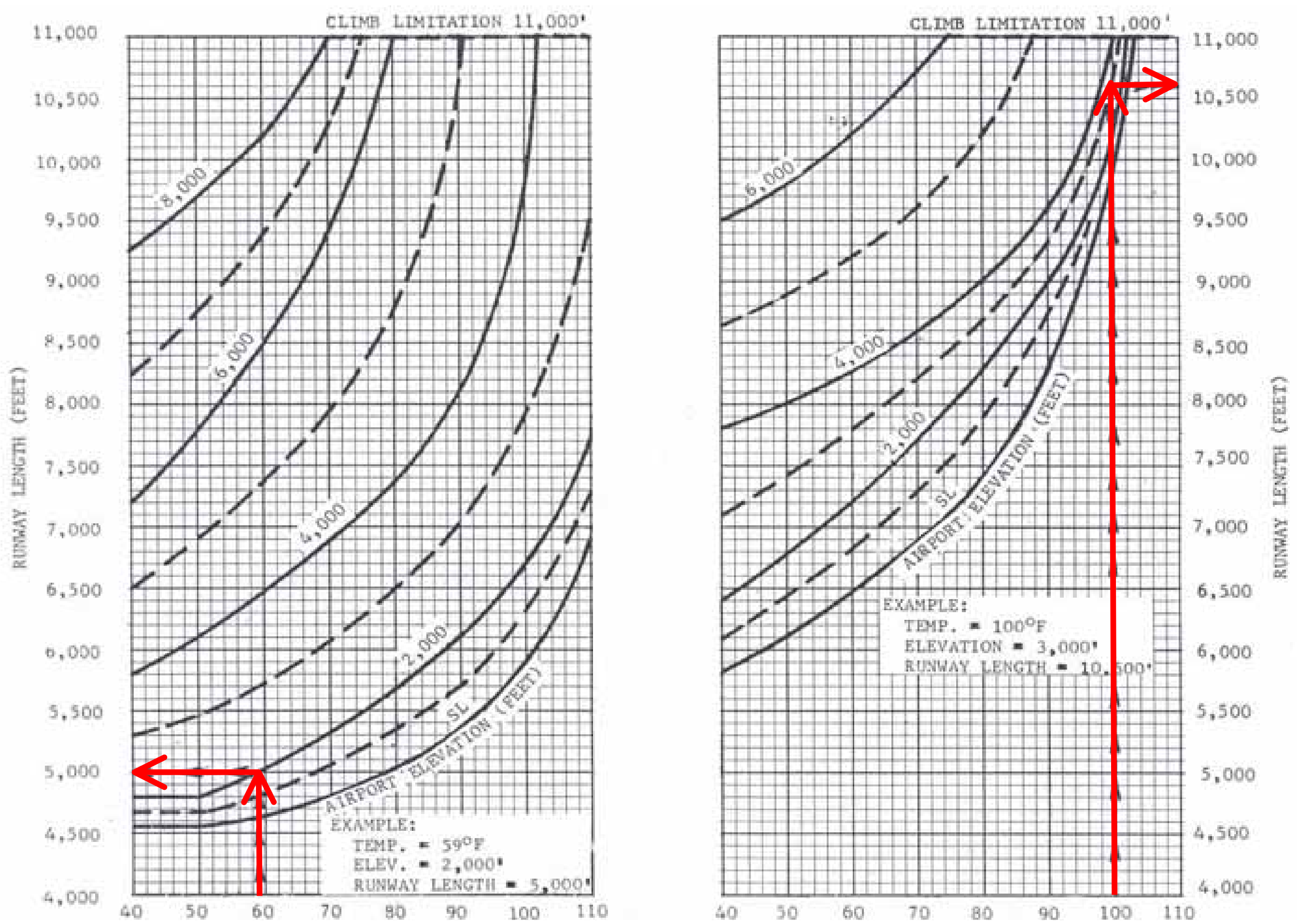
Figure 3-1. 75 Percent of Fleet at 60 or 90 Percent Useful Load



Mean Daily Maximum Temperature of Hottest Month of the Year in Degrees Fahrenheit

75 percent of feet at 60 percent useful load **75 percent of feet at 90 percent useful load**

Figure 3-2. 100 Percent of Fleet at 60 or 90 Percent Useful Load



Mean Daily Maximum Temperature of Hottest Month of the Year in Degrees Fahrenheit

100 percent of feet at 60 percent useful load **100 percent of feet at 90 percent useful load**

Table 3-1. Airplanes that Make Up 75 Percent of the Fleet

Manufacturer	Model	Manufacturer	Model
Aerospatiale	Sn-601 Corvette	Dassault	Falcon 10
Bae	125-700	Dassault	Falcon 20
Beech Jet	400A	Dassault	Falcon 50/50 EX
Beech Jet	Premier I	Dassault	Falcon 900/900B
Beech Jet	2000 Starship	Israel Aircraft Industries (IAI)	Jet Commander 1121
Bombardier	Challenger 300	IAI	Westwind 1123/1124
Cessna	500 Citation/501Citation Sp	Learjet	20 Series
Cessna	Citation I/II/III	Learjet	31/31A/31A ER
Cessna	525A Citation II (CJ-2)	Learjet	35/35A/36/36A
Cessna	550 Citation Bravo	Learjet	40/45
Cessna	550 Citation II	Mitsubishi	Mu-300 Diamond
Cessna	551 Citation II/Special	Raytheon	390 Premier
Cessna	552 Citation	Raytheon Hawker	400/400 XP
Cessna	560 Citation Encore	Raytheon Hawker	600
Cessna	560/560 XL Citation Excel	Sabreliner	40/60
Cessna	560 Citation V Ultra	Sabreliner	75A
Cessna	650 Citation VII	Sabreliner	80
Cessna	680 Citation Sovereign	Sabreliner	T-39

Table 3-2. Remaining 25 Percent of Airplanes that Make Up 100 Percent of Fleet

Manufacturer	Model
Bae	Corporate 800/1000
Bombardier	600 Challenger
Bombardier	601/601-3A/3ER Challenger
Bombardier	604 Challenger
Bombardier	BD-100 Continental
Cessna	S550 Citation S/II
Cessna	650 Citation III/IV
Cessna	750 Citation X
Dassault	Falcon 900C/900EX
Dassault	Falcon 2000/2000EX
Israel Aircraft Industries (IAI)	Astra 1125
IAI	Galaxy 1126
Learjet	45 XR
Learjet	55/55B/55C
Learjet	60
Raytheon/Hawker	Horizon
Raytheon/Hawker	800/800 XP
Raytheon/Hawker	1000
Sabreliner	65/75

Note: Airplanes in tables 3-1 and 3-2 combine to comprise 100% of the fleet.

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CHAPTER 4. RUNWAY LENGTHS FOR REGIONAL JETS AND THOSE AIRPLANES WITH A MAXIMUM CERTIFICATED TAKEOFF WEIGHT OF MORE THAN 60,000 POUNDS (27,200 KG)

401. DESIGN GUIDELINES. The design procedure for this weight category requires the following information: the critical design airplanes under evaluation and their APMs, the maximum certificated takeoff weight or takeoff operating weight for short-haul routes, maximum certificated landing weight, airport elevation above mean sea level, effective runway gradient, and the mean daily maximum temperature of the hottest month at the airport. Apply the procedures in this chapter to each APM to obtain separate takeoff and landing runway length requirements. Apply any takeoff and landing length adjustments, if necessary, to the resulting lengths.

402. DESIGN APPROACH. The recommended runway length obtained for this weight category of airplanes is based on using the performance charts published by airplane manufacturers, i.e., APMs, or by contacting the airplane manufacturer and/or air carriers for the information. Regardless of the approach taken by the airport designer, the design procedure described below must be applied to the information/performance charts. Both takeoff and landing runway length requirements must be determined with applicable length-adjustments in order to determine the recommended runway length. The longest of the takeoff and landing runway length requirements for the critical design airplanes under evaluation becomes the recommended runway length.

a. Airport Planning Manual (APM). Each airplane manufacturer's APM provides performance information on takeoff and landing runway length requirements for different airplane operating weights, airport elevations, flap settings, engine types, and other parameters. It is noted that airplane manufacturers do not present the data in a standard format. However, there is sufficient consistency in the presentation of the information that allows their application in determining the recommended runway length as described in paragraph 403.

b. United States Federal Aviation Regulations (FAR) and European Joint Aviation Regulations (JAR) or Certification Specifications (CS).

(1) Recently CS have replaced the European JARs that were previously issued by the Joint Aviation Authorities of Europe. Today the European Aviation Safety Agency (EASA) issues all CS**.**

(2) Airport designers and planners should be aware that some APM charts provide curves for both FAR and JAR (or CS) regulations. That is, a chart may contain dual curves labeled "FAR" and curves labeled "JAR." In the case for air carrier operators under the authority of the United States, the airport designer must use the curves labeled "FAR." In the case of foreign air carrier operators who receive approves by their respective foreign authority, such as EASA, the airport designer must use the curves authorized by the foreign authority, i.e., curves labeled "JAR," "CS", or "FAR." Therefore, the recommended labeled-curves that airport designers must use are those that the authorizing aviation authority approved for the air carrier's airplane fleet**.**

c. Airplane Manufacturer Website. Appendix 1 provides the website addresses of the various airplane manufacturers to assist in obtaining APMs or for further consultation.

403. PROCEDURES FOR DETERMINING RECOMMENDED RUNWAY LENGTH. Determine both takeoff and landing runway length requirements as prescribed below, select the longest resulting takeoff and landing runway lengths, then apply any length adjustments described in the following subparagraphs. The longest resulting runway length between the takeoff and landing runway lengths for the critical design airplanes under evaluation becomes the recommended runway length. Appendix 3 offers several examples that employ the design guidelines and procedures. *It is noted that the charts used in this procedure are provided by the airplane manufacturers for information only and not for flight operations. The pilot must use the FAA-approved flight manuals to conduct flight operations*.

a. The Temperature Parameter in APM Takeoff Charts. The parameter airport temperature is used only for takeoff length determinations by setting it equal to the "mean daily maximum temperature of the hottest month at the airport." In turn, APMs provide takeoff runway length data in terms of airport elevation and standard day temperatures (SDT). Figure 4-1 shows how APMs correlate SDTs with airport elevations. Fortunately many airplane manufacturers provide at least two takeoff runway length requirement charts, one at SDT (59° F (*15°*

C)) and one at SDT + some additional temperature, for example, SDT + 27° F (*SDT + 15°C*). The latter chart corresponds to 59° F + 27° F = 86° F (*15°C + 15°C = 30°C.*) Hence, the *potential benefit* for airport designers is quick and easy takeoff length determinations when the value of airport temperature, "mean daily maximum temperature of the hottest month at the airport," *equals or is less than* the provided SDT. In order to *augment this benefit*, it is acceptable for airport designers to use a SDT chart if it is no more than 3° F (1.7° C) lower than the recorded value for the "mean daily maximum temperature of the hottest month at the airport". For example, a SDT+ 27° F (*STD + 15°C*) chart could be used when airport temperatures are equal to or less than 89° F (3° F + 86° F) (*30°C [15°C + 15°C]*). If no SDT chart is available for the recorded airport temperature, consult the airplane manufacturer directly to obtain the takeoff length requirement under the same conditions outlined in this paragraph.

Table 4-1. Relationship Between Airport Elevation and Standard Day Temperature

Airport Elevation [1]		**Standard Day Temperature [1] (SDT)**	
Feet	Meters	° F	° C
0	0	59.0	15.00
2,000	609	51.9	11.04
4,000	1,219	44.7	7.06
6,000	1,828	37.6	3.11
8,000	2,438	30.5	-0.85

Note 1: Linear interpolations between airport elevations and between SDT values are permissible.

b. Landing Length Requirements. For the airplane model with, if provided, the corresponding engine type under evaluation:

(1) Locate the landing chart with the highest landing flap setting (if more than one flap setting is offer), zero wind, and zero effective runway gradient. If the chart does not indicate the wind or effective runway gradient conditions, assume they are equal to zero.

(2) Enter the horizontal weight axis with the operating landing weight equal to the maximum certificated landing weight. Linear interpolation along the weight axis is allowed. Do not exceed any indicated limitations on the chart.

(3) Proceed vertically to the airport elevation curve, sometimes labeled "pressure altitude." Interpolation between curves is allowed. It is noted that some charts simultaneously show both the *"dry runway"* and *"wet runway"* curves. Use the *"wet runway"* curve. Wet runway conditions are required only for turbojet-powered airplanes (see paragraph 508). See step (5) below for the turbo-jet powered airplanes when the chart only provides "*dry runway*" curves.

(4) Proceed horizontally from the wet runway curve to the length axis to read the runway length. Linear interpolation along the length axis is allowed.

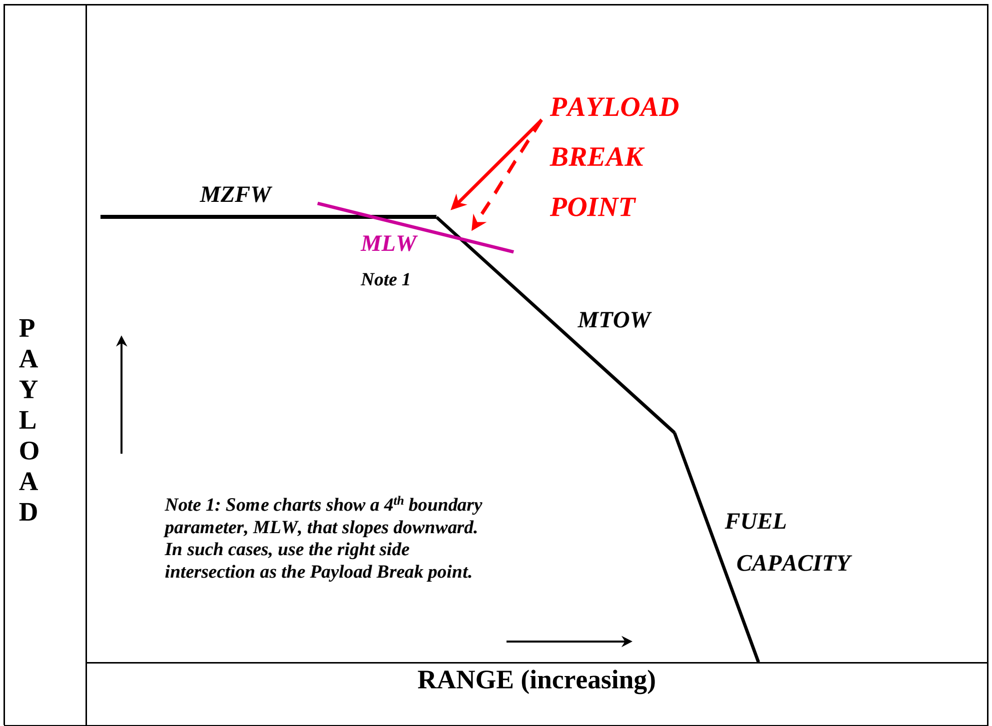
(5) Increase the obtained landing length for "dry runway" condition by 15 percent for those cases noted in paragraph 508. No landing length adjustment is necessary by regulation for non-zero effective runway gradients for any airplane type.

c. Takeoff Length Requirements. For the airplane model with, if provided, corresponding engine type under evaluation:

(1) Locate the takeoff chart with dry runway, zero wind, and zero effective runway gradient conditions for the appropriate SDT chart (within the temperature range for the airport's mean daily maximum temperature of the hottest month at the airport). If the chart does not indicate the "zero wind" or "zero effective runway gradient" conditions, assume they are equal to zero, but this is not a conservative assumption.

(2) Enter the horizontal weight axis with the operating takeoff weight equal to maximum certificated takeoff weight. For Federally funded projects, the airport designer must take into account the length of haul (range) that is flown by airplanes on a *substantial* use basis. The length of haul range will determine the operating takeoff weight for the design airplanes under evaluation. Long-haul routes should set the operating takeoff weight equal to the MTOW while short-haul routes should apply the actual operating takeoff weight. The Payload Break point as shown in figure 4-1 in conjunction with the *Payload-Range* charts provided by APMs for the design airplane(s), determine whether or not to use MTOW. Figure 4-1 illustrates a generic Payload-Range chart with Range and Payload axes, the Payload Break point, and the boundary parameters. For length of haul ranges that equal to or exceed the Payload Break point, the operating takeoff weight is set equal to the MTOW. For all the other cases, set the design operating takeoff weight equal to the actual operating takeoff weight. For the latter case, *AC 120-27D, Aircraft Weight and Balance Control*, provides average weight values for passengers and baggage for payload calculations for short-haul routes.

Figure 4-1 Generic Payload-Range Chart



MLW maximum design landing weight
MTOW maximum design takeoff weight (some APMs label it Brake Release)
MZFW maximum design zero fuel weight (some APMs label it Maximum Design Payload)

(3) Proceed vertically to the airport elevation curve without exceeding any indicated limitations, such as, maximum brake energy limit, tire speed limit, etc. Interpolation between curves is allowed because the chart is used for airport design as compare to flight operations. It is also noted that some airport elevations curves show various flap settings along the curve. In such cases, continue to use the same airport elevation curve.

(4) Proceed horizontally from the airport elevation curve to the runway length axis to read the takeoff runway length. Linear interpolation along the runway length axis is allowed.

(5) Adjust the obtained takeoff runway length for non-zero effective runway gradients (see paragraph 509). In those cases the airport designer must increase the obtained length by 10 feet (3 m) per foot (0.3m) of difference in runway centerline elevations between the high and low points of the runway centerline elevations.

d. Final Recommended Runway Length. The final recommended runway length is the longest resulting length after any adjustments for all the critical design airplanes that were under evaluation.

404. EXAMPLES. Appendix 3 provides example scenarios utilizing APM performance charts.

CHAPTER 5. DESIGN RATIONALE

501. INTRODUCTION. This chapter explains the application of eight factors that affect runway lengths. Previous chapters describe how to use performance curves and tables to determine the recommended runway length. However, the airport designer has the option to determine the recommended runway length by obtaining data provided in airplane flight manuals and then equally applying the eight variable factors discussed in this chapter and all other factors mentioned in the respective chapters. Table 5-1 summarizes the eight variable factors. For Federally funded projects the eight variable and other factors mentioned need to be applied in a manner to produce the shortest runway length.

502. AIRPLANES. The design criterion is to catalog the current or forecasted critical design airplane(s) that will use the runway and require the longest runway length.

503. LANDING FLAP SETTINGS. The design criterion is to select the landing flap setting that produces the shortest runway length. Figures in chapters 2 and 3 are based on this design criterion. Chapter 4, which relies on the use of an APM, directs the airport designer to select the flap setting that generates the shortest runway length from among the certificated landing flap settings.

504. AIRPLANE OPERATING WEIGHTS. The recommended runway length is based on expected airplane operating weights during takeoff and landing operations. The expected landing weight is the lower of the maximum allowable landing weights for the three conditions specified in subparagraph 504a and the takeoff weight is the lower of the maximum allowable takeoff weights for the seven conditions specified in subparagraph 504b.

a. Maximum Allowable Landing Weight. The airplane's maximum allowable landing weight is the lower of the following three conditions:

(1) Maximum structural landing weight.

(2) Climb limited landing weight.

(3) Runway length-limited landing weight (insufficient available runway length).

b. Maximum Allowable Takeoff Weight. The airplane's maximum allowable takeoff weight is the lower of the following:

(1) Maximum structural takeoff weight.

(2) Climb limited takeoff weight.

(3) Tire speed limited takeoff weight.

(4) Brake energy limited takeoff weight.

(5) Takeoff weight limited by maximum landing weight.

(6) Obstacle clearance limited takeoff weight.

(7) Runway length-limited takeoff weight (insufficient available runway length).

c. Operating Weights for Design. The design criterion is based on the following:

(1) Small Airplanes 12,500 pounds (5,670 kg) or less MTOW. Figures 2-1 and 2-2 along with the guidelines in chapter 2 provide recommended runway lengths by a single curve that incorporates both maximum allowable takeoff and landing weights.

(2) Large Airplanes over 12,500 pound (5,670 kg) MTOW.

i. Chapter 3. The curves of figures 3-1 and 3-2 provide runway lengths based on the percentage of fleet and percent of useful load. The curves used the lesser of the maximum allowable takeoff and landing weights as described above or the weight of the airplane with useful load.

ii. Chapter 4, Using Airplane Planning Manuals (APMs).

(a) For landing, use the maximum allowable landing weight excluding limitations of subparagraph 504a(3). In nearly all cases, the weight is set to the maximum structural landing weight.

(b) For takeoff, use maximum allowable takeoff weight, excluding limitations of subparagraph 504b(5), (6), and (7). For Federally funded projects, the airport designer must take into account the length of haul (range) that is flown by airplanes on a *substantial* use. In this case, use the determined length of haul (range) and compare it to the Payload Break point of the Payload-Range chart in the APM (see paragraph 403(c) for an explanation.) For ranges greater than or equal to the Payload Break point, set the operating takeoff weight equal to MTOW excluding limitations of subparagraph 504b(5), (6), and (7). For ranges less than the Payload Break point, use the calculated operating takeoff weight for the given range, i.e., short-haul routes. In many cases, the weight is set to the MTOW, thus resulting in a runway that permits airplanes to operate at full payload service capabilities.

505. AIRPORT ELEVATION. The design criterion is to substitute airport elevation above mean sea level for pressure altitude. This substitution is acceptable since the two are approximately equal and the probability of these conditions occurring simultaneously is relatively remote. Therefore, any difference would be slight.

506. TEMPERATURE. The design criterion is to use the mean daily maximum temperature of the hottest month at the airport. This temperature is readily available and yields a realistic operational length.

a. Application. Airport designers using chapters 2 and 3 are to apply the actual temperature value to the provided figures. Airport designers using an APM are to employ either the tables from the APM when the actual temperature falls within a prescribed temperature range or, when it falls outside the prescribed temperature range, to contact the airplane manufacturer directly for the applicable runway table.

b. Availability of Temperature Data. This information can be obtained from the publication "Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree-Days" (Climatography of the United States No.81). This is the official source for the mean maximum temperature for the hottest month. The latest data, averaged over a period of thirty years, may be obtained from the National Climatic Data Center, Federal Building, Asheville, North Carolina 28801. Phone: (828) 271-4800; fax: (828) 271-4876; or website: http://www.ncdc.noaa.gov/oa/ncdc.html (specify the state when ordering).

507. WIND. The design criterion is based on the condition of zero wind velocity for both takeoff and landing operations for all airplane weight categories. The figures in chapters 2 and 3 are based on zero wind conditions. Users of APMs are instructed to select the zero wind curves.

508. RUNWAY SURFACE CONDITIONS. The design criterion is to address wet, slippery runway surface conditions for only landing operations and only for turbojet-powered airplanes. The design criteria follows the 14 Code of Federal Regulations requirement that dry runway landing distances for turbojet-powered airplanes must be increased 15 % when landing on wet or slippery runways. Therefore, the obtained runway lengths from this AC for turbojet-powered airplanes are further increased by 15 percent. Many airplane manufacturers' APMs for turbojet-powered airplanes provide both dry runway and wet runway landing curves. If an APM provides only the dry runway condition, then increase the obtained dry runway length by 15 percent. The landing portion of the curves in figures 3-1 and 3-2 are based on dry runway conditions. Thus, as instructed by chapter 3, increase the landing dry lengths for turbojet-powered airplanes by 15 percent to increase the landing length, but not more than 5,500 feet (1,676 meters), whichever is less.

509. MAXIMUM DIFFERENCE OF RUNWAY CENTERLINE ELEVATION. The design criterion is to address uphill longitudinal runway profiles for takeoff operations of large airplanes. A runway whose centerline elevation varies between runway ends produces uphill and downhill conditions, which in turn, cause certain airplane weight categories to require longer operational lengths. This AC addresses the uphill condition, termed "*effective runway gradient,*" for *takeoff* operations by using the maximum difference of runway centerline elevation. For airplanes over 12,500 pounds (5,670 kg) maximum certified takeoff weight, the recommended runway length for takeoff derived from the curves of figures 3-1 and 3-2 or from the APMs must be increased by 10 feet per foot of difference in centerline elevations between the high and low points of the runway centerline elevations. Airport designers using APMs should also apply the same adjustment because APMs use zero effective runway gradients in their takeoff curves. This adjustment to the obtained runway length approximates the operational increase required to overcome the uphill effective runway gradient. For airplanes of 12,500 pounds (5,670 kg) or less MTOW, no operational requirement for an increase to the obtained runway length for takeoff is necessary to compensate for non-zero effective runway gradients. In the case for landing operations, no operational requirement for an increase to the obtained runway length for landing is necessary to compensate for non-zero effective runway gradients.

Table 5-1. Rationale Behind Recommendations for Calculating Recommended Runway Lengths

Variable Factors and Paragraph References		Family Groupings Consult Advisory Circular Figures 2-1 and 2-2	Family Groupings Consult Advisory Circular Figures 3-1	Family Groupings Consult Advisory Circular Figures 3-2	Airplane Performance Characteristics Non-Turbojet/Turbojet (Consult Airplane Manufacturer's Airport Planning Manuals (APM) Chapter 4)
Airplane Type (Paragraph 502)		Based on number of seats	Based on percent of fleet		Specific manual for each airplane
Flap Setting (Paragraph 503)		Shortest runway length			Shortest runway length
Operating Weights (Paragraph 504)	Takeoff	Maximum takeoff weight	Based on percent of useful load		Located in airplane general characteristics
	Landing	Maximum landing weight	Based on percent of useful load		Located in airplane general characteristics
Airport Elevation (Paragraph 505)		Indicated on AC curves			Indicated on APM curves
Temperature (Paragraph 506)	Takeoff	Indicated on AC curves			Indicated on APM curve
	Landing	Indicated on AC curves	Independent of results		Independent of results
Wind (Paragraph 507)	Takeoff	Zero wind			Zero wind
	Landing	Zero wind			Zero wind
Runway Surface Conditions (Paragraph 508)	Takeoff	Independent of results			Independent of results
	Landing	Independent of results	Dry		Wet (turbo) Dry (non-turbo)
Difference in Centerline Elevation (Paragraph 509)	Takeoff	Independent of results	Zero		Zero
	Landing	Independent of results			Independent of results
Runway Length for Takeoff		Airplane takeoff distance	Larger of airplane takeoff distance or accelerated stop distance		Larger of airplane takeoff distance or accelerated stop distance
Runway Length for Landing		Airplane takeoff distance	Airplane dry landing distance divided by 0.6		If available, airplane wet landing distance divided by 0.6. Otherwise, airplane dry landing distance divided by 0.6 then multiplied by 1.15

APPENDIX 1. WEBSITES FOR MANUFACTURERS OF AIRPLANES OVER 60,000 POUNDS (27,200 KG)

Airplane Manufacturers	Website
Airbus	www.airbusworld.com/ (Registration required)
Antonov	www.antonov.com
BAE Systems (military aircraft)	www.baesystems.com
Boeing	www.boeing.com/airports
Bombardier	www.bombardier.com
Bristol (British Aircraft Corporation)	www.baesystems.com
Canadair	www.canadair.com
Dassault Aviation	www.dassault-avaition.com
de Havilland (Hawker Siddley Group, now British Aerospace)	www.dhsupport.com
Embraer	www.embraer.com
Fairchild Dornier	www.fairchilddornier.com
Fokker	www.fokker.com
General Dynamics (Gulfstream Aerospace Corporation)	www.generaldynamics.com
Grumman	www.northgrum.com
Gulfstream (General Dynamics Corporation)	www.gulfstream.com
Hawker Siddeley Group (British Aerospace Corporation)	www.bombardier.com
Ilyushin	No existing web page Mailing address: 45g Liningradsky Prospekt 125190 Moscow Phone: 7 (095) 157-3312
Kawasaki (military aircraft)	www.khi.co.jp
Lockheed Martin (military aircraft)	www.lmco.com
MAI	www.merlinaircraft.com
McDonnell Douglas	www.boeing.com
Saab Aircraft	www.saabaircraft.com

Airplane Manufacturers	Website
Short Brothers (Bombardier)	www.bombardier.com
Tupolev	www.tupolev.ru

APPENDIX 2. SELECTED FEDERAL AVIATION REGULATIONS CONCERNING RUNWAY LENGTH REQUIREMENTS

Part	Section
Part 23: Airworthiness standards: Normal, utility, acrobatic, and commuter category airplanes	Section 45: General
Part 25: Airworthiness standards: Transport category airplanes	Section 105: Takeoff
Part 25: Airworthiness standards: Transport category airplanes	Section 109: Accelerate-stop distance
Part 25: Airworthiness standards: Transport category airplanes	Section 113: Takeoff distance and takeoff run
Part 91: General operating and flight rules	Section 605: Transport category civil airplane weight limitations
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 173: General
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 177: Airplanes: Reciprocating engine-powered: Takeoff limitations
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 189: Airplanes: Turbine engine powered: Takeoff limitations
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 195: Airplanes: Turbine engine powered: Landing limitations: Destination airports
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 197: Airplanes: Turbine engine powered: Landing limitations: Alternate airports
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 199: Non-transport category airplanes: Takeoff limitations
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 203: Non-transport category airplanes: Landing limitations: Destination airport
Part 121: Operating requirements: Domestic, flag, and supplemental operations	Section 205: Non-transport category airplanes: Landing limitations: Alternate airport
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 367: Large transport category airplanes: Reciprocating engine powered: Takeoff limitations
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 375: Large transport category airplanes: Reciprocating engine powered: Landing limitations: Destination airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 377: Large transport category airplanes: Reciprocating engine powered: Landing limitations: Alternate airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 379: Large transport category airplanes: Turbine engine powered and Takeoff limitations
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 385: Large transport category airplanes: Turbine engine powered: Landing limitations: Destination airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 387: Large transport category airplanes: Turbine engine powered: Landing limitations: Alternate airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 393: Large non-transport category airplanes: Landing limitations: Destination airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 395: Large non-transport category airplanes: Landing limitations: Alternate airports
Part 135: Operating requirements: Commuter and on demand operations and rules governing persons on board such aircraft	Section 398: Commuter category airplanes performance operating limitations

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APPENDIX 3. EXAMPLES USING AIRPLANE PLANNING MANUALS

EXAMPLE SCENARIO #1. BOEING 737-900

1-1. INFORMATION. This example scenario, involving a Boeing 737-900, allows the airport designer to use published information in the airplane manufacturer's airport planning manual (APM). That is, the airport's mean daily maximum temperature for the hottest month falls within the permissible temperature range for the provided SDT + Temp chart. The airport designer will determine the separate length requirements for takeoff and landing, make necessary adjustments to those lengths, and then select the longest length as the recommended runway length. The example also assumes that the length of haul is of sufficient range so that the takeoff operating weight is set equal to the MTOW.

1-2. DATA. The calculation will use the following design conditions:

a.	Airplane	Boeing 737-900 (CFM56-7B27 Engines)
b.	Mean daily maximum temperature of hottest month at the airport	84° Fahrenheit (28.9° C)
c.	Airport elevation	1,000 feet
d.	Maximum design landing weight (see table A3-1-1)	146,300 pounds
e.	Maximum design takeoff weight (non-Federally funded project; see table A3-1-1)	174,200 pounds
f.	Maximum difference in runway centerline elevations	20 feet

1-3. CALCULATIONS. The steps used in the calculations are those provided in paragraph 403, noting applicable conditions. Figures A3-1-1 and A3-1-2 are used for the calculations. It is noted that the charts are only for airport design purposes and not for flight operations.

a. Landing Length Requirement (see figure A3-1-1).

(1) Step 1 – the Boeing 737-900 APM provides three landing charts for flap settings of 40-degrees, 30-degrees, and 15-degrees. The 40-degree flap setting landing chart, figure A3-1-1, is chosen since, it results in the shortest landing runway length requirement.

(2) Steps 2 and 3 – Enter the horizontal weight axis at 146,300 pounds and proceed vertically and interpolate between the airport elevations "wet" curves of sea level and 2,000 feet for the 1,000-foot wet value. Wet curves are selected because the airplane is a turbo-jet powered airplane (see paragraph 508). Interpolation is allowed for both design parameters.

(3) Step 4 – Proceed horizontally to the length axis to read 6,600 feet. Interpolation is allowed for this design parameter.

(4) Step 5 – Do not adjust the obtained length since the "Wet Runway" curve was used. See paragraph 508 if only "dry" curves are provide.

(5) The length requirement is 6,600 feet. **Note:** Round lengths of 30 feet and over to the next 100-foot interval. Thus, the landing length for design is 6,600 feet.

b. Takeoff Length Requirement (see figure A3-1-2).

(1) Step 1 – The Boeing 737-900 APM provides a takeoff chart at the standard day + 27°F (SDT + 15° C) temperature applicable to the various flap settings. Notice that this chart can be used for airports whose mean daily maximum temperature of the hottest month at the airport is equal to or less than 85.4° F (29.7° C). Since the given temperature for this example is 84° F (28.9° C) falls within this range, select this chart. See figure A3-1-2.

(2) Steps 2 and 3 – Enter the horizontal weight axis at 174,200 pounds and proceed vertically and interpolate between the airport elevation curves of sea level and 2,000 feet for the 1,000-foot value. Interpolation is allowed for both design parameters. **Note**: As observed in this example, a takeoff chart may contain under the “Notes” section the condition that linear interpolation between elevations is invalid. Because the application of the takeoff chart is for airport design and not for flight operations, interpolation is allowed.

(3) Step 4 – Proceed horizontally to the length axis to read 8,800 feet. Interpolation is allowed for this design parameter.

(4) Step 5 – Adjust for non-zero effective runway gradient (see paragraph 509).

$$8{,}800 + (20 \times 10) = 8{,}800 + 200 = 9{,}000 \text{ feet}$$

(5) The takeoff length requirement is 9,000 feet. **Note:** Round lengths of 30 feet and over to the next 100-foot interval. Thus, the takeoff length for design is 9,000 feet.

1-4. ANSWER.

Max. Landing Design Weight	146,300 pounds
Max. Takeoff Design Weight	174,200 pounds
Landing Length	6,600 feet
Takeoff Length	9,000 feet

Select the longest length for airport design. In this case, the takeoff length of 9,000 feet is the recommended runway length.

**Table A3-1-1. Boeing 737-900 General Airplane Characteristics
(Reference document number: D6-58325-3)**

CHARACTERISTICS	UNITS	737-900	
MAX DESIGN TAXI WEIGHT	POUNDS	164,500	174,700
	KILOGRAMS	74,616	79,243
MAX DESIGN TAKEOFF WEIGHT	POUNDS	164,000	174,200
	KILOGRAMS	[illegible]	79,016
MAX DESIGN LANDING WEIGHT	POUNDS	[illegible]	146,300
	KILOGRAMS	[illegible]	66,361
MAX DESIGN ZERO FUEL WEIGHT	POUNDS	138,300	140,300
	KILOGRAMS	[illegible]	63,639
OPERATING EMPTY WEIGHT (1)	POUNDS	[illegible]	94,580
	KILOGRAMS	[illegible]	42,901
MAX STRUCTURAL PAYLOAD	POUNDS	43,720	45,720
	KILOGRAMS	19,831	20,738
SEATING CAPACITY (1)	TWO-CLASS	177	177
	ALL-ECONOMY	189	189
MAX CARGO - LOWER DECK	CUBIC FEET	1,835	1,835
	CUBIC METERS	52.0	52.0
USABLE FUEL	US GALLONS	6875	6875
	LITERS	26,022	26,022
	POUNDS	46,063	46,063
	KILOGRAMS	20,894	20,894

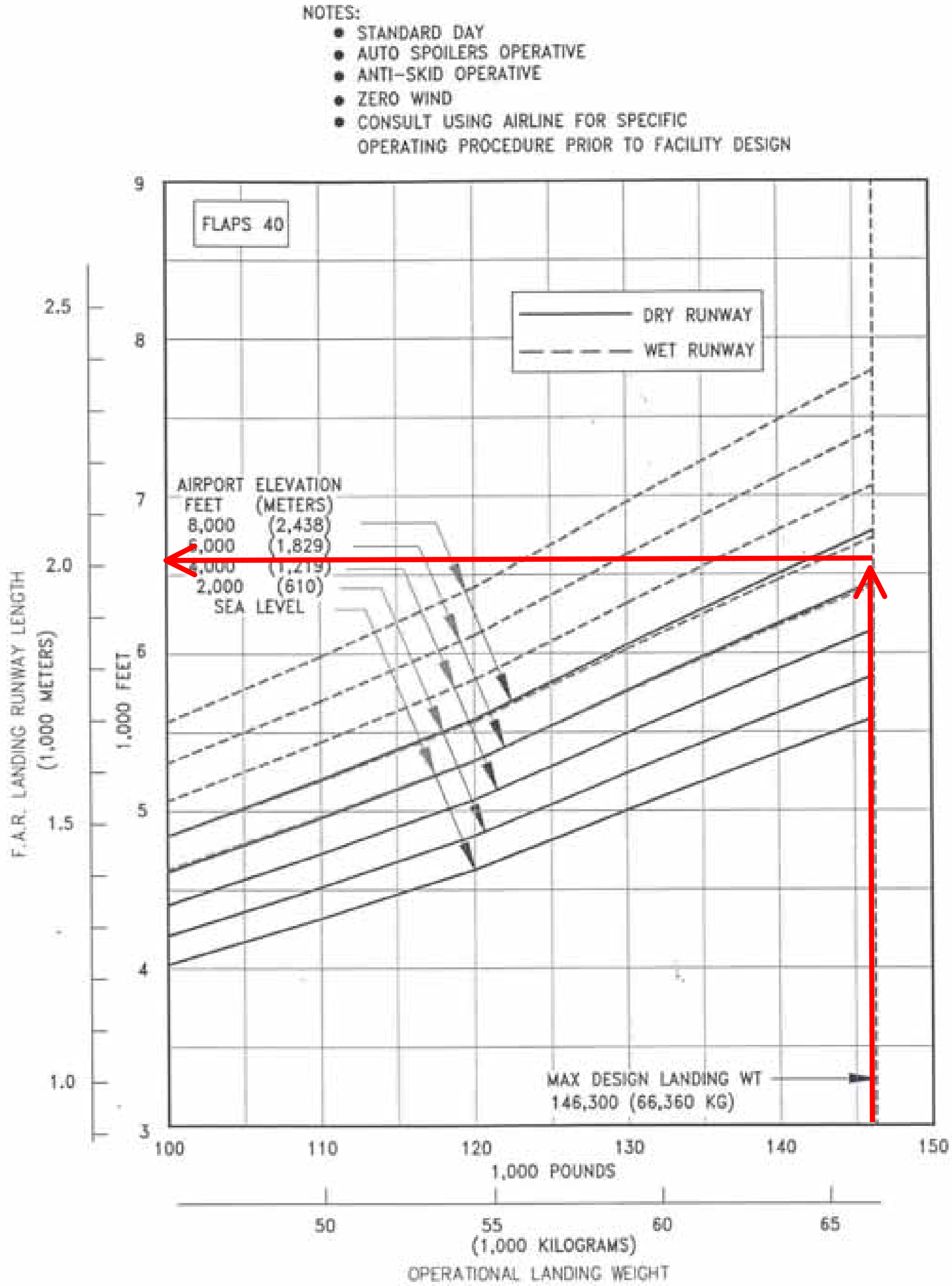
Takeoff Weight

Landing Weight

NOTE: (1) OPERATING EMPTY WEIGHT FOR BASELINE MIXED CLASS CONFIGURATION. CONSULT WITH AIRLINE FOR SPECIFIC WEIGHTS AND CONFIGURATIONS.

2.1.4 GENERAL CHARACTERISTICS
MODEL 737-900

Figure A3-1-1. Landing Runway Length for Boeing 737-900 (CFM56-7B27 Engines)
(Not for Flight Operations)
(Reference document number: D6-58325-3)

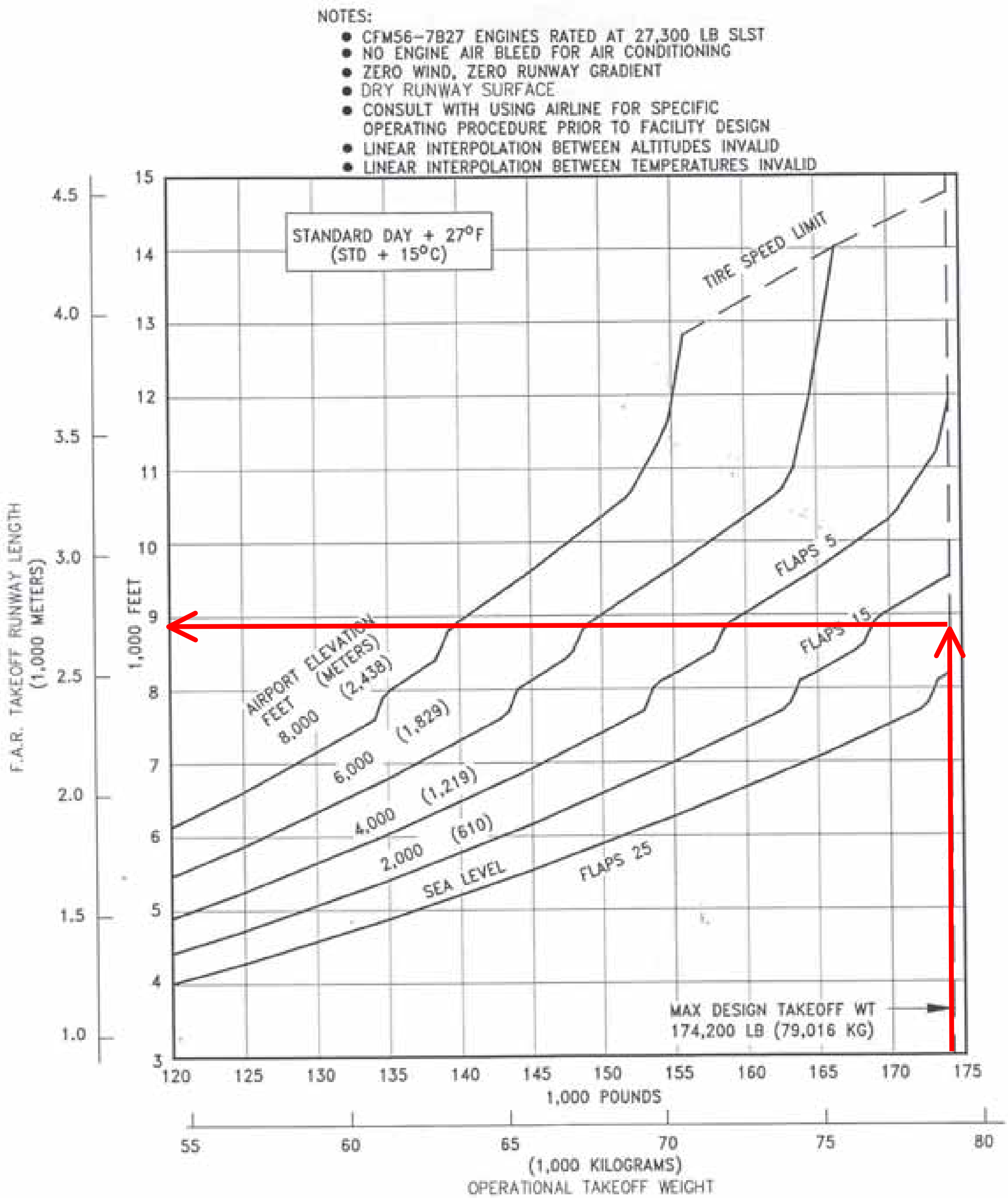


3.4.10 F.A.R. LANDING RUNWAY LENGTH REQUIREMENTS - FLAPS 40
MODEL 737-900

D6-58325-3

DECEMBER 2001 103

Figure A3-1-2. Takeoff Runway Length for Boeing 737-900 (CFM56-7B27 Engines)
(Not for Flight Operations)
(Reference document number: D6-58325-3)



3.3.46 F.A.R. TAKEOFF RUNWAY LENGTH REQUIREMENTS
STANDARD DAY +27°F (STD + 15°C), DRY RUNWAY
MODEL 737-900 (CFM56-7B27 ENGINES AT 27,300 LB SLST)

D6-58325-3

DECEMBER 2001 87

EXAMPLE SCENARIO #2. SAAB FAIRCHILD 340B

2-1. INFORMATION. This example scenario, involving a SAAB Fairchild 340B, allows the airport designer to use published information in the airplane manufacturer's airport planning manual (APM) instead of the figures provided in chapter 3 of this AC. The airport designer will determine the separate length requirements for takeoff and landing, make necessary adjustments to those lengths, and then select the longest length as the recommended runway length. The example also assumes that the length of haul is of sufficient range so that the takeoff operating weight is set equal to the MTOW.

2-2. DATA. The calculation will use the following design conditions:

a.	Airplane	Saab 340B (CT7-9B Engines)
b.	Mean daily maximum temperature of hottest month at the airport	74° Fahrenheit (23.3° C)
c.	Airport elevation	Sea level
d.	Maximum design landing weight (see table A3-2-1)	28,000 pounds
e.	Maximum design takeoff weight (non-Federally funded project; see table A3-2-1)	28,500 pounds
f.	Maximum difference in runway centerline elevation	20 feet

2-3. CALCULATIONS. The steps used in the calculations are those provided in paragraph 403, noting applicable conditions. Figures A3-2-1 and A3-2-2 are used for the calculations. It is noted that the charts are only for informational design purposes and not for flight operations.

a. Landing Length Requirement (see figure A3-2-1).

(1) Step 1 – the SAAB 340 APM provides two landing charts one for a flap setting of 25-degrees and one for a flap setting of 35-degrees. The 35-degree flap setting landing chart, figure A3-2-1, is chosen since it results in the shorter landing runway length requirement.

(2) Steps 2 and 3 – Enter the horizontal weight axis at 28,000 pounds and proceed vertically to the airport elevation curve for sea level. Select the dash curve labeled "FAR" and not the solid curve labeled "JAR" (see subparagraph 402b).

(3) Step 4 – Proceed horizontally to the length axis to read 3,450 feet.

(4) Step 5 – Do not adjust the obtained length for wet landing operations for the SAAB 340B since it is not a turbojet-powered airplane. The 15-percent adjustment applies only to turbojet-powered airplanes (see paragraph 508).

(5) The landing length requirement is 3,450 feet. **Note:** Round lengths of 30 feet and over to the next 100-foot interval. Thus, the landing length for design is 3,500 feet.

b. Takeoff Length Requirement (see figure A3-2-2).

(1) Step 1 – the SAAB 340 APM provides a takeoff chart at the standard day + 18°F (10° C) temperature for flap setting of 15-degrees. Notice that this chart can be used for airports whose mean daily maximum temperature of the hottest month at the airport is equal to or less than 80°F (26.7° C). Since the given temperature for this example is 74° F (23.3° C) falls within this range, select this chart. See figure A3-2-2.

(2) Steps 2 and 3 – Enter the horizontal weight axis at 28,500 pounds and proceed vertically to the airport elevation curve for sea level. Select the dash-curve labeled "FAR" and not the solid-curve labeled "JAR" (see subparagraph 402b). Interpolation is allowed for both design parameters.

(3) Step 4 – Proceed horizontally to the length axis, the result is 4,375 feet.

(4) Step 5 – Adjust for non-zero effective runway gradient (see paragraph 509).

$$4{,}375 + (20 \times 10) = 4{,}375 + 200 = 4{,}575 \text{ feet}$$

(5) The takeoff length requirement is 4,575 feet. **Note:** Round lengths of 30 feet and over to the next 100-foot interval. Thus, the takeoff length for design is 4,600 feet.

2-4. ANSWER.

Max. Landing Design Weight	28,000 pounds
Max. Takeoff Design Weight	28,500 pounds
Landing Length	3,500 feet
Takeoff Length	4,600 feet

Select the longest length for airport design. In this case, the takeoff length of 4,600 feet is the recommended runway length.

Table A3-2-1. SAAB 340 Airplane Characteristics
(Reference number SAAB 340 ACAP 000)

Takeoff Weight

SAAB 340
Airplane Characteristics

Weights

AIRLINER TYPICAL SPEC. WEIGHTS	340A lb	340A Kg	340B lb	340B Kg
MAX DESIGN TAXI WEIGHT (MTW)	28300	12835	28800	13065
MAX DESIGN TAKE-OFF WEIGHT (MTOW)	28000	12700	28500	12930
MAX DESIGN LANDING WEIGHT (MLW)	27200	12340	28000	12700
MAX DESIGN ZERO FUEL WEIGHT (MZFW)	25700	11660	26000	11795
OPERATIONAL EMPTY WEIGHT (OEW)	17615	7990	17715	8035
PAYLOAD (P/L)	8085	3670	8285	3760

Landing Weight

**Figure A3-2-1. Landing Runway Length for SAAB 340B (CT7-9B Engines)
(Not for Flight Operations)
(Reference number SAAB 340 ACAP 000)**

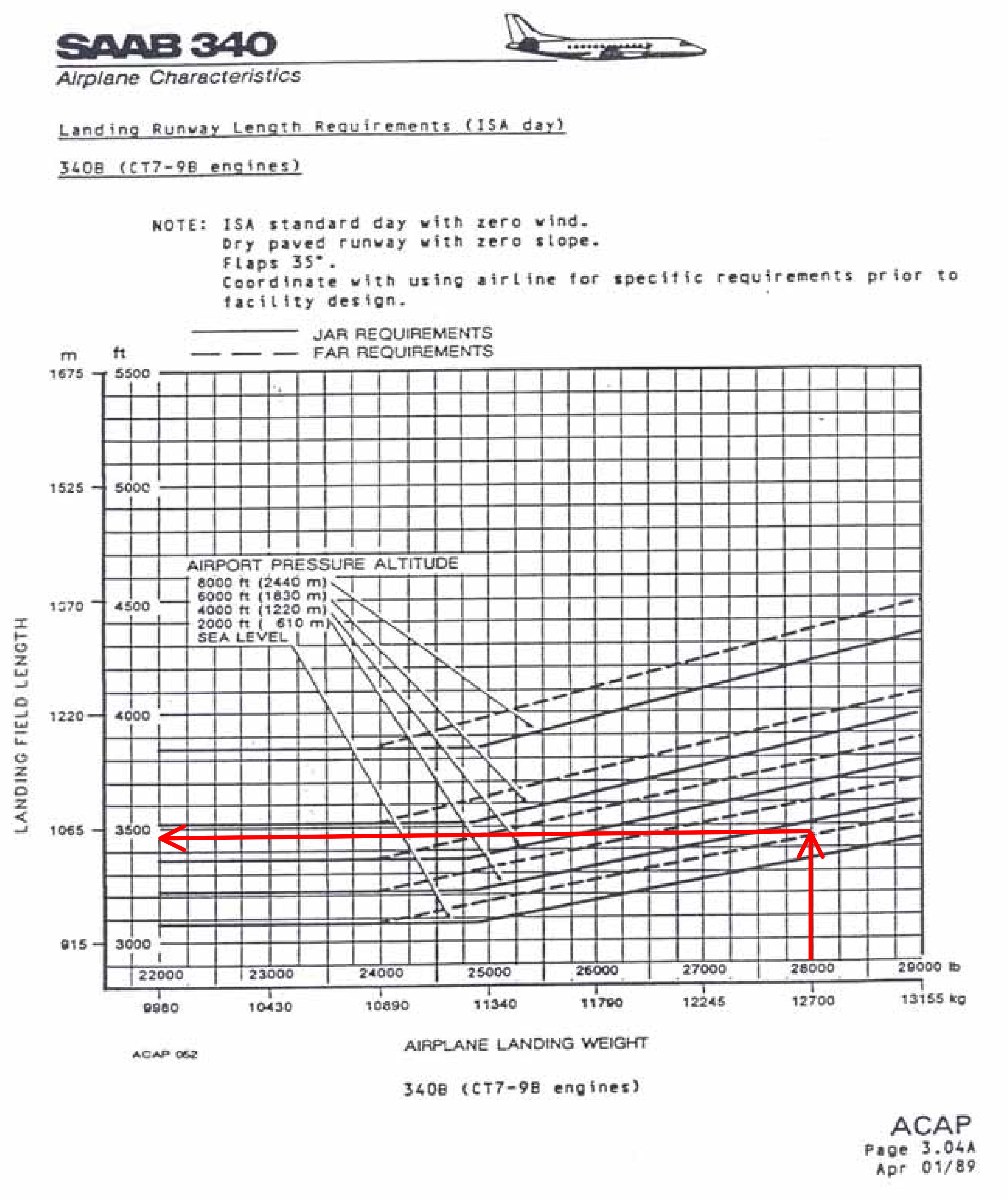


Figure A3-2-2. Takeoff Runway Length for SAAB 340B (CT7-9B Engines)
(Not for Flight Operations)
(Reference number SAAB 340 ACAP 000)

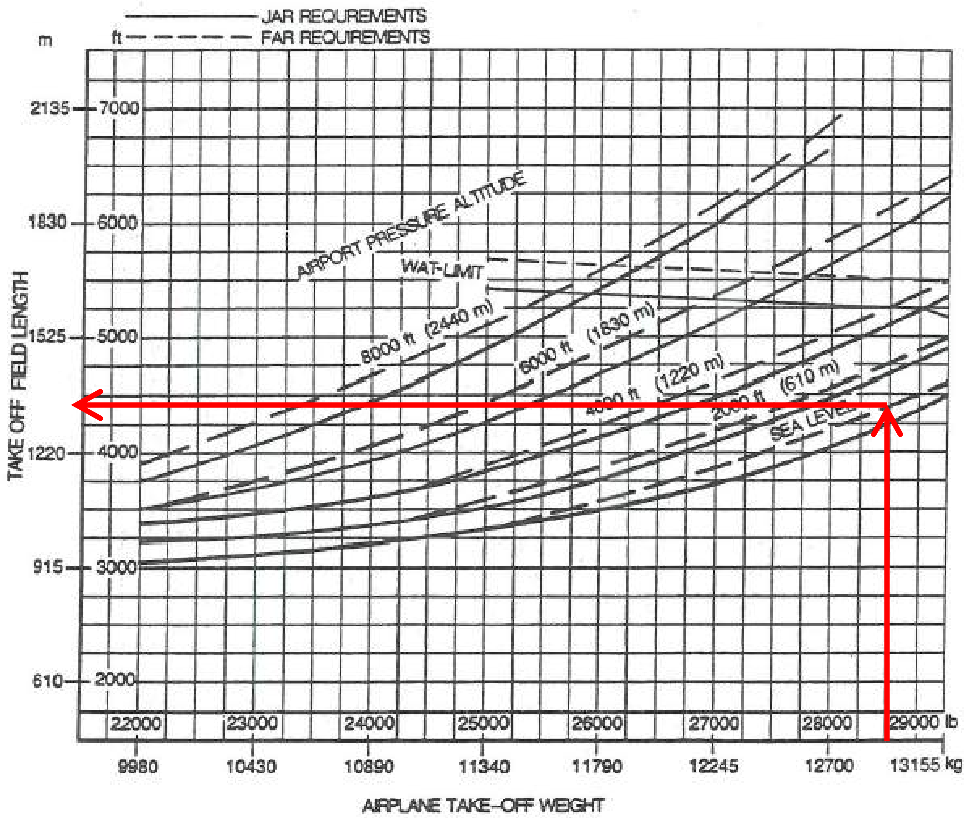
SAAB 340

Airplane Characteristics

Take-Off Runway Length Requirements (ISA day +10°C)

340B (CT7-9B engines)

NOTE: ISA standard day +10°C with zero wind.
Max. take-off power.
Dry paved runway with zero slope.
Flaps 15°
Environmental control system off.
De-icing system off.
Coordinate with using airline for specific requirements prior to facility design.



ACAP 043

340B (CT7-9B engines)

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Ann Arbor Municipal Airport (ARB), Ann Arbor Michigan - Draft Environmental Assessment FAA Combined Comment Matrix

--May thru October 2016--

Comment Number	Page Number	Section Number	Paragraph	FAA Comment	MDOT Comment Resolution
1	1	title page	n/a	Need statement that "This Environmental Assessment becomes a *Federal* document…" before the FAA signature block, per FAA Order 1050.1F paragraph 6-2.1(a).	Revised draft EA
2	1	title page	n/a	Federal signature block should read "Responsible FAA Official"	Revised draft EA
3	9, 10 & 12	1.3 & 1.4	all	The Intro and background sections are discussing the State Standards. What are the Federal Requirements, in addition to the State reqmts? Critical Aircraft (1.5.1) & use of runway, Aircraft Activity (1.5.2) and Characteristics /Recommendations (1.5.3) all need to be in the background section before purpose and need section. Info in P & N needs to be in the background section.	On April, 21 2015 the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft. AERO put significant effort into modeling this draft after the Bolingbrook example and believes the content is consistent. The draft EA was revised to try and clarify the issue raised here, yet remain consistent with the example previously provided.
4	10	1.3	6	Need a discussion of the SBGP so that the reader is better able to understand the division of porposed actions between state and Federal	Revised draft EA
5	10	1.3	6	The paragraph is implying that the ALP is "fully approved".. If this were the case, it would have been unconditionally approved rather than conditionally approved. - Remove, "…it is in fact a fully approved ALP" - Add "conditional" to the last sentence, "...prior to AERO signing the conditional approval letter."	Revised draft EA
6	12	1.3	2	Please explain why the comments from the ADO were not addressed.	Revised draft EA
7	12	1.4	3	Is the purpose to meet the "FAA design objectives" or to accommodate the runway length needed by critical aircraft? This is implying that FAA is forcing the runway extension. Recommend changing the wording to clarify that aircraft are currently impacted by the shorter runway length. Is "increasing the line of sight for ATCT personnel" (presumably to improve a hotspot) more of a Need than a purpose?	Revised draft EA

8	12	1.4	4	States that the Need is to allow aircraft to operate at "Optimum Capabilities", should this include why there's a need to operate at "optimum capabilities"? Where are aircraft going, how often is the runway length affecting users?	In response to FAA's question regarding the need to allow the majority of critical aircraft to safely operate at their optimum capabilities without weight restrictions, we reference Paragraph 103 of FAA Advisory Circular 150/5325-4B, *Runway Length Requirements for Airport Design* . This paragraph states "The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions". The term "regularly use it" is further identified by the FAA as being the volume of usage provided by the runway's particular critical aircraft category (a minimum of 500 Annual Itinerant Operations). As far as FAA questions related to where the aircraft are going, an Origin-Destination Analysis was conducted using records obtained from the FlightAware Instrument Flight Rules (IFR) flight plan database associated with ARB. Flight operations were verified between ARB and at least 31 other states (approximately 63% of the continental U.S.). A list of all of the states involved is included in User Survey Supplemental Report No. 2, which is included in Appendix A-2 of the Draft EA. Additional information related to both of the above paragraphs is included in Sections 1.5.1, 1.5.2, and 1.5.3 of the Draft EA. Revised draft EA where appropriate.
9	12	1.4	3	Another sentence should be added after the first sentence of the paragraph to explain that the Purpose includes lengthening and shifting the runway. The second sentence is a Need and should be placed in the following paragraph.	Revised draft EA
10	12	1.4	all	Use of the term "Safely" implies the airport is not safe currently.	Revised draft EA
11	12	1.4	all	The purpose and needs statement should be complete and concise. This would include stating the problem that is looking to be addressed. A statement of overall safe and efficient and usable is a general statement and should be tightened up to reflect the discussion that follows. It is confusing on why the line of sight issue is singled out in the statement. Consider revising this statement.	On April, 21 2015 the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft. AERO put significant effort into modeling this draft after the Bolingbrook example and believes the content is consistent. The draft EA was revised to try and clarify the issue raised here, yet remain consistent with the example previously provided.
12	12	1.4	4	Clarify why the statement regarding aircraft says majority and not "all' aircraft?	Revised draft EA

13	13	1.5.1	2	Clarify whether the critical aircraft is properly grouped; is it okay to use the category B-II Small Aircraft? Cross reference B-II Large in the document.	The critical aircraft category of "B-II Small Aircraft" is properly grouped. In conducting the analysis of the critical aircraft, the distinction between Small versus Large category aircraft was considered in order to determine which Runway Length Curves in FAA Advisory Circular 150/5325-4B would be applicable to ARB. The curves in Chapter 2 are applicable to Small category aircraft, and the curves in Chapter 3 are applicable to Large category aircraft. The FAA recommended runway length of 4,200' was obtained from Figure 2-2 of Chapter 2. Had the critical aircraft at ARB been determined to be of the Large category, Tables 3-1 and 3-2 of Chapter 3 show that a much longer runway length would have been recommended by the FAA Advisory Circular. As far as FAA's request to cross reference the B-II Large category in the EA document, it is clearly referenced in section 1.5.3.
14	13	1.5.1	5	This paragraph is general in nature. A runway of 4,300 feet would allow without load restrictions… why 4,300's, why not 4,500, 5,000, or 10,000. The paragraph should instead define the runway length needs of the aircraft regularly using the runway, including haul lengths and loads rather than suddenly put out that 4,300 ft. would satisfy it.	As explained in Section 1.5.3, The FAA recommended runway length of 4,200 feet at ARB was obtained by calculation following the methodology referenced in Chapter 2 of FAA Advisory Circular 150/5325-4B, "Runway Length Requirements for Airport Design," a publication that is used nationally by the agency. The methodology and figures referenced in this section of the AC result in recommended runway lengths that are airport-specific, and they can vary by hundreds of feet from site to site, depending on the specific airport elevations and mean daily maximum temperatures used in the calculations. For example, if a representative higher-elevation airport in the Denver area had an elevation of 5,000 feet MSL, interpolation of Figure 2-2 of Chapter 2 of the AC shows that a runway length of approximately 5,000 feet in length would be recommended for the same B-II Small category of critical aircraft. In Michigan, airport elevations at our public-use airports only range from 578 feet to 1,622 feet MSL. The AERO runway length recommendation of 4,300 feet is a statewide standard for all airports in the state with category B-II critical aircraft classifications, as identified in Table 40 of the Michigan Airport System Plan (MASP). Since airport elevations and mean maximum temperatures do not vary significantly from airport to airport in Michigan, as opposed to many other states, AERO uses a single runway length recommendation for all airports of the same critical aircraft classification.
14 Cont.	13	1.5.1	5		The reason that the preferred alternative in the draft EA references a runway length of 4,300 feet is that this length meets both FAA and AERO runway length recommendations for critical aircraft in the B-II Small category.

15	13	1.5.1	6	The example seems to be an extreme case, how often does this user use the airport and what type of B-II aircraft is it? Why do they base at ARB instead of another close airport if they cannot use the aircraft to it's max capability above 40 degree F?	This user flies approximately 200 operations from ARB annually in Cessna 560 Excel jet. The user's business is based in Ann Arbor and the proximity to the airport provides convenience and a significant time savings over other local airports.
16	14	1.5.1	1	"Part 135 operators must reduce the useable length of the runway by anywhere from 20-35% based on runway conditions" has this quote been verified through citation to the actual Part 135?	The corporate pilot quotation regarding Part 135 operators has been verified to 14 CFR 135.385 paragraphs (b) and (f).
17	14	1.5.2	2	"Also, approximately 67% of the IFR flight plan records examined were between ARB and out-of-state locations." It's not clear how far of a distance these itinerant operations are going.. Are they all to surrounding States or are the haul length further?	The first sentence of Section 1.5.2 of the draft EA refers the reader to User Survey Supplemental Report No. 2 in Appendix A-2 for full details regarding the Origin-Destination Analysis. Exhibit No. 2 in the User Survey Supplemental Report lists the names of all 31 states (and Washington DC) that were associated with flights to and from ARB, as obtained from just the IFR Flight Plan database of FlightAware. Potentially, there are even more states associated with ARB flights than those confirmed by the referenced FlightAware records. Nonetheless, the records reviewed confirm that direct flights were conducted from ARB to other airports located in states as far away as Arizona, Texas, Florida, and Maine, just to name a few. The confirmation of flight operations between ARB and at least 31 other states verifies that operations are not confined to the few states surrounding Michigan, and that flights with long distance stage lengths are being conducted.
18	14	1.5.2	2	Second half of paragraph: Why are NetJets and AvFuel further called out in the two final sentences? What about the other six companies?	While many of the large corporations listed as users of ARB are commonly known, NetJets and AvFuel were lesser known entities that are active at the airport. NetJets because of the variety of businesses they serve and AvFuel because they are a local business.
19	16	1.5.3	FAA	Clarify why 4,200' (AC 150/5325-4B) would not support the Purpose and Need (P& N) as opposed to the requested 4,300.'	As explained in section 1.5.3 of the draft EA, utilization of current FAA runway design standards results in a recommended runway length of 4,200 feet at ARB. Utilization of current AERO runway design standards results in a recommended runway length of 4,300 feet. Although the recommendations are very similar, the reason that 4,300 feet was referenced in the draft EA in meeting the purpose and need is that it meets both the FAA and AERO current standards for runway length recommendations based on the critical aircraft category of aircraft.
20	16	1.5.3	FAA	Why isn't 4,200' listed as an alternative?	As explained in Comment 19 shown above, the reason that a runway length of 4,200 feet was not included as an alternative is that it is very similar in length to the 4,300 foot long alternative, and it does not meet current AERO runway design standards.
21	16	1.5.3	3	"The AERO recommendation of 4,300 feet is a statewide standard…" Recommend including how AERO developed their standard. What is this length based on, is it a random length they chose or does it meet the requirements identified in the P&N (optimum capabilities of the critical aircraft at ARB)?	Revised draft EA

22	16	1.5.3	4	Clarify whether the category B-II Small Aircraft requires a runway length of up to 4,300, or do the larger B-II airplanes require this length? The Small B-II may be on the lower end of the spectrum?	Revised draft EA
23	16/17	1.5.4	8 (last)/several	Clarify why User-Survey Reports were heavily relied upon? Why not TAF and Tower Counts? TAF was very close to accurate, however it is not logical to conclude (quantitative to qualitative) that ops will increase, because TAF may not always support constant increase. (Justify, e.g. is there a new coach that may boost attendance for Michigan games which will increase probability of increased attendance/travel?)	The reason that User Survey Reports were relied upon in this study is that they distinguish between the various aircraft makes and models, while the TAF and Tower Counts do not. From the various make and model information, aircraft approach categories, design groups, weight classifications (large vs. small), and critical aircraft categories can be determined. The TAF shows total numbers of forecasted operations, but no distinction of aircraft makes or models. The Tower Counts show historical numbers of total operations, but no distinction of aircraft makes or models. All three data sources (user surveys, TAF reports, and Tower Count reports) are useful for different aspects of analysis and forecasting, and all of these sources were used appropriately in this study. As stated in paragraph 1.5.4, the current TAF (which is prepared by FAA personnel and updated annually) forecasts continually increasing operations at ARB from year 2014 through year 2040, and the current MASP (which is prepared by MDOT personnel and updated periodically) also forecasts similar numbers of continually increasing operations through year 2030.
24	17	1.5.4	4	The paragraph indicates that the TAF is used to project forecasted operations to 2040. Does the airport have a locally developed forecast to compare this to? Does the airport understand how the TAF was developed and if it's really a good indicator of B-II itinerant ops?	While the airport does not have a locally developed forecast, the current FAA-developed TAF as well as the current MDOT-developed MASP both show continually increasing operations at ARB from present date at least through the year 2030. It is logical to conclude that all categories of aircraft that use the airport would show some increase in their annual operational numbers as part of the overall increase in activity. But even if category B-II operations remained at the level of the 538 annual operations that were documented in year 2014, and the entire increase in operations was attributed solely to increased activity by the smaller categories of aircraft (highly unlikely – especially if the runway is extended to 4,300 feet in length as proposed), the justification for the proposed project would still be substantiated both presently and through future years.
25	17	1.5.4	5	"…it is logical to conclude that operations by B-II category aircraft and larger will also increase beyond the 551 that were documented in 2014." Table 1-1 indicates that the 5-year trend from 2010 to 2014 is a steady or downward trend in B-II ops. Why is it logical to believe B-II ops will increase given the history of ops at the airport? - does the 551 include just B-II aircraft or B-II and larger as indicated in the paragraph? - How many of the 551 ops by B-II aircraft are by the representative King Air 200 or aircraft with 10 or more passenger seats?	Changes made and clarification added to Section 1.5.4 as requested. A table has also been added to User Survey Report No. 4 (Exhibit 1 of Appendix A-4 of the draft EA) which clarifies the number of annual operations conducted in 2014 by specific aircraft models and groupings (B-II, B-III, and C-III). As a result of preparing the table and analyzing and categorizing the operations by specific aircraft models, the operations performed exclusively by category B-II aircraft have been revised to 538 instead of the 551 that were mentioned in the previous draft of the EA. A total of 544 annual operations were performed by the combined B-II and Larger categories of aircraft. The text in Section 1.5.4 as well as numbers shown in Table 1-1 have been revised accordingly.

25 Cont.	17	1.5.4	5		In answer to FAA's question regarding a "steady or downward trend in B-II ops" from year 2010 to 2014: Table 1-1 of the draft EA does show minor fluctuations in the levels of estimated annual B-II operations during this time frame, from a low of 537 to a high of 600. These numbers were based on the minor fluctuations in total operations that occurred during the same time frame. The trend is not a steady downward trend as FAA suggests, but rather the numbers fluctuate both downwards and upwards. The numbers are also relatively close to each other, as opposed to being drastically different. The severe and multi-year economic recession that originated in 2009 likely played a role in the minor fluctuations of the total operations at ARB during the time frame in question, and as a result the minor fluctuations in the number of estimated B-II operations. Since the TAF (which is prepared by FAA personnel) shows that Total Annual Operations at ARB are forecasted to increase every year beyond year 2014, it is logical to conclude that operations by B-II category aircraft will also increase beyond the 538 that were documented in 2014. As noted in the text of revised Section 1.5.4 of the draft EA, even if B-II category operations do not increase in the future, but remain the same as in year 2014 (very unlikely if total operations are increasing), justification for the proposed runway extension would still be substantiated through the year 2040.
25 Cont.	17	1.5.4	5		In answer to FAA's questions regarding more details of operations performed by "B-II" versus "B-II and Larger" categories of aircraft, as well as more specifics regarding individual aircraft types, the information is shown in Exhibit 1 of User Survey Report No. 4 (see Appendix A-4 of the draft EA).
26	17	1.5.4	6	"These numbers have been calculated based on the percentage of actual B-II operations to actual Total Operations…" Why wasn't flight aware and FAA data used to determine actual usage by B-II aircraft over more years? Was FAA or Flight Aware data compared to the Airport User Survey data used for 2007, 2009, and 2014?	Changes made and clarification added to Section 1.5.4 as requested. In answer to FAA's questions, FlightAware data was used in the determination of B-II operations for survey data years 2007 and 2009, and FAA's Traffic Flow Management System Counts (TFMSC) data was used in the determination of B-II operations for survey data year 2014. This is clearly explained in User Survey Report Nos. 2, 3, and 4 (see Appendices A-2, A-3, and A-4 of the draft EA). Also, Exhibit 1 in each of these three reports shows a listing of the specific B-II category aircraft that were included in these records. Operational data obtained from both the FlightAware and the TFMSC sources is considered the most accurate available, as it is based on actual documented operations obtained from Flight Plans filed by pilots, over an entire calendar year of time. None of the data is based on estimates of annual operations generated by pilots, or proration of partial year survey data, as is common in conducting many other operational surveys.
27	20	1.6	first	First sentence should read: "The City of Ann Arbor proposes to extend and shift 160' the existing…"	Revised draft EA

28	20	1.6	2	"…as it does not currently meet the FAA design objectives" Recommend that all references to "FAA design objectives" be removed… the purpose should not be to meet FAA design objectives or put the onus on the FAA causing the runway length, but their user need for the longer runway	Excerpt directly from Purpose and Need...The **Purpose** of the proposed actions is to provide facilities at ARB that fully accommodate the operational requirements of critical aircraft currently using the airport, while at the same time enhancing safety. Revised draft EA as appropriate.
29	20	1.6	3	First sentence should read: "The existing runway approach light system pilots use to identify…"	Revised draft EA
30	20	1.6	3	After the second sentence, the remainder of the paragraph should read: "Due to difficulty in maintaing the system, the ODALS are currently temporarily out of service. Due to the fact that the Runway 24 end is proposed to be relocated, the FAA is proposing to permanenty decommission and remove the ODALS according to an FAA airspace letter signed on May 13, 2015, Airspace Case Number 15-AGL-14NR (Appendix H). A new runway approach lighting system will not be constructed as part of the proposed action."	Revised draft EA
31	20	1.6	4	Clarify throughout the document the direction of rw/taxi shifting and extension - either west or southwest	Revised draft EA where appropriate.
32	20	1.6	4	The Shift and Extension of the existing runway should be clarified, is the physical pavement going to be shifted and extended or is the pavement just going to be extended and the Runway 24 threshold moved 150 ft. If the remaining 150 ft pavement remains, is it usable? How will the existing taxiway across the threshold be handled (to the southeast)?	Revised draft EA to clarify, details contained in "proposed action" bulleted list.
33	20	1.6	5	delete entire paragraph, as this is not the appropriate section for this discussion.	Revised draft EA
34	20	1.6	6	Paragraph should read: "Implementation of the Preferred Alternative would meet the Purpose and Need by adequately addressing the needs of the…"	Revised draft EA
35	21	1.6	first bullet	To clarify the meaning, please reword this bullet	Revised draft EA
36	21	1.6	second bullet	specify that the parallel taxiway is designated Alpha	Revised draft EA
37	21	1.6	bullets 1, 2, 3	Clarify that 150' is being removed from the northeast end of the runway and added to the southwest end. Runway is being extended by 795'; please label the taxiway and rw; delineate why it is being extended by 945' if the new runway portion will be 795' once the 150' is newly constructed.	Revised draft EA (addressed by Comment #35)
38	21	1.6	bullets 1, 2, 3 & 4	Clarify whether entire runway is being reconstructed, or just portions to determine impacts.	There are no proposed actions to reconstruct the entire runway and the draft EA is clear that the proposed actions only impact the proposed 795' extension and the proposed 150' shift.
39	21	1.6	bullet 5	Reiterate throughout the document direction of the shift/extension	Revised draft EA where appropriate.
40	21	1.6	seventh bullet	Should read: "Relocate airport-owned Precision Approach…"	Revised draft EA
41	21	1.6	tenth bullet	Should read: "Relocate/reconstruct FAA-owned Ruwnay 6 Runway End Identifier…"	Revised draft EA
42	22	1.7.1	after first bullet	add new second bullet: "FAA acceptance of relocated NAVAIDs (REIL)	Revised draft EA

43	22	1.7.1	third bullet	I was unaware that this project would use AIP funds. If this is not the case, reword with the correct funding source or delete	In a December 2013 email between the FAA-Region and MDOT-AERO, the funding sources intended for the project were clarified and remain the same, State Apportionment, Non-primary Entitlements and State/Local Shares will be used.
44	22	1.7.1	3	This bullet needs to be removed. There are no AIP funds being sought or provided for this proposed action.	State Apportionment and Non-primary Entitlements are AIP funds.
45	22	1.8	all	The section labeled, "Other considerations" should be included in the purpose and needs section. These issues kept separate from the statement objectives makes it difficult to have a clear purpose and need statement and to recognize these as part of the project.	On April, 21 2015 the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft. AERO put significant effort into modeling this draft after the Bolingbrook example and believes the content is consistent. The draft EA was revised to try and clarify the issue raised here, yet remain consistent with the example previously provided.
46	22	1.8.1	1	"The proposed shift would enahance operatinal safety, and possibly prevent a runway incursion, by expanding the view of the hold area and paralle taxiway to ATCT personnel." Therefore, please clarify, does this this shift cause other operational issues with the existing Northeasternmost hangar apron view still blocked from ATCT line of sight? How will aircraft taxi to the Southeast hangar section? - Is 150 ft enough of a shift to remove the hot spot?	With the proposed shift of the A1 connector from Alpha Taxiway to Runway 06/24 to the southwest, the Line of Sight issue will be significantly improved. Aircraft entering the Movement Area from Echo, Delta and Charlie (east facing hangars only) will still have limited visual oversight by controllers. This will be a significant improvement over current conditions where all aircraft using the taxiway hold area of Runway 24 are in a restricted visibility area. The existing Delta taxiway from the southeast hangars will be shifted to the southwest as well under the proposed project. This will allow them full access from Runway 06/24 to the southeast hangar area with full visual access from the control tower. The proposed 150' shift will significantly improve the safety of ground operations of taxiing aircraft. While some visual restrictions for aircraft originating from the northeastern most T hangars will remain, it will be up the FAA to determine if this area should still be designated as a "hot spot."
47	23	1.8.1	second on page	In response to the first sentence, clarify what type of "more negative impacts" would there be?	Revised draft EA
48	23	1.8.1	2	"…than with the runway theshold shift alternative"… is the preferred alternative to shift the threshold only and leave the pavement, or to shift and remove the 150 ft of pavement?	Revised draft EA to clarify, details contained in "proposed action" bulleted list. (Section 1.6)
49	23	1.8.1	3	"…raising the tower in its existing location would very likely result in the tower penetrating the 7:1 transitional surfaces…" Has an airspace study been completed to determine if this is a hazard?	Changes made and clarification added to Section 1.8.1. In answer to FAA's question, yes an airspace study was completed to determine if a raised tower would become a hazard. See revised Section 1.8.1 for details.
50	23	1.8.1	4	How old is the ATCT? Is it due for a modernization or rehab that might cause it to be beneficial to move it?	The ATCT was constructed in the mid-1970's and the attached office structure was constructed around 2003. The ATCT exterior was rehabbed within the last 5 years. The Airport is unaware of any pending plans for additional modernization or rehab.
51	23	1.8.1	4	Delete "disruption of Airport Traffic Control operations"	Revised draft EA
52	23	1.8.2	1	"The proposed shift of the Runway 24 threshold would also allow for a clear 34:1 approach slope…" Why are they protecting for a 34:1 approach slope when the minimums for existing approaches are 1 mile? 34:1 is typically required for minimums below 3/4 mile. If the 34:1 doesn't apply, why would this be a "concern"?	The 34:1 approach slope is planned for future developments at ARB on the current ALP. (Sheet 4 - "Airport Layout Plan (Future)") Plus, any lowering of obstacles in the approach to a runway is an improvement and should always be attempted to improve the safety of the flying public.

53	23	1.8.2	5	Justify the slope gradient based on page 2 of the AC 150/5325 (10) Effective Runway Gradient	The justification of the slope gradient based on page 2 of the AC 150/5325 (10) Effective Runway Gradient will be accomplished once detailed design is performed on the preferred alternative.
54	24	1.8.3	1	Regarding 150/5235 4-B, Figures AC 2-1 and 2-2, an engineer from ARPs stated that the charts support the runway being extended to 4,150 when the temperature is higher than 82.5◦. But if the sponsor believes the longer runway is necessary please justify.	The mean daily maximum temperature of the hottest month of the year at ARB is 83.0 degrees F (July). The airport elevation is 839' MSL. When these numbers are factored into Figure 2-2 of FAA AC 150/5325-4B, the resulting recommended runway length is 4,200'. See the draft EA for additional information regarding the FAA recommendation of 4,200' versus the MDOT recommendation of 4,300'. (Section 1.5.3)
55	24	1.8.3	3	Please explain what is meant by a "local objective"	A "local objective" is a goal set by Ann Arbor Municipal Airport leadership that would be obtained by the implementation of the proposed airfield improvements.
56	24	1.8.3	3	several comments. How many overruns occurred? This objective should not be labeled as a local. The runway design criteria accounts for RSAs an RPZ for the critical aircraft.	Eleven overruns have been documented. If additional overruns occurred, the Airport has been unable to find verifiable documentation for them. As overruns are not officially recognized by the FAA or AERO as justification for extending a runway, the objective of keeping aircraft on the pavement is a local one. While the existing RSA and RPZ meet the design criteria for critical aircraft, the Airport believes that keeping aircraft on pavement instead of transitioning to an RSA or RPZ reduces the hazard to aircraft, their occupants and the airport facilities.
57	24	1.8.4	1	This section is being viewed as part of the justification for the statement. Commerce can not be of the P/N. Otherwise, other commerce alternatives will have to be included. Suggest that this section be removed.	On April, 21 2015 the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft. AERO put significant effort into modeling this draft after the Bolingbrook example and believes the content is consistent. The items included as "Other Considerations" are not items to justify the proposed project but are other items that will be impacted if the proposed project is constructed. These items are of significant interest or impact that they warrant explanation.
58	25	1.9	third bullet	How would the project "enhance operational safety in low-visibility conditions" without installing an ILS? Would providing a 34:1 approach really be enough to make this claim?	In answer to FAA's question, the project would enhance operational safety in low visibility conditions by providing a greater margin of safety between the approaching aircraft and the obstacles on the ground in the Runway 24 approach area. Since the 34:1 approach surface provided by the proposed project is flatter than the existing 20:1 approach surface, obstacles with heights just below the 34:1 surface would be farther away (vertically) from overflying aircraft than obstacles with heights just below the 20:1 surface. The greater vertical distance of object-free airspace would obviously increase the margin of safety in low visibility conditions.
59	25	1.9	last bullet	explain "local objective"	(Addressed by Comment #55)
60	25	1.9	all	The summary should be moved up and be made part of the P/N statement and renamed objectives. The document to this point uses safely through out. Either remove the language or change to enhanced safety.	MDOT-Aero and the FAA-Region have had previous discussion regarding the summary, the summary will be left in place. Revised draft EA to address safely/enhanced safety where appropriate.

61	26	2	1	include the number of alternatives at the beginning of the sentence. Drop the rest of the sentence after "project"	Revised draft EA
62	26	2.1.1	3	In regards to the second and third sentences of the paragraph: Does the fact that B-II aircraft still land at ARB instead of nearby YIP demonstrate that the restrictions put on those aircraft by the short runway are not significant, otherwise these users would land at YIP instead? For clarity, this should be rebutted in order to strengthen the Purpose and Need	The Ann Arbor Municipal Airport cannot dictate which airfield a pilot uses. Many factors go into that aircraft operator's decision on where to operate from. B-II aircraft are a regular user of the Airport and the existing runway configuration does not satisfy the FAA design objective of providing sufficient runway length to allow airplanes that regularly use it to operate without weight restrictions. The proposed project would also result in ARB achieving full compliance with all AERO basic development standards outlined in the MASP 2008 for category B-II airports.
63	26-28	2.1	all	What were the criteria used to dismiss these alternatives. For example, there is no mention of environmental impacts etc. in the purpose and needs statement	As is consistent with the standard EA process, alternatives are most commonly dismissed because they failed to meet the Purpose and Need or other alternatives had less harmful impacts on the environment.
64	28	2.2	1	how were these alternatives deemed feasible?	As is consistent with the standard EA process, alternatives are typically only carried forward if they meet the Purpose and Need and avoid, minimize, and/or appropriately mitigate impacts on the environment.
65	29	2.2	3	Build Alt 3 - label the parallel taxiway that will be extended; will a portion of the taxiway or all be demolished and reconstructed? Or new construction to southwest?	Existing taxiway connector Alpha1 will be demolished on the northeast end of the runway and reconstructed 150' to the southwest. The parallel taxiway will be extended with new construction to the southwest. Revised draft EA.
66	33	Figure 3.4	map	For clarity please label the taxiway and runway and the lengths, on the same map	Revised draft EA
67	34	2.3.1	2	The airport is currently safe. This section implies the airport is unsafe.	Revised draft EA
68	35	2.3.3	1	Line of sight is not listed as an objective. Need to make sure the P/N statement is concise, clearly stated, focus, with justification and objectives. Please provide better clarity/flow when tracking the P/N section.	Line of Sight is shown as a "Need" in the revised Purpose & Need section and is consistently addressed in each of the alternative evaluations.
69	35	2.4	1	Clarify that the preferred ALT 3 is to remove 150' from the east end of the runway, (adding back 150' on the west end) plus the adding the 795' and shifting to the southwest	Revised draft EA
70	35	2.4	2	Add on to end of first sentence: "except for the ODALS."	Revised draft EA
71	35	2.4	2	Third sentence should read: "FAA approval for the relocation of the REILS will be required as part of the proposed action."	Revised draft EA
72	35	2.4	2	Fifth sentence should read: "If the decommissioning proposal is finalized, the approach lighting system will be removed and no relocation will occur."	Revised draft EA

73	36-68	3	all	This section needs to use the environmental impact categories specified in FAA Order 1050.1F, paragraph 4-1	The draft EA has been in process continually since 2009 and significant effort has gone into preparing it in accordance with FAA Orders 1050.1E and 5050.4B. Also, as previously mentioned in this comment matrix the FAA-Region provided a 2011 Environmental Assessment from Bolingbrook's Clow International Airport, as an example for MDOT-AERO to follow while re-organizing and revising this draft, it was also prepared in accordance with 1050.1E. Because this change would result in no change to content and the regulatory agencies, tribes and public have previously reviewed the draft EA as is, MDOT-AERO proposes to leave the draft EA unchanged.
74	36	3.1	1	What about the other noise impacts, such as from construction activities?	Noise associated with construction activities is covered in Construction Impacts category not the Noise category. (Section 3.15) Revised draft EA to clarify.
75	36	3.1	all	What about evaluation of the no action alternative for noise impacts?	Included in Section 3.1.2
76	36	3.1.1	1	The title of the methodologies need to be included in the paragraph	They are described in the same section.
77	37	3.1.1	last four bullets on page	Update these sources with more recent versions	These are the original sources used for the 2009 Noise Impact Analysis and should remain for consistency. MDOT-Aero reevaluated the 2009 study in 2015 and found it to be substantially valid. (Section 3.1.3)
78	39	3.1.3	all	Why not just redo the noise analysis with 2015 data?	The effort, timing and cost associated with redoing the noise analysis does not seem prudent, especially for little anticipated change in fleet mix and night operations, and a forecasted decrease in annual operations from the level analyzed in the original 2009 noise analysis. MDOT-Aero reevaluated the 2009 study in 2015 and found it to be substantially valid. (Section 3.1.3)
79	41	4.1	map	Noise Contour - Existing Conditions, please clarify the year.	Revised draft EA
80	42	4.2	map	No build - are the existing conditions still the same? Reasonable representation?	Revised draft EA. MDOT-Aero reevaluated the 2009 study in 2015 and found it to be substantially valid. (Section 3.1.3)
81	43	4.3	map	Preferred Alternative - Please delineate the projection out for the next five years	Revised draft EA. MDOT-Aero reevaluated the 2009 study in 2015 and found it to be substantially valid. (Section 3.1.3)
82	46	Figure 4.4		Is a newer source available than June 2011?	No
83	49	Figure 4.7		Is a newer source available than June 2011?	No
84	50	3.3.2	4	Update U.S. Census data with more recent source	Revised draft EA
85	51	3.3.2	1	Update U.S. Census data with more recent source	Revised draft EA
86	51	3.3.2	2	Update U.S. Census data with more recent source	Revised draft EA
87	52	3.3.4	4	Update U.S. Census data with more recent source	Revised draft EA
88	53	Table 3-2		Update U.S. Census data with more recent source	Revised draft EA

89	55	3.4	1	According to the Federal Register EPA 40 CFR Part 81 which was published in January of 2015, using the latest information from 2012 Annual Fine Particulate Matter NAAQS, Washtenaw (Livingston, Macomb etc.) County; PM 2.5 is Unclassified attainment. Clarify that the data submitted is correct.	The following is an excerpt directly from the 2014 Michigan Annual Air Quality Report published in June 2015 - All Michigan counties from 2010-2014 met the 1997 annual PM2.5 standard of 15 µg/m3 and the 2006 24-hour PM2.5 standard of 35 µg/m3. The EPA designated Michigan in attainment of these standards in August 2013. In December 2012, the EPA revised the annual primary standard to12 µg/m3 while the annual secondary standard remained at 15 µg/m3. The primary and secondary 24-hour standard remained as 35 µg/m3. The EPA has not made designations for the 2012 NAAQS revisions; however, PM2.5 concentrations are below 12 µg/m3 throughout Michigan. (DEQ 2016 Attainment Map Appendix C)
90	55	3.4	3	In regard to air quality, please provide the data from MDEQ (Do not see in Appendix D - there is a Land and Water Management and Wetlands letter)	Appendix D is specifically for "Early Agency Coordination" documentation, Appendix H is for "Additional Agency Correspondence" and includes the letter from MDEQ to EPA.
91	55	3.4	4 thru 7	The discussion does not quite fit affected environment. In terms of air quality what is the baseline conditions.	This language was not included in the first draft EA, however during discussions with the FAA-Region during review of this draft EA, this language was specifically recommended and later provided by the FAA-Region for inclusion into this draft.
92	56	3.4	3	Is there are more recent study than the L&B study from 1996?	No
93	56	3.4	3	Fourth sentence: which standards is this referring to?	NAAQS as referenced in the following sentence.
94	56	3.4	3	Last sentence: The reference to "proposed projects at general aviation airports" is very broad. How could the report know the extent of future projects at all GA airports in MI, especially if the report in 20 years old?	It is assumed that the report considered past GA airport projects and their typical scope and impacts when referencing proposed projects and made the general assertion that those projects are typically not of the scale to contribute to any NAAQS exceedances.
95	56	3.4	4	Please reword paragraph, as it is very confusing	Revised draft EA
96	56	3.4	4	It is not clear if this area is in a nonattainment area or maintenance area. Also not how this estimate was achieved. What calculations, models and sources were used. The citing of the court case should be removed and CAA regulations should be cited.	Based on the 2014 Annual Air Quality Report all of Michigan is in attainment. The following is an excerpt directly from the 2014 Michigan Annual Air Quality Report published in June 2015 - "Michigan ambient NO2 levels have always been well below the NAAQS. Since March 3, 1978, all areas in Michigan have been in attainment for the annual NO2 NAAQS...all monitoring sites have had an annual NO2 concentration at less than half of the 0.053 ppm NAAQS. As such, the DEQ requested a designation of unclassifiable/attainment for the entire state. Unclassifiable/attainment means that there are no air quality measurements that would justify classifying these attainment areas as either serious or moderate nonattainment areas." (DEQ 2016 Attainment Map Appendix C)
97	56	3.4	5	First sentence referenres NOX - what about the other NAAQS?	Revised draft EA.
98	56	3.4	5	Last sentence: replace "should" with "would"	Revised draft EA
99	57	3.5	1	How was it determined that the water quality is degraded. Was MDEQ contacted? With out some reliable way of establishing this the baseline for environmental conditions is not met.	There was no formal determination that it is degraded, only as it states, that it is "likely degraded", based on the existing conditions, observations and characteristics provided. Given that this is primarily a storm water dominated system, as described, it doesn't seem unreasonable to conclude that it is likely degraded, as it is common thought that many storm water dominated systems are.

100	57	3.5.1	4	Please clarify the status of the NPDES permit, as mentioned in secton 4.2.2? The reason for the permit should also be stated.	There are two distinctly different NPDES Storm Water Discharge Permits at ARB, one permanent for municipal storm water discharges and the other temporary for storm water discharges associated with construction activity. Revised draft EA to clarify.
101	57	3.5.2	2	Did not find a map that shows the 14 soil units and how their location to the proposed action site	Revised draft EA
102	58	3.5.2	1	Did not find a map that shows the wellhead area in relationship to the proposed action site.	A map of the City of Ann Arbor's Wellhead Protection Areas is now included. (Appendix H) The airport is located within the Steere Farm Wellhead Protection Area.
103	58	3.5.2	4	What about soils? The paragraph also mentions a new water line. Please provide more info on the water line.	The City replaced an existing raw (untreated) water line with a new 30" raw water line in 2010 along the east side of the airport. (Appendix H)
104	61	3.7	1	What were the results of the survey?	Revised draft EA
105	61	3.7	3	Did SHPO/THPO provide concurrence? If so, please state so.	Yes. Revised draft EA
106	61	3.8	2	Fourth sentence: be more location-specific, as the way the sentence is worded makes it sound the grassy meadows are within the RSA.	Revised draft EA
107	61	3.8	2	Last sentence: This discussion should be expanded. What does the agreement call for? Why does it exist?	This discussion is already included in Section 3.9 Threatened & Endangered Species and Section 4.2 Mitigation Measures.
108	62	3.8	4	Third sentence: What does the Audubon society think of this? Were they contacted as part of the EA public outreach process?	Revised draft EA
109	63	3.9	1	Update June 2009 survey, as this is already seven years old.	Revised draft EA
110	63	3.9	3	Last sentence: Did Audubon agree with this as well?	Revised draft EA
111	63	3.9	3	Update letters from 2009 for preferred alternative (Department of Natural Resources have instructions that may have changed)	As soon as this draft EA is finalized, the regulatory agencies will be contacted in writing and given the opportunity to review, comment and/or update their instructions.
112	63	3.1O	1	Update June 2009 survey. As part of the wetlands analysis, was USACE contacted? If so, did they make a jurisdictional determination? Are there any wetlands on the Rwy 06 approach, as the USFWS map depicts a wetland area. What about the removal of the ODALS - will this action impact the wetlands?	Review of available data sources was completed in 2015 and appear largely consistent with what was found in 2009. MDOT-AERO will complete a real-time field review of project areas to confirm the presence of wetlands, or lack thereof, during project design to ensure proper permitting requirements are met, if necessary. In Michigan, the USACE only retains authority over certain wetlands, the USEPA has agreed that MDEQ has compliance responsibilities over all the rest. Both MDOT-AERO and MDEQ have concluded that the wetlands at ARB are not regulated by USACE.
113	64	3.11	3 and 4	Was the floodplain analysis and conclusion confirmed with the local Floodplain Administrator?	The floodplain impacts were discussed at a meeting of MDOT Statewide Environmental Permit Coordinators and Resource Specialists. This level of analysis is adequate for draft EA purposes and the regulatory agency will be involved, as necessary, prior to the project being finalized.
114	64	3.11	3	Agencies should be changed to Agency. A flood plain map that shows the flood plain and the floodway with the proposed action should be included to support the discussion.	Revised draft EA (Appendix H)

115	64	3.12	1	See US Department of Agriculture NRSC letter, dated September 3, 2009, signed by Steve Olds. Update needed since this Agency requested follow up. See Appendix D-7	The following is an excerpt directly from the September 2009 NRCS Letter - "Some prime and farmland of local importance would be impacted by the project. If the project proceeds, I would urge you to utilize NRCS standards and specifications for conservation practices..." The draft EA is still in process and cannot proceed until that process is completed. Revised draft EA to clarify. As soon as this draft EA is finalized, the regulatory agencies will be contacted in writing and given the opportunity to review, comment and/or update their instructions.
116	66	3.14	1	Last sentence: delete "within the light lane"	Revised draft EA
117	66	3.14	2	Second sentence: Wouldn't these impacts be noted here? Where else would they be noted?	Revised draft EA
118	67	3.17		Why is this a separate section, as it is not an impact category?	Hazardous Waste Sites are an impact category under 1050.1E. (Addressed by Comment No. 73.)
119	67	3.18	1	Change to ASTM International Standard 1527-13	Revised draft EA
120	68	3.18	2	Last sentence: Add that any contamination encountered would be characterized and handled in accordance with state regulations	This language is already included later in the "Consequences of the Preferred Alternative" paragraph of Section 3.18 as appropriate.
121	69	4		The title of this section sounds like Section 3. What is the purpose of this section? Recommend changing the title to mitigation.	Revised draft EA
122	69	4	-	Title should be changed to Mitigation. EC was included in the previous section	Revised draft EA
123	-	-	-	In regard to the comment concerning Wildlife Hazards. The existence of the various nature features and species of concern should be assessed and part of the EA. FAA does not agree with the position that changing the profile of the airport will not change the relationship to the wildlife and their use of attractants. Only a certified Airport Wildlife Biologist is qualified to make that determination. The response to previous comment did not cite the participation of a certified Airport Wildlife Biologist.	This comment was not included in the revised draft EA, however it was included in the Response to Comments (Appendix K) . MDOT-AERO did consult with a certified Airport Wildlife Biologist from USDA when preparing the Response to Comments.
124	69	4.2.1	1	Last sentence: Does Audubon agree with this?	Revised draft EA
125	70	4.2.2	1	What about BMPs for air and water quality?	Addressed in Consequences of Preferred Alternative Sections of their respective impact categories.
126	71	5	1	The last public meeting was held six years ago; a new meeting will be needed.	This language is already included later in Section 5.2.2 Public Hearing.
127	71	5.1	1	What were the agencies' comments, at least in summary? What was MDOT's response?	Agency comments are provided in Appendix D and MDOT Responses are provided in Appendix K.
128	71	5.1	3	What did the local tribes say? Provide a summary.	Agency comments are provided in Appendix D and MDOT Responses are provided in Appendix K.
129	72	5.2.2	4	Add that another public meeting will be held.	This language was already included in the last paragraph of Section 5.2.2. Revised draft EA to clarify.

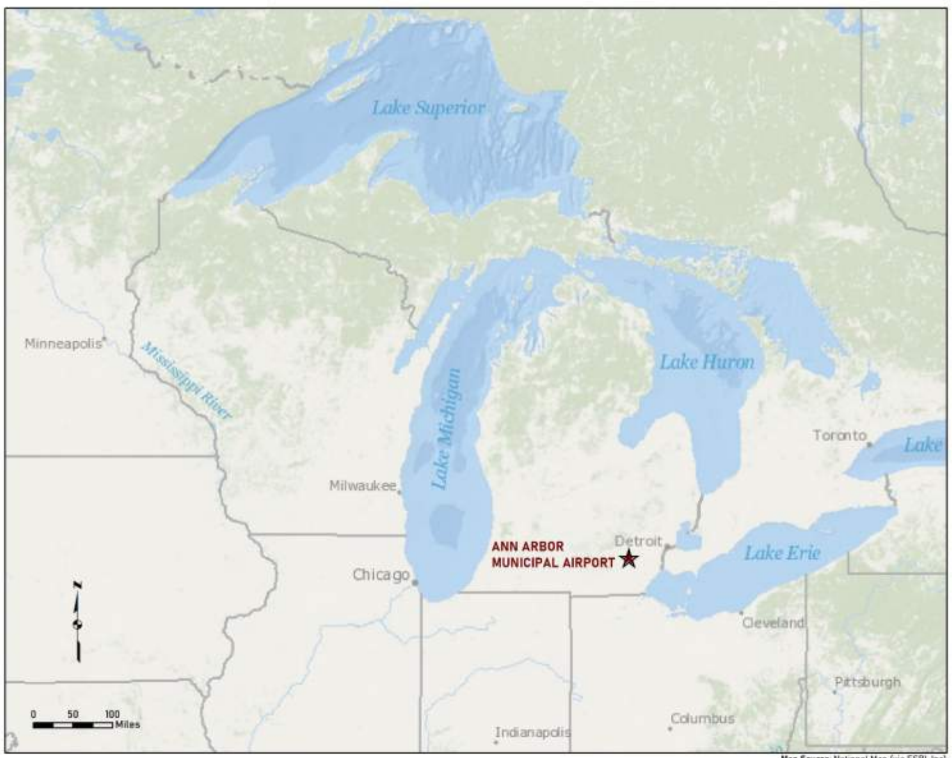
Chapter 1.0 Purpose and Need - DRAFT

Commented [LS(1]: This is a public document; therefore, please add graphics, photos, call-out boxes to describe/show/illustrate technical terms or equipment on an airport to ensure that this is readable and understandable for the general reader.

1.1 Introduction

The Ann Arbor Municipal Airport (ARB or Airport) is a public-use, general aviation airport owned and operated by the City of Ann Arbor. The Airport is within Pittsfield Charter Township, Washtenaw County, in southeastern Michigan (**Figure 1.0 Location Map**). Locally, ARB is approximately four miles south of downtown Ann Arbor, approximately 40 miles west of Detroit, and 10 miles west of Ypsilanti (**Figure 1.1 Vicinity Map**).

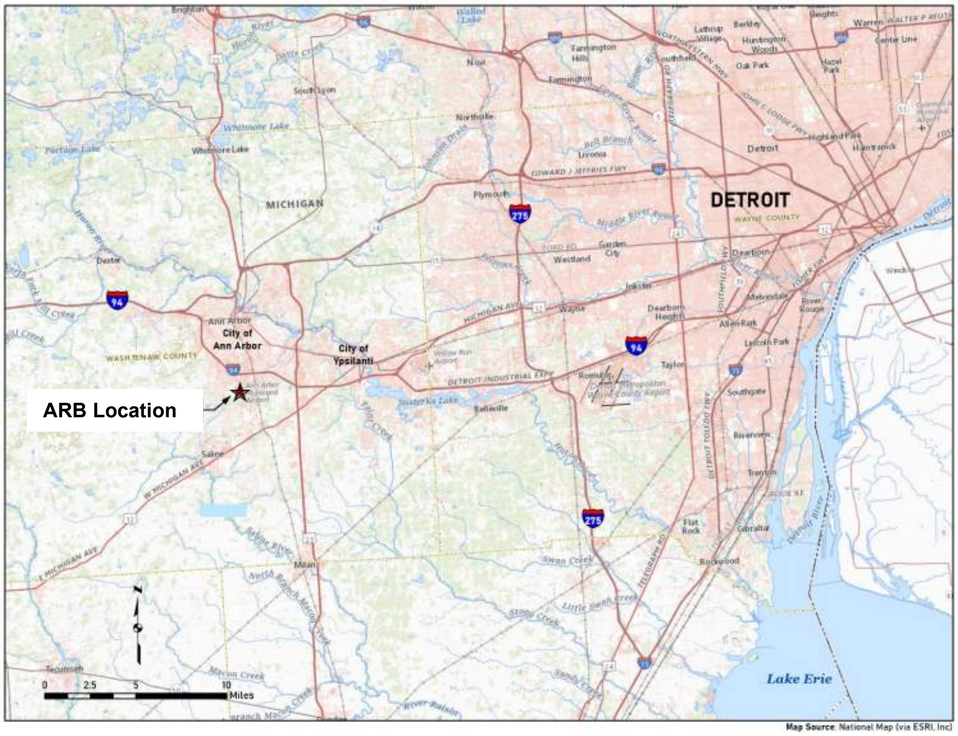
Figure 1.0 Location Map



Source: Mead & Hunt, 2020

Ann Arbor and the surrounding area is home to many prominent businesses and institutions with the University of Michigan being the area's largest employer. Manufacturing, health care, automotive, information technology, and biomedical research companies account for major employers in the region.

Figure 1.1 Vicinity Map



Source: Mead & Hunt, 2020

With many technological-driven industries, there is often a need for air transportation to bring workers, clients, suppliers, customers, and time sensitive parts/supplies to and from the region. These businesses operate a combination of turboprop driven and business jet aircraft. ARB is a vital transportation link and an economic driver for the community.

The Airport is also included in the Federal Aviation Administration (FAA) National Plan of Integrated Airport Systems (NPIAS). This designation is indicative of its significance in the national air transportation system. At the state level, the Michigan Department of Transportation Office of Aeronautics (MDOT AERO) classifies the Airport as a Tier-I, general aviation airport. Tier-I airports represent essential and critical state airport system goals and according to MDOT AERO should be developed to their full and appropriate extent[1].

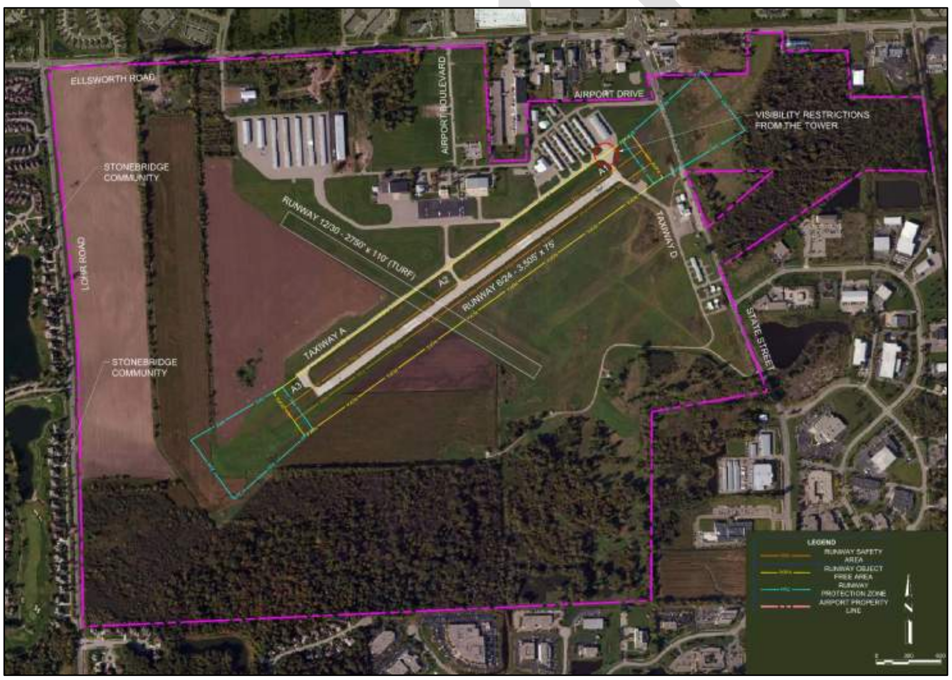
The Airport's primary runway, Runway 6/24, is paved and has a length of 3,505 feet with a width of 75 feet and is oriented in a northeast/southwest direction. ARB also has a turf runway, Runway 12/30, that is 2,750 feet in length and 110 feet in width and is oriented in a northwest/southeast direction. Runway 12/30 is used

1 2017 Michigan Aviation System Plan, Michigan Department of Transportation Office of Aeronautics, Page 2-9.

when weather permits and is not utilized by jet aircraft. Taxiway A parallels Runway 6/24 and has connector taxiways A1, A2, and A3 that provide access between the runway and the parallel taxiway. Several other connectors provide access between the parallel taxiway and the main apron with numerous hangars located on the airfield. **Figure 1.2 Existing Airfield Configuration** illustrates the airfield configuration and property boundary of ARB.

Runway 6/24 is equipped with Medium Intensity Runway Lighting (MIRL). The approach end of Runway 6 is equipped with a 4-light precision approach path indicator (PAPI), while the approach end of Runway 24 is equipped with a 2-box visual approach slope indicator (VASI). Both navigational aids are owned by ARB and assist aircraft with vertical guidance when landing. ARB is also served by an airport traffic control tower (ATCT) that manages the landing and departure of aircraft.

Figure 1.2 Existing Airfield Configuration



Source: Mead & Hunt, 2020

In addition to the ARB owned navigational aids described above, Runway End Identifier Lights (REIL) are also located at the approach end of Runway 6 but are owned by the FAA. Until recently, the approach to Runway 24 was equipped with FAA owned Omnidirectional Approach Lighting System (ODALS); however, they were decommissioned and removed in the summer of 2020. For additional maps and information on the Airport including its history, existing facilities, and the role it plays in the community and the region, see **Chapter 3.0 Affected Environment**.

Generally, after an airport project is identified through the planning process, but prior to moving into the design and construction phase, an environmental analysis such as this Environmental Assessment (EA) is required by the National Environmental Policy Act (NEPA) of 1969. The results of this EA, including input from federal, state, and local agencies, and the public, will guide the decisions made by the FAA and MDOT AERO. At that time, the project may be cleared to proceed with final design and construction or will be required to undergo additional environmental analysis.

1.2 Proposed Action

The Airports Proposed Action (i.e. project) is XXX

The major Federal Action includes the federal funding of the construction of XXXX, and the unconditional approval of the ALP for the project. This includes:

- Unconditional Approval of the portion of the ALP that depicts the components of the proposed project and its connected actions pursuant to 49 USC 40103(b), 44718, and 47101(a)(16), and Title 14 CFR Parts 77 and 157.
- Determination of eligibility for federal assistance under the federal grant-in-aid program authorized by the Airport and Airway Improvement Act of 1982, as amended (49 USC 47101, et seq).
- Approval of an application for federal assistance for eligible components of the proposed project using federal funds from the AIP.

Commented [LS(2]: Please note that this would include those components of the project that were identified in the 163 determination letter that the FAA has authority over. In addition, any elements of the project that the FAA does not have authority over but DEPENDS UPON those components of the project that the FAA has authority over is included in the NEPA analysis, as noted in the first bullet. In Chapter 2, it will be more clear when you list those items of the project and its connected actions.

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1.32 Project Purpose and Need for the Proposed Action

1.3.1 Purpose of the Proposed Action

The purpose of the Airports proposed action project is to improve operational utility of the Airport by meeting the takeoff and landing distance requirements of aircraft that currently operate at the Airport and are projected to steadily increase operations over time. ARB is also proposing to enhance safety by providing a clear line-of-sight for ATCT personnel resulting in an unobstructed view of the north end of Taxiway A as shown on **Figure 1.2 Existing Airfield Configuration**.

The purpose of the proposed project is to also revise the existing Airport Layout Plan (found in **Appendix X ALP**) to confirm that proposed alterations do not adversely affect the safety, utility, or efficiency of the Airport. Pursuant to 49 U.S.C. §47107(a)(16)(B), the FAA (under authority delegated from the Secretary of Transportation) will review and approve or disapprove only those portions of the project (or any subsequent revision to the project) that materially impact the safe and efficient operation of aircraft at the Airport or that would adversely affect the safety of people or property on the ground adjacent to ARB as a result of aircraft operations, or that adversely affect the value of prior federal investments to a significant extent.

1.3.2 Need for the Proposed Action

The following objectives will be used to evaluate alternatives on how they best support the need for the proposed action(s):

~~1.2.1~~1.3.2.1 Meet Runway Requirements of Current and Future Users

The proposed ~~project~~ action is needed because Runway 6/24 was designed to serve primarily small piston driven aircraft; however, the Airport receives regular use by small turboprop and business jet aircraft that require a longer runway to operate at a greater capacity than they do today.

Analysis of current Airport operations found that aircraft with similar operational performance characteristics routinely use ARB and have runway requirements that exceed the current 3,505-foot length of Runway 6/24 under standard operating conditions. For these users to conduct operations on the existing runway length, undue concessions in reduced fuel, passengers and/or cargo loads are often needed. Diversions to other airports are also commonly needed when runway surfaces are contaminated with snow or ice, or during the summer months when higher temperatures reduce aircraft performance. Higher temperatures cause ambient air to thin thus requiring longer runway lengths for landing and takeoff operations. ~~FAA Advisory Circular (AC) 150/5325-4B *Runway Length Requirements for Airport Design*, states "*The design objective for the main primary runway is to provide a runway length for all airplanes that will regularly use it without causing operational weight restrictions.*"~~

To document and justify the need to provide enhanced Airport facilities for current and future users of the Airport, FAA and MDOT AERO reviewed a report titled *Runway 6/24 Extension Justification Study* (Study) that was completed in 2021 (found in **Appendix X Runway Justification Study)**. The Study documented the types of aircraft that operate at ARB and then determined the number of current and projected operations ARB could expect in the future. The Study then developed prudent and feasible alternatives to meet the performance requirements of current and future users of the Airport. The intent of the Study was to document, justify, and recommend alternatives to meet the demands of aircraft types regularly using ARB, including operating weight, takeoff on a hot day, and landing on a contaminated (ice or snow) runway.

An important aspect of the Study that helped determine that Runway 6/24 was inadequate for existing and future users started with the identification of a grouping of aircraft types with similar performance characteristics that conduct~~ed~~ at least 500 annual operations at ARB. ~~Aircraft with at least 500 annual operations are known as the critical aircraft.~~ As stated in FAA AC 150/5000-17, *Critical Aircraft and Regular Use Determination*, ~~the FAA also supports the grouping of aircraft types to determine the critical aircraft. FAA guidance states that~~ the critical aircraft for an airport may be a single type of aircraft or a grouping of types of aircraft with similar characteristics that conducts at least 500 annual operations at an airport. The performance requirements of critical aircraft help determine runway length needs.

Commented [LP(3]: Section 6.3, Recommended Runway Length, of the justification study notes that, "The inclusion of the contaminated runway length distances cannot be used to justify runway length under FAA funding requirements; rather, these runway length needs are included to demonstrate the benefit additional runway length would provide when contaminates are present on its surface." Recommend clarifying that contaminated runways are not used in the runway length requirements and discussion is included just as an additional benefit.

Commented [LP(4]: Recommend deleting this quote from the AC. The reference is being taken out of context to indicate that the FAA standard is to design a runway without causing operational weight restriction and insinuate that there are users taking weight restrictions often. The rate of users taking weight restrictions has not been documented (at least in the justification report). The design approach used in the 2 approaches taken in the justification report also have different guidelines and approaches dependent on aircraft MTOW.

Commented [LP(5]: These 3 sentences all repeat the same information about critical aircraft being a single or group that conducts at least 500 ops. Recommend condensing to a single sentence.

The results of the Study found that the Airport Reference Code (ARC) classification of B-II aircraft types are the most demanding grouping of aircraft that currently conduct more than 500 operations per year at ARB. Thus, the Study concluded that existing and future critical aircraft for the design of Runway 6/24 is B-II aircraft. With this understanding, a runway length that meets the demands of B-II aircraft is needed at ARB.

As shown in **Table 1-1 Current and Future Operations by ARC Classification**, the ARC grouping of B-II aircraft types includes both jet and turboprop aircraft types.

AIRPORT REFERENCE CODES (ARC)

Aircraft Approach Category (AAC)

- Category A: Aircraft approach speed less than 91 knots
- **Category B: Aircraft approach speed 91 knots or more but less than 121 knots**
- Category C: Aircraft approach speed 121 knots or more but less than 141 knots
- Category D: Aircraft approach speed 141 knots or more but less than 166 knots
- Category E: Aircraft approach speed 166 knots or more

Airplane Design Group (ADG)

- Group I: Wingspan less than 49 feet
- **Group II: Wingspan 49 feet or more but less than 79 feet**
- Group III: Wingspan 79 feet or more but less than 118 feet
- Group IV: Wingspan 118 feet or more but less than 171 feet
- Group V: Wingspan 171 feet or more but less than 214 feet
- Group VI: Wingspan 214 feet or more but less than 262 feet

Note: ARB classifications are in **bold** and underlined.
Source: FAA AC 150/5300-13A, *Airport Design*

The forecasts of future aviation operations prepared as part of the Study also indicated that B-II small turboprop and jet aircraft operations will slowly increase over time at ARB. Understanding that this demand will increase also supports the need of providing improved B-II facilities. Thus, it is prudent for ARB to meet B-II critical aircraft standards to accommodate, in whole or part, both turboprop and jet aircraft on Runway 6/24.

Providing a B-II runway would meet the operational demands of current and future users by eliminating weight concessions and allowing aircraft to operate at greater capacities, thus resulting in a more efficient operating environment. For details of the runway justification process including operations, forecasts, runway length analysis, alternatives, and recommendations see **Appendix X Runway Justification Study**.

Table 1-1 Current and Future Operations by ARC Classification

Physical Class	Representative Aircraft	Representative ARC	2019	Forecasts			
				2023	2028	2033	2038
Jet	C56X - Excel XLS	B-II*	263	283	302	321	338
Jet	E55P - Phenom 300	B-II*	97	104	112	118	125
		Subtotal Jets	**360**	**387**	**414**	**439**	**462**
Turbine	TBM8 - TBM-850	A-I	150	161	172	183	193

Turbine	BE20/B350 - King Air	B-II*	966	1,040	1,111	1,178	1,241
		Subtotal Turbine	**1,116**	**1,201**	**1,283**	**1,361**	**1,434**
Piston	C172 - Cessna 172	A-I	2,876	3,016	3,225	3,427	3,613
		Subtotal Piston	**2,876**	**3,106**	**3,225**	**3,427**	**3,613**
Other	EC55 - EC-155	n/a	67	70	75	80	84
		Subtotal Other	**67**	**70**	**75**	**80**	**84**

~~1.2.2~~1.3.2.2 Provide an Unobstructed View of the Taxiway A

The proposed project is also needed to address obstructed views of the northern end of Taxiway A from the ATCT. Currently, there is limited visibility of the intersection of Taxiway A and Connector Taxiway A1 (illustrated on **Figure 1.2 Existing Airfield Configuration)** by personnel working in the ATCT. Lack of visual supervision of taxiing aircraft can lead to movement complications and miscommunications.

Source: FAA TFMSC database (2019), Projections: Mead & Hunt, Inc. (2020)

* Denotes B-II aircraft groupings operating at ARB

There are two hangars located north of Taxiway A that obstruct the view from the ATCT. This condition fails to meet FAA guidance regarding visibility of the movement area of an airfield. According to FAA AC Order 6480.4B, *Airport Traffic Control Tower Siting Process*, the entire movement area of the airfield should be observable from the ATCT to control aircraft movement and operations in a safe and efficient manner. Under existing conditions, this criterion is not met.

By providing a clear line-of-sight from the ATCT, air traffic controllers will have an unobstructed view of the entire length of Taxiway A. This improved condition will enhance safety of ground operations by taxiing aircraft and improve the overall utility for users of the Airport.

1.~~3~~4 Summary of Existing and Projected Operations

As part of the *Runway 6/24 Extension Justification Study* described above, historical and future trends of aviation activity were completed for ARB. The Study analyzed past, current, and projected operations from 2005 through the year 2039 and found that passenger and aircraft activity at the Airport have fluctuated in recent history. This is not uncommon in comparison to many U.S. airports as economic uncertainty and increased travel costs have impacted aviation usage.

It should be noted that the economy of the United States and the aviation industry had a near complete shutdown in April 2020 due to the COVID-19 pandemic. The pandemic greatly impacted operations at ARB. However, operations have rebounded quickly and now nearly match the totals from 2018 and 2019. Therefore, it is anticipated that operations will fully recover to pre-COVID levels in 2021.

A summary of the forecasts is presented in **Table 1-2 Projections Summary**. These figures illustrate that there is anticipated gradual growth in aircraft activity at ARB with total operations expected to increase from the 2019 level of 76,428 to 84,336 in 2039. For details of existing and projected aviation forecasts at ARB see **Appendix X Runway Justification Study**.

Table 1-2 Projections Summary

	Itinerant Operations			Local Operations			
Year	Air Taxi	General Aviation	Military	General Aviation	Military	Total Operations	Based Aircraft
Historical							
2005	2,105	24,942	17	40,871	5	67,940	164
2006	2,082	26,530	263	42,910	0	71,785	148
2007	1,876	25,483	243	45,251	0	72,853	148
2008	1,198	22,677	42	40,991	2	64,910	136
2009	376	21,195	22	35,508	8	57,109	141
2010	208	21,102	33	42,629	7	63,979	129
2011	272	21,016	36	35,893	2	57,219	129
2012	474	23,285	51	39,737	3	63,550	168
2013	556	21,943	40	35,202	3	57,744	175
2014	524	21,728	57	35,051	3	57,363	176
2015	524	22,373	47	33,953	18	56,915	182
2016	568	23,761	72	33,933	49	58,383	188
2017	564	24,213	68	37,112	9	61,966	178
2018	570	24,196	41	38,264	31	63,102	164
2019	550	28,126	76	47,653	23	76,428	164
Projected							
2024	596	30,465	76	47,494	23	78,654	163
2029	636	32,547	76	47,264	23	80,546	163
2034	675	34,524	76	47,123	23	82,421	162
2039	711	36,357	76	47,168	23	84,336	162
CAGR (2019-2039)	*1.29%*	*1.29%*	*0.00%*	*-0.05%*	*0.00%*	*0.49%*	*-0.05%*

Source: Historical Operations – FAA OPSNET, Historical Based Aircraft – FAA TAF, Projections – Mead & Hunt

1.5 Required Environmental Review

REPLACE TEXT WITH INSERT FROM RST PREPARED BY MEAD and HUNT AND COMPLETED LEGAL SUFFICIENCY REVIEW

Federal financial participation in projects through the Airport and Airway Improvement Act of 1982 (AIP), requires environmental review under the National Environmental Policy Act (NEPA). In addition, FAA must approve the Airport Layout Plan (ALP) elements associated with the proposed action evaluated under NEPA. An Environmental Assessment (EA) is a document prepared under NEPA that evaluates the effects of a proposed action on the surrounding natural, social, and economic environments. This EA is prepared under the requirements of the Title V of Public Law 97-248 of the Airport and Airway Improvement Act of 1982, NEPA, and FAA Order 5050.4B, *National Environmental Policy Act Implementing Instructions for Airport Actions* (April 2006). The EA also meets the requirements of FAA Order 1050.1F, *Environmental Impacts: Policies and Procedures,* dated July 2015.

The intent of the EA is to provide the environmental documentation necessary to assist local, state and federal officials in evaluating the proposed action at RST. The EA evaluates the proposed action and a full range of alternatives to the proposed action that meet the purpose and need identified in the EA. The analysis also identifies and discusses measures to avoid, minimize, and mitigate possible environmental impacts.

The EA is prepared to comply with NEPA. The FAA must evaluate the EA under NEPA and, if the project does not have the potential for significant impacts, issue a Finding of No Significant Impact (FONSI), or if it does have significant impacts, prepare a federal Environmental Impact Statement (EIS).

Rochester International Airport / Draft EA 1

~~The Airport is subject to federal and state environmental review because it is a federally obligated airport and must meet its federal grant assurance requirements. The proposed Airport improvements require an environmental evaluation be prepared under the direction of NEPA. NEPA requires any action that involves federal funding or federal permits undergo an environmental analysis that evaluates and documents the effects of the proposed project on the surrounding natural, social, and economic environment.~~

~~The intent of this EA is to provide the environmental documentation necessary to assist local, state, and federal agencies in evaluating the proposed development in a brief and concise format documenting only information deemed relevant to the project. Any information used from other studies or reports will be referenced only, directing the reader to other sources for more information as applicable.~~

~~This EA is being developed to determine whether any potential impacts associated with the proposed action are significant enough to necessitate a greater level of environmental analysis that would be typically achieved through an Environmental Impact Statement (EIS) or additional technical studies.~~

~~The proposed action will be evaluated, along with a range of alternatives that includes a No-Build/Do Nothing alternative to identify a Preferred Alternative that meets the project's purpose and need. This analysis will also include measures to avoid, minimize, and mitigate possible adverse environmental impacts associated with the Preferred Alternative.~~

~~This EA has been prepared in accordance with the requirements of NEPA, FAA Order 5050.4B, *NEPA Instructions for Airport Actions*, and FAA Order 1050.1F, *Environmental Impacts Policies and Procedures*,~~

42 U.S.C. 4332(2)(c), 49 U.S.C. 3030, 23 U.S.C. 138, and Council on Environmental Quality (CEQ) guidelines.

1.6 Requested Federal Action

This EA will be submitted to the FAA and MDOT AERO for evaluation. If the agencies conclude the proposed action will not cause a significant environmental impact, they may issue a final federal environmental determination. If it is found that a major or significant impact will result from the proposed action, the FAA / MDOT AERO may request additional environmental review or not approve the project.

1.7 Projected Time Frame of Improvements

The proposed project timeframe (pending available funding and approval of this EA) is:

- Final EA submitted for review and approval: Winter 2022
- Project design begins: Spring 2022
- Project construction begins: Fall 2022

Chapter 2.0 Alternatives Considered - DRAFT

2.1 Introduction

In accordance with the Council on Environmental Quality (CEQ) regulations found in 40 Code of Federal Regulations (CFR) § 1502.14(d), an environmental review process requires that ~~prudent and feasible~~reasonable alternatives be identified and evaluated that might accomplish the objectives of a proposed project. This requires the FAA to identify potential alternatives that are available to achieve the purpose and need for a given project and present the basis used to make an informed decision regarding the selection of a Preferred Alternative .

~~As the lead federal agency, the Federal Aviation Administration (FAA) is responsible for complying with the policies and procedures of the National Environmental Policy Act (NEPA) of 1969 and other related environmental laws, regulations, and orders applicable to FAA actions. This requires the FAA to identify potential alternatives that are available to achieve the purpose and need for a given project and present the basis used to make an informed decision regarding the selection of a Preferred Alternative.~~

NEPA and FAA regulations do not require the inclusion of a specific number of alternatives or a specific range of alternatives in an Environmental Assessment (EA). However, an EA must consider the proposed action and the consequences of taking no action. For alternatives that were considered but eliminated from further study, the airport must briefly explain why such alternatives were eliminated from further consideration.

Pursuant to FAA regulations set forth in Order 1050.1F, *"Environmental Impacts: Policies and Procedures,"* an alternatives discussion should include:

- A list of alternatives considered, including the proposed action and the no action alternative
- Any connected ~~or cumulative~~ actions associated with each alternative
- A concise statement explaining why any initial alternatives were eliminated from further study
- A statement identifying a Preferred Alternative if one has been identified
- Any other applicable laws, regulations, executive orders and associated permits, licenses, approvals, and reviews required to implement a project alternative

This chapter documents different options that may reasonably meet the needs of the proposed project at the Ann Arbor Municipal Airport (ARB or Airport), as explained in **Chapter 1.0 Purpose and Need**. It should be noted that preliminary costs for build alternatives are provided; however, comprehensive costs will be developed during the final design of the Preferred Alternative.

See **Appendix XX Runway Justification Study** for aircraft types that operate at ARB and the number of current and projected operations the Airport can expect in the future. This study also helped in developing build alternatives to meet the project's purpose and need.

Commented [LS(1]: I do not believe that there are 4f impacts – if there is, please keep the prudent and feasible terminology with some reference to Section 4(f); if not 4(f) resource, please replace with "reasonable"

Commented [LS(2]:

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Commented [LS(4]:

Commented [FJ(5]: Would be redundant to chapter 1.

Commented [LS(6]: Typically you are unable to do so until going thru the environmental impacts analysis so it is not necessarily appropriate to imply that this is required in chapter 2.

Commented [LS(7]: 1050 4.2.d refers to the types of impacts that are described in the environmental impacts chapter (direct/indirect/ and cumulative).

Commented [LS(8]: i.e whether the alternative(s) were not considered reasonable (did not meet the purpose and need).

The following alternatives are presented and discussed in this chapter:

- ➢ No Build ~~(Do Nothing)~~ Alternative – Maintain Existing 3,505 Feet of Runway Length
- ➢ Build Alternatives:
  - Alternative 1 – Extend 720 Feet at the Approach End of Runway 24
  - Alternative 2 – Shift Runway 150 Feet Southwest and Extend 720 Feet at the Approach End of Runway 6
  - Alternative 3 – Extend 360 Feet at both ends of Runway 6/24

> **Commented [LS(9]:** The no build alternative maintains the existing runway; therefore it is not a do nothing or no action alternative.

2.2 Safety Areas and FAA Design Standards

Safety areas, as defined by the FAA in Advisory Circular (AC) 150/5300-13A, Change 1, *Airport Design*, are of importance in evaluating potential alternatives because they are a controlling factor for each runway end and for determining potential impacts. This section includes a definition of the different safety areas important to this project and required by FAA design standards.

Runway Safety Area (RSA): The RSA is a two-dimensional graded area surrounding the runway surface and is constructed to enhance the safety of airplanes in the event of an unintended excursion from the runway's paved surface. This area must be:

- Cleared and graded with no potentially hazardous humps, ruts, depressions, or other surface variations
- Adequately drained to prevent water accumulation
- Capable of supporting snow removal equipment, rescue and firefighting equipment, and occasional aircraft passage without causing structural damage to the aircraft
- Free of objects, except for those that need to be in the RSA because of their function, and then, to the extent practical, mounted on low impact (frangible) structures
- Capable, under normal (dry) conditions, of supporting airplanes without causing structural damage to the airplanes or injury to their occupants

> **Commented [LP(10]:** Recommend using wording from the Design AC Section 307.b.(3), "Capable, under dry conditions, of…"

> **Commented [LP(11]:** This may be redundant to 3rd bullet. While injury to occupants is discussed in the historic development of the RSA section of the Design AC (307.a.(1)), the wording in the Design AC standards section (307.b.) is captured in the 3rd bullet.

Runway Object Free Area (ROFA): A ROFA is a two-dimensional ground surface surrounding a runway. The ROFA clearing standards preclude above ground objects protruding above the RSA edge elevation, except those required to be within the ROFA for navigation, ground maneuvering, aircraft taxi, and aircraft holding purposes. No other objects are permitted.

> **Commented [LP(12]:** Recommend using "protruding above the nearest point of the RSA," language from the Design AC (Section 309) rather than "RSA edge elevation"

Runway Protection Zone (RPZ): The RPZ is a trapezoidal shaped area centered on the extended runway centerline and extended off each runway end. The function of an RPZ is to enhance the protection of people and property on the ground~~, protect airspace,~~ and prevent incompatible land uses. Airports are encouraged by the FAA to control the land within an RPZ to clear RPZ areas of incompatible objects and activities ~~prevent the creation of hazards to landing and departing aircraft.~~

> **Commented [LP(13]:** Recommend deleting reference to "protecting airspace." Protecting airspace is not a function identified in Design AC RPZ section (310).

> **Commented [LP(14]:** Recommend deleting and replacing with "clear RPZ areas of incompatible objects and activities." This more closely matches language in the Design AC (Section 310)

To determine potential RPZ impacts of the proposed project, a separate technical report (RPZ Analysis) was completed for Runway 6/24 and found in **Appendix XX RPZ Analysis**. The RPZ Analysis evaluated land uses within the RPZs of each build alternative to determine incompatible land uses. The findings of each build alternative are included below.

2.3 No-Build Alternative – Maintain Existing 3,505 Feet of Runway Length

The No-Build Alternative assumes that no action would be taken to address the needs of the Airport as identified in **Chapter 1.0 Purpose and Need**. Under this alternative, ARB would remain in its current state with no plans to meet the documented needs of current and future users for a longer runway. Under this alternative, the limited visibility of the intersection of Taxiway A and Connector Taxiway A1 experienced by the air traffic control tower (ATCT) would remain unchanged.

The No-Build Alternative does not meet the project's purpose and need of providing an air transportation facility that meets the takeoff and landing distance requirements of aircraft that currently operate at the Airport and are projected to steadily increase operations over time ~~that complies with FAA Advisory Circular (AC) 150/5325-4B *Runway Length Requirements for Airport Design*~~ and provide a clear line-of-sight for ATCT personal as defined in FAA AC Order 6480.4B, *Airport Traffic Control Tower Siting Process*.

Although the No-Build Alternative does not meet the purpose and need of the proposed project, it does serve as a baseline of comparison for environmental impacts associated with other build alternatives and is, therefore, retained for analysis and carried forward for review.

2.4 Alternative 1 – Extend 720 Feet at the Approach End of Runway 24

Under this alternative, Runway 6/24 would be extended 720 feet to the northeast at the approach end of Runway 24 to provide a total length of 4,225 feet of available runway length (**Figure 2.1 Alternative 1 – Extend 720 Feet at the Approach End of Runway 24**). Taxiway A would be extended to match the runway extension and a new connector taxiway (Taxiway A1) would be constructed to align with the relocated threshold of Runway 24. Existing Taxiway D would also be reconstructed to match the runway extension and be designed to intersect Runway 6/24 at a 90-degree angle. All applicable navigational aids (NAVAIDs), lighting, and signage would be relocated to match the proposed runway extension and would meet FAA design standards.

Taxiway D would be realigned so that it has a standard 90-degree intersection with Runway 6/24 to comply with FAA AC 150/5300-13A Change 1, Section 401.b.(5).(g) *Indirect Access* (herein referenced as Indirect Access). FAA design standards discourage direct access from an apron to a runway without requiring a turn by aircraft prior to reaching the runway. Direct access configurations can lead to confusion when pilots expect to maneuver onto a parallel taxiway but instead enter a runway.

This alternative would also require State Street to be reconstructed outside of the relocated Taxiway D, the RSA, and the ROFA. The existing roadbed of State Street through these areas would be closed and the pavement removed. Two options for relocating State Street are shown on **Figure 2.1 Alternative 1 –**

Commented [LP(15]: Per the Interim Guidance on Land Uses Within a Runway Protection Zone, (September, 2012) the RPZ Alternatives Analysis identifies and documents the full range of alternatives that could
1. Avoid introducing the land use issue within the RPZ
2. Minimize the impact of the land use in the RPZ
3. Mitigate risk to people and property on the ground.

Did the RPZ analysis evaluate the 3 items above, or did it only determine incompatible land uses?

Commented [LS(16]: For each alternative, it may be helpful to have a subsection for each item from the purpose/need statement so that it is clear whether the alternative is reasonable (meets the purpose and need for the proposed project).

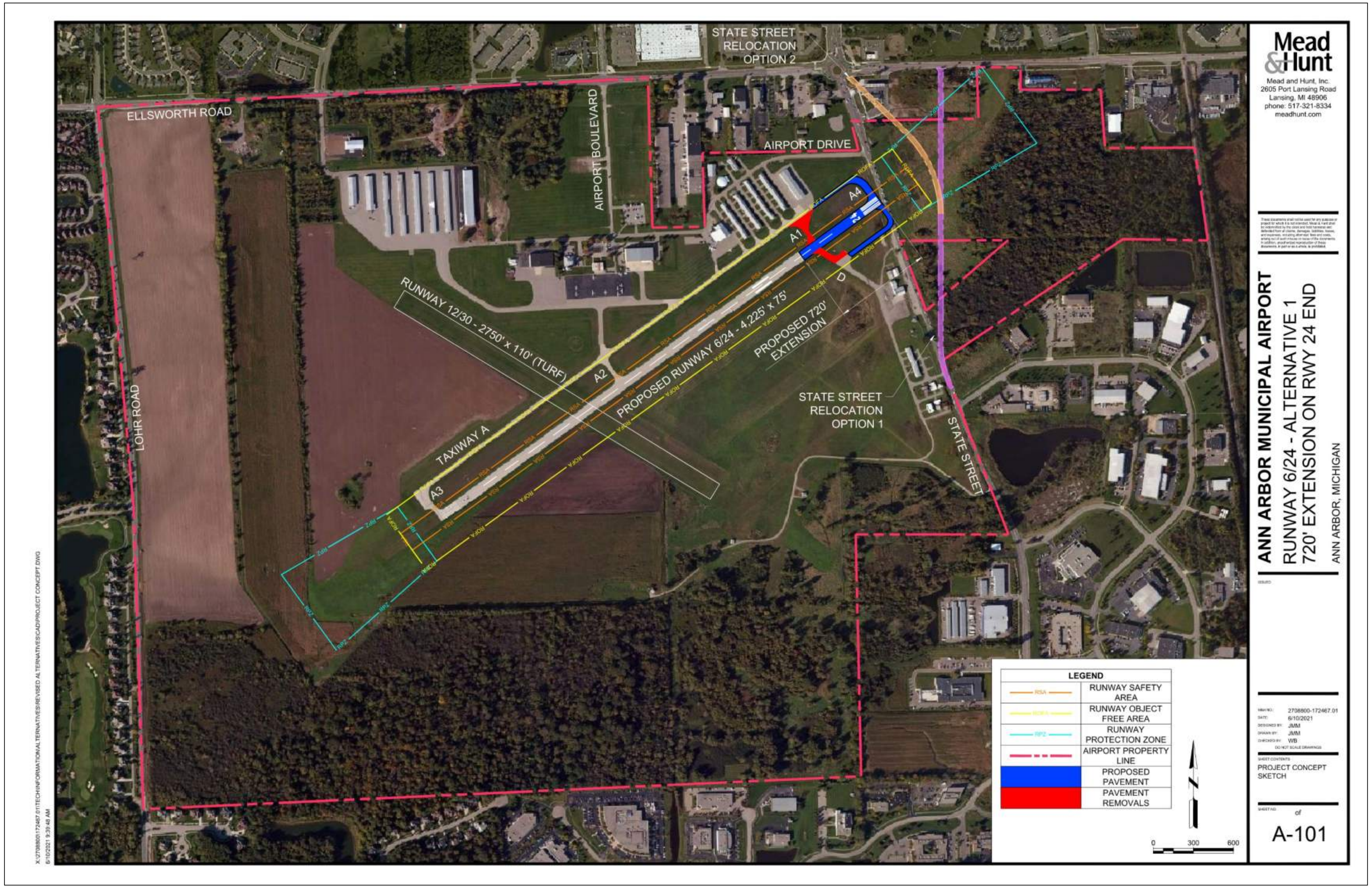
2.3.1 Meet Runway Requirements for Current and Future Users
2.3.2 Provide Unobstructed Views of Taxiway A

Commented [LP(17]: Recommend deleting reference to the FAA Runway Length AC and matching the P&N Section 1.3.1, "The purpose of the Airports proposed action is to improve operational utility of the Airport by meeting the takeoff and landing distance requirements of aircraft that currently operate at the Airport and are projected to steadily increase operations over time"

Extend 720 Feet at the Approach End of Runway 24. Any property that is not owned or controlled by ARB within the RSA and ROFA would require either acquisition or an avigation easement.

As previously mentioned, a separate RPZ Analysis evaluated land uses within the relocated RPZ off the end of Runway 24. The analysis found few incompatible land uses beyond the two State Street relocation options. Generally, roads within an RPZ are undesirable and should be avoided, if possible.

Figure 2.1 Alternative 1 – Extend 720 Feet at the Approach End of Runway 24



Source: Mead & Hunt, Inc.

Preliminary investigations indicate that regulated wetlands are found throughout the area east of State Street. It is likely that both State Street alignment options would cause impacts to regulated wetlands.

The primary advantage of Alternative 1 is that it offers 4,225 feet of usable runway length that meet the needs of existing turboprop and jet aircraft that currently operate at the Airport and are forecasted to grow modestly in the future. This alternative would also realign Taxiway D so that it has a standard 90-degree intersection with the Runway 6/24 to comply with FAA AC 150/5300-13A, Change 1.

Disadvantages of Alternative 1 include the relocation of State Street around the approach end of Runway 24 and its associated RSA & ROFA surfaces. The State Street relocation would also cause business and private property impacts where it connects to Ellsworth Road, likely causing land and commercial acquisitions. Also, there may be considerable community, road, and wetland impacts during construction and realignment of State Street.

Commented [FJ(18]: Will there be tree removal impacts?? Acreages if so?

Another disadvantage of Alternative 1 is that the ATCT will continue to have visibility deficiencies at the intersection of Taxiway A and connector Taxiway A1 when aircraft and ground vehicles are in the area. According to FAA AC Order 6480.4B, *Airport Traffic Control Tower Siting Process*, the entire movement area of the airfield should be observable from the ATCT to control aircraft movement and operations in a safe and efficient manner.

Alternative 1 is not considered a ~~prudent and feasible~~ reasonable alternative because it fails to meet the project's purpose and need of addressing visibility issues experienced by the ATCT. Although Alternative 1 provides adequate runway length for current and future users, it fails to provide line-of-sight for the entire movement area of the airfield.

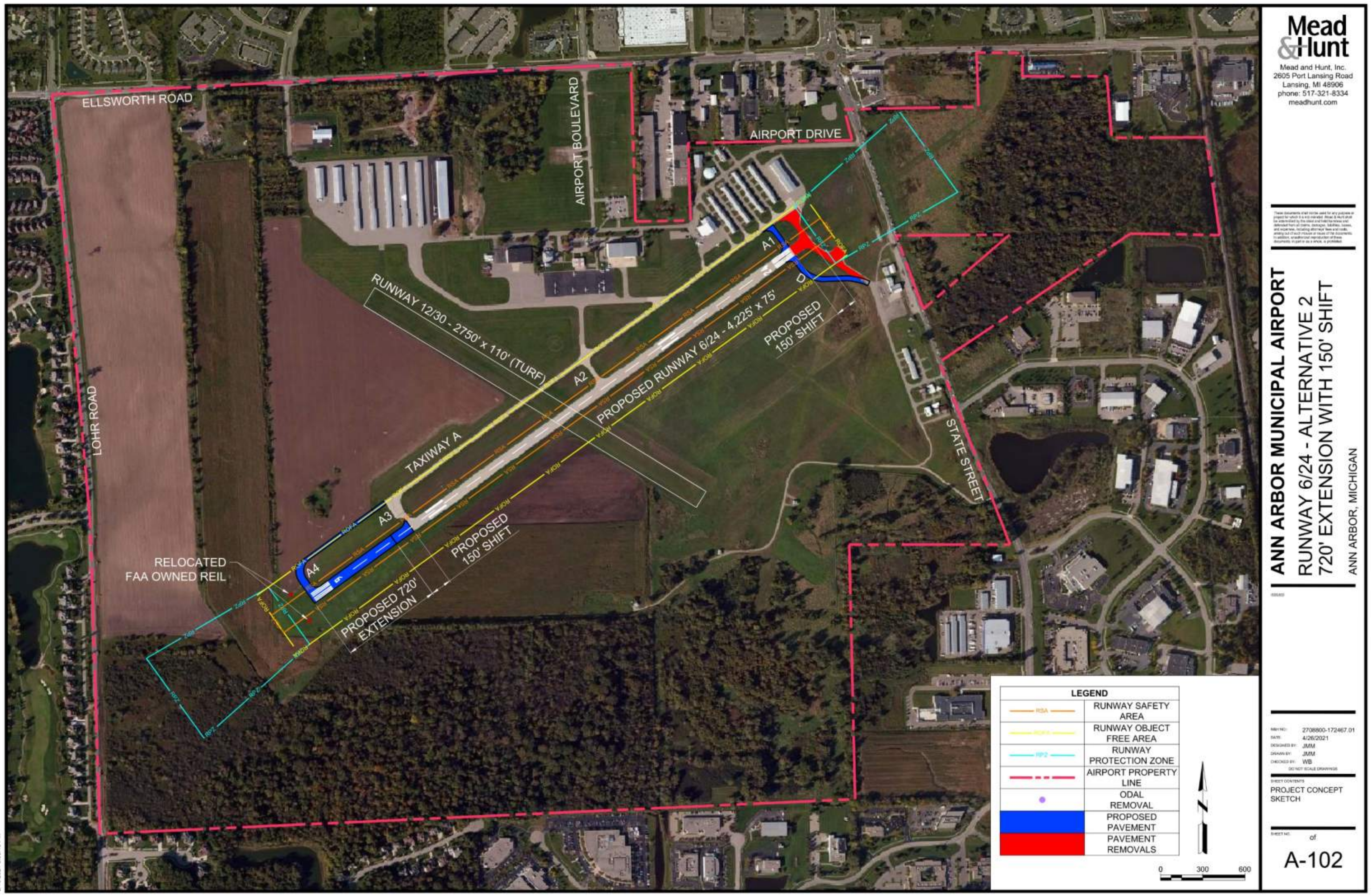
Alternative 1 is the most expensive of the build options, with a preliminary cost estimate of $10.9 million. This alternative is approximately three times more expensive than Alternative 2.

2.5 Alternative 2 – Shift Runway 150 Feet Southwest and Extend 720 Feet at the Approach End of Runway 6

With this alternative, Runway 6/24 would be shifted 150 feet to the southwest and then extended 720 feet at the approach end of Runway 6 to provide 4,225 feet of usable runway length (**Figure 2.2 Alternative 2 – Shift Runway 150 Feet Southwest and Extend 720 Feet at the Approach End of Runway 6**). The shift would be accomplished by constructing an additional 150 feet of runway length at the end of Runway 6 and removing 150 feet of existing pavement at the Runway 24 end. The runway shift would provide clear visibility and line-of-sight of the intersection of Taxiway A and connector Taxiway A1 for ATCT personnel.

Taxiway A would be extended to the southwest to match the additional runway length and a new connector taxiway (Taxiway A4) would be constructed to align with the relocated threshold of Runway 6. All applicable navigational aids (NAVAIDs), lighting systems, and signage would be relocated to match the proposed runway extension and would meet FAA standards including the relocation of existing FAA owned Runway End Identifier Lights (REILs) found at the approach end of Runway 6.

Figure 2.2 Alternative 2 – Shift Runway 150 Feet Southwest and Extend 720 Feet at the Approach End of Runway 6



Source: Mead & Hunt, Inc.

Existing Taxiway D would be relocated 150 feet to the southwest and reconstructed to comply with FAA Indirect Access guidance. This guidance prohibits direct access from an apron to a runway without requiring a turn by aircraft prior to reaching the runway.

Alternative 2 also corrects the geometry of the intersection of Taxiway A1 and Taxiway D with Runway 6/24 so that they intersect Runway 6/24 at right angles. This proposed design reduces pilot confusion and improves situational awareness.

The RPZ Analysis found no incompatible land uses within either runway's relocated RPZ. No RSA or ROFA impacts are expected with this alternative.

Commented [LP(19]: The existing State Street would be considered an incompatible land use.

Commented [FJ(20R19]: But, state street could stay due to RPZ Alt Analysis determination.

There are few environmental concerns or potential impacts associated with Alternative 2. There are two regulated wetlands and a constructed agricultural drainage ditch off the end of Runway 6. Preliminary design indicates that both regulated wetlands can be avoided with no impacts expected. The RSA and ROFA of Runway 6 will intersect a constructed agricultural ditch; however, the ditch flows inside an existing culvert at this location, therefore, ditch impacts are not expected. There is one regulated wetland complex in the vicinity of Runway 24 and proposed relocated Taxiway D. Analysis indicates that the construction of Taxiway D can be designed to avoid impacts to this wetland.

Commented [FJ(21]: Show the wetlands on your exhibit.

Alternative 2 offers many advantages over the other build alternatives. Alternative 2 provides 4,225 feet of needed runway length for turboprop and jet aircraft that currently operate at ARB and are projected to grow moderately in the future. Alternative 2 provides additional runway length entirely within the existing property boundary without requiring the relocation of State Street or causing property or road construction impacts. Although there are regulated environmental resources in the area, impacts to wetlands or agricultural ditches are not expected.

Commented [FJ(22]: Tree impacts?

Additionally, Alternative 2 corrects the geometry of the intersection of Taxiway A1 and Taxiway D with Runway 6/24 so that pilot visibility is maximized thus increasing safety. Shifting the runway 150 feet to the southwest also eliminates the obstructed view from the ATCT so that air traffic controllers can view the entire movement area of Runway 6/24.

This 150-foot shift and runway extension to the southwest also keeps the RPZ at the approach end of Runway 6 and Runway 24 entirely within existing Airport property, eliminating the need for land acquisition or easements to control land uses within these areas. With Alternative 2, a greater percentage of the Runway 24 RPZ will be on ARB property due to the 150-foot shift than previously, thus improving the existing condition and giving the Airport more control of its RPZ.

Commented [FJ(23]: Than previously what? Prior to the project?

While Alternative 2 has many advantageous, one minor disadvantage is the need to relocate the FAA owned REILs at the approach end of Runway 6. This will require the Airport to coordinate with the FAA during final design and construction.

Alternative 2 is considered a ~~prudent and feasible~~ reasonable alternative because it fully meets the project's purpose and need and has minimal community, road, and environmental impacts. Alternative 2 is the least expensive of the build options, with a preliminary cost estimate of $3.1 million. This alternative is considerably less expensive when compared to Alternative 1 and Alternative 3.

2.6 Alternative 3 – Extend 360 Feet at Both Ends of Runway 6/24

Alternative 3 proposes to achieve a runway length of 4,225 feet with the construction of a 360-foot extension on each end of Runway 6/24 (**Figure 2.3 Alternative 3 – Extend 360 Feet at Both Ends of Runway 6/24**). At the approach end of Runway 6, a 360-foot extension of the runway and Taxiway A as well as the construction of a new Taxiway A4 connector, to align with the new runway threshold would be constructed.

At the approach end of Runway 24, a 360-foot extension of the runway and Taxiway A would occur as well as a relocation of Taxiway A1. Existing Taxiway D would be reconstructed to match the runway extension and be designed to intersect Runway 6/24 at a 90-degree angle to address the indirect access issue. Existing pavements of Taxiway A1 and Taxiway D would be removed under this new taxiway configuration.

All applicable navigational aids (NAVAIDs), lighting systems, and signage would be relocated to match the proposed runway extensions at each runway end and would meet FAA design standards including the relocation of existing FAA owned REILs found at the approach end of Runway 6.

With the runway extending to the northeast, State Street would be relocated so its new alignment is constructed around the approach end of Runway 24 and the associated RSA and ROFA surfaces as shown on **Figure 2.3 Alternative 3 – Extend 360 Feet at Both Ends of Runway 6/24**. Much like Alternative 1, this alternative requires State Street to be relocated, but to a lesser degree. Acquisition of land is expected with the relocated State Street and avigation easements within the relocated RPZ at the approach end of Runway 24 for portions outside of the existing airport property will be needed. No RSA or ROFA impacts are anticipated with the 360-foot extension of Runway 6 to the southwest.

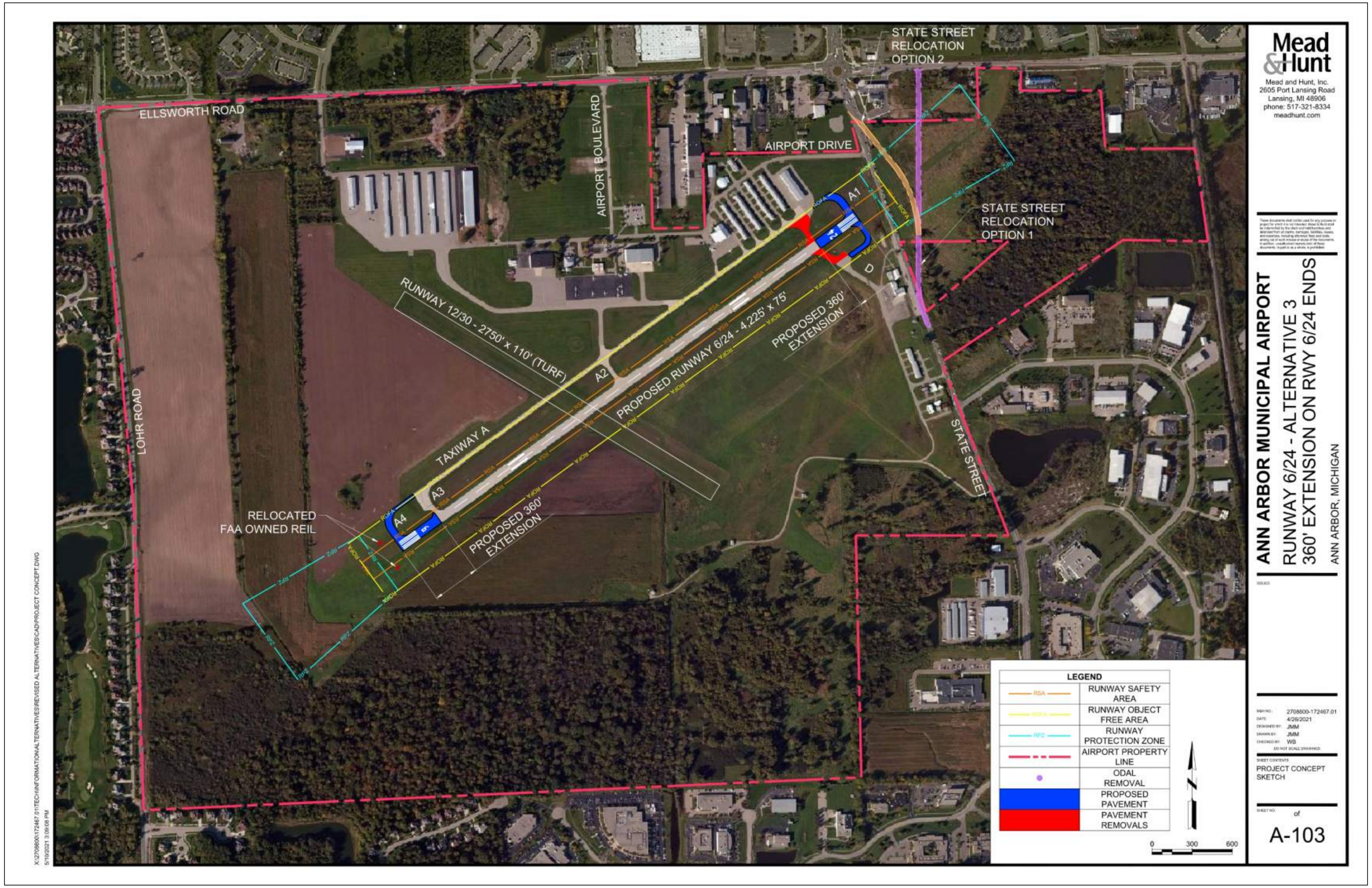
The RPZ Analysis found no incompatible land uses within the relocated Runway 6 RPZ. The analysis found no incompatible land uses within the relocated Runway 24 RPZ beyond the two State Street relocation options.

Environmental impacts can be expected with the 360-foot extension to the northeast as regulated wetlands are found throughout the area east of State Street in the Runway 24 approach. As with Alternative 1, it is likely that both State Street alignment options would impact regulated wetlands. There are few environmental concerns or potential impacts associated with the extension of Runway 6 to southwest. Although two regulated wetlands and a constructed agricultural drainage ditch were previously delineated off the end of Runway 6, these resources are well outside the area of construction and would not be impacted by the 360-foot extension.

Commented [FJ(24]: Show wetlands on exhibit.

The primary advantage of Alternative 3 is that it provides 4,225 feet of usable runway length for turboprop and jet aircraft that currently operate at the Airport. This alternative would also realign Taxiway D so that it has a standard 90-degree intersection with the Runway 6/24 to address direct access issues.

Figure 2.3 Alternative 3 – Extend 360 Feet at Both Ends of Runway 6/24



Source: Mead & Hunt, Inc.

Disadvantages associated with Alternative 3 include the relocation of State Street around the approach end of Runway 24 and its associated RSA & ROFA surfaces. Like Alternative 1, this alternative would cause business and private property impacts where State Street connects to Ellsworth Road, likely causing land and commercial acquisitions. Also, community and road disruptions during construction are likely and wetland impacts with the realignment of State Street may also be expected.

Another disadvantage of Alternative 3 is that the ATCT will continue to have visibility concerns at the intersection of Taxiway A and connector Taxiway A1. Although the alignment of the intersection of Taxiway A1 with Runway 6/24 is improved so that it intersects at a right angle, the relocation of the intersection farther to the northeast would not allow air traffic controllers in the ATCT to view this area clearly, further complicating the current line-of-sight issue. According to FAA guidance, the entire movement area of the airfield should be observable from the ATCT. Under this alternative, FAA criterion would not be satisfied, and the existing condition would remain unresolved.

To implement this alternative, coordination with the FAA would be required to relocate the FAA owned REILs at the approach end of Runway 6 during final design and construction.

Alternative 3 is not considered a ~~prudent and feasible~~reasonable alternative because it fails to meet the project's purpose and need of addressing ATCT visibility issues associated with the intersection of Taxiway A and connector Taxiway A1. Although Alternative 3 provides adequate runway length for current and future users, it fails to provide line-of-sight for the entire movement area of the airfield.

Alternative 3 is the second most expensive of all the build options, with a preliminary cost estimate of $9.9 million. This alternative is approximately three times more expensive than Alternative 2.

2.7 ~~Summary of Impacts~~Comparison of Alternatives

Table 2.1 Summary of ~~Impacts~~ Alternatives Comparison provides an overview of ~~the anticipated impacts of~~ each build alternative in comparison to the purpose and need for the proposed project. ~~Potential impacts~~ Categories of interest are color coded either in "red" or "green" to aid in a visual understanding of the advantages and disadvantages of each alternative. Red indicates the alternative with the highest impact in a specific category while green indicates the alternative with the lowest impact in a particular category. The same criteria are used for each build alternative as to allow an "apples-to-apples" comparison to better evaluate the alternatives. The No-Build Alternative is shown for comparison purposes. For a detailed discussion of potential environmental impacts, see **Chapter 4.0 Environmental Consequences**.

2.8 ~~Selection of the Preferred Alternative~~Alternatives Considered but Discarded from Further Analysis

After a thorough analysis of the advantages and disadvantages of each alternative, the alternative that best meets the project's purpose and need, while minimizing impacts to the built and natural environment is Alternative 2 (see **Figure 2.2 Alternative 2 – Shift Runway 150 Feet Southwest and Extend 720 Feet at the Approach End of Runway 6** for an graphic representation of the proposed alternative).

Commented [LS(25]: Please note that alternatives are not based on economics; alternatives are selected based on the ability to best meet purpose and need while minimizing impacts. The statement as written is fine, but wanted to have some clarity on the assumption that alternatives are chosen based on economics, rather than purpose and need and impacts.

Commented [LS(26]: Rather than making the selection of the preferred without first going thru the environmental analysis I would suggest at end of chapter two discard the alternatives that do not meet purpose and need. This gives the general public an understanding of each alternative rather than showing that the proponent already made their decision on the preferred without the env analysis, so it is best to discard and move into the next chapter with the no build and build alternative (Alt. 2) since you have provided good justification why alternatives 1 and 3 do not meet purpose and need.

Commented [LS(27]: The environmental impacts analysis has not been discussed at this point, other than the wetlands and water resources in the table. Please revise so that you do not give impression that this alternatives comparison includes all environmental impact categories and that only these two categories are applicable.

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Alternative 2 offers many advantages over the other alternatives. Alternative 2 provides 4,225 feet of needed runway length for turboprop and jet aircraft that currently operate at ARB. Alternative 2 would be built entirely within the existing property boundary without requiring the relocation of State Street or causing property or road construction impacts. Although there are regulated environmental resources in the project area, impacts to wetlands or other environmental resources are not anticipated with Alternative 2.

Shifting the runway 150 feet to the southwest eliminates the obstructed view from the ATCT so that air traffic controllers can view the entire movement area of Runway 6/24. Alternative 2 also corrects the geometry of the intersection of Taxiway A and Taxiway A1 with Runway 6/24 so that pilot visibility is maximized, and FAA design standards are met.

The 150-foot shift and runway extension to the southwest keeps the RPZ at the approach end of Runway 6 and Runway 24 entirely within existing ARB property, thus eliminating the need for land acquisition or easements to further control land uses within these areas.

Although Alternative 1 and Alternative 3 partially meet the project's purpose and need by providing adequate runway length to meet the needs of Airport operators, both alternatives fail to address ATCT visibility issues and will continue to have line of sight deficiencies when aircraft and ground vehicles are operating in the northeastern portion of Taxiway A.

Alternative 1 and Alternative 3 also require the relocation of State Street around the approach end of Runway 24 and its associated RSA and ROFA surfaces. Relocating State Street is likely to cause business and private property impacts, resulting in land and commercial acquisitions. Also, community, road, and wetland impacts during construction and realignment of State Street are likely. Lastly, Alternative 1 and Alternative 3 are significantly more expensive than Alternative 2.

Alternative 2 is considered the most ~~prudent and feasible~~ reasonable alternative when compared to the other alternatives. The recommendation that Alternative 2 be selected as the Preferred Alternative for this project has been accepted by the Airport and the Michigan Department of Transportation Office of Aeronautics. As a result, Alternative 2 is carried forward into the EA for additional analysis, public comment, and agency review.

Commented [LS(28]: Perhaps it would be best to state that the airport and MI DOT has recommended that Alternative 2 be carried forward into the EA for additional analysis rather that identifying as preferred without the environmental analysis (also since you are using feasible and prudent, it appears that there may be a 4f resource???)

Commented [FJ(29]: Since 163 is completed, this reference should state "Airport Sponsors proposed project" rather than preferred alternative. We can talk on next meeting as to how to reference and respond as one FAA.

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For a detailed discussion of potential impacts of the Preferred Alternative, see **Chapter 4.0 Environmental Consequences**.

Table 2.1 Summary of ~~Impacts~~Alternatives Comparison					
Category	**Criteria**	**No-Build Alternative**	**Alternative 1**	**Alternative 2 (Preferred Alternative)**	**Alternative 3**
Meets Project Purpose and Need	Provides 4,225 ft of Runway Length for Current and Future Users	**No**	**Yes**	**Yes**	**Yes**
	Provides an Unobstructed View of Taxiway A and Airfield Movement Areas	**No**	**No**	**Yes**	**No**
Airport Environment	Realigns Taxiway D to Comply with FAA AC 150/5300-13A	**No**	**Yes**	**Yes**	**Yes**
	Requires Road Relocations	**No**	**Yes**	**No**	**Yes**
	Expected Property Acquisitions and/or Easements	**No**	**Yes**	**No**	**Yes**
	Expected Commercial / Private Property Impacts	**No**	**Yes**	**No**	**Yes**
	Potential RSA / ROFA / RPZ Impacts	**No**	**Yes**	**No**	**Yes**
	Level of Construction Difficulty	**N/A**	**High**	**Low**	**High**
Natural Resources	Potential Impacts to Wetlands	**No**	**Yes**	**No**	**Yes**
	Anticipated Impacts to Water Resources	**No**	**No**	**No**	**No**
Cost	Estimated Cost to Implement (2021 dollars)	**$0**	**$10.9 million**	**$3.1 million**	**$9.9 million**
The colors "green" and "red" represent a specific ~~impact category~~ category of interest considered to have the least (green) or the most (red) quantity of expected impacts when compared to the other build alternatives.					

Source: Mead & Hunt, Inc.

Commented [FJ(30]: Yes & no does not lead the reader to understand what the wetland impacts are for each alternative. There should be estimates included for each alternative for full disclosure. Also will there be tree impacts? If so a line for tree impacts as well. This will then provide information on potential endangered species impacts related to the Northern Long Eared Bat and Indiana Bat.

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RESEARCH

Residential exposure to aircraft noise and hospital admissions for cardiovascular diseases: multi-airport retrospective study

Andrew W Correia *quantitative analyst*[1], Junenette L Peters *assistant professor*[2], Jonathan I Levy *professor*[2], Steven Melly *geographic information systems specialist*[3], Francesca Dominici *professor, associate dean of information technology*[4]

[1]NMR Group, Somerville, MA, USA ; [2]Department of Environmental Health, Boston University School of Public Health, Boston, MA, USA; [3]Department of Environmental Health, Harvard School of Public Health, Boston; [4]Department of Biostatistics, Harvard School of Public Health, Boston, MA 02115-6018, USA

Abstract

Objective To investigate whether exposure to aircraft noise increases the risk of hospitalization for cardiovascular diseases in older people (≥65 years) residing near airports.

Design Multi-airport retrospective study of approximately 6 million older people residing near airports in the United States. We superimposed contours of aircraft noise levels (in decibels, dB) for 89 airports for 2009 provided by the US Federal Aviation Administration on census block resolution population data to construct two exposure metrics applicable to zip code resolution health insurance data: population weighted noise within each zip code, and 90th centile of noise among populated census blocks within each zip code.

Setting 2218 zip codes surrounding 89 airports in the contiguous states.

Participants 6 027 363 people eligible to participate in the national medical insurance (Medicare) program (aged ≥65 years) residing near airports in 2009.

Main outcome measures Percentage increase in the hospitalization admission rate for cardiovascular disease associated with a 10 dB increase in aircraft noise, for each airport and on average across airports adjusted by individual level characteristics (age, sex, race), zip code level socioeconomic status and demographics, zip code level air pollution (fine particulate matter and ozone), and roadway density.

Results Averaged across all airports and using the 90th centile noise exposure metric, a zip code with 10 dB higher noise exposure had a 3.5% higher (95% confidence interval 0.2% to 7.0%) cardiovascular hospital admission rate, after controlling for covariates.

Conclusions Despite limitations related to potential misclassification of exposure, we found a statistically significant association between exposure to aircraft noise and risk of hospitalization for cardiovascular diseases among older people living near airports.

Introduction

Exposure to aircraft noise has been associated with physiological responses and psychological reactions,[1 2] such as sleep disturbances, sleep disordered breathing, nervousness, and annoyance.[2 3] However, the extent to which exposure to aircraft noise might increase the risk of adverse health outcomes is not well studied. Recent literature, primarily from one multicenter European study, has provided evidence of a relation between aircraft noise and hypertension outcomes, including incidence of hypertension,[4] self reported hypertension,[3] increased blood pressure,[5-8] and antihypertensive medication use.[1-11] These findings are supported by a broader literature, which evaluated the association between residential exposure to noise and cardiovascular disease and found substantial evidence for biological plausibility and positive associations between noise and hypertension, myocardial infarction, and ischemic heart disease.[12] Potential biological mechanisms may include induced release of stress hormones[13-15] and indirect effects on sympathetic activity, which is associated with adverse metabolic outcomes.[15-18]

However, few studies of the relation between aircraft noise and cardiovascular disease have been conducted to date,[1] in part because these studies have small numbers of airports and therefore do not have sufficient statistical power. One study in the Netherlands examined a single airport and had somewhat inconsistent findings, with an association between airport noise and hospital discharge for myocardial infarction in women but

Correspondence to: F Dominici fdominic@hsph.harvard.edu

Extra material supplied by the author (see http://www.bmj.com/content/347/bmj.f5561?tab=related#datasupp)

Technical appendix

EXHIBIT 7, Page 1 of 11

not in men.[19] A large national scale study in Switzerland found evidence of an association between exposure to aircraft noise and myocardial infarction mortality.[20] To our knowledge, no study has been conducted to date that includes a large study population across multiple airports to estimate the association between exposure to aircraft noise and hospital admissions for cardiovascular outcomes. The rigorous estimation of this association requires a sufficiently large number of airports with large surrounding populations, and sufficient variation in the exposure to aircraft noise. We applied statistical methods (hierarchical Poisson regression models) to estimate the association between zip code level exposure to aircraft noise and zip code level hospital admission rate for cardiovascular disease for each airport, and also to estimate this association by combining information across all the airports. The hierarchical Poisson regression model allows us to adjust for potential confounders both at the individual level and at the zip code level, and to estimate airport specific and overall associations between exposure to aircraft noise and health outcomes accounting for the clustering of the zip code level observations by airport.

In this study we use the large and nationally representative US population of Medicare enrollees to evaluate the association between airport related noise and the risk of hospital admission for cardiovascular disease in the population aged 65 years or more residing near airports in the contiguous states. Understanding the link between aircraft noise and cardiovascular disease outcomes is important in characterizing the potential benefits of intervention strategies.[21]

Methods

We obtained the study population from Medicare billing claims for the year 2009. In the United States, unless affected by some specific chronic condition, only people aged 65 or more are eligible for the national insurance program, Medicare. Our study population (6 027 363 people aged ≥65 years enrolled in Medicare and residing in the 2218 zip codes close to the 89 airports) corresponds to approximately 15% of the entire US population of older people.

From the claims, we extracted individual level information regarding the date of hospitalization, length of hospital stay, the associated primary and secondary diagnostic and procedure codes (international classification of diseases), and the costs billed to Medicare. Additional individual level data included age, sex, race, and zip code of residence.

We examined five cause specific cardiovascular hospital admissions based on ICD-9 codes (international classification of diseases, 9th revision) for primary diagnosis: heart failure (ICD-9 428), heart rhythm disturbances (426 to 427), cerebrovascular events (430 to 438), ischemic heart disease (410 to 414, 429), and peripheral vascular disease (440 to 448). A variable for total cardiovascular disease admissions was calculated as the sum of hospital admissions for all these causes.

Noise exposure estimates

The US Federal Aviation Administration provided us with aircraft noise contours in decibels (dB) for 89 airports in the contiguous states. These noise levels were estimated at the centroid of each census block surrounding each of the 89 airports out to a minimum of 45 dB, where a census block is the smallest geographic entity for which population data are available in the US census. Noise contours were obtained using the Integrated Noise Model version 7.0a.[22] The noise descriptor used was day-night sound level (DNL), which adds a 10 dB “penalty” to night time (that is, 10 pm-7 am).[23] Medicare data provide residential information at the zip (postal) code level only. Zip codes are larger geographical areas that are comprised of census blocks (on average there are 168 census blocks per zip code). Therefore, we aggregated the noise exposure across census blocks to obtain an estimate of zip code level (technically, zip code tabulation area) exposure to noise. More specifically, we constructed the following two exposure metrics at zip code level: population weighted average noise (arithmetic mean) among the census blocks within each zip code, where each census block was weighted by the size of the population aged 65 or more obtained from the 2010 US census, and the 90th centile noise exposure among the census blocks within each zip code that contained at least one person aged 65 or more.

Several zip codes were intersected by the 45 dB noise contour at their respective airports, meaning they were comprised of census blocks with noise exposures of both 45 dB or more and less than 45 dB. To calculate our noise exposure metrics for these zip codes, we assigned a value of 45 dB to the census blocks outside the 45 dB contour, whereas census blocks inside the 45 dB contour were assigned their actual value, as estimated by the Integrated Noise Model. We considered only zip codes with census blocks within the 45 dB contour with people aged 65 or more that had Integrated Noise Model estimates when constructing the 90th centile noise exposure variable; for the 90th centile noise exposure there were 1928 such zip codes, with a combined population of 5 523 788 people aged 65 or more. Since Integrated Noise Model estimates were made at census block centroids, some zip codes were excluded because all census block centroids were outside the 45 dB contour.

In our preliminary analyses we developed other candidate noise metrics, including the variance of noise exposure across census blocks within each zip code and percentage of population above various noise thresholds, but focused on the population weighted average and 90th centile noise exposure given their distribution of values and interpretability. More details on the calculation of our two exposure metrics can be found in the technical appendix (see supplementary file).

Outcomes

For each zip code included in the analysis, we calculated the number of hospital admissions and the number of people at risk (Medicare enrollees) separately by two age groups (>75 or ≤75), sex, and race (white (non-Hispanic) or non-white). We conducted the analysis for hospital admissions for all cardiovascular diseases (our main analysis) and separately for cerebrovascular disease, ischemic heart disease, and heart failure. Preliminary analyses indicated that heart rhythm disturbances and peripheral vascular disease were too infrequent to analyze as stand alone outcomes.

Potential confounders

To adjust for the potential confounding effect of socioeconomic status, we extracted several zip code level variables from the 2000 US census. Extensive preliminary analyses led to the selection of percentage Hispanic and median household income as the two key variables that were included in the regression model. To adjust for the potential confounding effect of exposure to air pollution, we also calculated zip code level fine particulate matter ($PM_{2.5}$) and ozone concentrations for 1165 and 779 zip codes, respectively, out of the 2218 zip codes included in the analyses. Air pollution data were obtained from the US Environmental Protection Agency’s air quality system database, and we calculated zip code level averages by taking the average of the air pollution concentrations across all the monitors that fell in that zip code. In addition, as near-roadway air pollution and noise could both serve as confounders, we estimated zip code level road density. The technical appendix describes how road density was estimated (see supplementary file).

Statistical analysis

The dataset included hospital admission counts, number of people at risk, exposure to aircraft noise, and potential confounders for 2218 zip codes surrounding 89 airports. We used hierarchical Poisson regression models with airport specific random effects to estimate, for each airport and on average across airports, the percentage increase in the zip code level hospital admission rate associated with a 10 dB increase in the zip code level aircraft noise. We denote this percentage increase as the relative rate.

In more detail, the hierarchical Poisson regression model can be described in two stages. Firstly, we specified a Poisson regression model for zip code level data to estimate the relative rate as defined above for each airport adjusted by individual level variables (age, sex, and race) and zip code level potential confounders (socioeconomic status and air pollution). Secondly, we combined information across airports to estimate the relative rate on average across all airports. The model estimated airport specific relative rates and the average relative rate across all airports accounting for the clustering of the zip code level observations within each airport and for potential differences across airports in the association between noise and hospitalization rates. The technical appendix provides details on the mathematical formulation of the hierarchical Poisson regression model (see supplementary file).

To investigate the role of the potential confounding factors, we constructed three hierarchical Poisson regression models for each cardiovascular outcome and for each noise metric (population weighted average and 90th centile). Model 1 did not include any zip code level confounders and only controlled for individual level variables (age, sex, and race). Model 2 additionally controlled for zip code level socioeconomic status and demographic variables (median household income and percentage Hispanic). Model 3 additionally controlled for zip code level exposure to air pollution (fine particulate matter and ozone); model 3 was fitted to a substantially smaller dataset of 779 zip codes rather than the 2218 zip codes used for models 1 and 2, because of the limited availability of air pollution data. In secondary analyses of models 2 and 3 we evaluated the potential confounding effect of zip code level road density (a proxy for road noise and near-road air pollution).

Threshold analysis

We conducted additional analyses to quantify the evidence of a potential non-linearity in the association between exposure to aircraft noise and hospital admission rate for cardiovascular disease. We used total hospitalizations for cardiovascular disease as the outcome and the 90th centile noise exposure metric. In the hierarchical models, we replaced the aircraft noise exposure variable (originally defined as a continuous variable) by a categorical variable indicating low, medium, or high exposure to aircraft noise. A zip code was designated as low exposure for noise levels of 50 dB or less (47% of the study population), medium exposure for noise levels greater than 50 dB but 55 dB or less (30%), and high exposure for noise levels greater than 55 dB (23%). Under this model we could estimate three different percentage increases in hospital admission rates for cardiovascular disease corresponding to: medium versus high exposure, low versus high exposure, and low versus medium exposure. Categorizing the exposure in this way, we could detect evidence of a threshold effect if, for example, we found no evidence of an increase in the cardiovascular disease hospitalization rate when noise increases from low to medium, but statistically significant evidence of an increase in the cardiovascular disease hospitalization rate when noise increases from medium to high. Such a scenario would suggest that any relation between noise exposure and cardiovascular disease hospitalizations only occurs for noise exposures above 55 dB. All statistical analyses were performed using R version 2.15.2. The technical appendix provides more details regarding statistical methods (see supplementary file).[24 25]

Population attributable fraction

To facilitate the interpretation of our findings, we estimated the population attributable fraction for aircraft noise as well as for fine particulate matter and ozone. The population attributable fraction can be interpreted as the percentage reduction in hospitalizations for cardiovascular disease that would occur if each of these risk factors was reduced to a level that represents theoretical minimum risk, termed the counterfactual exposure distribution.[26] For aircraft noise, we used the 90th centile exposure metric, and we considered the counterfactual level of exposure for all zip codes as 45 dB (the lowest level of exposure evaluated in our study). Similarly, for both fine particulate matter and ozone we used the minimum concentration within our domain as the counterfactual level of exposure (4.8 $\mu g/m^3$ and 17.6 ppb, respectively). All relative risk estimates were taken from an expanded version of model 3, which incorporated additional zip code level covariates that could potentially confound air pollution effects but had no influence on the association between aircraft noise and hospitalization for cardiovascular disease. For each risk factor we estimated the population attributable fraction across all zip codes that had exposure data for that risk factor. To ensure that the population attributable fraction estimates were comparable to one another, given air pollution data from only a subset of zip codes, we also calculated the population attributable fraction for noise for the subset of zip codes with data on air pollution. More detail about the calculation is available in the technical appendix (see supplementary file).

Results

Overall, there were 2218 zip codes (779 with both fine particulate matter and ozone data) and 6 027 363 Medicare enrollees residing within the 45 dB contour level of the 89 airports. The number of zip codes (Medicare enrollees) surrounding each airport ranged from seven (n=8556) to 107 (n=482 200). The table⇓ summarizes the population characteristics, and figure 1⇓ provides a map presenting the 89 airports displayed by size of the population aged 65 or more within the 45 dB contour level.

Figure 2⇓ shows the estimated relative rates for cardiovascular disease hospitalizations averaged across all airports for both the population weighted noise exposure and the 90th centile of noise exposure. For the 90th centile of noise exposure variable, controlling for age, sex, and race, an increase of 10 dB was associated with an increase of 2.9% (95% confidence interval 0.8% to 5.0%) in hospital admission rate (model 1). In model 2, which additionally controls for zip code level socioeconomic status and demographic variables, the estimated relative rate was only marginally significant (1.6%, 95% confidence interval −0.2% to 3.5%). In model 3, adding pollution variables to model

2, an increase in the 90th centile of noise of 10 dB was associated with an increase of 3.5% (95% confidence interval 0.2% to 7.0%) in the relative rate of having a cardiovascular disease hospitalization. Models 1 to 3, when fitted to only the 779 zip codes with both fine particulate matter and ozone data, yielded consistently positive and statistically significant estimates of the relative rate of cardiovascular disease hospitalizations associated with a 10 dB increase in the 90th centile of noise (fig 2). Figure 3⇓ displays the airport specific and aggregated relative rates (for model 3) of having a cardiovascular disease hospitalization per 10 dB increase in the 90th centile of noise exposure. In secondary analyses (data not shown), we observed that the relation of noise to cardiovascular disease hospitalizations was almost entirely attributed to within airport and across zip code variations in noise exposure rather than to variations between airports. Indeed, the average within airport standard deviation of our 90th centile noise exposure was 4.7 dB, whereas the average between airport standard deviation of the 90th centile noise exposure was only 1.7 dB, indicating that most of the information used to estimate the noise-cardiovascular disease relation in our models was from variability in exposure within airports, rather than from variability in exposure between airports.

For population weighted noise exposure, there was an estimated 6.9% increase (95% confidence interval 2.4% to 11.6%) in the cardiovascular disease hospital admission rate associated with a 10 dB increase in noise in model 1; however, after controlling for socioeconomic status, demographic, and pollution variables (models 2 and 3), this association was no longer statistically significant. Figure 4⇓ shows the airport specific estimated associations for model 3 for population weighted noise. The standard errors of the airport specific estimates were consistently larger than those estimated in models using the 90th centile of noise exposure, due potentially in part to the relatively limited variability of population weighted noise across zip codes within the dataset (see table). Because of this larger standard error in models using the population weighted noise exposure, we focused subsequent analyses on the 90th centile of noise exposure.

Considering subcategories of cardiovascular disease outcomes, we observed generally consistent patterns among models. For example, in model 1, an increase in the 90th centile of noise of 10 dB was associated with cerebrovascular disease and heart failure, with a marginal association for ischemic heart disease. Relative rate estimates were similar across outcomes (fig 5⇓). For model 2, relative rate estimates for all three outcomes declined in magnitude and lost statistical significance. Inclusion of pollution variables (model 3) led to stable or increased relative rate estimates for all three outcomes, relative to model 2. These estimates lacked statistical significance other than for ischemic heart disease but were similar in magnitude to the estimates from model 1. For the population weighted noise exposure, a similar pattern was observed (fig 5).

We found that associations were not sensitive to adjustment for our proxy for road noise and near-road air pollution (road density). In models 2 and 3, the overall estimates per 10 dB increase in the 90th centile of noise without road density were 1.6% (95% confidence interval −0.2% to 3.5%) and 3.5% (0.2% to 7.0%), respectively, and with road density the estimates were 1.6% (−0.4% to 3.5%) and 3.4% (0.3% to 6.7%), respectively.

Figure 6⇓ summarizes the results using the categorized 90th centile noise exposure variable (low, medium, or high). In model 3—controlling for socioeconomic status, demographic, and pollution variables—we found statistically significant evidence of an increase in the hospital admission rate for cardiovascular disease when comparing high versus medium exposure and high versus low exposure, but we did not find statistically significant evidence of an increase when comparing medium versus low exposure. This indicates lack of an association between the 90th centile exposure to aircraft noise and hospital admission rate for cardiovascular disease for noise levels below 55 dB but evidence of an association for noise levels higher than 55 dB.

From the estimation of the population attributable fraction we found that, in total, 2.3% of hospitalizations for cardiovascular disease in our Medicare cohort were attributable to aircraft noise. Twenty three per cent of our Medicare cohort was exposed to greater than 55 dB using the 90th centile exposure metric, and this population contributed half of the attributable hospitalizations. In comparison, across the zip codes with air pollution data, 6.8% of hospitalizations for cardiovascular disease were attributable to fine particulate matter and 4.2% to ozone. The population attributable fraction for noise was similar in the subset of zip codes with air pollution data (2.2%).

Discussion

We estimated the association between residential exposure to aircraft noise and hospitalization rates for cardiovascular disease in the largest population of older people (≥65 years) in the United States studied to date. In models only controlling for individual demographics, we found that this association was positive and statistically significant using both of our noise exposure metrics. The results were attenuated after additionally controlling for area level socioeconomic status and demographic factors. However, the positive association generally persisted, with the most adjusted model accounting for individual level and zip code level variables as well as regional air pollution—particularly for the 90th centile of noise exposure variable, which had greater variability across zip codes than the population weighted average, and correspondingly had greater statistical significance. Positive associations were also observed for individual cardiovascular hospitalization outcomes, but statistical power was reduced.

Comparison with other studies

Our findings add to previous literature in several key ways. Firstly, we investigated the noise-cardiovascular hospitalization relation across gradients of airport noise exposure levels for the largest number of airports and population of older people studied to date. We used administrative data capturing the majority of older US adults, who represent an age group at greater risk for cardiovascular disease. We thus had a large number of events, increasing our power to detect relations. We used hierarchical Poisson regression models to estimate airport specific associations while utilizing information from each airport for a pooled estimate. Secondly, we evaluated the relation of noise with cardiovascular hospitalization as the outcome, which, to our knowledge, has been rarely considered in previous noise studies. An ecological study of 62 municipalities around an airport in Amsterdam found no clustering of cardiovascular hospitalizations in areas close to the airport,[27 28] but we improve on this study by assessing the relation for individual at risk people and by estimating the whole exposure-response relation. Thirdly, our study provides evidence within the United States, where the housing stock and other factors may differ from the European populations generally studied in the past. US studies have been more limited and have not yielded interpretable evidence. For example, the only major US study to date that investigated the relation between aircraft noise and mortality[29] was conducted more than 30 years ago, focused on a single airport, and was critiqued for inadequately controlling for age/sex/race, and other analytical flaws.[30] Fourthly, we accounted for the potential confounding of regional air pollution and near-road air pollution/noise.

The estimated associations of similar magnitude across several cardiovascular disease specific outcomes are broadly consistent with the literature. For example, in areas with more aircraft noise, more people were receiving medical treatment for heart trouble and had a "pathological heart shape."[31] A 2009 review of epidemiological studies found sufficient evidence of positive relations between aircraft noise and high blood pressure and use of cardiovascular medication.[32] One study included in this review investigated the relation between aircraft noise and incidence of hypertension and found a positive association, particularly in older people.[33] Hypertension is not typically a primary reason for hospital admission, so it was not specifically included in our analyses, but hypertension is associated with multiple cardiovascular sequelae that would contribute to hospitalizations.

Our study suggests that although an exposure-response relation exists between noise and cardiovascular admission rates, there may also be a threshold for the effect of noise exposure on cardiovascular disease hospitalizations. Results from our models using a categorized exposure variable showed consistent statistically significant associations in only the highest exposure group (>55 dB). These findings are broadly consistent with previous literature suggesting the possibility of a threshold effect for the aircraft noise-cardiovascular disease relation. In a categorical analysis, Huss and colleagues[20] observed significant mortality from myocardial infarction with aircraft noise only in the highest group of 60 dB (A weighted) or more. Other studies found associations with hypertension outcomes with levels 50 dB (A weighted) or more,[4 33] but did not see results with categories further divided above 50 dB (A weighted) likely due to small numbers in higher categories.[4] It should be noted that our noise exposure metrics were calculated differently from those in prior studies, given zip code level residential resolution, so the noise level at which effects are seen cannot be directly compared.

We did not find statistically significant evidence of heterogeneity in the relation between aircraft noise and cardiovascular hospitalization across airports. In addition we found that evidence of an association between aircraft noise and cardiovascular hospitalization was mainly attributable to variation in noise exposure within airports and not differences between airports. As proposed elsewhere,[11] any observed heterogeneity may reflect differences across the country in sound transmission from outdoors to indoors (where most exposure would be anticipated to occur). This could include structural attributes of the housing stock, frequency of open windows, or degree of soundproofing. Heterogeneity may also reflect differences in the type of aircraft and the frequency of over-flights between airports, although this would be incorporated to some extent in Integrated Noise Model inputs and outputs.

In addition, although aircraft related noise has a different profile from that of traffic related noise, our findings are consistent with the traffic noise-cardiovascular disease health literature. For example, in models controlling for individual characteristics, zip code level socioeconomic status and demographics, and air pollution, we found the strongest association (positive and statistically significant) with hospitalizations for ischemic heart disease, consistent with conclusions of an expert report regarding likely mechanisms of noise related health effects.[12] Our findings were also consistent with studies looking jointly at noise and air pollution. For example, Beelen and colleagues[34] found excess cardiovascular mortality in the highest category of road traffic noise, which was reduced slightly after controlling for air pollution. Huss and colleagues[17] found that the association between aircraft noise and mortality from myocardial infarction was not attenuated with adjustment for air pollution. De Kluizenaar and colleagues[35] found that after controlling for particulate matter (PM_{10}), the relation between road traffic noise and hypertension became marginally significant. We found that controlling for air pollution and road traffic density did not attenuate the relative rate for both of the aircraft noise exposure metrics. It is worth noting that air pollution is less correlated with aircraft noise than it is with road traffic noise.[20]

Limitations of this study

Our analysis has limitations. Although Medicare data covers nearly the entire US older population, this database was developed for administrative purposes and has been shown to be subject to misclassification[36 37] and geographic variability in evaluation and management.[38 39] We only used primary diagnosis, which should reduce misclassification of outcomes,[40] and our analyses of combined cardiovascular disease outcomes are unlikely to have significant misclassification.

Other limitations of the Medicare data include limited individual data on risk factors. For example, we were not able to control for smoking and diet, strong risk factors for cardiovascular disease. These variables would only confound the association between aircraft noise and hospitalization for cardiovascular disease if there were significant correlations between aircraft noise exposures and these risk factors. Noise contours display fairly sharp gradients and skew as a function of prevailing wind directions, given runway orientation, and arrival and departure patterns, which may limit spatial confounding. It is possible that socioeconomically patterned risk factors such as smoking are spatially correlated with aircraft noise, as property values have been found to relate to noise levels.[41] However, property value is not simply tied to aircraft noise levels but is affected by a complex interplay of several factors (for examples, amenities).[42] Our estimates were generally robust to socioeconomic status covariates at area level, but we lacked the individual level addresses and socioeconomic status characteristics to formally address this question. In addition, our zip code level socioeconomic status and demographic variables were taken from census 2000 data because only limited socioeconomic status information from census 2010 was available at the zip code level at the time of our analysis. We thus assumed that patterns of zip code level socioeconomic status remained similar over that time. More generally, the availability of only zip code level address information can lead to exposure misclassification. Noise gradients are substantial at close proximity to airports, and we were unable to differentiate among individuals' noise exposure within zip codes. However, the use of a study population closely aligned with census data (given near universal enrollment of older people in Medicare) allowed us to reasonably estimate a representative zip code resolution population exposure, with error most likely to be Berksonian with unbiased regression coefficients and inflated standard errors. There remains the possibility of downward bias in our estimates due to aggregation effects, but bias has been shown to be limited when within area variance is small relative to between area variance.[43 44] Between zip code variance in noise is larger than within zip code variance, especially for the 90th centile noise exposure, so we would not anticipate substantial bias. However, there is some chance for attenuated effect estimates for the population weighted noise

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exposure because of comparatively smaller between zip code variance in this exposure metric.

Using the Integrated Noise Model to predict noise exposure also has limitations. The model uses average annual input conditions. Therefore, values may lack precision because certain local acoustical variables, such as humidity effects, ground absorption, individual aircraft directivity patterns, and sound diffraction around terrain or buildings, are not averaged or may not be explicitly modeled.[22] That said, the Integrated Noise Model is well established internationally[4] and is the required noise assessment tool in the United States for airport noise compatibility planning and environmental assessments and impact statements.[22] Each of our derived exposure metrics had its own inherent limitations, with the population weighted average potentially reducing the contrast between zip codes, and the 90th centile of noise exposure not capturing the exposure profile of the entire zip code. Our data were not separated by time of day, so we were not able to analyze the effect of night time noise. This is particularly relevant as recent studies found associations of night time noise on cardiovascular related outcomes[5 9] suggesting that sleep interference may mediate the effect of noise on cardiovascular health. However, the Integrated Noise Model outputs did up-weight night time noise, partially accounting for this phenomenon.

Conclusions and future research

We found that aircraft noise, particularly characterized by the 90th centile of noise exposure among census blocks within zip codes, is statistically significantly associated with higher relative rate of hospitalization for cardiovascular disease among older people residing near airports. This relation remained after controlling for individual data, zip code level socioeconomic status and demographics, air pollution, and roadway proximity variables. Our results provide evidence of a statistically significant association between exposure to aircraft noise and cardiovascular health, particularly at higher exposure levels. Further research should refine these associations and strengthen causal interpretation by investigating modifying factors at the airport or individual level.

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Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any commercial entities for the submitted work; no financial relationships with any commercial entities that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: Studies using national data repositories and area level exposure data do not require ethical approval in the United States. All authors had full access to the data and take full responsibility for their integrity.

Data sharing: No additional data available.

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What is already known on this topic

Noise has been associated with hypertension, myocardial infarction, and ischemic heart disease

Aircraft noise in particular has been associated with several hypertension outcomes

Few studies, however, have investigated the relation of aircraft noise to cardiovascular disease, in part because studies surrounding a small number of airports are not typically adequately powered

What this study adds

Long term exposure to aircraft noise is positively associated with hospitalization for cardiovascular disease

The association between aircraft noise and hospitalization for cardiovascular disease is not confounded by air pollution, road density, or area level socioeconomic status

There may be a threshold for the association between aircraft noise and hospitalization for cardiovascular disease

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Table

Table 1| Distribution of zip code level exposure for 2218 zip codes and risk factor data for about six million national insurance plan (servicing those aged ≥65 years) enrollees residing near airports in United States, 2009. Values are percentages unless stated otherwise

Characteristics	Median (interquartile range)
>75 years old (among population aged ≥65)	42.7 (37.3-47.7)
Black ethnicity	5.5 (1.8-20.2)
Hispanic	6.2 (2.1-19.8)
Median household income ($000s)	45.1 (34.9-57.3)
Graduated high school	82.9 (72.8-90.0)
Fine particulate matter ($PM_{2.5}$; annual average, μg/m^3)*	10.2 (9.1-11.3)
Ozone (annual average, ppb)†	25 (22-28)
Population weighted noise (dB, DNL)	45.9 (45.1-48.6)
90th centile of noise among populated census blocks (dB, DNL)	50.3 (47.5-54.5)
Hospital admission rate per 100 000 population:	
All cardiovascular	6288.9 (5064.7-7697.6)
Cerebrovascular events (stroke)	1343.3 (1092.5-1652.2)
Ischemic heart disease	1568.2 (1173.7-1987.8)
Heart failure	1576.4 (1125.2-2142.9)
Heart rhythm disturbances	1222.8 (932.1-1531.2)
Peripheral vascular disease	421.9 (280.3-582.7)

DNL=day-night sound level.
*1165 zip codes with data for $PM_{2.5}$.
†779 zip codes with data for ozone.

Figures

Fig 1 Map of 89 airports in contiguous states included in analysis. Size of circles is proportional to size of population aged 65 or more residing within 45 dB contour lines surrounding each airport

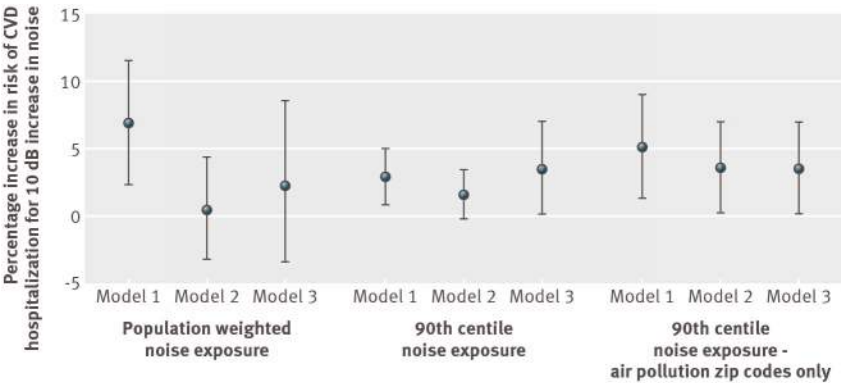

Fig 2 Overall estimates (averaged across 89 airports) of percentage increase in hospital admission rate for cardiovascular disease (CVD) associated with 10 dB (day-night sound level) increase in both exposure variables (population weighted noise exposure and 90th centile noise exposure) for each of the models. Model 1 controls for individual demographics (age, sex, and race); model 2 additionally controls for zip code level socioeconomic status and demographics (% Hispanic and median household income); and model 3 adds to model 2 by also controlling for annual average fine particulate matter and ozone levels. Panel 3 shows models 1 to 3 fitted to only the 779 zip codes with both air pollution variables

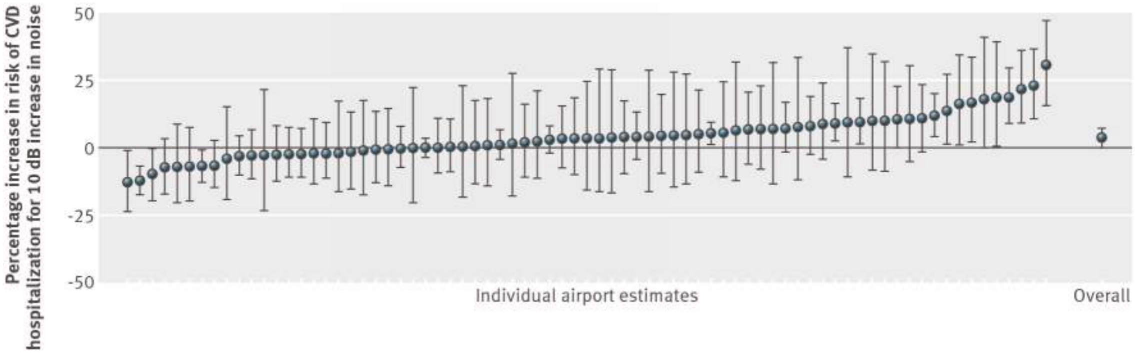

Fig 3 Airport specific and overall estimates of percentage increase in hospital admission rate for cardiovascular disease (CVD) associated with 10 dB (day-night sound level) increase in 90th centile noise exposure among census blocks within zip codes. Model controls for individual demographics (age, sex, and race), zip code level socioeconomic status and demographics (% Hispanic and median household income), and annual average fine particulate matter and ozone levels (model 3). Airport specific estimates are arranged from lowest to highest values

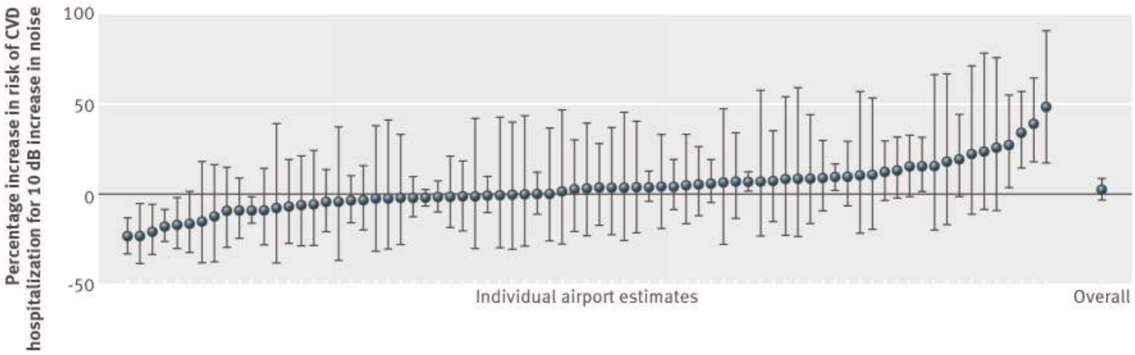

Fig 4 Airport specific and overall estimates of percentage increase in hospital admission rate for cardiovascular disease (CVD) associated with 10 dB (day-night sound level) increase in the population weighted noise exposure. This model controls for individual demographics (age, sex, and race), zip code level socioeconomic status and demographics (% Hispanic and median household income), and annual average fine particulate matter and ozone levels (model 3). Airport specific estimates are arranged from lowest to highest values

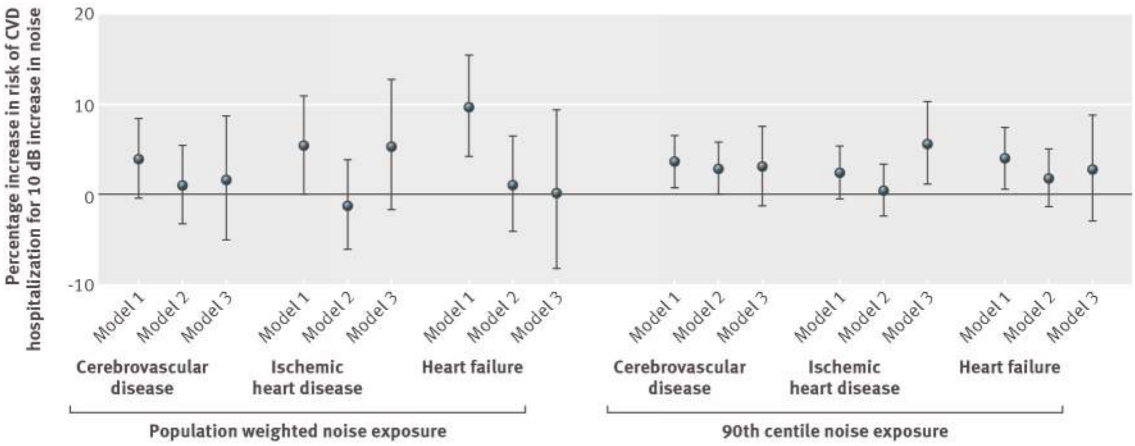

Fig 5 Overall estimates of percentage increase in hospital admission rate for specific cardiovascular diseases (CVD) associated with 10 dB (day-night sound level) increase in noise exposure. Results are reported for cerebrovascular disease (stroke), ischemic heart disease, and heart failure, and for both exposure variables (population weighted noise exposure and 90th centile noise exposure) for each of the three models. Model 1 controls for individual demographics (age, sex, and race); model 2 additionally controls for zip code level socioeconomic status and demographics (% Hispanic and median household income); and model 3 adds to model 2 by also controlling for annual average fine particulate matter and ozone

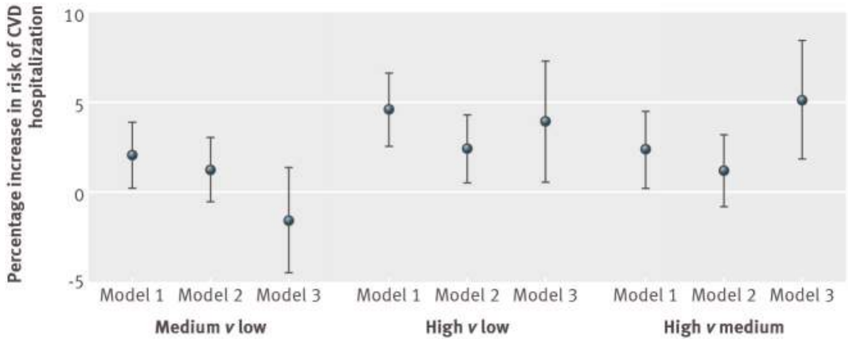

Fig 6 Estimated relative rates of cardiovascular disease (CVD) hospitalization from models using categorized 90th centile of noise exposure. Low noise indicates <50 dB, medium noise indicates 50-55 dB, and high noise indicates >55 dB. Model 1 controls for individual demographics (age, sex, and race), model 2 additionally controls for zip code level socioeconomic status and demographics (% Hispanic and median household income), and model 3 adds to model 2 by also controlling for fine particulate matter and ozone levels

RESEARCH

Aircraft noise and cardiovascular disease near Heathrow airport in London: small area study

Anna L Hansell *assistant director*[1] *honorary consultant*[2], Marta Blangiardo *non-clinical lecturer in biostatistics*[1], Lea Fortunato *research associate*[1], Sarah Floud *PhD student*[1], Kees de Hoogh *senior research officer*[1], Daniela Fecht *research associate*[1], Rebecca E Ghosh *research associate*[1], Helga E Laszlo *acoustician*[1], Clare Pearson *research assistant*[1], Linda Beale *honorary research fellow*[1], Sean Beevers *senior lecturer in air quality modelling*[3], John Gulliver *lecturer in environmental science*[1], Nicky Best *professor in statistics and epidemiology*[1], Sylvia Richardson *visiting professor in biostatistics*[1] *director*[4], Paul Elliott *director*[1]

[1]UK Small Area Health Statistics Unit, MRC-PHE Centre for Environment and Health, Dept Epidemiology and Biostatistics, School of Public Health, Imperial College London, W2 1PG, UK; [2]Imperial College Healthcare NHS Trust, London, UK; [3]Environmental Research Group, MRC-PHE Centre for Environment and Health, King's College London, UK; [4]MRC Biostatistics Unit, Cambridge, UK

Abstract

Objective To investigate the association of aircraft noise with risk of stroke, coronary heart disease, and cardiovascular disease in the general population.

Design Small area study.

Setting 12 London boroughs and nine districts west of London exposed to aircraft noise related to Heathrow airport in London.

Population About 3.6 million residents living near Heathrow airport. Risks for hospital admissions were assessed in 12 110 census output areas (average population about 300 inhabitants) and risks for mortality in 2378 super output areas (about 1500 inhabitants).

Main outcome measures Risk of hospital admissions for, and mortality from, stroke, coronary heart disease, and cardiovascular disease, 2001-05.

Results Hospital admissions showed statistically significant linear trends (P<0.001 to P<0.05) of increasing risk with higher levels of both daytime (average A weighted equivalent noise 7 am to 11 pm, $L_{Aeq,16h}$) and night time (11 pm to 7 am, L_{night}) aircraft noise. When areas experiencing the highest levels of daytime aircraft noise were compared with those experiencing the lowest levels (>63 dB *v* ≤51 dB), the relative risk of hospital admissions for stroke was 1.24 (95% confidence interval 1.08 to 1.43), for coronary heart disease was 1.21 (1.12 to 1.31), and for cardiovascular disease was 1.14 (1.08 to 1.20) adjusted for age, sex, ethnicity, deprivation, and a smoking proxy (lung cancer mortality) using a Poisson regression model including a random effect term to account for residual heterogeneity. Corresponding relative risks for mortality were of similar magnitude, although with wider confidence limits. Admissions for coronary heart disease and cardiovascular disease were particularly affected by adjustment for South Asian ethnicity, which needs to be considered in interpretation. All results were robust to adjustment for particulate matter (PM_{10}) air pollution, and road traffic noise, possible for London boroughs (population about 2.6 million). We could not distinguish between the effects of daytime or night time noise as these measures were highly correlated.

Conclusion High levels of aircraft noise were associated with increased risks of stroke, coronary heart disease, and cardiovascular disease for both hospital admissions and mortality in areas near Heathrow airport in London. As well as the possibility of causal associations, alternative explanations such as residual confounding and potential for ecological bias should be considered.

Introduction

Although the literature on population annoyance associated with aircraft noise is extensive,[1 2] little research has been conducted on the potential effects of aircraft noise on cardiovascular health.[2] Most studies of the health effects associated with aircraft noise have focused on blood pressure and the risk of hypertension.[3-8] The few reports of aircraft noise and risk of stroke, coronary heart disease, or cardiovascular disease are inconsistent,[9-12] partly reflecting reduced statistical power

Correspondence to: P Elliott p.elliott@imperial.ac.uk

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Supplementary information

because of the small proportion of the population exposed to high aircraft noise levels.[10 11]

Noise levels show a graded, direct relation with prevalence of annoyance. This is greater for aircraft noise than for other environmental noise sources—that is, road traffic or rail[1]; community annoyance due specifically to aircraft noise seems to have increased in the past 30 years.[13] Noise is associated with activation of the sympathetic nervous system.[14] In animal models, chronic exposure to noise leads to increases in blood pressure,[15 16] and in humans noradrenaline (norepinephrine) levels,[17] whereas acute exposure to non-habitual loud noise increases adrenaline (epinephrine) levels.[17] Experimental studies of humans acutely exposed to noise at very high level also show increases in blood pressure[18] and heart rate.[19]

Heathrow airport, situated in a densely populated area in west London, is one of the busiest airports in the world. Reports have shown an association between aircraft noise, especially at night, and hypertension,[3] acute increases in blood pressure,[7] and self reported cardiovascular disease[12] in the population living near airports, including Heathrow. We investigated the risks of stroke, coronary heart disease, and cardiovascular disease hospital admissions and mortality in areas exposed to aircraft noise near Heathrow airport.

Methods

We carried out analyses comparing rates of hospital admissions for cardiovascular disease and mortality in neighbourhoods (small areas) exposed to different levels of aircraft noise related to Heathrow airport. We used a standard noise metric, the A weighted equivalent (Aeq) sound pressure level (L), denoted as L_{Aeq}. The human ear is more sensitive to some frequencies than others. The L_{Aeq} devalues lower frequencies compared with medium and higher frequencies,[20] and uses a set of mathematical curves to adjust the sound pressure level to the relative loudness perceived by human hearing. We defined daytime noise ($L_{Aeq,16h}$) as the average A weighted equivalent noise from 7 am to 11 pm and night time noise (L_{night}) from 11 pm to 7 am.

Study area and population

The study area comprised 12 London boroughs and nine districts west of London exposed to aircraft noise related to Heathrow airport, defined as being partly or wholly within the 2001 50 dB noise contour for Heathrow aircraft during the daytime ($L_{Aeq,16h}$) supplied by the Civil Aviation Authority (fig 1⇓). Additionally, we had confounder data for particulate air pollution and road traffic noise for the 12 London boroughs (data for districts outside London were not readily comparable with the data available for London).

We defined neighbourhoods (small areas) by using the national census geographical units, which are census output areas and super output areas. The study area comprised 12 110 census output areas (average 297 inhabitants, area 0.13 km^2) and 2378 super output areas (1510 inhabitants, area 0.65 km^2). We used the census output area as the unit of analysis for hospital admissions and the super output area, an aggregate of on average five census output areas, for mortality as the numbers of deaths were insufficient for meaningful analyses at census output area level. We used Office for National Statistics annual mid-year population estimates by age and sex for 2001-05 at London borough or district level, which we then disaggregated to census output areas and super output areas using the UK 2001 census age-sex distribution.

Aircraft noise data

From the Civil Aviation Authority we obtained aircraft noise data related to Heathrow airport for 2001 on 10 m × 10 m grids. The noise data had been modelled using the UK Civil Aircraft Noise Contour Model ANCON, which uses information on flight paths of arriving and departing aircraft along with factors such as height, speed, and engine power to derive noise at ground level.[21]

We calculated population weighted annual average noise levels for daytime and night time aircraft noise for census output areas and super output areas. This was done because the noise grid was smaller than the area of the census output area or super output areas and populations are not evenly distributed (for example, a census output area has on average 125 addresses and six postcodes that may cluster to one or other side of the census output area) so a simple area averaging would not accurately represent population exposures (see supplementary appendix).

Health data

We extracted post coded data on hospital admissions (main reason for admission, first episode of stay in a given year) and deaths (by underlying cause) for the study area, 2001-05, from Office for National Statistics and Department of Health data held by the UK Small Area Health Statistics Unit at Imperial College London. Data were obtained for stroke (ICD-10 codes I61, I63-I64, international classification of diseases, 10th revision), coronary heart disease (ICD-10 I20-I25), and cardiovascular disease (ICD-10 Chapter I) and then linked these by postcode (average 23 households) to census output area and super output area.

Data on potential confounders

We included ethnicity, deprivation, and a smoking proxy at census output area and super output area level as potential confounders. Area level ethnic composition and deprivation from the 2001 census were obtained from the Office for National Statistics. For the two major ethnic groups in London, we categorised areas by South Asian ethnicity (census term "Asian or Asian British," for which we included only "Indian," "Pakistani," and "Bangladeshi") and black ethnicity (census term "Black or Black British," which includes "Black Caribbean," "Black African," and "Other Black"). We used the following cut points: the national average (%) for England and Wales at census output area level (4% for South Asian, 2% for black ethnicity), double the national average (8%, 4%), and 50% South Asian or black ethnicity—areas where these comprised the majority ethnic group. This gave us four categories for each ethnicity, where the reference categories were less than or equal to the national average (%) for that ethnic group (≤4% for South Asian and ≤2% for black ethnicity). The deprivation score used was Carstairs index,[22] categorised in fifths. As a proxy measure for area level smoking we used smoothed lung cancer mortality (ICD-10 codes C33-C34) relative risk estimates, 2005, for census output areas and super output areas,[23] since data on individual smoking or smoking prevalence were not available.

For the 12 London boroughs within the study area we also obtained data on air pollution and daytime road noise. For air pollution, the Environmental Research Group at King's College London provided estimates of annual mean particulate matter of 10 microns or less (PM_{10}) at spatial resolution of 20 m × 20 m for 2001, using dispersion modeling as detailed in the London Emissions Toolkit and London Air Pollution Toolkit.[24] We obtained data on daily average road traffic noise for 2001 from the Department for Environment, Food and Rural Affairs (Defra), expressed in continuous A weighted equivalent sound pressure levels ($L_{Aeq,16h,road}$) on 10 m × 10 m grids at 1 dB resolution between ≥50 dB and ≤75 dB. Road traffic noise data (major roads) had been generated to comply with the European Noise Directive 2002/49/EC (http://ec.europa.eu/environment/noise/directive.htm) and modeled using the calculation of road traffic noise method at a height of 4 m above ground using characteristics of the road network.[25] We linked the air pollution and road noise data to census output area and super output area using population weighting (see supplementary appendix).

Statistical analyses

Correlations between aircraft noise and potential confounders were assessed using Goodman Kruskal tau rank correlation coefficients.

For the entire study area we carried out a small area analysis of aircraft noise and the three cardiovascular outcomes, adjusted for potential confounders at area level (census output area or super output area): age, sex, South Asian and black ethnicity, deprivation, and smoking proxy (lung cancer mortality risk). We conducted a sensitivity analysis for the 12 London boroughs (London area) additionally including particulate air pollution (PM_{10}) and road noise as potential confounders.

We grouped daytime aircraft noise and road noise into six categories from ≤51 to >63 dB in increments of 3 dB, which represents a doubling in sound intensity that is just perceptible as a change in loudness to the human ear. For aircraft noise, 57 dB L_{Aeq} is taken as the point at which noticeable community annoyance starts to occur[26 27]; the Civil Aviation Authority attempts to minimise areas exposed to this level of noise or higher, measured as the daytime $L_{Aeq,16h}$ over a 92 daytime summer period.[27] Our $L_{Aeq,16h}$ aircraft noise categories include a 57 dB cut point, although we use an annual not summertime average (fig 1). Night time aircraft noise affected fewer areas (fig 1), and 5 dB categories (≤50, >50-55, and >55 dB) were used.

To aid comparisons between daytime and night time aircraft noise, we also ran daytime analyses using the same 5 dB categories. The correlation between daytime and night time aircraft noise categories was almost perfect (τ ≥0.98, see supplementary table 2) so we did not include these together in the statistical models, but analysed them separately.

To allow for small numbers and unstable rates of hospital admissions and mortality we used random effects models to produce smoothed relative risk maps. To examine the effects of noise we fitted Poisson regression models with an additional random effect term to account for over-dispersion and residual heterogeneity, using the R software (www.r-project.org/) and tested for linear trend across noise categories using the median noise value for each category.

Results

Figure 1 shows the study area; the population (2001 census) was 3.6 million. During 2001-05, 189 226 first episodes of hospital stay in a given year for cardiovascular disease (16 983 stroke, 64 448 coronary heart disease) and 48 347 cardiovascular disease related deaths (9803 stroke, 22 613 coronary heart disease) occurred in the study area (table⇓). Supplementary figures 1 and 2 show the maps of hospital admissions at census output area level and mortality at super output area level, respectively. Only 2% or fewer of the study population lived in areas exposed to the highest category of daytime (>63 dB) or night time (>55 dB) aircraft noise (see supplementary table 1).

The area affected by night time noise was less extensive than that for daytime noise (fig 1). Supplementary figure 3 shows the spatial distributions of the confounder data. Areas with a high proportion of South Asian and black ethnicity population were concentrated in the north eastern and eastern part of the study area, respectively, which were also areas with higher deprivation and higher risks of lung cancer. Within the London area, higher levels of PM_{10} were found in the eastern part towards central London; distributions of both PM_{10} and road noise differed from that of aircraft noise (supplementary figure 3 and figure 1). Correlations between aircraft noise and potential confounders are shown in supplementary table 2 where τ=1 denotes perfect positive correlation and τ=−1 denotes perfect negative correlation. Correlations between confounders and aircraft noise were all ≤|0.30|. In the London boroughs, aircraft noise was modestly correlated with PM_{10} (τ=−0.2 for daytime noise and τ=-0.3 for night time noise) but not with road traffic noise (τ ≤0.02).

Hospital admissions

Figure 2⇓ and supplementary table 3 show the results for hospital admission for daytime and night time noise adjusted for age and sex, and with additional adjustment for ethnicity, deprivation, and the smoking proxy. For each of stroke, coronary heart disease, and cardiovascular disease the pattern was of increasing risk of admission with increasing aircraft noise, and all linear tests for trend were statistically significant (P<0.001 to P<0.05). The risk of coronary heart disease in particular, and to a lesser extent cardiovascular disease, was noticeably reduced by adjustment for multiple confounders, in particular South Asian ethnicity.

In multiple adjustment models, for daytime aircraft noise (>63 dB *v* ≤51 dB) the relative risk for stroke was 1.24 (1.08 to 1.43), for coronary heart disease was 1.21 (1.12 to 1.31), and for cardiovascular disease was 1.14 (1.08 to 1.20). Corresponding relative risks for night time noise (>55 dB *v* ≤50 dB) were 1.29 (1.14 to 1.46), 1.12 (1.04 to 1.20), and 1.09 (1.04 to 1.14). Results using the same categories for daytime as for night time noise (supplementary table 3) suggested higher relative risks for night time noise.

Mortality

Figure 3⇓ and supplementary table 4 show the results for mortality for daytime and night time noise. The relative risks of mortality were numerically similar to those for hospital admissions at the higher noise levels, although confidence intervals were wider, reflecting the smaller numbers of events. In multiple adjusted models, for daytime aircraft noise (>63 dB *v* ≤51 dB) the relative risk for stroke mortality was 1.21 (95% confidence interval 0.98 to 1.49), for coronary heart disease was 1.15 (1.02 to 1.30), and for cardiovascular disease was 1.16 (1.04 to 1.29). The corresponding relative risks for night time aircraft noise (>55 dB *v* ≤50 dB) were 1.23 (1.02 to 1.49), 1.11 (0.99 to 1.24), and 1.14 (1.03 to 1.26). Results using the same categories for daytime as for night time noise (supplementary table 4) suggested higher relative risks for night time noise. Tests for linear trend across noise categories in the fully adjusted models were significant (P<0.05) for daytime noise and coronary heart disease but not for stroke or cardiovascular disease, nor night time noise.

Sensitivity analyses

Results were materially unchanged with additional confounder adjustment for particulate air pollution and road traffic noise in the 12 London boroughs (data not shown).

Discussion

In this small area study covering a population of 3.6 million people living near Heathrow airport in London, we identified significant excess risks of stroke, coronary heart disease, and cardiovascular disease, especially among the 2% of the population affected by the highest levels of daytime and night time aircraft noise.

Strengths and weaknesses of this study

Strengths of this study include the large general population sample, inclusion of both incident events (hospital admissions) and mortality, and wide range of aircraft noise levels, providing sufficient statistical power to detect modest associations. Common to some other epidemiological studies,[11 12] we analysed aircraft noise separately from other transport noise as it is currently unclear whether noise may be additive or whether aspects of noise such as sound frequency and number and duration of noisy events may be important. Limitations include inability to adjust for confounders at individual level. We were able to adjust at small area level for ethnicity, deprivation, and a smoking proxy (and additionally for particulate air pollution and road traffic noise for a subset of 2.6 million people), but we did not have access to individual level information on confounders such as smoking; therefore results at the area level may not be applicable to individuals (ecological fallacy). Admissions for coronary heart disease and to a lesser extent for cardiovascular disease were particularly affected by adjustment for South Asian ethnicity, which itself is strongly associated with risk of coronary heart disease[28]; hence these risk estimates should be interpreted cautiously. We restricted our hospital admission analyses to the first admission within one calendar year; as we did not link across years it is possible that some may be readmissions if they occurred in different calendar years. However, point estimates at higher noise levels were similar for mortality and hospital admissions, making it less likely that this was an important source of bias.

We examined exposures to aircraft noise in 2001 and health outcomes in 2001-05. We were unable to distinguish between short and longer term effects of noise in the present study and this needs to be examined in further research. Some studies[9 12] have suggested larger effect estimates with longer duration of residence, but this may reflect exposure misclassification among more recent residents. Our data on noise exposure are left censored because of concerns about the accuracy of noise models at low levels. It is difficult to determine the resulting misclassification bias; this may also have affected the size of our risk estimates by restricting the range of noise levels across which effect sizes were estimated. A further potential source of bias is that we did not have information on migration in and out of the study areas.

Possible explanations and implications in the context of previous studies

Potential for causality of the observed associations needs to be considered in the context of previous studies, including consideration of biological plausibility and coherence. Much of the research effort concerning adverse effects of noise on cardiovascular health has focused on effects on blood pressure and risk of hypertension, hypertension being the leading cause of stroke and a major risk factor for heart disease.[29] Acute exposure to noise activates the neuroendocrine system, leading to short term increases in heart rate or blood pressure, or both[18-30] and in stress hormone levels[31]; neuroendocrine effects are also seen with chronic exposures[17] offering potential mechanisms by which environmental noise may be related to cardiovascular risk. Although these effects have mainly been studied at high exposure levels in the occupational[30 32] or experimental setting,[31] they may also occur at ambient environmental noise levels.[31] In a study conducted near four European airports (including Heathrow), noise disturbance by aircraft noise at night was associated with short term increases in blood pressure of 6-7 mm Hg.[7]

Increased risks of stroke and coronary heart disease would be expected if such physiological changes were to lead to sustained raised blood pressure.[29] A meta-analysis published in 2009[8] of five studies (totalling nearly 45 000 participants) of aircraft noise and risk of long term hypertension gave a pooled relative risk estimate of 1.13 (95% confidence interval 1.00 to 1.28) per 10 dB increase. A subsequent study of approximately 5000 adults in Sweden found long term effects on hypertension risk only in subgroup analyses, but half the study population had a family history of diabetes, which may affect generalisabilty.[5]

The previous literature concerning aircraft noise and cardiovascular disease and mortality is sparse and not fully consistent. In a cross sectional study of people living near seven European airports (including Heathrow), a significant association was observed between night time average aircraft noise and self reported heart disease and stroke (odds ratio 1.25, 95% confidence interval 1.03 to 1.51) in those who had been living in the same place for 20 or more years.[12] A census based study of 4.6 million adults aged more than 30 years in Switzerland reported an association with mortality from myocardial infarction in those exposed to the highest level of aircraft noise and who had lived at least 15 years in their place of residence; no associations were seen with stroke or cardiovascular mortality.[9] A study of adults aged 45-85 years living in Vancouver, Canada[10] did not find associations of aircraft noise with coronary heart disease mortality, neither did a population based study of about 57 000 adults aged 50-64 years in Denmark with stroke mortality.[11] These previous studies had lower population exposures to aircraft noise than in London.

As with our findings for aircraft noise, significant associations have been reported for road traffic noise and heart disease[10-35] and stroke.[11] A meta-analysis of 24 population studies of road traffic noise found a dose-response association with hypertension,[36] with a combined odds ratio of 1.03 (95% confidence interval 1.01 to 1.06) per 5 dB increase of road traffic noise, in the range 45-75 dB.

We were unable to distinguish between night time and daytime noise as they were highly correlated and so their effects could not be differentiated. More research is needed to determine if night time noise that disrupts sleep may be a mechanism underlying observed associations.[2]

Conclusions

How best to meet commercial aircraft capacity for London and other major cities is a matter of active debate, as this may provide major economic benefits. However, policy decisions need to take account of potential health related concerns, including possible effects of environmental noise on cardiovascular health. Our results suggest that high levels of aircraft noise are associated with an increased risk of stroke,

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coronary heart disease, and cardiovascular disease. As well as the possibility of causal associations, alternative explanations should be considered. These include the potential for incompletely controlled confounding and ecological bias, as we did not have access to individual level confounder data such as ethnicity and smoking. Further work to understand better the possible health effects of aircraft noise is needed, including studies clarifying the relative importance of night time compared with daytime noise, as this may affect policy response.

We dedicate this paper to Lars Jarup who helped initiate this project and passed away in 2010. We thank Peter Hambly, Margaret Douglass, Eric Johnson, Kayoung Lee, and David Morley for technical support and the advisory group members: Tim Williams, Yvette Bosworth (Defra), Stephen Turner (Bureau Veritas/Defra), and Nigel Jones (Extrium) who provided traffic noise data, and Darren Rhodes and Kay Jones (Civil Aviation Authority) who provided aircraft noise data.

Contributors: PE and ALH with MB, LF, SF, KdH, DF, LB, and SR conceived and designed the study. MB, LF, SF, KdH, DF, REG, LB, JG, and SB were involved in data extraction and preparation. JG, KdH, and DF were responsible for the Geographical Information System analyses. JG, KdH, and HEL interpreted the aircraft noise data. LF and MB with REG and CP carried out the statistical analyses, supervised by PE, ALH, SR, and NB. The analyses were interpreted by PE, ALH, MB, LF, NB, SR, HEL, and JG. ALH and PE drafted the initial report; all coauthors revised the report and approved the final version. MB and LF contributed equally to this paper and are joint second authors. PE is the guarantor of this paper.

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Ethical approval: The study was commissioned by the Department of Health in England; ethical approval was obtained from the National Research Ethics Service reference 12/LO/0566 and the Imperial College Research Ethics Committee.

Data sharing: Data are available from the data providers on application with appropriate ethics and governance permissions, but we do not hold data provider, ethics, or governance permissions to share the dataset with third parties.

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What is already known on this topic

Few studies have examined aircraft noise and risk of incident or fatal cardiovascular disease or stroke

Previous studies have found an increased risk of hypertension associated with aircraft noise and increased risk of hypertension, stroke, and coronary heart disease with road traffic noise

These findings are consistent with those from studies of occupational noise exposure, and experimental studies examining short term effects of noise on the cardiovascular system

What this study adds

Areas with high levels of aircraft noise related to Heathrow airport in London had increased risks of stroke, coronary heart disease, and cardiovascular disease

Interpretation should consider not only causal associations but also possible alternative explanations such as residual confounding and ecological bias

Table

Table 1| Summary statistics for population data (2001) and health data (2001-05)

Variables	Total	Mean (SD) by geographical unit, 2001	
		Super output area (n=2378)	Census output area (n=12 110)
Population (2001 census)	3 591 719	1510 (140)	297 (74)
Mortality:			
Stroke (I61, I63, I64)*	9803	4 (4)	—
Coronary heart disease (I20-I25)*	22 613	10 (6)	—
Cardiovascular disease (Chapter I)	48 347	20 (12)	—
Hospital admissions:			
Stroke (I61, I63, I64)*	16 983	—	1 (2)
Coronary heart disease (I20-I25)*	64 448	—	5 (4)
Cardiovascular disease (Chapter I)*	189 226	—	16 (8)

*ICD-10 codes (international classification of diseases, 10th revision).

Figures

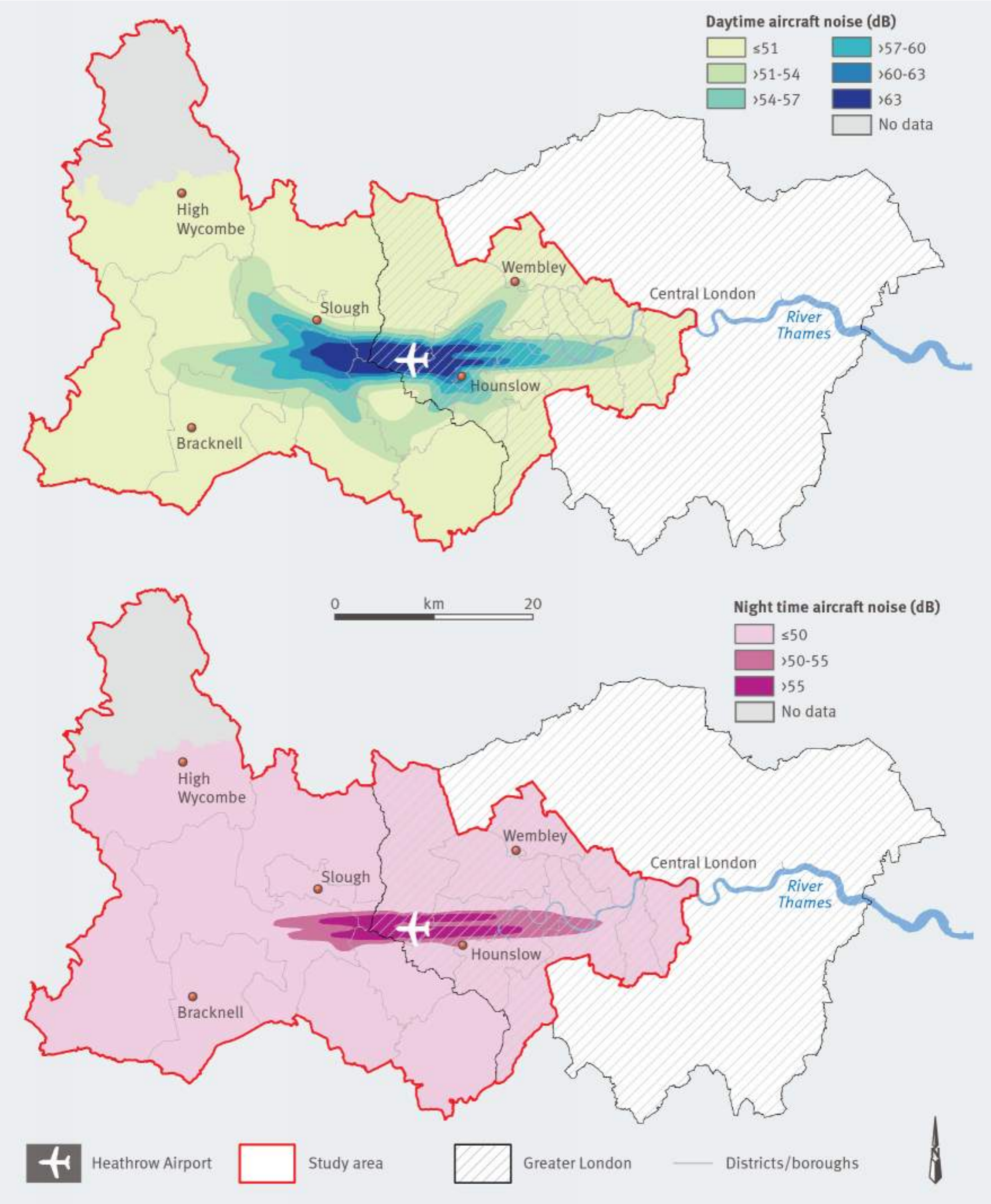

Fig 1 Contextual maps of study area and Heathrow airport showing (top) London boroughs and districts outside London overlaid with the 2001 annual average aircraft daytime (7 am-11 pm, $L_{Aeq,16h}$) noise contours; (bottom) annual average night time noise contours (11 pm-7 am, L_{night})

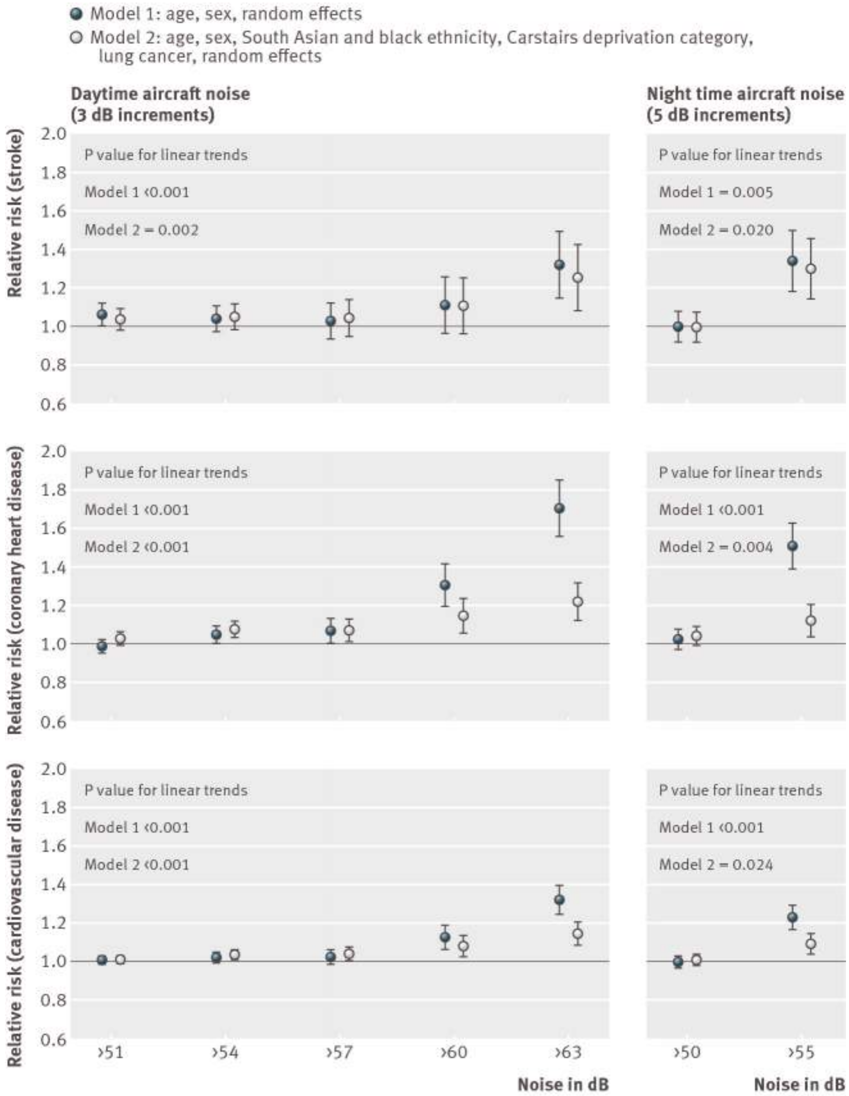

Fig 2 Relative risks (95% confidence intervals) for associations between hospital admissions for stroke, coronary heart disease, and cardiovascular disease in 2001-05 and annual population weighted average daytime aircraft noise (relative to ≤51 dB) and night time aircraft noise (relative to ≤50 dB) in 2001, census output areas

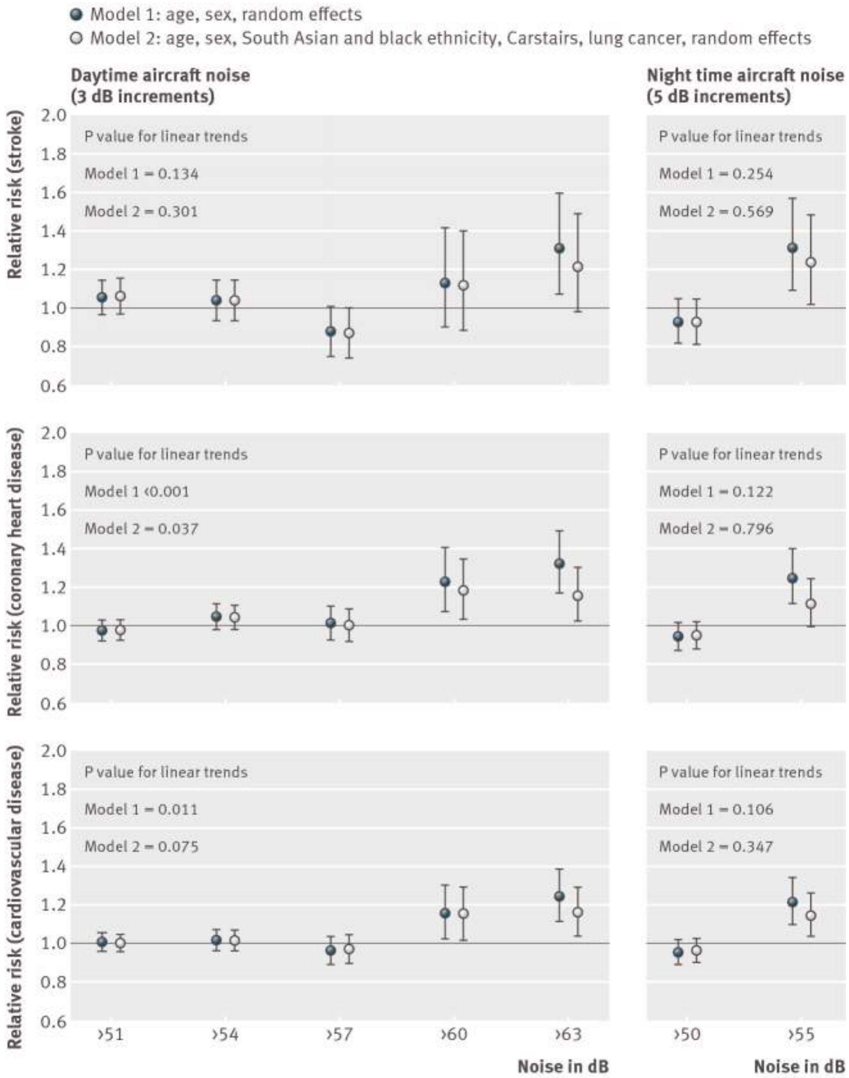

Fig 3 Relative risks (95% confidence intervals) for associations between mortality from stroke, coronary heart disease, and cardiovascular disease in 2001-05 and annual population weighted average daytime aircraft noise (relative to ≤51 dB) and night time aircraft noise (relative to ≤50 dB) in 2001, super output areas

E-039

Reported Heart Disease and Stroke in Relation to Aircraft and Road Traffic Noise in Six European Countries – the HYENA Study

Authors:

Sarah Floud, Imperial College London, United Kingdom
Marta Blangiardo, Imperial College London, United Kingdom
Charlotte Clark, Queen Mary University of London, United Kingdom
Wolfgang Babisch, Department of Environmental Hygiene, Federal Environment Agency, Germany
Danny Houthuijs, National Institute for Public Health and the Environment, The Netherlands
Göran Pershagen, Institute of Environmental Medicine, Karolinska Institute, Sweden
Klea Katsouyanni, Department of Hygiene, Epidemiology and Medical Statistics, Medical School, National and Kapodistrian University of Athens, Greece
Manolis Velonakis, Laboratory of Prevention, Nurses School, National and Kapodistrian University of Athens, Greece
Ennio Cadum, Environmental Epidemiologic Unit, Regional Agency for Environmental Protection, Italy
Anna Hansell, Imperial College London, United Kingdom, *a.hansell@imperial.ac.uk*

Background: Studies on the health effects of aircraft and road traffic noise exposure suggest excess risks of hypertension and myocardial infarction.

Objectives: Our aim was to assess the risk of cardiovascular disease in relation to noise from aircraft and road traffic.

Methods: This cross-sectional study measured cardiovascular disease as a diagnosis by a doctor of myocardial infarction, angina pectoris or stroke, after moving to current address, as reported by 4,861 participants living near airports in six European countries (UK, Germany, Netherlands, Sweden, Italy and Greece). Exposure was assessed using models with 1dB resolution (5dB for UK road traffic noise) and spatial resolution of 250mx250m for aircraft and 10mx10m for road traffic noise. Data were analysed using multilevel logistic regression.

Results: We found an elevated risk of cardiovascular disease in relation to average daily road traffic noise exposure after adjustment for major confounders (OR 1.19 (95% CI 1.00, 1.41)) per 10dB; participants aged 65-70 yrs were at particular risk (OR 1.34 (1.03, 1.74)). We also found an excess risk of cardiovascular disease in relation to aircraft noise at night which lost statistical significance after adjustment for confounders (OR 1.12 (0.98, 1.21)). Exposure to aircraft noise in the day was not associated with an increased risk of cardiovascular disease (OR 1.06 (0.92, 1.21)).

Conclusions: Our results suggest exposure to road traffic noise is associated with increased risk of cardiovascular disease, with a greater effect in older people. Exposure to aircraft noise at night may also be a risk factor for cardiovascular disease.

Keywords: aircraft noise, road traffic noise, cardiovascular disease, cross-sectional study, transport

Aircraft Noise, Air Pollution, and Mortality From Myocardial Infarction

Anke Huss,[a,b] Adrian Spoerri,[a] Matthias Egger,[a] and Martin Röösli,[c,d] for the Swiss National Cohort Study Group

Objective: Myocardial infarction has been associated with both transportation noise and air pollution. We examined residential exposure to aircraft noise and mortality from myocardial infarction, taking air pollution into account.

Methods: We analyzed the Swiss National Cohort, which includes geocoded information on residence. Exposure to aircraft noise and air pollution was determined based on geospatial noise and air-pollution (PM_{10}) models and distance to major roads. We used Cox proportional hazard models, with age as the timescale. We compared the risk of death across categories of A-weighted sound pressure levels (dB(A)) and by duration of living in exposed corridors, adjusting for PM_{10} levels, distance to major roads, sex, education, and socioeconomic position of the municipality.

Results: We analyzed 4.6 million persons older than 30 years who were followed from near the end of 2000 through December 2005, including 15,532 deaths from myocardial infarction (ICD-10 codes I 21, I 22). Mortality increased with increasing level and duration of aircraft noise. The adjusted hazard ratio comparing ≥60 dB(A) with <45 dB(A) was 1.3 (95% confidence interval = 0.96–1.7) overall, and 1.5 (1.0–2.2) in persons who had lived at the same place for at least 15 years. None of the other endpoints (mortality from all causes, all circulatory disease, cerebrovascular disease, stroke, and lung cancer) was associated with aircraft noise.

Conclusion: Aircraft noise was associated with mortality from myocardial infarction, with a dose-response relationship for level and duration of exposure. The association does not appear to be explained by exposure to particulate matter air pollution, education, or socioeconomic status of the municipality.

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From the [a]Institute of Social and Preventive Medicine (ISPM), University of Bern, Bern, Switzerland; [b]Institute for Risk Assessment Sciences, University of Utrecht, Utrecht, The Netherlands; [c]Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Basel, Switzerland; and [d]University of Basel, Basel, Switzerland.

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Correspondence: Matthias Egger, Institute of Social and Preventive Medicine (ISPM), Finkenhubelweg 11, CH-3012 Bern, Switzerland. E-mail: egger@ispm.unibe.ch.

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Effects on the cardiovascular system have been reported for acute and chronic noise, occupational and residential exposure, and different types of noise—in particular, noise from aircraft and roads.[1–5] Reported health effects for chronic exposure include, for example, hypertension,[6,7] myocardial infarction,[5] cardiovascular morbidity or mortality,[2,8] and increased use of medication for cardiovascular conditions.[9]

Air pollution has also been recognized as a potential risk factor for adverse cardiovascular outcomes, including myocardial infarction.[10,11] Road traffic is an important source of both noise and air pollution, which makes it difficult to disentangle their independent associations with cardiovascular events. Indeed, measures of noise and air pollution from roads are often highly correlated.[2,12–14] Several investigators have called for studies that simultaneously examine effects of air pollution and noise,[15–17] but few such studies have been performed.[2,5,9]

The correlation with air pollution is considerably weaker for noise from aircraft than from roads, which should facilitate controlling for air pollution when examining the effects of noise. We used the data of the Swiss National Cohort[18,19] to examine the association between aircraft noise and mortality from myocardial infarction and selected other causes, taking levels of air pollution into account.

METHODS

Study Population

The Swiss National Cohort links the national census with mortality and emigration records using deterministic and probabilistic record linkage.[18] The present analysis was based on the 4 December 2000 census data and on mortality and emigration data for the period 5 December 2000 to 31 December 2005, with causes of death coded according to the 10th revision of the International Classification of Diseases, Injuries and Causes of Death (ICD-10). Enumeration in the 2000 census is near-complete; coverage was estimated at

98.6%.[20] In persons older than 30 years, 95% of deaths could be successfully linked to a 2000 census record. We excluded persons younger than age 30 years, for whom linkage is less complete.[18] We also excluded people with missing building coordinates because these coordinates were necessary to determine exposure.

The database contains information on age, sex, marital status, and education. There are also variables at the level of the municipality and residential building, describing, for example, the degree of urbanization and socioeconomic characteristics of the municipality, the age of the house and whether it had been renovated. The geocoded places of residence are also included in the census data. In general, these coordinates give a location within a few meters of the building midpoint. Data of the census of 1990 were used to identify the place of residence at that time. The censuses of 2000 and of 1990 also include information on whether persons had lived at the same place 5 years before each census, ie, in 1995 or in 1985. We were thus able to identify persons who had lived at the same place for at least 5, 10, or 15 years. The Cantonal ethics committees of Bern and Zurich approved the Swiss National Cohort.

Outcomes

Outcomes were death from acute myocardial infarction and deaths from all circulatory diseases (regardless of whether the cause of death was listed as primary or concomitant cause on the death certificate) and deaths from all causes. We also considered cancer of the trachea, bronchus or lung as an indication of smoking behavior, and stroke, which is related to hypertension. Table 1 lists the ICD-10 codes of the causes of death analyzed.

Exposure to Aircraft Noise

There are 65 civil airports and airfields in Switzerland. For the largest airport, Zurich, a dedicated noise exposure model describes yearly average exposures for the years 2001–2005 in 1 dB(A) steps and a resolution of 100 × 100 m for day (6 AM–10 PM) and night exposure for the "first hour of the night" (10 PM–11 PM), "second hour of the night" (11 PM–midnight), and the rest of the night (only the airports of Zurich, Geneva, and Basle have air traffic after 10 PM). The model from the Federal Office of Civil Aviation was used for the other 64 airports (the 2 national airports in Basle and Geneva, 11 regional airports, and 51 smaller airfields). The model includes isophones in 5 dB(A) categories. We used L_{DN}A-weighted sound pressure levels, ie, time-weighted energy based means calculated from day (6 AM–10 PM) and night (10 PM–6 AM) sound pressure levels. In this calculation, night sound pressure levels receive a 10 dB(A) penalty,[21] as previously applied by others.[2,5,9,22] We analyzed exposure in 5 dB(A) categories (<45, 45–49, 50–54, 55–59, and ≥60 dB(A)).

Exposure to Air Pollution

We analyzed individual levels of exposure to background air pollution concentration at the place of residence, using a dispersion model for PM_{10} developed by the Federal Office for the Environment for the year 2000.[23,24] The models have a resolution of 200 × 200 m. The average exposure (in $\mu g/m^3$) at the place of residence was used in the analysis. As a proxy for traffic-related air pollutants, we also considered the proximity of the place of residence to the "major road network" and the "interconnecting road network," using data from the Swiss TeleAtlas database. The major road network includes motorways, slip roads, and other roads of high importance. The "interconnecting road network" describes main roads between towns and main traffic connections within the larger cities. We used corridors of <50, 50–99, 100–199, and ≥200 m around these roads.

Statistical Analyses

We analyzed the association between aircraft noise and cardiovascular mortality using Cox proportional hazard models, with age as the underlying timescale. Time was measured from the date of birth, with delayed entry: participants entered the risk set on the 5th of December, the day after the national census. Follow-up time was censored on the earliest of emigration, death from a cause other than the outcome, or 31 December 2005. Person-years of observation were calculated as the interval between 5 December 2000 and death, emigration or 31 December 2005. We compared the risk of death across exposure categories and by the duration of living in exposed corridors (for at least 5, 10, or 15 years). Noise

TABLE 1. ICD-10 Codes, Total Number of Deaths, and Number of Deaths in People Who Lived >15 Years at the Same Residence. Swiss National Cohort Study, 5 December 2000 to 31 December 2005

Cause of Death	ICD-10 Codes	No. Deaths Included in Analysis	No. Deaths in People Who Lived >15 Years at the Same Residence
Acute myocardial infarction	I 21, I 22	15,532	8192
All circulatory disease	I 00–I 99	177,836	86,999
Cancer of the trachea, bronchus or lung	C 33, C 34	14,095	7415
Stroke	I 60–I 64 (excluding I 63.6)	25,231	12,102

ICD-10 indicates 10th revision of the International Classification of Diseases, Injuries and Causes of Death.

TABLE 2. Characteristics of Study Population (n = 4.6 million) by Aircraft Noise and Air Pollution Categories

Exposure	Total Study Population %	Women %	Age (Years) Median	Tertiary Education %	Unemployed %	Foreign Nationals %	Old Building, Not Renovated %[a]
Aircraft noise (dB(A))							
<45	91.4	52	50.7	19	2	17	26
45–49	3.5	52	50.7	20	3	21	25
50–54	2.9	52	50.2	18	3	25	30
55–59	1.9	51	49.7	20	3	26	27
≥60	0.3	49	49.1	16	4	30	30
Distance to main road (m)							
≥200	17.2	52	51.2	21	2	12	21
100–199	23.4	53	50.9	21	2	16	23
50–99	23.6	53	50.6	20	2	18	26
<50	35.8	52	50.2	17	3	22	29
PM_{10}[b] (per 10 $\mu g/m^3$)							
<18.8	50.0	52	50.5	18	2	13	21
18.8–39.7	40.0	53	50.9	20	3	21	29
≥39.8	10.0	53	50.5	22	4	28	38

[a]Persons living in a building older than 30 years that had never been renovated.
[b]Cut-offs correspond to median and 90th percentile.

exposure below 45 dB(A) was used as the reference category. We tested models for the proportionality assumption using statistical tests based on Schoenfeld residuals; the assumption was met for all exposure variables.

Models were adjusted for sex (model I), sex and demographic, socioeconomic and geographical variables (model II), and additionally for air-pollution levels (PM_{10}) and distance to major roads (model III). These variables included civil status (single, married, divorced, widowed), nationality (Swiss, other), educational level (primary, secondary, tertiary), setting (urban, rural), language region (German, French, Italian), type of building (older than 30 years without renovation vs. other), and socioeconomic status of the municipality (Sotomo Index[25]). Using the fully adjusted model (model III), we performed stratified analyses by age (30–72.8, 72.9–82.3, >82.3 years, corresponding to the 33.3rd and 66.6th percentiles of age at death for myocardial infarction), sex, duration of living at the place of residence (at least 5, 10, or 15 years), and whether the building was old without having undergone major renovation work (30 years or older). We tested for interaction between these variables and the effect of exposure to aircraft noise by comparing models with and without interaction terms using likelihood ratio tests. Data were analyzed in Stata (version 10, Stata Corporation, College Station, TX). Results are presented as hazard ratios (HRs) with 95% confidence intervals (CI).

RESULTS

Of 7.29 million persons recorded in the 2000 census, 2.59 million (36%) were excluded because they were younger than 30 years at the census. Another 113,855 persons (2%) were excluded because of missing building coordinates. The analyses were based on 4,580,311 people, 22,512,623 person-years, and 15,532 deaths from acute myocardial infarction. The number of deaths from the other causes is given in Table 1; 282,916 people died of any cause.

Table 2 shows the characteristics of the study population by aircraft-noise and air-pollution categories. With increasing exposure to noise, the proportion of persons with tertiary education declined, whereas the proportion unemployed, the proportion of foreign nationals, and the proportion of people living in old and unrenovated buildings increased. Similar trends were seen with decreasing distance to major roads and increasing PM_{10} values.

Table 3 gives the results from the Cox regression models for death from acute myocardial infarction and from all circulatory disease. The risk of death from myocardial infarction was higher in people exposed to aircraft noise of 60 dB(A) or more. The association became stronger when models were adjusted for sociodemographic and geographical variables and PM_{10} air pollution levels, with the strongest association being observed in the fully adjusted analysis restricted to persons who had been exposed for 15 years or longer (HR = 1.5 [95% CI = 1.0–2.2]). Figure 1 shows fully adjusted HRs of death from myocardial infarction across exposure to aircraft noise, stratified by duration of exposure at the same place of residence; the increase in the risk of death from myocardial infarction became stronger with both increasing level and increasing duration of exposure. The risk of death from myocardial infarction was also higher in those living near a major road (<100 m). This association was again strongest in the fully adjusted

TABLE 3. Risk of Death From Selected Causes by Aircraft Noise and Air Pollution Exposure Categories, Switzerland, 2000–2005

	Hazard Ratios (95% Confidence Intervals)			
Exposure	**Model I**	**Model II**	**Model III**	**Model III Subpopulation**[a]
Acute myocardial infarction				
Aircraft noise (dB(A))				
<45	1.00	1.00	1.00	1.00
45–49	0.96 (0.87–1.04)	1.00 (0.91–1.10)	1.02 (0.93–1.12)	1.03 (0.90–1.17)
50–54	0.97 (0.88–1.07)	1.01 (0.91–1.11)	1.02 (0.92–1.13)	1.05 (0.91–1.21)
55–59	0.98 (0.86–1.11)	1.04 (0.91–1.18)	1.05 (0.92–1.19)	1.14 (0.96–1.37)
≥60	1.27 (0.94–1.71)	1.28 (0.95–1.73)	1.30 (0.96–1.76)	1.48 (1.01–2.18)
Distance to major road (m)				
≥200	1.00	1.00	1.00	1.00
100–199	0.97 (0.92–1.02)	0.98 (0.93–1.04)	0.99 (0.94–1.04)	1.02 (0.95–1.10)
50–99	1.07 (1.02–1.12)	1.08 (1.03–1.14)	1.09 (1.03–1.15)	1.18 (1.10–1.27)
<50	1.10 (1.05–1.15)	1.10 (1.05–1.15)	1.10 (1.05–1.16)	1.17 (1.09–1.24)
Air pollution (per 10 $\mu g/m^3$ PM_{10})	0.98 (0.97–0.99)	0.99 (0.97–1.00)	0.98 (0.97–1.00)	0.99 (0.97–1.01)
All circulatory disease				
Aircraft noise (dB(A))				
<45	1.00	1.00	1.00	1.00
45–49	1.06 (1.03–1.09)	1.03 (1.00–1.05)	1.02 (0.99–1.04)	1.04 (1.00–1.08)
50–54	0.96 (0.93–0.99)	1.01 (0.97–1.04)	1.00 (0.97–1.03)	1.04 (0.99–1.09)
55–59	0.93 (0.89–0.97)	1.01 (0.97–1.06)	1.01 (0.97–1.05)	0.98 (0.92–1.04)
≥60	1.03 (0.92–1.14)	1.00 (0.90–1.11)	0.99 (0.89–1.09)	1.03 (0.89–1.18)
Distance to major road (m)				
≥200	1.00	1.00	1.00	1.00
100–199	1.00 (0.99–1.02)	1.02 (1.00–1.03)	1.02 (1.00–1.03)	0.99 (0.97–1.01)
50–99	1.01 (1.00–1.03)	1.04 (1.02–1.05)	1.04 (1.02–1.05)	1.03 (1.00–1.05)
<50	1.01 (1.00–1.03)	1.04 (1.03–1.06)	1.04 (1.03–1.06)	1.06 (1.04–1.08)
Air pollution (per 10 $\mu g/m^3$ PM_{10})	1.00 (1.00–1.01)	1.00 (0.99–1.00)	1.00 (0.99–1.00)	1.00 (1.00–1.01)
Cancer of the trachea, bronchus, or lung				
Aircraft noise (dB(A))				
<45	1.00	1.00	1.00	1.00
45–49	0.91 (0.83–1.00)	0.92 (0.84–1.02)	0.85 (0.77–0.94)	0.81 (0.70–0.93)
50–54	1.07 (0.97–1.18)	1.06 (0.96–1.17)	1.02 (0.93–1.13)	0.97 (0.85–1.12)
55–59	1.01 (0.89–1.14)	1.04 (0.92–1.18)	1.02 (0.90–1.16)	1.03 (0.87–1.23)
≥60	1.09 (0.80–1.48)	1.13 (0.83–1.53)	1.01 (0.74–1.37)	0.79 (0.48–1.29)
Distance to major road (m)				
≥200	1.00	1.00	1.00	
100–199	1.12 (1.06–1.18)	1.10 (1.04–1.17)	1.09 (1.03–1.15)	1.05 (0.98–1.13)
50–99	1.19 (1.13–1.26)	1.16 (1.09–1.22)	1.13 (1.07–1.19)	1.06 (0.99–1.15)
<50	1.29 (1.23–1.36)	1.22 (1.16–1.28)	1.19 (1.13–1.25)	1.10 (1.03–1.18)
Air pollution (per 10 $\mu g/m^3$ PM_{10})	1.05 (1.04–1.06)	1.05 (1.04–1.07)	1.05 (1.03–1.06)	1.05 (1.03–1.07)
Stroke				
Aircraft noise (dB(A))				
<45	1.00	1.00	1.00	1.00
45–49	0.99 (0.92–1.06)	0.96 (0.89–1.03)	0.97 (0.90–1.04)	1.03 (0.92–1.14)
50–54	0.94 (0.87–1.02)	0.96 (0.89–1.05)	0.97 (0.89–1.05)	1.02 (0.90–1.15)
55–59	1.01 (0.91–1.12)	1.06 (0.95–1.17)	1.06 (0.95–1.18)	0.96 (0.82–1.13)
≥60	0.84 (0.62–1.15)	0.82 (0.60–1.11)	0.83 (0.61–1.13)	0.88 (0.58–1.34)
Distance to major road (m)				
≥200	1.00	1.00	1.00	1.00
100–199	1.00 (0.97–1.05)	1.02 (0.98–1.06)	1.02 (0.98–1.06)	0.97 (0.91–1.03)
50–99	0.97 (0.93–1.01)	0.99 (0.95–1.03)	0.99 (0.96–1.04)	0.98 (0.92–1.04)
<50	0.99 (0.96–1.03)	1.01 (0.98–1.05)	1.02 (0.98–1.06)	1.03 (0.98–1.09)
Air pollution (per 10 $\mu g/m^3$ PM_{10})	0.99 (0.98–0.99)	0.99 (0.98–1.00)	0.99 (0.98–1.00)	0.99 (0.97–1.00)

Model I, adjusted for sex, using age as the underlying time scale (all models).

Model II, adjusted for sex, civil status (single, married, divorced, widowed), nationality (Swiss, other), educational level (primary, secondary, tertiary), setting (urban, rural), language region (German, French, Italian), type of building (older than 30 years without renovation versus other), and socioeconomic status of the municipality.

Model III, adjusted for the same variables as in model II and all 3 exposure variables (noise, distance, PM_{10}) in the same model.

Major roads include motorways, slip roads, and main roads between towns and main traffic connections within the larger cities.

[a]Model III, analysis restricted to persons who lived at least 15 years at the same place of residence.

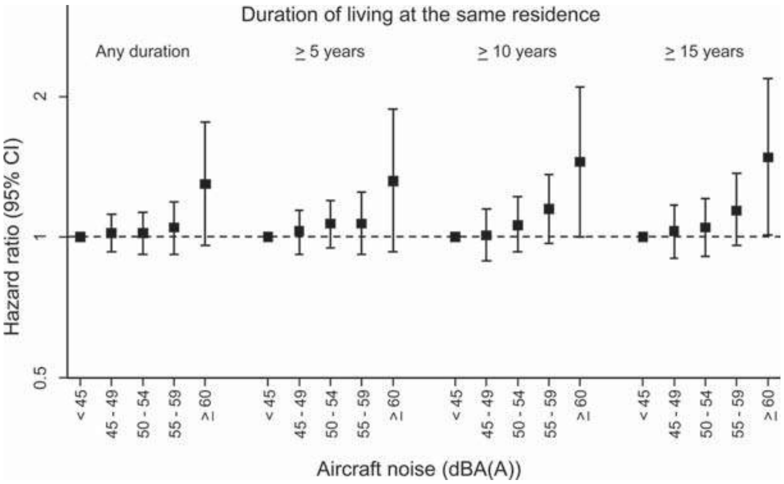

FIGURE 1. Mortality from myocardial infarction and estimated exposure to aircraft noise, Switzerland, 2000–2005. Results from model III are shown for persons who at the time of census had lived in the same place of residence for any duration, or for at least 5, 10, or 15 years.

model, restricted to people who had been exposed for at least 15 years (Table 3). No association was seen with increasing concentrations of PM_{10}.

The risk of death from all circulatory disease was not associated with aircraft noise or levels of PM_{10}, although it was slightly increased near major roads (Table 3). Similarly, mortality from cancer of the trachea, bronchus, or lung was not increased in those exposed to high levels of aircraft noise, but it was increased among people living close to a major road and among people exposed to high levels of PM_{10}. The association with distance to major roads was attenuated when adjusted for sociodemographic and geographical variables. No associations were observed with the risk of death from stroke (Table 3). Finally, there was little evidence for an association with mortality from all causes, in either sex-adjusted or fully adjusted analyses. The HR comparing ≥60 dB(A) with <45 dB(A) for death from all causes from the fully adjusted analysis (model III) was 1.0 (95% CI = 0.96–1.1).

Results were similar in sensitivity analyses when considering day-time or night-time exposures rather than time-weighted energy-based means (data not shown). Fully adjusted HRs from model III comparing highest (≥60 dB(A)) with lowest (<45 dB(A)) levels of exposure to aircraft noise tended to increase with increasing age, and were higher in men compared with women. Noise exposure was also higher for people living in old buildings that had not been renovated compared with new or renovated buildings (Fig. 2). Formal tests of interaction, however, failed to reach conventional levels of statistical significance ($P > 0.32$).

Additional information is provided in 2 supplementary online tables. eTable 1 (http://links.lww.com/EDE/A426) shows the distribution of person-years and deaths in each exposure category. eTable 2 (http://links.lww.com/EDE/A426) gives Pearson correlation coefficients showing that daytime exposure ($L_{Aeq,\ day}$) was correlated with $L_{Aeq,\ night}$ and with L_{DN} exposure. Correlation between aircraft noise and distance to roads or PM_{10} levels was weak, with Spearman rank correlation coefficients ranging from 0.01 to 0.22.

DISCUSSION

This large national linkage study found that people exposed to high levels of noise from aircraft were at increased risk of dying from myocardial infarction. The association was strongest in those who had lived at the same highly exposed location for at least 15 years. We found no association of fatal myocardial infarction with levels of background PM_{10} levels, although the risk of death from myocardial infarction was higher among persons living near a major road. The strength of the association between aircraft noise and death from

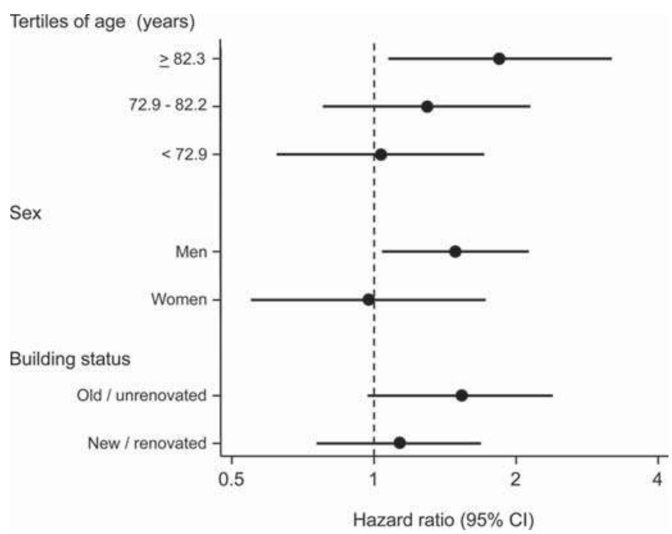

FIGURE 2. Mortality from myocardial infarction comparing highest (≥60 dB(A)) with lowest (<45 dB(A)) levels of exposure to aircraft noise, stratified by age, sex, and status of building. Results from model III are shown for persons who at the time of census had lived in the same place of residence for any duration.

myocardial infarction was not attenuated when the analysis was adjusted for distance to major roads and for levels of PM_{10}. As expected, the correlation of aircraft noise with the other 2 exposures was weak, which made it possible to include all 3 variables in the multivariable model. Finally, there was little evidence of an association between aircraft noise and all circulatory diseases.

Confounding by lifestyle factors associated with socioeconomic position is of concern, as we observed that living in highly exposed areas in the vicinity of airports was associated with lower educational level. Earlier analyses of the Swiss National Cohort found substantial educational gradients in mortality and life expectancy; life expectancy at age 30 was 7 years greater in men with university education compared with men who had compulsory education only.[18,26] It is therefore noteworthy that statistical adjustment for educational level and other variables related to socioeconomic position at the level of the building and community did not affect the strength of the association between exposure to aircraft noise and mortality from myocardial infarction. Also, no association emerged between mortality from all causes and exposure to aircraft noise, both in sex-adjusted and maximally adjusted analyses. Taken together, it thus seems unlikely that the association is explained by factors associated with lower education and socioeconomic position in those exposed to aircraft noise.

The Swiss National Cohort combines 2 population registers that are virtually complete: the national census and national routine mortality data. This, in combination with the use of dispersion models rather than individual measurements to assess exposure, essentially excludes bias due to selective participation. The use of dispersion models may, however, have introduced exposure misclassification; a person's exposure to aircraft noise will be modified by building characteristics as well as lifestyle factors. Such misclassification will probably be nondifferential, and is unlikely to explain the increased mortality we observed for myocardial infarction but not for other causes of death. Incomplete linkage of deaths might also have introduced bias. Most deaths (95%) could be linked to a census record, but results could have been distorted if the completeness of death linkage was itself related to noise exposure. Foreign nationals were more common among those exposed to high levels of aircraft noise, and linkage rates were slightly lower in foreign than in Swiss nationals (92% compared with 95%). Studies from New Zealand and Northern Ireland found that deaths in socioeconomically disadvantaged persons were less likely to be successfully linked to a census record.[27,28] We cannot directly examine this in the Swiss cohort due to missing data on socioeconomic position on the death certificate, but such bias is also likely in our study. Under-ascertainment of deaths in highly exposed people, which would have biased results toward the null, is therefore more likely than over-ascertainment of deaths.

Bias in coding of deaths must also be considered. If the probability of recording myocardial infarction, lung cancer, or stroke on the death certificate was affected by exposure status, bias could be introduced. Such cause of death attribution bias was, for example, observed in a sample of US death certificates: compared with data from a cohort study in the same population, lung cancer was less likely to be recorded as the underlying cause if the decedent had never smoked, and more likely to be recorded as an underlying cause if the person who died was a smoker.[29] Such bias is, however, unlikely in studies of aircraft noise.

What mechanisms other than confounding and bias might be at work? Exposure to high levels of aircraft noise could increase levels of psychologic stress, leading to hypertension and ultimately increasing the risk of death from ischemic heart disease.[30] Hypertension and psychosocial factors, including perceived stress and depression, may account for a substantial proportion of the risk of myocardial infarction worldwide.[31] Higher levels of stress may also be related to smoking.[32] A review of the literature on stress hormones and noise concluded that there were unequivocal effects of noise exposure on the endocrine system, but that it was unclear whether the findings from experimental studies translated into health hazards.[33] More recently a substudy of the Hypertension and Exposure to Noise near Airports project, a multicenter cross-sectional study in 6 European countries, found that morning saliva cortisol levels tended to be increased in people exposed to aircraft noise.[34] In the main study,[7] night-time exposure to aircraft noise increased the risk of hypertension. We found no association between exposure to aircraft noise and mortality from stroke, which is closely related to hypertension. Similarly, we found no association with mortality from lung cancer, which is closely related to smoking.

We also observed an increased risk of myocardial infarction in people living close to a major road (<100 m) but no association with background PM_{10} levels. Exposure to high levels of road traffic noise might explain this finding, but the lack of data on road traffic noise is a limitation of our study. A national noise database suitable for reliably assigning traffic noise levels to individuals is in development in Switzerland.[35] Alternatively, the increased risk associated with living near a major road might be related to high levels of ultrafine particles. In a Dutch cohort study,[36] cardiopulmonary mortality was more strongly associated with locally generated pollutants than with background air-pollution levels.

Several recent reviews and meta-analyses have examined the association between transportation noise exposure and cardiovascular outcomes.[1,30,37] In 2002, Van Kempen et al[30] concluded that the evidence for an association was inconclusive because of limitations in exposure characteriza-

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tion, lack of adjustment for important confounders, and possible publication bias. More recently, Babisch[1,37] argued that the evidence for an association between transportation noise and cardiovascular risk has become stronger in recent years, with a consistently increased risk of ischemic heart disease in those exposed to aircraft or road traffic noise above 60 dB(A). Previous studies also found duration of exposure to be relevant, with higher risks in persons having been exposed at least 10 to 15 years.[38,39] Although the majority of transportation-noise studies have excluded women, there is some evidence that sex could modify effects.[37] We found increased risks in men but not in women, confirming results from some[7,38] but not all previous studies.[2,5] Our stratified analyses also suggest that effects might depend on building characteristics; low levels of insulation against noise in old buildings that had not been renovated could explain the higher risk observed in their inhabitants. For all stratified analyses, formal tests of interaction failed to reach conventional levels of statistical significance.

In conclusion, our study adds to a growing body of evidence supporting a link between high levels of exposure to aircraft noise over extended periods of time and mortality from myocardial infarction. It is unlikely that our results are explained by confounding by socioeconomic position in those exposed to aircraft noise. If the association is causal, the mechanisms that may be involved are unclear. When examining mortality from stroke or lung cancer, we found no indirect evidence supporting the hypothesis that hypertension or smoking might act as intermediate factors on the causal pathway. Cardiovascular risk factors were not assessed in this large linkage study, and therefore, we could not examine their possible role in mediating or confounding the association between aircraft noise and myocardial infarction.

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Exposure-response relationship of the association between aircraft noise and the risk of hypertension

Wolfgang Babisch, Irene van Kamp[1]

Department of Environmental Hygiene, Federal Environment Agency, Germany, [1]Centre for Environmental Health Research, The National Institute for Public Health and Environmental Protection, The Netherlands

Abstract

Noise is a stressor that affects the autonomic nervous system and the endocrine system. Under conditions of chronic noise stress the cardiovascular system may adversely be affected. Epidemiological noise studies regarding the relationship between aircraft noise and cardiovascular effects have been carried out on adults and on children focussing on mean blood pressure, hypertension and ischemic heart diseases as cardiovascular endpoints. While there is evidence that road traffic noise increases the risk of ischemic heart disease, including myocardial infarction, there is less such evidence for such an association with aircraft noise. This is partly due to the fact that large scale clinical studies are missing. There is sufficient qualitative evidence, however, that aircraft noise increases the risk of hypertension in adults. Regarding aircraft noise and children's blood pressure the results are still inconsistent. The available literature was evaluated for the WHO working group on "Aircraft Noise and Health" based on the experts' comprehensive knowledge in this field. With respect to the needs of a quantitative risk assessment for burden of disease calculations an attempt was made to derive an exposure-response relationship based on a meta-analysis. This association must be viewed as preliminary due to limitations which are concerned with the pooling of studies due to methodological differences in the assessment of exposure and outcome between studies. More studies are needed to establish better estimates of the risk.

Keywords: Aircraft noise, hypertension, cardiovascular risk, meta-analysis, exposure-response relationship, risk assessment

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Introduction

The auditory system is continuously analyzing acoustic information, which is filtered and interpreted by different brain structures. The hypothesis that long-term exposure to environmental noise – including aircraft noise – causes adverse health effects is based on three major findings and facts:

1. Laboratory studies show that exposure to acute noise affects the sympathetic and endocrine system, resulting in unspecific physiological responses (e.g. heart rate, blood pressure, vasoconstriction, stress hormones, EEG).[1-8]
2. Noise-induced instantaneous autonomic responses do not only occur in waking hours but also in sleeping subjects even when no EEG awakening is present.[9-12] They do not fully adapt on a long-term basis although a clear subjective habituation occurs after a few nights.[13,14] Repeated arousal from sleep is associated with a sustained increase in daytime blood pressure.[15] The cortical perception of the sound as well as sub-cortical reflections due to the direct nervous interactions of the acoustic nerve with hypothalamic structures stimulates the autonomous nervous system. From this the hypothesis emerged that long-term exposure to noise adversely affects the homeostasis of the human organism, including metabolic function and the cardiovascular system.[16-20] Persistent changes in endogenous risk factors due to noise-induced dysregulation promote the development of chronic disorders such as atherosclerosis, hypertension and ischemic heart diseases and others in the long run.
3. Although effects tend to be diluted in occupational studies due to the "healthy worker effect", epidemiological studies carried out in the occupational field have shown that employees working in high noise environments are at a higher risk for high blood pressure and myocardial infarction.[21-26] Similar effects may occur with respect to community noise.

The general stress theory referring to the sympathetic-adrenal-medullar system (SAM axis) and the pituitary-adrenal-cortical system (hypothalamic-pituitary-adrenal = HPA axis) is the rationale for the non-auditory physiological effects of noise.[27,28] The biological plausibility derives from laboratory experiments on acute noise effects. Epidemiological studies have been carried out assessing the relationship between road and aircraft noise on cardiovascular endpoints.

Protocol of the Review

The focus here is on epidemiological studies or surveys directly related to associations between aircraft noise and cardiovascular disease (CVD) outcomes. Many environmental noise studies refer to road traffic noise, serving as an approximation of effects of transportation noise, in general. In accordance with the reaction model, the endpoints considered in this review are primarily of cardiovascular nature. Noise research has been focusing on these endpoints for reasons of statistical power (high prevalence in the general population) and their impact on public health.[29] A distinction is made between the effects on adults and on children. Clinical manifestations of cardiovascular diseases are not very likely in young people. Therefore blood pressure reading is the major outcome that has been studied in children and adolescents. In adults, however, manifestations of high blood pressure (hypertension) and ischemic heart diseases (myocardial infarction, angina pectoris, ischemic signs in the ECG, heart failure) are major outcomes of interest. The diagnosis is either based on self-reported doctor-diagnosed occurrence and/or treatment of disease, hospital admission rates, drug medication intake, or on actual blood pressure measurements (taken at rest). The same applies to the assessment of exposure. It is either based on self-reported traffic volume (e.g. type of street) or subjective perception of the noise (disturbance/annoyance), or on modeled noise contours (noise maps, isophones) or noise measurements taken near the subjects' houses. Finally, the type of study (ecologic, descriptive (e.g. cross-sectional study), and analytic (e.g. case-control study, cohort study) is considered as a decision criterion.

Identification of Relevant Studies

The selection of relevant studies is made on comprehensive previous reviews[21,30,31] and the experts' knowledge about new publications and ongoing research in this field. In a recent review update[32,33] altogether 61 epidemiological studies were identified that addressed the association between transportation noise and cardiovascular endpoint; 20 of which referred to commercial aircraft noise,[34-55] 8 to military aircraft noise, 32 to road traffic noise, and 13 to other environmental noise sources. The cardiovascular chapters of the WHO reports "Night Noise Guidelines"[12] and "Environmental Noise Burden of Disease" refer to this review.[56] Studies focusing on low flying jet-fighter noise showed higher blood pressure readings in children but not in adults.[57-61] The effects may largely be due to anxiety and fear rather than to the noise stress as such. These studies are therefore not considered in this present summary on the effects of aircraft noise. However, studies regarding noise from aircraft operations around airfields, which is comparable to commercial aircraft noise (no steep level increases) are considered.[50,62] New aircraft noise studies are now available that were not considered in previous reviews.[63-69]

Evaluation criteria for the validity of studies with respect to possible exposure misclassification, confounding, selection bias, recall and observation bias were: Objective (noise level) vs. subjective exposure assessment, objective (clinical) vs. subjective assessment of outcome, type of study, reasonable control of confounding factors, statistical methods of analyses, peer-reviewed reference.

Studies on Adults

Some studies are not feasible for a synthesis or a meta-analysis, either because only sparse information is given with respect to the study design and selection criteria or confounding factors are insufficiently accounted for.[34,53] Some study results are only preliminary or not yet peer-reviewed.[46,54,55,68] However, in those cross-sectional studies - although mostly not significant - higher mean blood pressure readings or a higher prevalence of cardiovascular disorders or medication intake were found in exposed subjects compared with non-exposed, supporting the hypothesis as such (consistency).[70]

Repeated studies carried out around Schiphol airport in the Netherlands looking at aircraft noise and drug medication either on an individual level (self-reported medication intake) or on a spatial level (prescribed medication purchased by pharmacies) revealed higher relative risks of cardiovascular medication ranging between 1.2 and 1.4 for a noise level difference of approximately 10 dB(A).[37,47,64] When comparing the noise exposure throughout the whole day (L_{den}) with the noise exposure during the night (L_{night}) effects were stronger with respect to L_{den}. In the most recent phase of the Schiphol environment and health monitoring programme a higher risk of approximately 1.8 was found for the same noise level difference.[65,66] In a longitudinal approach a decrease in the purchase of cardiovascular and antihypertensive drugs was found after a reduction of night flights.[39] A recent cross-sectional study carried out around Cologne airport in Germany demonstrated higher individual prescriptions of antihypertensive and cardiac drugs in subjects exposed to high levels of aircraft noise, particularly, during the night and the early morning hours (3-5 hrs).[63] The study was unbiased with respect to the assessment of exposure and outcome because objective data were used (noise contours, health insurance records). However, no data regarding individual confounders were available, only spatially aggregated covariates could be considered. Higher risks were found for subjects where L_{night} exceeded 39 dB(A). Preliminary results from a Swedish follow-up study carried out around Stockholm's airport suggest a higher intake of antihypertensive medication in subjects exposed to noise levels ('FBN') of more than 55 dB(A) compared to less exposed (relative risk 1.6). The results are based on a small sub-sample of the total cohort.[55]

Regarding the prevalence of hypertension and heart problems much information is derived from Dutch studies carried out around Schiphol airport.[37,38,65,66,71,72] The assessment of high blood pressure and ischemic heart problems was based on clinical measurements,[37,38] medical interviews,[37,38] hospital admission rates,[65,66] and self-reported hypertension.[65,66] In the

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older studies, a non-significant increase in risk of heart disease was found ranging between 1.1 and 1.4 in people (males and females taken together) who were exposed to 'NNI' >37 (approximately L_{dn} > 62 dB(A)).[37] For hypertension a significantly higher risk of 1.7 (95% CI = 1.4-2.2) was found for this noise level difference of approximately 10 dB(A).[37] Regarding the prevalence of all cardiovascular diseases, including high blood pressure, a significant relative risk of 1.8 was found.[38] In the later studies, no noise effects were found with respect to hospital admissions for cardiovascular diseases.[65,66] However, a statistical significant effect of L_{den} was found on self-reported hypertension. When the noise level increases by 3 dB(A) the odds ratio was 1.2, which corresponds with a relative risk of approximately 1.8 for a 10 dB(A) difference in noise level, confirming the earlier studies. In a new multi-centred study carried out around six European airports a significant increase in the risk of hypertension of 1.1 (95% CI = 1.0-1.3) for a 10 dB(A) difference of aircraft noise during the night (L_{night}) was found.[67] Hypertension was determined by a combination of three criteria: Measured resting blood pressure (systolic/diastolic blood pressure >140/90 mmHg), self-reported doctor-diagnosed hypertension, anti-hypertensive medication (ATC coding). Across categories no clear exposure-response relationship was found. However, the large confidence intervals did not discard the assumption of a linear relationship. No such association was found with respect to the exposure during the day, possibly due to exposure misclassification (time spent away from home). Thus, a smaller relative risk was found for the 24 hr noise indicator L_{den} of 1.1 (95% CI = 0.9-1.3) per 20 dB(A). [Note: Because the data were previously not published by the Hyena group, the exact data are given here (OR per 10 dB(A) = 1.037, 95% CI = 0.962-1.119)].

A Swedish study carried out around Stockholm's major airport assessed the prevalence of (self-reported doctor-diagnosed) high blood pressure by postal questionnaire. An exposure-response association between aircraft noise and high blood pressure was found with relative risks ranging between 1.1 and 2.1 for noise levels between approximately 'FBN' = 53 to 63 dB(A).[52] When noise categories were combined, the effect was significant for 'FBN' > 55 dB(A). The trend analysis resulted in a relative risk of 1.3 (95% CI = 0.8-2.2) per 5 dB(A). Studies carried out around the Kadena military airfield on the Japanese island of Okinawa also demonstrated an exposure-response relationship of an increasing prevalence of clinically assessed hypertension with increasing noise exposure.[50,73,74] The effects were found at higher noise levels than for civil airports ('WECPNL' > 75 dB, approximately L_{dn} > 60 dB(A). This may be due to the fact that night- and weekend-flights were largely omitted. However, older noise data were used which might not have adequately reflected the exposure when the health data were assessed. Only one prospective study assessing disease incidence is known. The study was carried out around Stockholm's major airport. The association between aircraft noise and high blood pressure was investigated. Subjects exposed to weighted energy-averaged levels ('FBN') above 50 dB(A) had a significant relative risk of 1.2 for the development of hypertension over the 10-year follow-up period compared with less exposed.[69] The increase in risk per 10 dB(A) was 1.2 (95% CI = 1.0-1.2). The effect was particularly found in older people, which may reflect longer years of residence.

Studies on Children

Most evidence in relation to aircraft noise on children is derived from school studies carried out in Los Angeles,[40,41] the Munich Airport study,[42,43,75] the Sydney Airport study,[44,45] and the RANCH study.[76]

In studies around the Los Angeles airport blood pressure differences of 2 to 7 mmHg were found between groups of exposure depending on the years enrolled in school. The results may be confounded by incomplete control of ethnicity.[45] Blood pressure measures were taken during quiet periods in school, in order to exclude acute noise effects. Longitudinal measurements after a year failed to show a relationship between noise exposure at school and a change in blood pressure, probably due to selective migration of the schoolchildren. The cross-sectional study around the old Munich airport revealed a borderline significant effect of 2 mmHg higher systolic blood pressure readings in schoolchildren from noise exposed areas ($L_{eq,\ 24hr}$ = 68 dB(A)) as compared to unexposed children ($L_{eq,\ 24hr}$ = 59 dB(A)). No noise effect was found with regard to diastolic blood pressure.[42] Longitudinal studies carried out around the new airport showed a 2 to 4 mmHg larger increase in BP readings in exposed children than in their counterparts from the quiet areas 18 months after the opening of the new airport. However, the well-matched children from the exposed and the control group had the same absolute blood pressure. The higher change in blood pressure was due to lower values at the beginning of the follow-up. The cross-sectional study around Sydney Airport revealed a non-significant relation between aircraft noise and diastolic and systolic blood pressure in children.[45]

In a cross-sectional study carried out around Schiphol and Heathrow airports on schoolchildren (RANCH) a non-significant relationship was found between aircraft exposure at school (LAeq, 7-23 hr) and measured systolic blood pressure, diastolic blood pressure and heart rate after adjustment for relevant confounders.[76] However, aircraft noise at home (expressed as LAeq, 7-23hr) was significantly related to higher systolic (0.10 mmHg/dB(A)) and diastolic (0.19 mmHg/dB(A)) blood pressure. Chronic aircraft noise exposure during the night (LAeq, 23-7hr) at home was also positively associated with blood pressure. This latter association was significant only for systolic blood pressure. In the pooled data-set an increase of 0.09 mmHg/dB(A) was found. Due to significant differences in noise effects between the two centres no univocal conclusions about the association between aircraft noise exposure and blood pressure in children could be drawn.[76] Explanations put forward concern differences in flight pattern variation, and aircraft fleet. Also differences in schooling systems and teachers' attitudes towards noise might have differential effects on the children's reactions to noise. None of these could be tested on the available data. Finally, even though the results were adjusted for ethnic differences and diet residual confounding due to these factors might explain the differences.[77]

Meta Analysis

Different approaches have been used to assess pooled effect estimates and exposure-response relationships in order to carry out a quantitative risk assessment. Van Kempen *et al.* [21] calculated uniform regression coefficients across all noise categories within individual studies ('regression approach'). The regression coefficients were then pooled over all studies. Babisch[32] calculated pooled relative risks for individual noise categories from different noise studies, which were then considered for an exposure-response relationship ('category approach'). Both approaches have advantages and disadvantages. The regression approach has the advantage that regression coefficients can easily be pooled regardless of actual noise levels; only the slopes (regression coefficient) of the exposure-response relationships of individual studies are taken into account, regardless of (different) noise level ranges and possible thresholds of effect. For example, some studies showed high risks at relatively low noise levels,[52] while others showed an increase of risk only at higher noise exposures.[50] The category approach is noise level oriented. Only relative risks from different studies referring to the same noise category are pooled to derive an exposure-response curve. This has the advantage that possible thresholds of effects can be determined. The approach also accounts for non-linear associations. It is less likely to obscure possible higher risks in higher noise categories where the numbers of subjects are often small - which is the case in random population samples given the empirical noise distributions, and specifically around large airports. For example, in case of j-shaped or quadratic associations an overall regression coefficient underestimates the risks in higher noise categories, simply because the slope of the regression line is primarily determined by the larger numbers of subjects in the lower exposure categories, where effects may be smaller. The disadvantage of this approach is that it relies on relatively homogeneous and comparable noise indicators in order to pool the effect estimates from different studies within noise categories. One could think of studies where relationships within the studies reflect true associations (slope), but the noise assessment in absolute terms may not be comparable due to methodological reasons (e.g. measurement vs. modeling, different calculation methods, different time periods, weighing factors, different reference points, different sides of the house, etc.).

For both approaches it is essential that critical decisions are made as to which studies are included in the meta-analyses and which are not. Studies that are not suitable with respect to issues of exposure misclassification, selection bias, observation bias, or confounding should be excluded from the meta-analyses. Only very few epidemiological studies are available on adults, in which the association between aircraft noise and clinical states of cardiovascular diseases were assessed. Five studies appear reasonably valid for further consideration because minimum requirements regarding the validity of the assessment of exposure, outcome and the statistical control for confounding factors were fulfilled.[37,50-52,67,69] However, noise level related data pooling ('categorical approach') is difficult due to the fact that different (national) exposure indices were used. A graphical presentation of results using approximations with respect to the common noise indicator L_{dn} is shown in Figure 1. No conclusions regarding possible threshold values or noise level related risks (in absolute terms) can be drawn.

When linear trend coefficients of all the five studies are calculated and pooled afterwards ('regression approach') the pooled effect estimate of the relative risk is 1.13 (95% CI = 1.00-1.28) per 10 dB(A). The results are shown in Table 1. The pooled effect estimate is significant. No major difference between fixed and random effect models is found when the individual coefficients obtained from the six airports of the HYENA study are considered individually in the meta-analysis to better account for the heterogeneity between individual studies. (Note: If the pooled Hyena results are used instead as shown in Figure 1, significant fixed and random effect estimates of 1.12 and 1.29, respectively, are calculated.) The result is almost the same when either the 'Okinawa study' (military aircraft noise, out-dated noise data) or the 'Stockholm1 study' (subjective assessment of exposure) or both are excluded from the meta-analysis due to their low

Table 1: Meta analysis of epidemiological studies of the association between aircraft noise and hypertension

Study	No. of subjects	Fixed weight	Random weight	Odds ratio per 10 dB(A)	95%-confidence interval	*P* value
Amsterdam	5,828	76.55	28.05	1.73	1.38 - 2.16	
Stockholm 1	2,959	3.75	3.46	1.69	0.61 - 4.65	
Stockholm 2	2,392	140.37	33.65	1.21	1.03 - 1.43	
Okinawa	28,781	17.91	12.75	1.27	0.80 - 2.02	
Hyena-London	600	107.38	31.35	1.05	0.87 - 1.27	
Hyena-Berlin	972	209.93	36.56	1.18	1.03 - 1.35	
Hyena-Amsterdam	898	78.39	28.29	0.99	0.79 - 1.24	
Hyena-Stockholm	1,003	95.67	30.26	0.87	0.71 - 1.06	
Hyena-Athens	635	47.37	22.88	1.14	0.86 - 1.52	
Hyena-Milan	753	105.98	31.22	0.99	0.82 - 1.20	
Pooled fixed				1.13	1.06 - 1.20	0.000
Pooled random				1.13	1.00 - 1.28	0.044
Heterogeneity				Q = 26.13		0.002

Note: Individual logistic regression coefficients are pooled. The studies differ with respect to study type, hypertension criteria and exposure indicators

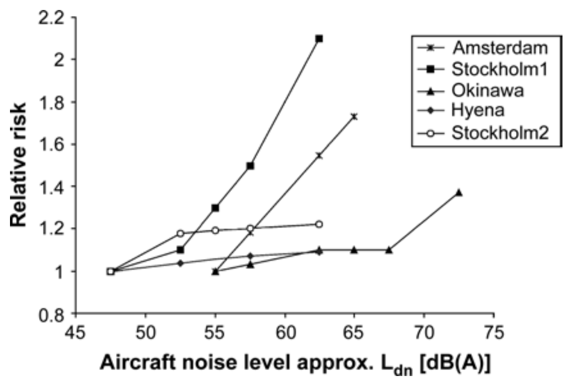

Figure 1: Association between aircraft noise level and the prevalence or incidence of hypertension

statistical weights (OR = 1.12, 95% CI = 0.98-1.28).

The calculations were made using the procedures 'Meta' and 'Metareg' of the statistical package STATA, Version 9. Individual odds ratios and confidence intervals were taken from summary reports[32] and the original publications for this purpose[67,69] to calculate regression coefficients of individual studies and odds ratios with respect to the weighted day/night noise indicator L_{dn}, which is supposed to be very similar to L_{den}.[78] Approximations for the conversion of noise indices were given elsewhere.[79]

The noise assessment in the studies was made according to national regulations and calculation methods that were used by the time the studies were carried out in those countries. In the Amsterdam study[37] the Dutch 'Kosten Units' noise index (B) was calculated which considers the average maximum noise level of overflights during a 24-hour period and the number of events which are weighted by the time of the day (day 1.33, evening 5.25, night 9.75). The averaging is done on a sound-energy basis. The assignment of noise levels was based on maps of aircraft noise (1974) as modelled by the National Aerospace Laboratory.[80] In the Swedish studies (Stockholm 1 and Stockholm 2)[52,69] the 24h-hour time weighted yearly equal energy level (FBN) was calculated; the number of events were weighted by the time of the day (evening 3, night 10). GIS-based noise dispersion models were used to define the noise contours. The Hyena consortium used the American INM (version 6.0) as uniform standard for all airports considered in the study to calculate yearly average noise contours for the day, the evening and the night (except the UK, where the national standard (Ancon model) was applied). The calculation was based on radar tracks of fight paths and the composition of aircrafts. The weighted 24-hour noise index L_{den} according to the European Noise Directive was calculated (weighting: Evening + 5 dB(A), night + 10 dB(A)). In the Japanese study[50,51] the noise assessment was based on continuous long-term and point selective short-term noise measurements based on monitoring programmes. The noise index WECPNL considers the average maximum noise level and the number of events. The events were weigthed by the time of the day (early evening 3, late evening and night 10). As pointed out earlier, the year of noise assessment did not coincident with the year of the health assessment, which raises some concern regarding exposure misclassification of which the direction of the impact on the results is unclear.

One also has to bear in mind that different criteria and assessment methods for hypertension were used. For example, some studies (Amsterdam, Stockholm1, Okinawa) refer to the 'old' WHO criterion of 160/100 mmHg,[37,51,52] others (Hyena, Stockholm 2) refer to the 'new' WHO criterion of 140/90 mmHg.[67,69] It was assumed that relative (noise) effects were independent of the absolute prevalence of hypertension depending on the cut-off criterion for high blood pressure.

Discussion

In the present summary, only those studies were considered in which aircraft noise was the explicit noise source. However, in a situation where information is lacking, the results of studies on the association between road traffic noise and myocardial infarction may also serve as an approximation for possible effects of aircraft noise. Considering the fact that at the same average noise level aircraft noise tends to be more annoying than road traffic noise,[81,82] this approximation may even underestimate the effects of aircraft noise. Differences in the acoustical characteristics of the type of noise (e.g. frequency spectrum, quasi continuous road noise vs. single event aircraft noise, maximum noise level, length of single events, number of events), as well as non-acoustical factors (e.g. fear of aircraft crashes, attitude towards airport, effectiveness of coping strategies) may have an impact not only on the subjective perception of the noise, but also on physical health. Since aircraft noise comes from the top shielding of buildings is less effective. Because there is no access to a quiet side, sleep may be more affected by aircraft noise on a population level.

The available results do not allow for a distinction between the sexes. Males have been studied much more often than females. There is some indication that males may be more affected by road traffic noise.[67,83-85] However, contradictory results were also found.[86] The data-base is too weak for final conclusions regarding any gender differences. Due to the use of different noise indicators in aircraft noise studies only very crude comparisons can be made between studies on the basis of common noise indicators, e.g. L_{dn} or $L_{Aeq,6\text{-}22hr}$. Most aircraft noise studies did not distinguish between day and the night. A road traffic noise study and two aircraft noise studies suggest that noise during the night may be more harmful than during the day.[63,67,87] However, no firm conclusions can be drawn about the relative contribution of day and night exposure because noise indices are usually highly correlated. One study suggests not only that noise during the night may be the primary source of adverse effects; it also shows that within the night period, effects due to noise in the early morning shoulder hours may be larger.[63]

The impact of noise on children's blood pressure is still not fully understood. Pre-dispositional and lifestyle factors seem to dominate and it is hard to study the influence of environmental noise separately. This might be one of the reasons why conclusions about the effect of noise exposure on children's blood pressure are limited and inconsistent. Methodological problems which arise are study size, insufficient contrast between noise levels, selection bias and insufficient adjustment for factors such as socioeconomic status, parental history, noise insulation and ethnicity. Moreover, most studies on cardiovascular effects in children have focused on school exposure while at least the combination of day- and night time exposure and the related lack of restoration might be of importance in the development of cardiovascular disease due to early childhood blood pressure changes.

Energy-based indicators of exposure (L_{eq}) are adequate and sufficient for the assessment of the relationship between long-term exposure to community noise and chronic diseases, e.g. cardiovascular disorders. These include $L_{day,16h}$, $L_{day,12h}$ + $L_{evening,4h}$, and $L_{night,8h}$. Different periods of the day should be considered. Only if detailed data are not available L_{24h} is recommended. Although L_{eq}-based indicators tend to be highly correlated in many exposure conditions, it remains unclear whether weighted indicators, such as L_{dn} or L_{den} reflect the physiological response of the human organism appropriately. However, when all information is available, weighted and non-weighted indicators can easily be calculated for use in health studies and related quantitative risk assessment.

Conclusion

The general conclusion is that there is sufficient evidence for a positive relationship between aircraft noise and high blood pressure and the use of cardiovascular medication. Depending on whether high blood pressure was assessed by a self-administered postal questionnaire or by clinical measurements in studies, the magnitudes and the possible thresholds of effect varied between and within studies.[66,68] Effects were more pronounced, when subjective measurements of high blood pressure were considered. This may raise questions regarding over-reporting.[66,68,88] The validity of study results appears to be even more a problem when subjective noise annoyance was considered for exposure.[47,65,66,68] The effect estimates tend to be larger but may be prone to over-reporting, particularly in cross-sectional studies where both, exposure and outcome, are assessed on a self-reported basis with the same questionnaire.

No single, generalized and empirically supported exposure-response relationship can be established yet for the association between aircraft noise and cardiovascular risk due to methodological differences between studies (noise assessment, noise indicators, definition of hypertension) and the lack of continuous or semi-continuous (multi-categorical) noise data provided in the publications. For the same reason no answer can be given regarding possible effect thresholds. However, in spite of these limitations an attempt has been made to derive a "best guess" estimate, which can be used for practical purposes of quantitative risk assessment for the moment until more data are available. The calculated relative risk for an increase ("regression approach") of the day/night average weighted sound pressure level of aircraft noise of 10 dB(A) based on the presented meta-analysis is OR = 1.13, 95% CI = 1.00-1.28, range = 45-70 dB(A). Since this effect estimate is based on different slopes from different studies with different noise level ranges and methods being used, a decision must be made by the user with respect to the noise level onset of the increase in risk. Road traffic noise studies suggest that the cardiovascular risk increases when the outdoor noise level during the day exceeds 60-65 dB(A) and 50-55 dB(A) during the night, respectively.[89] As to whether this information can be applied to aircraft noise remains unclear. However, this may be a conservative approach, considering the results of annoyance studies showing that aircraft noise effects may even be stronger than those of road traffic noise. Annoyance studies showed that aircraft noise was more annoying than road traffic noise of the same average noise level,[81,82] which might partly be explained by less exposure misclassification (no shielding of aircraft noise, no unexposed rooms). New aircraft noise studies suggest that the risk may increase at even lower night noise levels. It is therefore suggested to use $L_{den} \leq 50$ or $L_{den} \leq 55$ dB(A) as a reference category of the exposure-response relationship. The respective relative risks for subjects who live in areas where L_{den} is between 55 to 60 dB(A) and between 60 to 65 dB(A) would then approximate to 1.13 and 1.20, or 1.06 and 1.13, respectively.

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Address for correspondence:
Dr. Wolfgang Babisch,
Federal Environment Agency, Corrensplatz 1,
14195 Berlin, Germany.
E-mail: wolfgang.babisch@uba.de

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Is there an association between aircraft noise exposure and the incidence of hypertension? A meta-analysis of 16784 participants

Di Huang[1,2,3], XuPing Song[1,2,3], Qi Cui[1,2,3], Jinhui Tian[2,3], Quan Wang[2,3], Kehu Yang[1,2,3]

[1]*School of Public Health,* [2]*Evidence-Based Medicine Center, School of Basic Medical Sciences, Lanzhou University, Lanzhou,* [3]*Key Laboratory of Evidence Based Medicine and Knowledge Translation of Gansu Province, Lanzhou, China*

Abstract

To determine if aircraft noise exposure causes an increased incidence of hypertension among residents near airports. We conducted a meta-analysis of observational studies to evaluate the association between aircraft noise exposure and the incidence of hypertension. PubMed, Embase, Web of Science, the Cochrane Library, and the Chinese Biomedical Literature Database were searched without any restrictions. Odds ratios (ORs) with 95% confidence intervals (CIs) were extracted. The pooled ORs were calculated using both the fixed effects model and random effects model. All analyses were performed using STATA version 12.0 software (Stata Corporation, College Station, TX, USA). We examined five studies, comprising a total of 16,784 residents. The overall OR for hypertension in residents with aircraft noise exposure was 1.63 (95% CI, 1.14-2.33), and one of our included studies showed that there was no evidence that aircraft noise is a risk factor for hypertension in women. According to our subgroup analysis, the summary OR for the incidence was 1.31 (95% CI, 0.85-2.02) with I^2 of 80.7% in women and 1.36 (95% CI, 1.15-1.60) with moderate heterogeneity in men. The pooled OR for the incidence of hypertension in residents aged over 55 years and under 55 years was 1.66 (95% CI, 1.21-2.27) with no heterogeneity and 1.78 (95% CI, 1.33-2.39) with I^2 of 29.4%, respectively. The present meta-analysis suggests that aircraft noise could contribute to the prevalence of hypertension, but the evidence for a relationship between aircraft noise exposure and hypertension is still inconclusive because of limitations in study populations, exposure characterization, and adjustment for important confounders.

Keywords: Aircraft noise exposure, hypertension, meta-analysis

Introduction

Aircraft noise is an important environment health issue associated with sleep disturbance, annoyance, hearing loss, and cardiovascular diseases.[1-8] Correia[5] found that the aircraft noise was statistically associated with a higher relative rate of hospitalization for cardiovascular diseases among older people residing near airports. Hypertension is a major risk factor for cardiovascular disease, and the first survey in which it was reported that the exposure to aircraft noise may cause hypertension in humans was published in the 1970s.

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Noise is a ubiquitous part of human life and a major public health problem of modern times. Experimental studies have indicated that noise has the potential to trigger a physiological stress response by activating the sympathetic nervous system and causing arousal of the neuroendocrine system.[9] The release of stress hormones results in various acute hemodynamic and metabolic effects such as elevated blood pressure, aggregation of thrombocytes, and release of free fatty acids into the bloodstream.[10,11] Further, long-term noise exposure may lead to chronic dysregulation in the stress mechanism and increase the risk of hypertension.[12]

This suggestion has been explored in both epidemiologic and experimental studies. However, there are differences among the findings. Knipschild[13-15] and Rosenlund[6] reported the association between exposure to aircraft noise and hypertension, and implied that aircraft noise might be a risk factor for hypertension. In contrast, Goto's[16] study on the incidence of hypertension around airports reported no significant difference in areas with different levels of aircraft noise, while Eriksson[17] found significant differences between men and women in terms of the relationship between aircraft noise and the cumulative incidence of hypertension, noting an increased risk of hypertension in men but not in women. Therefore, we performed a meta-analysis on observational studies investigating the relationship between aircraft noise and hypertension.

Materials and Methods

Our meta-analysis was conducted following the checklist of items in the Meta-analysis Of Observational Studies in Epidemiology (MOOSE)[18] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statements.[19] Methodological reviews were as follows.

Search strategy

A comprehensive literature search of the following databases was conducted: PubMed, Embase, the Cochrane Library, Web of Science, and the Chinese Biomedical Literature Database, all of which were searched without year or language restrictions. We used combinations of the following keywords and corresponding medical subject headings (MeSH) terms for the literature search: "aircraft noise," "hypertension," "high blood pressure," etc. There were no restrictions on the language of publication during the document retrieval, and there was also no restriction placed on the geographical location of studies. The reference lists of the retrieved articles were also searched and relevant studies were checked manually to identify other literature related to our article topic.

Criteria for study selection

We first screened the identified abstracts or titles. For this meta-analysis, we included original studies that reported the causal link between aircraft noise exposure and hypertension, while studies on noise exposure from other sources (occupational, railway, industry, and road or neighborhood noise) were not included. The second screen was based on full-text review. Studies were considered eligible if they met the following criteria:

1. Cross-sectional, cohort, or case-control design;
2. The exposure of interest was aircraft noise;
3. The outcome of interest was hypertension, as defined by the following criteria:
    a. Diagnosis by a physician;
    b. Being under active treatment with a specific drug;
    c. Evidence from physical examination of the subjects and electrocardiographic, echocardiographic, or blood pressure laboratory measurements, or
    d. Through self-report;
4. Odds ratios (ORs) with corresponding 95% confidence intervals (CIs) were reported for the groups exposed versus the groups not exposed to aircraft noise. Ecological studies, editorials, case reports, and reviews were not considered eligible.

Data extraction and quality assessment

Two independent reviewers (Huang and Song) screened the resulting titles, abstracts, and even full texts to identify studies that met our inclusion criteria. Any disagreement was resolved by a third reviewer (Yang). The following variables were extracted from all studies: data about study characteristics (authors, year of publication, study design, and country), study population (number of cases, sex, and age), exposure level, and adjusted factors. Extracted data were entered into Microsoft Office Excel 2007 SP3 (Microsoft Corporation, WA, USA) and were checked by the third reviewer (Yang). The study quality was assessed by publication type (3 = peer-reviewed article, 0 = not peer reviewed), study design (1 = cross-sectional, 2 = case-control, 3 = cohort), validity of outcome assessment (0 = self-report, 3 = diagnosis by a physician or physical examination), control of confounding variables (0 = no control, 1 = age and sex only, 2 = age and sex with one or more major hypertension risk factors, 3 = age, sex, one or more major hypertension risk factors, as well as other factors), and response rate (0 = <80%, 3 = ≥80%). The total score was assessed as follows: very good = 10 points and above, good = 6-9 points, and fair = 5 points or below.[20]

Statistical analysis

The pooled estimates for dichotomous variables are reported as ORs with 95% CI. If ORs with 95% CI were not available, we calculated these from the raw data. Heterogeneity of effect sizes was assessed by Cochran's Q statistic (significance level set at $P < 0.10$) and the I^2 statistic, which is a quantitative measure of consistency across studies.[21] If heterogeneity was present (i.e., Q test result significant or $I^2 \geq 50\%$), a random effects method was used to estimate a pooled effect size; otherwise, the fixed effects model with inverse variance method was applied. Subgroup analysis was performed according to gender, age, and adjusted factors. All analyses were performed using STATA version 12.0. Also, $P < 0.05$ (two-tailed) was considered statistically significant except for the heterogeneity test, for which $P < 0.10$ (one-tailed) was used.

Results

Figure 1 summarizes the literature search process used in the present meta-analysis, which included five studies with data collected from a total of 16,784 subjects. Of these, four studies were cross-sectional[6,13,16,22] and one was a cohort study.[17] Two[6,17] studies were conducted in Europe, two[13,22] in Oceania, and one[16] in Asia. One study[13] was published before 2000 and the other four[6,16,17,22] after 2000. Characteristics of these included studies are summarized in Table 1. The evaluation of a risk bias in the included studies is shown in Table 2.

Figure 2 presents our combined meta-analysis of four studies.[6,13,17,22] The OR of hypertension in residents with aircraft noise exposure was 1.63 (95% CI, 1.14-2.33), with

Table 1: Characteristics of the included studies

First author	Year	Country	Study design	Population age (years)	Number of cases of hypertension	Exposure levels (dBA)	Adjustments	OR
Rosenlund *et al*.[6]	2001	Sweden	cross-sectional	19-80	2959	<55; ≥55	Age, sex, smoking, education, physical activity, fruit consumption and house type	Multivariable adjusted
Knipschild[13]	1977	Netherlands	cross-sectional	35-64	5828	20-40; 40-60	Not reported	Unadjusted
GOTO[16]	2002	Japan	cross-sectional	NA	1646	Unexposed; ≥75;	Anti-hypertension treatment, diet, alcohol consumption and smoking	Multivariable adjusted
Eriksson *et al*.[17]	2010	Sweden	cohort	35-56	4721	<50; ≥50	Age, socioeconomic status, smoking and body mass index, sex (total population only)	Multivariable adjusted
Black[22]	2007	Sydney	cross-sectional	15-87	1500	unexposed; ≥70;	Noise sensitivity, annoyance of traffic and aircraft noise, interaction between aircraft and traffic noise annoyance	Multivariable adjusted

Table 2: Assessment of the methodological quality of studies included in the meta-analysis on aircraft noise exposure and hypertension

Study	In peer-reviewed literature	Type of study	Validity of outcome assessment	Control of possible confounding variables	Response rate >80%	Total score
Rosenlund *et al*.[6]	3	1	3	3	0	10
Knipschil[13]	3	1	3	0	NA	7
GOTO[16]	3	1	3	2	NA	9
Eriksson *et al*.[17]	3	3	3	3	NA	12
Black[22]	3	1	3	2	0	9

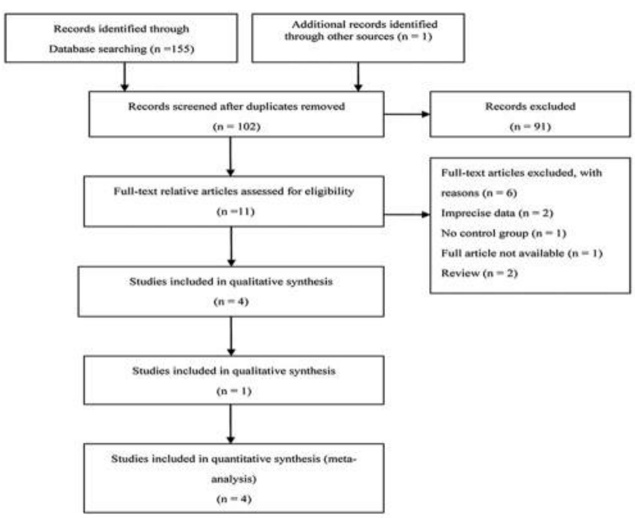

Figure 1: PRISMA diagram showing selection of articles for review

the aggregate results showing that significant heterogeneity existed in the included studies ($I^2 = 81.2\%$, $P = 0.001$). To assess the influence of the individual studies on the overall outcome, they were removed one by one and the substantial heterogeneity in the aircraft noise and hypertension association was attributed to one study,[17] as omitting this study resulted in a homogenous outcome whereby the pooled OR was 1.84 (95% CI, 1.51-2.24) with low heterogeneity ($I^2 = 13.5\%$, $P = 0.315$).

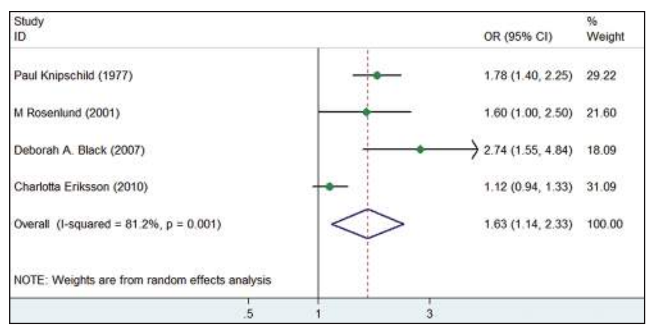

Figure 2: Forest plot of meta-analysis of hypertension in residents with aircraft noise exposure. Individual studies represented by OR and 95% CI

Only one study[16] reported the results with mean ± standard deviation (SD). The authors compared the blood pressure data of women ($N = 469$) living around an airport with women living in areas with no aircraft noise ($N = 1177$), controlling of variables such as antihypertension treatment, diet, alcohol consumption, and smoking. The study found no evidence of aircraft noise as a risk factor for hypertension in women.

Subgroup analysis

Subgroup analysis of gender

A subgroup analysis was performed according to gender. The pooled OR for the incidence of hypertension in men was 1.36 (95% CI, 1.15-1.60) with moderate heterogeneity ($P = 0.175$,

I^2 = 42.7%) [Figure 3]. The studies that reported women's OR for the incidence of hypertension had an overall OR of 1.31 (95% CI, 0.85-2.02), and substantial heterogeneity was observed (P = 0.006, I^2 = 80.7%) [Figure 4]. The analysis of sensitivity was done through exclusion, one by one, of the individual studies and the substantial heterogeneity in the aircraft noise and hypertension association was attributed to one study;[17] the aggregated OR was 1.81 (95% CI, 1.28-2.54) with I^2 of 0%.

Subgroup analysis of age

This subgroup analysis explored the impact of age with subjects grouped into those aged over and under 55 years. The pooled OR for the incidence of hypertension in residents aged over 55 years and those aged under 55 years were 1.66 (95% CI, 1.21-2.27) with I^2 of 0%, and 1.78 (95% CI, 1.33-2.39) with I^2 of 29.4%, respectively, [Table 3].

Subgroup analysis of unadjusted and multivariable adjusted OR

A subgroup analysis was conducted for unadjusted and multivariable adjusted ORs. Three studies[6,13,17] that reported unadjusted ORs for the incidence of hypertension had an overall OR of 1.56 (95% CI, 1.35-1.79) with no evidence of heterogeneity (P = 0.386, I^2 = 0%). The pooled OR for the incidence of hypertension in studies[6,17,22] with multivariable adjusted factors was 1.56 (95% CI, 0.88-2.78) with substantial heterogeneity (P = 0.001, I^2 = 85.6%). The high heterogeneity could be explained by the inconsistent adjustment factors [Table 3].

Discussion

This meta-analysis showed that there is a relationship between aircraft noise exposure and the prevalence of hypertension, and the results are consistent with a previous meta-analysis that found an increased risk of hypertension among populations with aircraft noise exposure.[23] One of our included studies[16] concluded that there was no obvious difference in blood pressure caused by aircraft noise in women in Fukuoka, Japan. Our gender-specific subgroup analysis also suggested that there is a relationship between aircraft noise exposure and the incidence of hypertension in men, but the relationship was not significant in women. A recent cohort study[17] reported an increased risk of hypertension in men but not in women, following long-term exposure to aircraft noise. This difference may be explained by the differing epidemiology and progression of cardiovascular diseases in men and women, and there is evidence of gender differences in the pathogenesis of cardiovascular diseases.[24-26] The risk of hypertension in residents was significantly associated with exposed aircraft noise according to age, with subjects aged under 55 years showing a slighter higher association than those over 55 years. One study[6] reported that hearing loss might protect against aircraft noise and that people who have an auditory deficiency are less sensitive to noise, which could partly explain the diverging results presented in this study. The overall unadjusted OR showed an increased risk of hypertension among people with aircraft noise exposure. The pooled OR in studies with multivariable adjusted factors showed a slightly weaker relationship between hypertension and aircraft noise exposure, with the high heterogeneity mainly attributed to the differing adjustment factors. In fact, it is hard to detect the health impact of noise from a single source, such as aircraft, because there are many noise sources presented in our daily life such as life events, shift work, and hypertension in parent(s), which may also be potential factors substantially influencing the noise effect. Therefore, we should be cautious in determining the adjustment factors in future studies.

Table 3: Subgroup analysis

Group	Hypertension			
	No. of studies	OR (95%CI)	$P_{heterogeneity}$	I^2 (%)
Total	4	1.63 (1.14, 2.33)	0.001	81.2
Sex				
Men	3	1.36 (1.15, 1.60)	0.175	42.7
Women	3	1.31 (0.85, 2.02)	0.006	80.7
Age				
<55 years	2	1.78 (1.33, 2.39)	0.234	29.4
≥55 years	2	1.66 (1.21, 2.27)	0.64	0
Adjustment for ORs				
Unadjusted	3	1.56 (1.35, 1.79)	0.386	0
Adjusted	3	1.56 (0.88, 2.78)	0.001	85.6

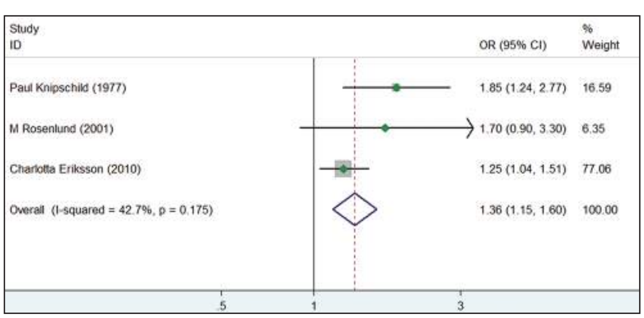

Figure 3: Forest plot of meta-analysis of hypertension in men with aircraft noise exposure. Individual studies represented by OR and 95% CI

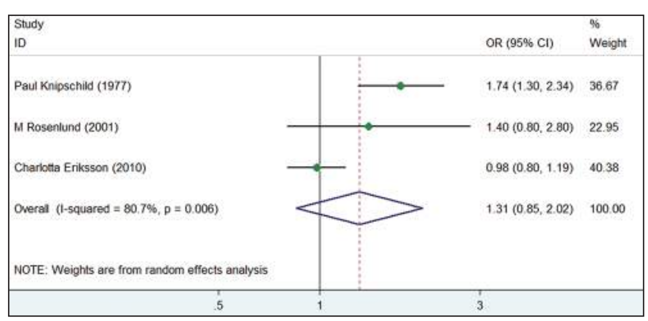

Figure 4: Forest plot of meta-analysis of hypertension in women with aircraft noise exposure. Individual studies represented by OR and 95% CI

The strength of this study is mainly related to the large number of subjects. In addition, many previous meta-analyses were focused on investigating the relationship between community noise and cardiovascular disease, while our paper aimed to study the association between aircraft noise and hypertension.

However, the limitations in the present meta-analysis should be acknowledged. Some factors added to the difficulty in interpreting the results of this review and high heterogeneity existed in several pooled results. First, the studies included in our meta-analysis used different study populations and different sampling methods to define airport noise levels. For instance, several studies had no clear-cut noise range, e.g., people exposed to <55 dB (A), for noise exposed groups or unexposed groups. Second, most data were abstracted without adjusting for confounding effects and inconsistent adjustment confounders; thus, the pooled results might be prone to bias.

Conclusion

This meta-analysis suggests that aircraft noise exposure may be associated with an increased risk of hypertension. However, the relationship was significant in men but not in women, and there was no significant difference in ages.

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Address for correspondence:
Prof. Kehu Yang,
No. 199 Dong Gang West Road, Cheng Guan District,
Lanzhou - 730 000, China.
E-mail: kehuyangebm2006@126.com

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Acute effects of night-time noise exposure on blood pressure in populations living near airports

Alexandros S. Haralabidis[1], Konstantina Dimakopoulou[1], Federica Vigna-Taglianti[2], Matteo Giampaolo[3], Alessandro Borgini[4], Marie-Louise Dudley[5], Göran Pershagen[6], Gösta Bluhm[6], Danny Houthuijs[7], Wolfgang Babisch[8], Manolis Velonakis[9], Klea Katsouyanni[1]*, and Lars Jarup[5] for the HYENA Consortium

[1]Department of Hygiene and Epidemiology, Medical School, National and Kapodistrian University of Athens, 75, Mikras Asias Street, Athens 11527, Greece; [2]Environmental Epidemiologic Unit, Regional Agency for Environmental Protection, Piedmont Region, Grugliasco, Italy; [3]Regional Agency for Environmental Protection, Lombardy Region, Milan, Italy; [4]Cancer Register and Environmental Epidemiology Unit, National Cancer Institute, Milan, Italy; [5]Department of Epidemiology and Public Health, Imperial College London, London, UK; [6]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden; [7]The National Institute for Public Health and the Environment, Bilthoven, The Netherlands; [8]Department of Environmental Hygiene, Federal Environmental Agency, Berlin, Germany; [9]Laboratory of Prevention, Nurses School, University of Athens, Athens, Greece

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Aims Within the framework of the HYENA (hypertension and exposure to noise near airports) project we investigated the effect of short-term changes of transportation or indoor noise levels on blood pressure (BP) and heart rate (HR) during night-time sleep in 140 subjects living near four major European airports.

Methods and results Non-invasive ambulatory BP measurements at 15 min intervals were performed. Noise was measured during the night sleeping period and recorded digitally for the identification of the source of a noise event. Exposure variables included equivalent noise level over 1 and 15 min and presence/absence of event (with LAmax > 35 dB) before each BP measurement. Random effects models for repeated measurements were applied. An increase in BP (6.2 mmHg (0.63–12) for systolic and 7.4 mmHg (3.1, 12) for diastolic) was observed over 15 min intervals in which an aircraft event occurred. A non-significant increase in HR was also observed (by 5.4 b.p.m.). Less consistent effects were observed on HR. When the actual maximum noise level of an event was assessed there were no systematic differences in the effects according to the noise source.

Conclusion Effects of noise exposure on elevated subsequent BP measurements were clearly shown. The effect size of the noise level appears to be independent of the noise source.

Keywords Environmental noise • Blood pressure • Night-time sleep • Acute effects • Epidemiological study

Introduction

Noise, defined as undesirable sound, is known to be a stress stimulus that can produce acute blood pressure (BP) elevation in animals[1] and in humans in laboratory or occupational settings.[2]

Persons exposed to high-level noise (including recorded industrial or transportation noise) in the laboratory showed BP rises during the stimulus and for seconds to minutes after its cessation.[3–6] In field studies, workers exposed to high-level industrial noise and having their BP measured via ambulatory BP monitoring (ABPM) showed BP increments during exposure and for a few hours after.[7,8] Although sound levels of transportation (mainly aircraft and road traffic) noise are usually lower, they may produce cardiovascular effects via the neuroendocrine system by causing emotional reactions and annoyance through interference with the individual's mental tasks, relaxation or

* Corresponding author. Tel: +30 210 746 2087, Fax: +30 210 746 2205, Email: kkatsouy@med.uoa.gr

Table 1 Descriptive characteristics of the 140 study subjects

	Athens (*n* = 43)	London (*n* = 16)	Milan (*n* = 50)	Stockholm (*n* = 31)
Gender [*n*; male (%)]	14 (32.6)	8 (50.0)	26 (52.0)	16 (48.5)
Age [years; mean (SD)]	53 (7.8)	58 (7.9)	56 (7.9)	56 (6.4)
Number of BP measurements per night [mean (SD)]	29 (6.2)	30 (4.4)	32 (3.8)	31 (5.2)
Systolic BP [mmHg; mean (SD)]	111 (17.3)	104 (13.2)	110 (15.1)	106 (16.3)
Diastolic BP [mmHg; mean (SD)]	66 (12.3)	62 (10.1)	66 (11.7)	63 (11.2)
Heart rate [b.p.m.; mean (SD)]	65 (9.7)	63 (9.2)	64 (10.7)	61 (8.8)
Number of aircraft events per night[a] median (25th—75th) percentile	19 (5–32)	0 (0–17)	2 (0–7)	0 (0–5)
Number of road traffic events per night[a] median (25th—75th) percentile	1 (0–9)	0 (0–38)	0 (0–1)	0 (0–6)
Number of indoor source events per night[a] median (25th—75th) percentile	14 (8–26)	5 (0–22)	14 (10–21)	9 (5–15)

[a]Event identified as present if measured LAmax >35dB.

sleep, at cortical (conscious) or subcortical level.[9–11] Indeed, systolic BP responses to moderate noise in field conditions were more consistent than those to intense noise in a laboratory on the same individuals.[12] Moreover, cardiovascular responses of the same individuals have been found greater during sleep than during wakefulness.[13] In a sleep laboratory, BP and heart rate (HR) increments were traced after tonal acoustic stimuli or recorded transportation noise; arousal was not needed for sound to produce cardiovascular effects.[14,15] Noise disturbance during sleep is regarded as one of the most important aspects of environmental noise exposure with possible effects on health.[11,13,16] However, field studies on the effects of noise on BP during sleep in real life conditions are lacking.

In the present study the effect of environmental noise on BP and HR during night-time sleep of persons living in the vicinity of four major European airports was investigated within the wider framework of the HYENA (hypertension and exposure to noise near airports) project.[17]

Methods

Sampling

The sample for the present study was selected from the main sample of the HYENA project[17] and consisted of subjects living around four European airports with night flights: Athens (Greece), Malpensa (Italy), Arlanda (Sweden) and London Heathrow (UK). The initial sample for the HYENA study[17] was 6000 persons living in the vicinity of the study airports. A total of 4861 persons (2404 men and 2457 women) between 45 and 70 years old at the time of interview participated in the study. The samples were representative from the populations exposed to various levels of aircraft and traffic noise around airports based on noise contours. Participation rates differed between the countries, from circa 30% in Italy and the UK, to 56% in Greece and 78% in Sweden. More details may be found in Jarup *et al*.[18] We selected subjects from various aircraft noise exposure categories, as assessed by the A-weighted annual equivalent noise level LAeq24h based on their residence, in order to obtain a larger variability in noise exposure situations.

The following exclusion criteria were applied: (1) antihypertensive medication, (2) diagnosis of diabetes mellitus, (3) diagnosis of obstructive sleep apnoea syndrome, (4) diagnosis of secondary hypertension, (5) working in night shift, (6) using sleeping pills and sedatives, (7) diagnosis of hearing impairment, (8) regular use of earplugs, (9) diagnosis of atrial fibrillation. Criteria 1–6 were applied as they affect the night-time BP; criteria 7 and 8 as they modify noise exposure; and criterion 9 as it hinders ABPM. Twenty-one subjects were excluded due to technical problems with the monitoring equipment. The final sample consisted of 140 subjects (*Table 1*). Approval for the study was granted by each centre's Ethical Committee.

Measurements and data management

Continuous noise measurement with the type I 'CESVA SC310' noise-meter[19] (time constant 'fast' 125 ms) as well as noise recording with an MP3 recorder connected to the noise-meter's high-quality microphone were done during the study night in each participant's bedroom. Each participant was followed up for one night. The noise level equivalents for every second, for every 1 min before and for every 15 min period between BP measurements were calculated as follows:

$$\mathrm{LAeq} = 10 \times \log\left(\sum_{i=1}^{t} 10^{\mathrm{LAeq1sec}/10}\right) - 10 \times \log(t)$$

where t is the 1 min or 15 min period in seconds.

Using playback and visualization of sound recordings on a computer, the source of each event was identified and synchronized with the sound measurements with a program written for this purpose. An event was defined as present if its indoor LAmax exceeded 35 dB. Noise events were classified into four categories according to source: indoor, aircraft, road traffic, and other outdoor. Other outdoor events were very rare and thus excluded from the analysis.

Non-invasive 24 h ABPM, with HR measurements, was performed at 15 min intervals with the validated 'Mobilograph' device,[20,21] including the study night. The 15 min frequency has been implemented before[7] and was chosen as optimal for frequent measurements without excessive sleep disturbance. The three instruments (noise meter, noise recorder, and ABPM device) and the participants' alarm clock were synchronized at 1 min precision.

Specially trained nurses installed the noise equipment, placed the ABPM device on the participants and gave them written instructions, during a home visit at least 3 h before normal sleeping time. Each participant was instructed not to engage in unusually heavy activity during the measurements' period and filled in a sleep log indicating actual sleeping times.

Statistical analysis

Linear mixed models which included random intercept and random coefficients for the various noise indicators were applied for each centre separately in order to assess acute effects of noise on BP and HR during night-time sleep. The number of repeated measurements per subject corresponds to the number of systolic and diastolic BP measurements (mmHg), as well as HR measurements (beats per minute—b.p.m.) during the self-reported sleeping period. The A-weighted indoor noise level equivalents of 1 min (LAeq1min) and of 15 min (LAeq15min) before BP measurements were used as short-term noise exposure variables. In this type of model, where an individual serves as his own 'control', there is no need to adjust for individual confounding factors. In order to account for the possible confounding effect of misreporting of sleeping and waking times (potentially associated with both BP and noise levels), the above noise exposure variables were also adjusted for the sequence of BP measurements, using 2 linear terms. The first linear term denoted the sequence of the BP measurements (1,2, . . . ,*k*) from the start to the middle of each persons sleep period and the second denoted the sequence of the BP measurements (1,2, . . . ,*k*) from the middle to the end of each persons sleep period. Other noise exposure variables were the presence or absence of a source-specific noise event during the 15 min periods and each source-specific event's LAmax. If more than one event were present in the 15 min interval, the higher LAmax was used. Since a noise stimulus may not have the same effect in the presence of other noise, in all models assessing the source-specific noise, we adjusted for the 10th percentile of the noise level equivalent (L90) in all the 15 min intervals. After obtaining the four centre-specific effects using random effect models, we then combined the centre-specific results using either fixed or random effects meta-analysis depending on the absence or presence of heterogeneity. All reported *P*-values are based on two-sided hypotheses and the significance level used was 5%.

Results

Table 1 shows the descriptive characteristics of the samples. The mean number of repeated BP measurements per night was similar in all centres (range 29–32). BP and HR displayed a normal distribution (data not shown). The number of aircraft events during the night-time sleep was higher in Athens compared with the other centres. The presence of subjects with no or few night aircraft events was explained by the sampling procedure through which a number of subjects were selected from the main sub-sample of low exposure to aircraft noise. In Milan and Stockholm, the number of indoor events was much larger than aircraft or traffic events. The median equivalent noise levels (LAeq15min, LAeq1min) for all centres were comparable. Also the source-specific LAmax (aircraft, road or indoor) was similar in the four samples (*Figure 1*).

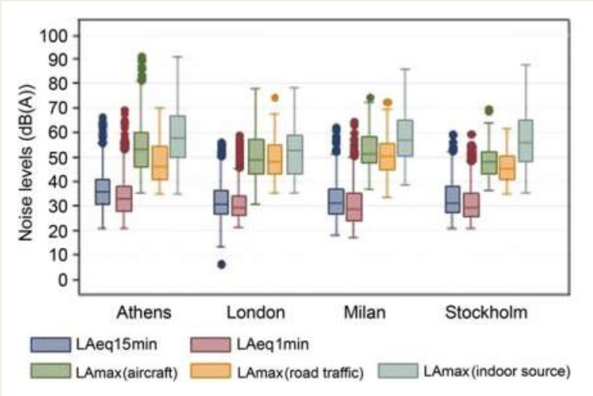

Figure 1 Box plots of the various noise indicators measured during the study night

Table 2 shows the pooled effect estimates of the noise exposure indicators on BP and HR. The measured noise 1 and 15 min before each BP measurement was associated with higher systolic and diastolic BP and with higher HR. For example, a 5 dB increment in LAeq15min was associated with a 0.63 mmHg increase in diastolic BP. The magnitude of the effect on BP was somewhat lower when the LAeq1min was considered but remains statistically significant. The effect remains similar when adjustment was applied for the sequence of measurements during sleep time. An increase in BP (6.2 mmHg for systolic, 7.4 mmHg for diastolic) and HR (by 5.4 b.p.m.) was observed over 15 min intervals in which an aircraft event occurs but for HR this was not statistically significant. A similar magnitude of increase in BP was observed during time periods with traffic or indoor source event. In contrast, the effect on HR was smaller during periods with indoor events and was not observed over periods with traffic events. When the actual noise level assessed by LAmax was taken into account (adjusting for the presence of an event from a specific source and for L90), a positive association was found between noise from all the three sources and BP, which was statistically significant and similar to the effect of measured noise from all sources. The corresponding effects on HR were lower than those from all sources and reached statistical significance only for indoor source noise.

The estimated effects of noise exposure on BP were consistent in each sample. The estimated effects on diastolic BP of measured noise by sample are shown in *Figure 2*. The estimates were practically identical for the three samples, whilst for London they were higher but associated with wider confidence intervals. In *Figure 3* a consistent pattern may be seen for the effects of source-specific noise in the four samples. The corresponding results for systolic BP were similar, with the exception of significant heterogeneity in the effects of indoor source noise events where the effect was highest in London and lowest in Stockholm, the only non-statistically significant effect. The effects for HR were less consistent between centres. However, the only model which displayed statistically significant heterogeneity was the one assessing the presence of aircraft events.

Table 2 Pooled effect estimates of various noise indicators on blood pressure (BP) and heart rate (HR) measurements. Results from fixed effects models (except where noted)

Model		Increase in systolic BP (mmHg) (95% CI)	Increase in diastolic BP (mmHg) (95% CI)	Increase in heart rate (b.p.m.) (95% CI)
1	LAeq(15 min)[a] (5 dB)	0.74 (0.40, 1.08)	0.63 (0.34, 0.91)	0.26 (0.07, 0.44)
2	LAeq(1 min)[b] (5 dB)	0.69 (0.36, 1.02)	0.55 (0.26, 0.84)	0.30 (0.12, 0.49)
3	LAeq(15 min)[c] (5 dB)	0.82 (0.48, 1.16)	0.62 (0.36, 0.88)	0.23 (0.07, 0.40)
4	LAeq(1 min)[d] (5 dB)	0.88 (0.54, 1.22)	0.50 (0.23, 0.78)	0.35 (0.17, 0.53)
5	Aircraft events[e] (yes = 1)	6.20 (0.63, 11.77)	7.39 (3.09, 11.69)	5.42[g] (−2.01, 12.85)
6	LAmax aircraft events[f] (5 dB)	0.66 (0.33, 0.98)	0.64 (0.37, 0.90)	0.18 (−0.04, 0.40)
7	Road traffic events[e] (yes = 1)	4.81 (−2.45, 12.06)	3.34 (−7.37, 14.04)	−2.76 (−7.30, 1.77)
8	LAmax road traffic events[f] (5 dB)	0.81 (0.46, 1.16)	0.55 (0.26, 0.83)	0.01 (−0.41, 0.42)
9	Indoor source events[e] (yes = 1)	7.39 (3.76, 11.02)	4.19 (0.65, 7.72)	3.00 (0.87, 5.13)
10	LAmax indoor source events[f] (5 dB)	0.87[g] (0.17, 1.57)	0.68 (0.43, 0.92)	0.21 (0.01, 0.41)

[a]Equivalent noise level of the 15 min before BP measurement.
[b]Equivalent noise level of the 1 min before BP measurement.
[c]Equivalent noise level of the 15 min before BP measurement, adjusted for the sequence of BP measurements from the start of the sleeping period to the middle of the night-time sleep, and from the middle of the night-time sleep to the wake-up period.
[d]Equivalent noise level of the 1 min before BP measurement, adjusted for the sequence of BP measurements from the start of the sleeping period to the middle of the night-time sleep, and from the middle of the night-time sleep to the wake-up period.
[e]Yes: event with indoor LAmax >35 dB present.
[f]Indoor LAmax of source-specific event adjusted for presence of event (yes: event with LAmax indoor >35 dB present) and for L90 in all 15 min time periods without the source-specific event.
[g]Results from random effects models in presence of significant heterogeneity.

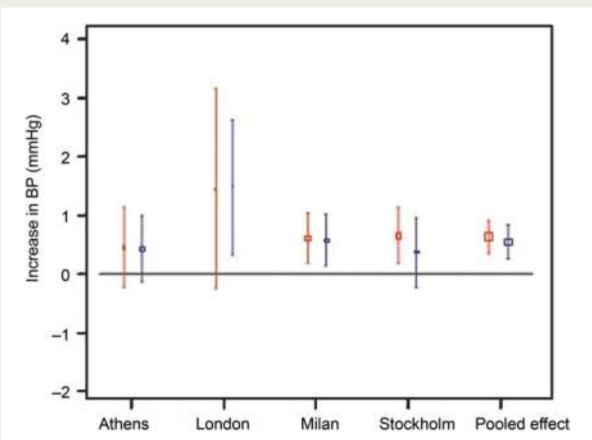

Figure 2 Centre-specific and pooled effect estimates of a 5 dB(A) increment in the equivalent noise level of 15 min (red) and 1 min (blue) before blood pressure (BP) measurement on diastolic BP

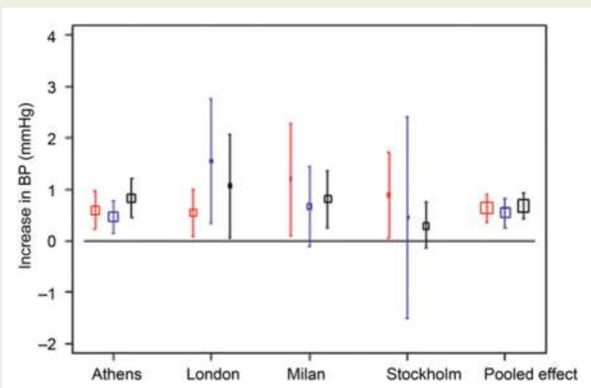

Figure 3 Centre-specific and pooled effect estimates on diastolic blood pressure (BP) and its 95% confidence Interval (CI) associated with an increase of 5 dB in LAmax of aircraft event (red), of road traffic event (blue) and of indoor event (black) during night-time sleep (source-specific event identified as present if indoor measured LAmax >35 dB)

Discussion

We studied the effect of noise on BP during sleep, a state of reduced sympathetic and increased parasympathetic autonomous nervous system (ANS) tone, leading to a decrease of BP and HR.[22]

We found that both systolic and diastolic BP levels as well as HR increased with higher noise levels during the preceding minutes, independently of the noise source and of the sequence of the measurement during sleep time, which indicates absence of habituation during the study night, a matter of controversy in studies on humans or on experimental animals.[13,23] These results are consistent with those reported by Carter *et al.*[15] in a laboratory where both BP and HR increased after noise stimuli. There are major differences between laboratory and real life conditions. In a laboratory, background noise is steady whilst in real life conditions the analysis has to adjust for variable noise sources. Davies *et al.*[14] studied five subjects and found an increase in diastolic BP from 4 to 6 mmHg associated with arousal according to sleep stage. We found an increase of 6–7 mmHg in diastolic BP according to the source of the noise event, not necessarily associated with awakening.

We also found significant increases in BP and, less consistently, HR when the source of the noise was taken into account. The effects of the source-specific noise were comparable for aircraft, traffic, and indoor events and were similar to those of the total measured noise.

In our study, one common source of indoor noise was snoring. Since in some cases the study subject is expected to be the snorer too (we could not assess this information) and his BP elevation could be due to disordered breathing,[24,25] the effect of indoor noise on BP that we report could be overestimated.

The effect of the measured noise level as well as the source-specific noise was weaker and less consistent on HR than on BP. This finding is in accordance with results from a sleep laboratory study[15] where a noise threshold was detected for the effects on HR but not on BP and with previously reported mechanisms of BP rise following noise exposure, which refer mainly to vasoconstriction.[2,26] Moreover, HR has a stronger circadian component which may mask other effects.[27]

The remarkable consistency of the estimated effects between the four centres strengthens the evidence for causality. The effects of noise exposure on BP per specific increase in noise levels were found similar in the four samples in spite of the fact that there were differences in the profiles of noise according to the source during the night. However, the indoor LAmax levels in the presence of an event were comparable in all the four centres.

In sleep laboratories, noise stimuli of levels comparable with those of real life produced cardiovascular responses for seconds.[13,14] However, in occupational or laboratory settings, BP elevations have been found to last for minutes or even hours[6–8] during wakefulness. Emotional responses such as anger or fear may magnify and prolong the effects, during night-time exposure to aircraft noise in real life conditions.[9] One drawback of our study is that BP was assessed every 15 min although the noise event could have happened anytime within this interval. As expected, the distribution of noise events over the 15 min intervals between BP measurements is uniform. Only 5–11.5% of events (the range reflects different sources and samples) occurred during the minute of measurement (6.7% expected). The design of our study might have led to the 'loss' of the effect on BP or HR if the noise event happened to occur during the first minutes of intervals between measurements and the effect was of short duration. However, the fact that the effects of noise during the preceding 1 and 15 min were of similar magnitude indicates more prolonged effects.

In this study, the indoor LAmax threshold for characterizing an event as 'present' was set at 35 dB. Awakening reactions are usually observed at LAmax values over 40–45 dB in the bedroom but recently lower thresholds have been also suggested.[11,28] However, according to sleep laboratory studies, haemodynamic changes can also occur at lower noise levels than the ones that cause EEG changes, although the effects are stronger when arousal coexists.[13,14] Indeed, autonomic responses like BP elevation have been used as a sensitive marker of sleep disturbance.[29,30] The finding that consciousness is not needed for sound to produce its cardiovascular effects is also supported by experiments in which anaesthetized animals demonstrated BP increment when exposed to intense noise[31] or BP reduction when exposed to music.[32,33] These outcomes are attributed to the subcortical connections of the auditory pathway with the ANS (amygdala, hippocampus, hypothalamus)[10] and justify the use of relatively low noise thresholds in the research of noise effects on BP during sleep.

To assess nocturnal BP, we used ABPM, which has been validated and used extensively for this purpose.[19,20] ABPM has been reported to affect sleep and night-time BP[34] during the cuff's inflation similarly to noise arousal stimuli,[14] although it is also supported, by means of intra-arterial recordings, that ABPM does not attenuate night-time BP reduction.[35] In any case, it can be argued that there is synergy and that the effects of noise would not be the same in the absence of ABPM during the study night. Because of this possibility, the frequency of BP measurements was kept at four per hour, although up to six measurements per hour have been used before.[36] Moreover, the body position during sleep can affect the ABPM measurements.[37] All measurements however in our study, irrespective of noise exposure level, were done with ABPM and there is no reason to assume that body position during sleep is related to noise exposure. The use of portable, non-invasive BP recorders that register BP continuously and correct automatically hydrostatic effects,[38] can be considered in future studies investigating the effect of noise on night-time BP in real life conditions.

Within the HYENA project we found effects of long-term noise exposure on the prevalence of hypertension[18] and the acute effects reported here. Absence of short-term habituation to the cardiovascular effects of noise, especially those during sleep, found here and also reported before,[13,16,39] as well as evidence from studies on sleep-disorder which indicate that repeated arousals are associated with a sustained increase in daytime BP,[40] support a link between acute and long-term effects of noise exposure on hypertension[41,42] and cardiovascular disease,[43] in line with the general stress theory.[44]

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CLINICAL RESEARCH

Effect of nighttime aircraft noise exposure on endothelial function and stress hormone release in healthy adults

Frank P. Schmidt[1], Mathias Basner[2], Gunnar Kröger[1], Stefanie Weck[1], Boris Schnorbus[1], Axel Muttray[3], Murat Sariyar[4], Harald Binder[4], Tommaso Gori[1], Ascan Warnholtz[1], and Thomas Münzel[1]*

[1]Department of Medicine II, University Medical Center, Johannes Gutenberg University Mainz, Langenbeckstrasse 1, 55131 Mainz, Germany; [2]Unit of Experimental Psychiatry, Division of Sleep and Chronobiology, Department of Psychiatry, University of Pennsylvania Perelman School of Medicine, Philadelphia, PA, USA; [3]Institut für Arbeits-, Sozial- und Umweltmedizin, University of Mainz, Mainz, Germany; and [4]Institute for Medical Biometry, Epidemiology and Informatics, University of Mainz, Mainz, Germany

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Aims

Aircraft noise disturbs sleep, and long-term exposure has been shown to be associated with increases in the prevalence of hypertension and an overall increased risk for myocardial infarction. The exact mechanisms responsible for these cardiovascular effects remain unclear.

Methods and results

We performed a blinded field study in 75 healthy volunteers (mean age 26 years), who were exposed at home, in random order, to one control pattern (no noise) and two different noise scenarios [30 or 60 aircraft noise events per night with an average maximum sound pressure level (SPL) of 60 dB(A)] for one night each. We performed polygraphy during each study night. Noise caused a worsening in sleep quality ($P < 0.0001$). Noise60, corresponding to equivalent continuous SPLs of 46.3 dB (Leq) and representing environmental noise levels associated with increased cardiovascular events, caused a blunting in FMD ($P = 0.016$). As well, although a direct comparison among the FMD values in the noise groups (control: 10.4 $\pm$ 3.8%; Noise30: 9.7 $\pm$ 4.1%; Noise60: 9.5 $\pm$ 4.3%, $P = 0.052$) did not reach significance, a monotone dose-dependent effect of noise level on FMD was shown ($P = 0.020$). Finally, there was a priming effect of noise, i.e. the blunting in FMD was particularly evident when subjects were exposed first to 30 and then to 60 noise events ($P = 0.006$). Noise-induced endothelial dysfunction (ED) was reversed by the administration of Vitamin C ($P = 0.0171$). Morning adrenaline concentration increased from 28.3 $\pm$ 10.9 to 33.2 $\pm$ 16.6 and 34.1 $\pm$ 19.3 ng/L ($P = 0.0099$). Pulse transit time, reflecting arterial stiffness, was also shorter after exposure to noise ($P = 0.003$).

Conclusion

In healthy adults, acute nighttime aircraft noise exposure dose-dependently impairs endothelial function and stimulates adrenaline release. Noise-induced ED may be in part due to increased production in reactive oxygen species and may thus be one mechanism contributing to the observed association of chronic noise exposure with cardiovascular disease.

Keywords Endothelial function • Aircraft noise • Cardiovascular risk

Introduction

The WHO estimates that in high-income Western European countries (population ~340 million) at least 1 million healthy life years are lost every year due to environmental noise.[1] The negative health outcomes of noise include annoyance,[2] sleep disturbance,[3] cardiovascular disease,[4,5] and impairment of cognitive performance in children.[6]

Aircraft noise has been shown to be more annoying than road- and railway noise at the same equivalent noise level.[7] Epidemiologic studies have demonstrated associations between long-term

* Corresponding author. Tel: +49 6131 17 7250, Fax: +49 6131 17 6615, Email: tmuenzel@uni-mainz.de

exposure to aircraft noise and an increased incidence of arterial hypertension and therefore cardiovascular disease.[7,8] The mechanisms underlying these adverse cardiovascular effects of aircraft noise are not fully understood. Nocturnal noise exposure seems to be more relevant for the genesis of cardiovascular disease than daytime noise exposure,[9] probably due to repeated autonomic arousals that have been shown to habituate to a lesser degree to noise than, e.g. cortical arousals.[10] In general, the risk increases with exposure duration, and is higher in those who decide to sleep with open windows.[11,12]

Undisturbed sleep of sufficient length is obligatory for the maintenance of daytime performance and health.[13] The human organism recognizes, evaluates, and reacts to environmental sounds even while asleep.[14] These reactions are part of an integral activation process of the organism that expresses itself, e.g. as changes in sleep structure or increases in blood pressure and heart rate.[10,15] Environmental noise may decrease the restorative power of sleep by means of repeatedly occurring activations (so-called *sleep fragmentation*) that are associated with more awakenings/arousals, less deep sleep and rapid eye movement sleep, and early awakenings in the morning. Although healthy subjects have been shown to habituate to aircraft noise exposure to a certain degree,[10] the habituation is not complete, and noise-induced awakenings and, especially, activations of the autonomic nervous system can still be observed in subjects that have been exposed to aircraft noise for several years.[16] Sleep disturbance and especially sleep restriction in turn have been shown to cause hormonal and metabolic changes,[17–19] which could predispose to a future development of cardiovascular disease.

Circadian changes related to altered sleep may also adversely affect the immune system[20,21] and may increase the responsiveness of the heart to hypertrophic stimuli.[22] Although plausible, the link between polysomnographic evidence of sleep disturbance during aircraft noise exposure and cardiovascular outcomes is not well established. It is largely unknown which changes or indices predict long-term risk.[23]

Furthermore, polysomnography (i.e. the simultaneous measurement of the electroencephalogram, electrooculogram, and electromyogram) is a complex and cumbersome method, which is not very well suited for larger studies in the general population.[24] Therefore, other methods, like actigraphy (a non-invasive technique to monitor human rest/activity cycles) and behaviourally confirmed awakenings, have been used in this context.

In the case of aircraft noise, hypertension may be a consequence of the noise-induced release of stress hormones such as epi- and norepinephrine and/or the development of vascular (endothelial) dysfunction. Endothelial dysfunction (ED) is considered an early step in the development of atherosclerotic changes of the vasculature (for review see[25]) and can be assessed non-invasively. Recent studies indicate that in patients with coronary artery disease and hypertension, ED assessment in the forearm may have prognostic implications.[25]

Based on these considerations, the primary aim of the present study was to test whether nocturnal exposure to aircraft noise may induce ED. The morning plasma level of adrenaline was a secondary endpoint. In a subgroup of noise 60 subjects, we also tested whether acute vitamin C challenges may improve ED.

Methods

The study was approved by the ethics committee of University Medical Center Mainz. All participants were volunteers and signed informed consent. Anti-aircraft noise activists were excluded from the study as were persons with high nighttime traffic noise exposure at home as determined by noise maps available from municipal online resources ($L_{A,eq,22\text{-}6h} > 40$ dB for aircraft noise and $L_{A,eq,22\text{-}6h} > 45$ dB for road and rail traffic noise).

Study population

The study enrolled 75 healthy non-smokers between 20 and 60 years of age. Before the study, audiometry was performed in all participants. Persons with an age-adjusted hearing loss of 20 dB or more on one or both ears were excluded from the study. Subjects with sleep disorders [score >10 on the Pittsburgh Sleep Quality Index (PSQI)][26] or psychiatric disorders (assessed by M.I.NI. Screen interview) were also ineligible. Study participants were instructed to refrain from consumption of coffee, tea, alcohol, sleep altering medications, and nicotine on the day prior to the study night. Otherwise, they were told to continue their usual diet and daily routines. Hormonal contraception was allowed but care was taken to synchronize study nights with the hormonal status. Other hormonal therapies were excluded.

Study procedures

After inclusion, participants returned to the laboratory for three visits. During the night preceding each visit, subjects were exposed in a randomized order to one of three noise patterns. One night served as the control night, and subjects were exposed to normal background noise. During the other two nights, subjects were exposed to recording reproducing different numbers of flights: Noise30 with playback of 30 aircraft noise events, and Noise60 with playback of 60 aircraft noise events. Study visits were prescheduled with at least three non-study nights between two study nights and on the same weekday if possible. In premenopausal women, the visits were scheduled to occur in the same phase of the hormonal cycle. Supplemental vitamins, alcohol, and caffeine containing beverages were prohibited on the evening and night before the study.

Participants were randomly given one of six different sequences of noise and control nights according to the randomization plan (C-30-60, C-60-30, 30-C-60, 30-60-C, 60-C-30, 60-30-C). At study onset, subjects and investigators were both blinded to the noise pattern sequence. Participants slept in their usual home environment and were asked to maintain their usual sleep–wake rhythm. They wore portable polygraphic screening devices (SOMNOwatch™ plus, SOMNOmedics, Randersacker, Germany) during the night with continuous recording of ECG, SpO_2, actimetry, light, and derived parameters as described in previous studies.[27–29]

In the noise exposure nights, the same aircraft noise event was played back repeatedly. It was originally recorded in the bedroom of a resident living in the vicinity of Düsseldorf airport (window tilted open), and was already used in previous studies on the effects of aircraft noise on sleep.[30,31] Noise patterns were recorded as MP3 files and played back on a standard portable audio system with a fixed speaker position relative to the head of the subject. The playback volume was levelled at each measurement site to guarantee similar SPLs at all study sites. During the night, the SPL was continuously recorded in the bedroom with class-2 sound level meters (Datalogger DL-160S, Voltcraft, Germany; Model 407764A Datalogger, Extech Instruments, USA) to assure subject compliance. They were placed on the nightstand close to the participants. All sound files were coded with a study number and were of equal length and file size, making inadvertent unblinding less likely. All noise patterns started with a constant tone of 30 s duration to allow

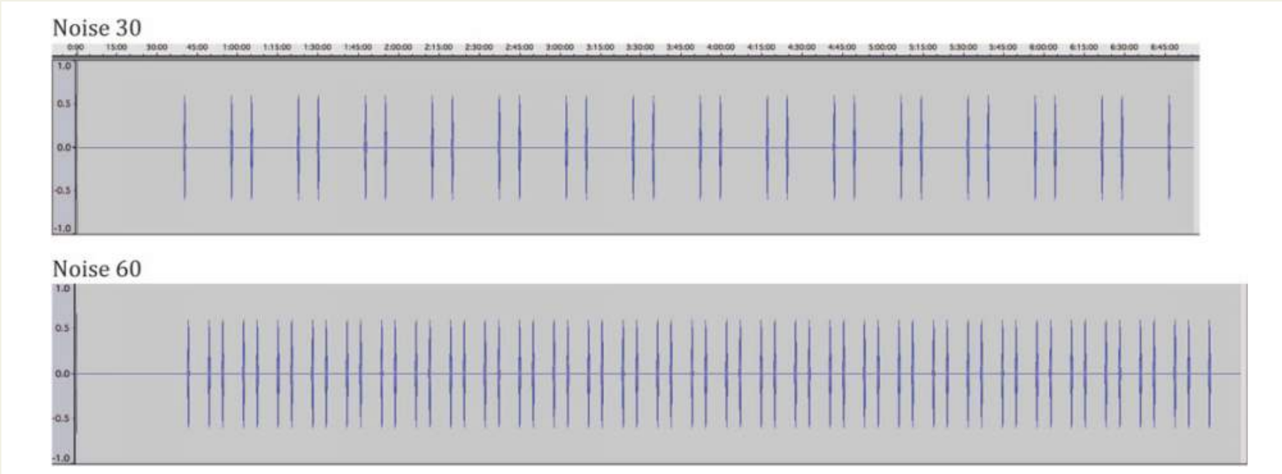

Figure 1 Schematic representation of the noise events.

testing of equipment function. The first aircraft noise event was played back after 39.5 min to facilitate sleep onset. The last aircraft noise event was played back after 415 min. Each noise event lasted roughly 45 s. Noise events followed a short–long–short pattern with time between events roughly 6:40 min and 16:40 min for Noise30 and 4:05 min and 6:40 min for Noise60 (*Figure 1*).

After the study night, participants returned to the study centre in a fasting state for further testing. Flow-mediated dilatation of the brachial artery was measured at the same time in the early morning and before 10 a.m. by a technician using standardized techniques described previously.[25,32,33] Briefly, brachial artery diameter is measured with a linear ultrasound probe at rest and after a 5 min occlusion period with a pressure cuff. Changes in diameter are given in percent and reflect the endothelial release of vasodilatory substances such as nitric oxide (NO). To address the role of reactive oxygen species in causing ED, FMD was also measured in a subset of five subjects exposed to Noise60 before and after administration of vitamin C (2 g, p.o.) as previously described.[34] After FMD measurement, blood samples were drawn and questionnaires were filled out. Blood samples were transported directly to a clinical laboratory for evaluation. Part of the blood was centrifuged, aliquoted, and frozen at below −62°C for later testing. Global noise sensitivity was measured using the Dortmund Noise Sensitivity Questionnaire.[35] The Horne-Ostberg Morningness-Eveningness Questionnaire (MEQ)[36] was used to assess individual chronotype. Pulse transit time (PTT, time between the R wave in the ECG and peak oxygen saturation measured at the tip of the first finger of the right hand) and heart rate accelerations (number of accelerations >20 bpm and >2 s per h) were calculated. Interleukin-6 and cortisol were measured in serum with chemiluminescence immunoassay. Adrenaline was measured from NH4-heparine anticoagulated blood drawn 30 min after puncture and cooled during transport to the lab.

Statistical analysis

The primary endpoint of the study was the change in %FMD induced by the different levels of noise. Secondary outcomes included the changes in all variables measured (neurohormones, PTT, inflammatory markers, etc), the existence of a relationship between dose of noise and blunting of FMD (dose–effect relationship), and whether Noise30 or Noise60 had a priming effect on the blunting in FMD induced by, respectively, Noise60 or Noise30. A separate study was conducted to test the effect of Vitamin C on FMD in subjects exposed to Noise60. Data are presented as mean ± standard deviation. The Kolmogorov–Smirnov test was used to assess whether the data were normally distributed. To address the primary endpoint, we first compared the effect of Noise60, which reproduces the increase in night noise previously shown to be associated with an increased incidence of cardiovascular events and prevalence of hypertension,[9] with the control visit. Further, a multi-factor ANOVA [taking into account noise exposure, night of exposure, and subject id (for subject-related differences)] was performed. A test for a monotone effect of the exposure (dose of nighttime aircraft noise: 0, 30, or 60) was performed by using exposure as a pseudo-continuous factor in the ANOVA. Further, a (*post hoc*) multi-factor ANOVA was performed with two additional factors: one for the comparison of FMD values after Noise60 in all subjects allocated to control–Noise30–Noise60 or Noise30–Noise60–control to FMD values of all other patients, and the other for the same comparison after Noise30 in all subjects exposed to Noise60 directly preceding Noise30. P-values <0.05 were considered significant. All tests were two-sided. P-values for secondary outcome variables are shown without adjustment for multiple testing. Based on the paper by Ghiadoni *et al*.,[37] a difference between means of 2% could be expected (with SD of about 3%). With a sample size of 75 and a standard deviation of FMD differences between Noise60 and control of 3%, one may expect to detect a FMD difference of 0.98% with a power of 80% at the alpha-level 0.05.

Results

Study population and setting

A total of 88 subjects were enrolled. Thirteen of them were excluded from the final analysis. Reasons for dropouts (3 study subjects before and 10 after the first study night) included the diagnosis of hyperthyroidism, relocation to noise-affected areas, protocol violations, and inadequate data recording quality. The study subjects included in the final analysis were on average 26 years (range 20–54 years) old, 61% were females. FMD data could not be analysed for one visit in two subjects. The study population did not have relevant sleep disorders as assessed with the PSQI, and had a moderate

Table 1 Baseline characteristics of the study population

Age	(min–max)	25.7 (20–54)
Gender	% female	61.3
Height	cm	174.6 ± 10.2
Weight	kg	67.7 ± 11.9
BMI	kg/m^2	22.1 ± 2.4
Baseline noise sensitivity, chronotype, sleep quality index		
NoiSeQ	0–3	1.22 ± 0.38
Horne–Östberg	14–86	49.41 ± 9.79
PSQI	0–21	3.73 ± 1.72
Laboratory values		
Total cholesterol	mg/dL	182.9 ± 32.9
LDL	mg/dL	104.7 ± 25.6
HDL	mg/dL	60.7 ± 15.3
Triglycerides	mg/dL	87.2 ± 41.9
C-reactive protein	mg/L	1.3 ± 1.5
Creatinin	mg/dL	1.0 ± 0.5
HbA1C	%	5.3 ± 0.5

Data are presented as mean ± SD.
NoiSeQ, Dortmund Noise Sensitivity Questionnaire with three greatest noise sensitivity; Horne-Östberg, Morningness-Eveningness Questionnaire; PSQI, Pittsburgh Sleep Quality Index.

trend towards evening chronotype (characteristics shown in *Table 1*). None reported significant diseases.

The average maximum SPL of aircraft noise events recorded in participants' bedrooms is presented in *Table 2*. Overall nighttime SPLs had average peak levels of 49.6 dB(A) (control), 59.9 dB(A) (Noise30), and 60.9 dB(A) (Noise60) (both $P < 0.0001$ compared with control). Corresponding equivalent continuous SPLs Leq(3) were 35.4 dB(A), 43.1 dB(A), and 46.3 dB(A), respectively. The mean time between awakening and start of image acquisition for FMD did not differ across visits ($P > 0.5$).

Control and noise exposure nights did not differ significantly with regard to outside and body temperatures, total time in bed or subjective well being prior to the study night (data not shown). All data were normally distributed.

Haemodynamic changes in response to night noise

As a secondary predefined endpoint, we also found a dose-dependent decrease in minimum PTT (*Table 2*) after the noise nights, which was mirrored by the changes in systolic blood pressure ($P = 0.11$ for the changes among visits, *Table 2*). Automated heart rate analysis detected no significant change in mean and maximum heart rate. Heart rate acceleration index as detected by the polygraphic device did not differ between noise exposure and control nights.

With increasing number of noise events, study subjects reported deteriorating sleep quality in the morning after the respective study night ($P = 0.001$).

Effects of nocturnal noise on endothelial function

The comparison of the FMD values measured after the control visit and the Noise60 visit demonstrated a blunting in endothelial responses after noise ($P = 0.016$). When all three levels of noise were compared, and noise exposure (0, 30, 60) was used as a pseudo-continuous covariate in the AN(C)OVA in order to test for a dose-dependency in the effect of noise on FMD, a linear relationship between FMD values and exposure was found ($P = 0.020$), confirming that the exposure to more severe noise causes more severe ED. Although a standard comparison among the three noise levels within the ANOVA, i.e. without assuming a monotone effect for dose as a pseudo-continuous covariate, did not reach statistical significance (control night: 10.4 ± 3.8%; after 30 noise events: 9.7 ± 4.1%; after 60 noise events: 9.5 ± 4.3%, $P = 0.052$, *Figure 2A*), the introduction of the two additional factors described in the Methods section evidenced a priming effect of Noise30 nights on the blunting in FMD induced by Noise60 ($P = 0.006$), i.e. Noise60 had the largest impact on FMD in the subjects who had already been exposed to Noise30. Finally, there was no effect of the randomization sequence (means after each visit adjusted for the effect of effect of noise: first visit: 9.8%, second visit: 10.0%, third visit: 9.4%, $P = 0.757$).

Noise had no effect on blood flow and reactive hyperaemia (control: 855 ± 357%; Noise30: 900 ± 423%; Noise60: 900 ± 389%, $P = 0.55$). As well, baseline arterial diameter did not significantly influence the effect of noise on FMD.

In order to study the mechanism of the blunting in FMD induced by Noise60, we tested the impact of acute challenges with vitamin C in five control subjects. In these subjects, 2 h after the administration of Vitamin C, FMD was markedly improved (*Figure 2B*, $P = 0.0171$). In contrast, in a separate control group of subjects exposed to Noise60 without Vitamin C, FMD did not change as an effect of time (11.21 ± 5.56%; FMD at 2 h: 11.47 ± 5.80%; $P = 0.842$).

Effects of night noise on neurohormones and markers of inflammation (*Table 2*)

We found a marked increase in plasma adrenaline concentrations between control and Noise30 and 60 exposure nights, respectively (control: 28.3 ± 10.9 ng/L; Noise30: 33.2 ± 16.6; Noise60: 34.1 ± 19.3 ng/L, $P = 0.0099$, *Figure 3*). In contrast, morning plasma levels of cortisol did not increase with noise exposure. Likewise, inflammatory markers IL-6 and C-reactive protein were unaffected by noise exposure.

Discussion

We demonstrate cardiovascular effects of nighttime aircraft noise in young and healthy individuals with low cardiovascular risk. Nighttime aircraft noise increased plasma epinephrine levels, worsened sleep quality, and decreased pulse transit time, a parameter of arterial stiffness, which varies inversely to arterial blood pressure. A dose-dependent decrease in endothelial function after exposure to increasing levels of noise was also observed. Acute Vitamin C challenges improved endothelial function in a separate group of subjects exposed to Noise60. We found no effect of aircraft noise

Table 2 Effects of nighttime noise on the quality of sleep, haemodynamic parameters, cortisol levels, and inflammation parameters

	Control	Noise 30	Noise 60	*P* (ANOVA)
PeakdB(A)	48.63 ± 3.47	59.89 ± 3.28	60.87 ± 2.46	<0.001
Leq3dB(A)	35.44 ± 8.08	43.12 ± 4.91	46.28 ± 3.89	<0.001
Sleep quality	6.70 ± 1.92	5.20 ± 2.28	4.37 ± 2.23	<0.001
Movement index	3.94 ± 5.40	3.06 ± 2.85	3.23 ± 3.44	0.639
Haemodynamic parameters				
HR mean	58.7 ± 7.6	59.5 ± 7.7	59.7 ± 7.8	0.345
HR max	102.6 ± 13.3	104.3 ± 13.2	106.9 ± 17.5	0.325
BPsys mean (mmHg)	109.8 ± 15.4	114.9 ± 13.9	115.2 ± 12.4	0.120
BP rise Index	2.3 ± 2.3	2.5 ± 2.32	3.8 ± 5.9	0.397
HR_accel Index	25.8 ± 32.4	22.8 ± 23.0	23.9 ± 26.5	0.215
Pulse transit time (ms)	271.8 ± 12.3	270.9 ± 18.7	264.9 ± 15.7	0.003
Laboratory parameters				
Adrenaline (ng/L)	28.3 ± 10.9	33.2 ± 16.6	34.1 ± 19.3	0.010
Cortisol (μg/L)	15.34 ± 5.47	16.43 ± 5.55	15.76 ± 5.78	0.197
Neutrophils (%)	51.0 ± 11.39	49.77 ± 9.48	50.04 ± 7.87	0.353
IL-6 (pg/mL)	2.6 ± 3.45	2.27 ± 1.25	2.57 ± 3.29	0.383
C-reactive protein (mg/L)	2.26 ± 6.30	2.27 ± 4.82	1.55 ± 2.16	0.512

Data are presented as mean ± SD.
Leq3 dB, long-term equivalent continuous sound level; PTT, pulse transit time; BP, blood pressure; HR accel, heart rate acceleration; IL-6, interleukin 6.

exposure on nocturnal motility, heart rate or blood cortisol, neutrophils, IL-6, or C-reactive protein.

Interestingly, a priming effect of aircraft noise on ED was observed, i.e. previous exposure to Noise30 caused Noise60 to have larger effects on endothelial function. These data demonstrate that aircraft noise can affect endothelial function, and that rather than habituation, prior exposure to noise seems to amplify the negative effect of noise on endothelial function. Although the mechanisms of these observations cannot be characterized at a molecular level *in vivo* in humans, it has been previously shown that other forms of mental stress lead to a decrease in endothelial function.[37–40] With regards to the molecular mechanisms, previous studies indicate that noise leads to an up-regulation, rather than a downregulation, of the eNOS.[41] Interestingly, such an increased eNOS activity does not necessarily result in improved endothelial responses. For instance, in animal models of diabetes and/or hypertension, increased expression of an uncoupled (superoxide-producing) eNOS is associated with impaired endothelial function (reviewed in[42]). Since measurements of NO and/or superoxide production in the local vascular microenvironment are impossible to perform in humans, this question cannot be addressed at the present time. The improvement in FMD observed in our study 2 h after application of the antioxidant vitamin C in subjects exposed to Noise60 is compatible with this evidence, and it suggests that exposure to aircraft noise might lead to ED due to increased vascular oxidative stress.[34]

We also demonstrate changes in PTT, a parameter that correlates inversely with changes in blood pressure. Briefly, PTT is measured as the time it takes a pulse wave to travel between two arterial sites. Rises in blood pressure cause vascular tone to increase, leading to increased arterial stiffness and a shorter PTT. As mentioned above, these data are compatible with those of the HYENA project, in which an increase prevalence of hypertension was reported in subjects exposed to nocturnal noise in the range of 50 dB (similar to our Noise60 condition; 46.3 dB).[9] Similarly, acute noise events were associated in this study with increased systolic and diastolic blood pressure by 6.2 and 7.4 mmHg, a phenomenon which, interestingly, was not necessarily associated with awakenings.

With regard to the pathophysiological mechanism behind the changes in blood pressure and vascular function, we also report elevated epinephrine levels after exposure to noise. It has been demonstrated that intermittent release of adrenaline may be implicated in the development of hypertension.[43] Epinephrine is released as a response to different stressors such as noise[44] and increases the release and the effects of norepinephrine.[45] Interestingly, increased epinephrine levels have been found in patients with borderline hypertension,[45,46] suggesting a role in the early history of hypertension.

Importantly, increased plasma catecholamines have also been shown to correlate negatively with endothelial function as measured by FMD.[47] A recent study has linked autonomic sympathetic activation to the development of hypertension in elderly patients independent of the cause of activation of the autonomic nervous system.[48]

Our results are congruent with the growing amount of data linking short sleep duration or sleep disturbances of various kinds to the development of cardiovascular disease. For example, shift work has been shown to cause impaired endothelial function, sympathetic activation, and metabolic changes.[49,50] Extensive evidence exists for the relation between obstructive sleep apnoea, hypertension, ED, and

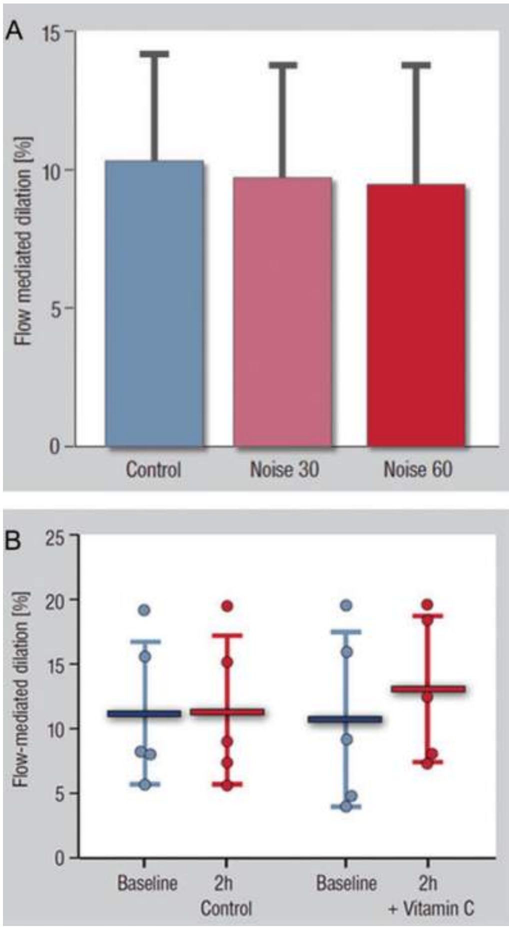

Figure 2 (*A*) Effects of Noise30 and Noise60 on flow-mediated dilation (FMD). Data are mean ± SD; $P = 0.020$ for a test using the level of noise a pseudo-continuous variable, demonstrating a linear relationship between FMD values and noise exposure. (*B*) Effects of Vitamin C (2 g, p.o.) in FMD of the brachial artery. 2 h after Vitamin C administration, the antioxidant improved significantly FMD in five control subjects exposed to Noise60. Date are presented as mean ± SD; $P = 0.0171$ for the effect of Vitamin C on FMD, paired *t*-test.

subsequently cardiovascular disease.[51] Recently, the restless legs syndrome has been identified as another cause for sleep disruption, and it has been shown to increase the risk for myocardial infarction in women.[52] There is ample evidence that nocturnal aircraft noise exposure disturbs and fragments sleep, leads to changes in sleep structure, increases sleepiness during the following day, and leads to impairments of cognitive performance.[10,23,53,54] The results of our study suggest that these changes in sleep structure negatively affect the cardiovascular system, and that these changes, in the case of long-term exposure, may predispose to the development of hypertension and cardiovascular disease.

The study by design eliminated noise adaptation processes, which can often mask effects of environmental influences. Therefore, it is unclear whether the negative cardiovascular effects observed in

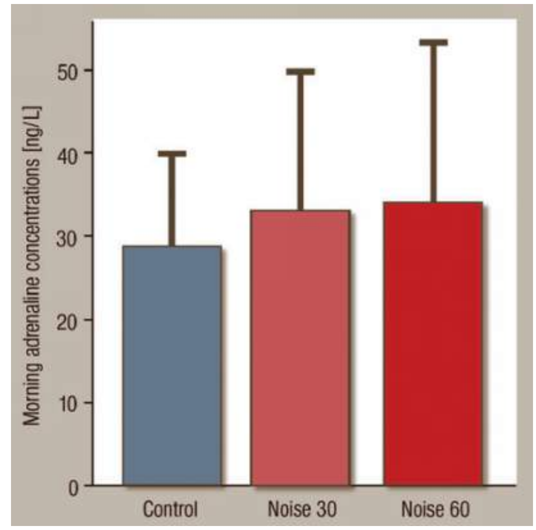

Figure 3 Effects of Noise30 and Noise60 on plasma adrenaline levels. Nighttime noise exposure significantly increases circulating catecholamine levels. Data are mean ± SD. $P < 0.01$, ANOVA.

this study persist after weeks or months with continued noise exposure. However, biologic adaptation is often incomplete and requires physiologic resources therefore also putting strain on the system as a whole. Effects of aircraft noise in population-based studies are likely to be mitigated by partial physiologic adaptation and avoidance of residential areas with high levels of noise exposure by highly sensitive individuals. Other environmental factors like air pollution, which has also been shown to influence endothelial function,[55] may interfere with noise effects in epidemiological studies. Therefore, data from interventional studies may be helpful in judging the effect of nocturnal noise on cardiovascular health and disease.

Limitations of the study

The protocol was designed as a field study with minimal sleep disruption due to environment and equipment, thus creating ecologically valid conditions. We avoided on purpose a pure laboratory environment where ambient conditions, sound levels, and external stimuli can be controlled at the expense of creating artificial rather than familiar conditions. Sleep quality is very sensitive to changes in surroundings and study subjects usually show more pronounced alterations of sleep in the laboratory than in the field.[56] There were no adaptation nights prior to study nights due to logistic constraints and because, since subjects were not required to sleep in non-familiar environments, our study design did not demand such adaptation. Reinforcing this, the analysis did not show a significant first-night effect for our primary outcome,[57] which supports the validity of our study design and results. Study subjects were healthy, young, and with a female majority and are therefore not representative of the whole population. In general, younger adults usually show less sleep problems and disturbance than older persons when exposed to noise, and the fact that noise had an impact also on such a low-risk population rather emphasizes the potential clinical relevance of the present findings. Finally, endothelium-independent vasodilation was not systematically measured and the data are not presented: nitroglycerin responses were measured initially, but these measures were discontinued due to refusal by many study participants related to the side effects of the drug.

Summary and conclusions

In a group of young and healthy volunteers, we found evidence for significant impairment of endothelial function after only one night of aircraft noise exposure with 60 noise events. Pointing to a significant contribution of oxidative stress in this phenomenon, these adverse changes of the vasculature were markedly improved by acute Vitamin C challenges. Endothelial dysfunction was paralleled by significant increases in circulating adrenaline levels and a substantial, dose-dependent decrease in sleep quality and an increase in systolic blood pressure. These findings indicate that hypertension observed in response to nighttime exposure to noise might be explained by increased sympathetic activation but also by the occurrence of vascular dysfunction. Accumulating data increasingly confirms that sleep disturbance of different causes might represent a novel, important health risk. An undisturbed night's sleep is important for health and well-being and should be protected as far as possible, and reducing nocturnal aircraft noise can therefore be regarded as a preventive measure for cardiovascular disease. Since the present studies demonstrate adverse effects of endothelial function and stress hormones in healthy adults, the implications for patients with known cardiovascular disease will need to be tested in further studies.

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Conflict of interest: none declared.

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ORIGINAL PAPER

Nighttime aircraft noise impairs endothelial function and increases blood pressure in patients with or at high risk for coronary artery disease

Frank Schmidt · Kristoffer Kolle · Katharina Kreuder · Boris Schnorbus · Philip Wild · Marlene Hechtner · Harald Binder · Tommaso Gori · Thomas Münzel

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Abstract

Aims Epidemiological studies suggest the existence of a relationship between aircraft noise exposure and increased risk for myocardial infarction and stroke. Patients with established coronary artery disease and endothelial dysfunction are known to have more future cardiovascular events. We therefore tested the effects of nocturnal aircraft noise on endothelial function in patients with or at high risk for coronary artery disease.

Methods 60 Patients (50p 1–3 vessels disease; 10p with a high Framingham Score of 23 %) were exposed in random and blinded order to aircraft noise and no noise conditions. Noise was simulated in the patients' bedroom and consisted of 60 events during one night. Polygraphy was recorded during study nights, endothelial function (flow-mediated dilation of the brachial artery), questionnaires and blood sampling were performed on the morning after each study night.

Results The mean sound pressure levels $L_{eq(3)}$ measured were 46.9 ± 2.0 dB(A) in the Noise 60 nights and 39.2 ± 3.1 dB(A) in the control nights. Subjective sleep quality was markedly reduced by noise from 5.8 ± 2.0 to 3.7 ± 2.2 (p \ 0.001). FMD was significantly reduced (from 9.6 ± 4.3 to 7.9 ± 3.7 %; p \ 0.001) and systolic blood pressure was increased (from 129.5 ± 16.5 to 133.6 ± 17.9 mmHg; p = 0.030) by noise. The adverse vascular effects of noise were independent from sleep quality and self-reported noise sensitivity.

Conclusions Nighttime aircraft noise markedly impairs endothelial function in patients with or at risk for cardiovascular disease. These vascular effects appear to be independent from annoyance and attitude towards noise and may explain in part the cardiovascular side effects of nighttime aircraft noise.

Keywords Endothelial function · Coronary artery disease · Night time aircraft noise · Arterial hypertension · Annoyance · Sleeping quality

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F. Schmidt · K. Kolle · K. Kreuder · B. Schnorbus · P. Wild · T. Gori · T. Münzel (✉)
2 Medical Clinic, Cardiology, University Medical Center Mainz, Johannes Gutenberg University, Langenbeckstrasse 1, 55131 Mainz, Germany
e-mail: tmuenzel@uni-mainz.de

M. Hechtner · H. Binder
Institute for Medical Statistics and Biometrics, Mainz, Germany

Introduction

The role of noise as an environmental pollutant affecting health has been increasingly recognized. While acute noise interferes with communication, disturbs sleep and causes annoyance, chronic noise exposure has been demonstrated to be associated with negative health outcomes (for review [1]). Studies demonstrated a significant increase in blood pressure (HYENA) in adults [2] and children (RANCH) [3], an increase in prescriptions of cardiovascular medications [4] as well as an increase in heart disease and stroke (for review [5]).

A recent investigator-blinded field study (The FLIGHT-Study) from our group demonstrated that simulated nighttime aircraft noise leads to endothelial dysfunction, worsening of sleep quality and increased vascular stiffness but no significant changes in blood pressure in young healthy volunteers [6].

In an accompanying editorial Charakido and Deanfield emphasized that when considering the relevance of the findings for long-term clinical outcomes as well as for the causal pathways to cardiovascular disease and complications, that it would be highly important to examine the effects of noise on endothelial function of patients with already established cardiovascular disease [7].

Thus, the FLIGHT-RISK study was set out to test the effect of nocturnal aircraft noise on endothelial function, stress hormone levels, blood pressure and inflammatory markers, sleeping quality, annoyance levels and coagulation markers in patients with established coronary artery disease or at high risk for developing coronary artery disease based on the Framingham score.

Methods

The study was approved by the local ethics committee. All volunteers signed informed consent. Anti-aircraft noise activists and airport employees were excluded from the study as were persons with high nighttime traffic noise exposure at home as determined by noise maps available from municipal online resources ($L_{A,eq,22\text{-}6h}$ [40 dB for aircraft noise and $L_{A,eq,22\text{-}6h}$ [45 dB for road and rail traffic noise).

Study population

Men and women between 30 and 75 years of age with either established cardiovascular disease or a 10y cardiovascular risk of at least 10 % as calculated by the Framingham General CVD risk calculator were enrolled.

Patients had to be in a stable clinical condition without hospitalization or medication change in the preceding four weeks. Patients with NYHA III-IV heart failure, severe aortic stenosis, uncontrolled blood pressure ([160/100 mmHg) and heart rate [120 bpm were excluded.

Persons with sleeping disorders (Pittsburgh sleep quality index, PSQI [10), sleep disordered breathing, hearing loss [30 dB(A) and shift workers were also excluded. All blood pressure agents except for nitrates were allowed, calcium-antagonists had to be stopped 48 h prior to testing.

Patients were mainly recruited via flyers and posters at the clinic and cardiologists offices.

Study procedures

After initial screening and baseline data collection, subjects were exposed to simulated aircraft noise and no noise conditions in a randomized, cross-over and investigator-blinded fashion. The noise simulation took place in the familiar surroundings of the participants' own bedrooms, thereby minimizing effects of an artificial laboratory situation.

The aircraft noise consisted of 60 repetitive noise events, which had been recorded near Düsseldorf airport (window tilted open) have been used in our previous study [6]. Silent periods of two different durations were inserted between noise events [6]. During the study nights, polygraphic data were collected with devices (SOMNOwatch, SOMNOmedics, Randersacker, Germany) worn on the participants' body. Sound pressure levels were continuously recorded in the bedroom with class-2 sound level meters to detect external noises and assure compliance. The noise started after a 39.5 min silent period to facilitate sleep onset. The last noise event was played back after 415 min, each noise event lasting roughly 45 s. After each study night, the participants returned to the study center for flow-mediated dilation (FMD) measurements and blood sample collection.

Study participants were instructed to refrain from the consumption of coffee, tea, alcohol, sleep altering medications and nicotine on the day prior to the study night.

Participants attitude towards air traffic, aircraft noise and airport expansion was assessed with a dedicated questionnaire consisting of 19 items contributing to a total score between 0–64 with higher values denoting a more negative attitude.

In a subset of patients (n = 19), citrated whole blood was centrifuged and frozen according to standard protocol for later analysis of coagulation factors.

FMD of the brachial artery was measured at the same time in the early morning by a technician using standardized technique described previously [8].

Blood pressure was measured continuously during the study night with the polygraphy device using the pulse transit time method. Given values are averaged over the 8 h period.

Statistical analysis

The level of significance for the primary endpoint (FMD) was set to 5 %. The analyses of secondary outcomes were regarded as explorative without adjustment for multiple testing. Differences between baseline characteristics were analyzed using paired t tests or paired Wilcoxon tests as appropriate. Linear mixed models were used to analyze differences between noise and control nights. These models were adjusted for gender, age, night sequence, PSQI, overall noise sensitivity (NoiSeQ), sleep related noise sensitivity, attitude towards aircraft noise, and morningness-eveningness questionnaire (MEQ).

An interim analysis was scheduled at 60 patients; the stopping rule was based on the Haybittle-Peto boundary, i.e. it was predefined that the trial should be stopped early

Table 1 Baseline characteristics of the study population

Parameter	Total (n = 60)
Age (year)	61.8 ± 9.2
Male (n %)	44 (73.3)
BMI (kg/m^2)	27.1 ± 3.7
Framingham score	26.0 ± 14.3
Previous MI (n %)	35(58.3)
CAD n (%)	50 (83.3)
1-vessel disease	18 (30)
2	17 (28.3)
3	15 (25)
Baseline noise sensitivity, sleep quality index, chronotype	
PSQI	4.4 ± 2.2
NoiSeQ	1.5 ± 0.4
Mequation (14–84)	59.3 ± 9.87
Laboratory values	
LDL (mg/dl)	102.6 ± 30.9
HDL (mg/dl)	49.8 ± 13.6
Triglycerides (mg/dl)	184.73 ± 105.1
CRP(mg/l)	2.5 ± 4.2
Creatinin (md/dl)	0.96 ± 0.20
Hemodynamic values	
Office BP (mmHg)	137/74
Heart rate (bpm)	61.0 ± 7.9
Medication n (%)	
ASS or clopidogrel	47 (78.3)
ACE-I/AT-1 antagonists	39 (65.0)
Beta-blockers	41 (68.3)
Statins	37 (61.7)
Diuretics	21 (35)

Data are presented as mean ± SD

BMI body mass index, MI myocardial infarction, CAD coronary artery disease, CRP C-reactive protein, NoiSeQ dortmund noise sensitivity questionnaire with three greatest noise sensitivity, MEQ (Horne-Östberg) morningness-eveningness questionnaire, PSQI pittsburg sleep quality index, BP blood pressure

for a p \ 0.001 between visits [9, 10]. Statistical analysis was performed using IBM SPSS Statistics Version 21.

Results

Patient characteristics and study variables (Table 1)

60 patients (m:w = 44:16) with a mean age of 61.8 ± 9.2 years were analyzed. The average calculated Framingham risk score was 26 %, (range 3–59 %). 50 patients had an established diagnosis of coronary artery disease (CAD) based on coronary angiograms (Table 1), the remaining ten had a Framingham risk score of 23.4 ± 11.4 %. The study population did not have relevant sleep disorders as determined with the PSQI. According to the MEQ, 25 % of patients were classified as evening types and 30 % as morning types, the rest in the indeterminate range. Further information about the study population is given in Table 2.

Table 2 Effects of nighttime noise on the quality of sleep, hemodynamic and neurohormonal parameters and markers for inflammation

	Control	Noise 60	P (mixed model)
L_{eq3} dB(A)	39.2 ± 3.1	46.9 ± 2.0	<0.001
Sleep quality	5.8 ± 2.0	3.7 ± 2.2	<0.001
PTT mean (ms)	322.3 ± 20.7	323.3 ± 20.4	0.450
PTT min (ms)	273.1 ± 21.1	273.3 ± 21.3	0.963
HR mean	60.7 ± 7.9	61.2 ± 7.9	0.320
HR max	93.1 ± 19.1	93.1 ± 14.3	0.951
BPsys mean (mm Hg)	129.5 ± 16.5	133.6 ± 17.9	0.030
BPrise	5.3 ± 7.8	6.4 ± 8.2	0.120
HR_accel	8.9 ± 15.3	13.5 ± 25.5	0.059
Adrenaline (ng/l)	36.8 ± 18.0	38.1 ± 27.6	0.504
Cortisol (1g/l)	11.7 ± 3.4	11.2 ± 3.3	0.219
Neutrophils (%)	60.3 ± 7.8	60.8 ± 8.0	0.585
IL-6 (pg/ml)	4.1 ± 6.3	4.1 ± 7.6	0.697
CRP (mg/l)	2.5 ± 4.2	2.5 ± 4.2	0.959

Data are mean ± SD

Bold values indicate statistically significance at the 5 % level

L_{eq3} dB long-term continuous sound level, PTT pulse transit time, HR heart rate, BPsyst systolic blood pressure, IL-6 interleukin 6, CRP C-reactive protein

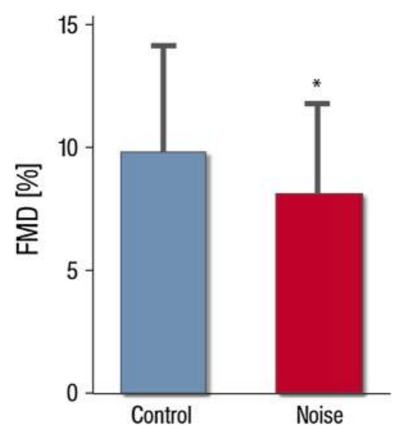

Fig. 1 Effects of nighttime noise on flow-mediated dilation (FMD) in patients with or being at risk for coronary artery disease. Data are mean ± SD of 60 patients, *p \ 0.001 adjusted for gender, age, night sequence, PSQI, overall noise sensitivity (NoiSeQ), sleep related noise sensitivity, attitude towards aircraft noise, and the results of the Morning Evening Questionnaire

There was no evidence for differences in outside temperatures (p = 0.411) or humidity (p = 0.815 between the study nights). Participants' blood pressure before the start of noise simulation were 137/74 mmHg (control night) and 136/75 mmHg (noise night; p = 0.556).

Averaged sound pressure levels $L_{eq(3)}$ were 46.9 ± 2.0 dB(A) in the noise nights and 39.2 ± 3.1 dB(A) in the control nights.

Primary outcome

Compared to study nights without noise simulation, FMD of the brachial artery was markedly reduced after nighttime aircraft noise exposure (FMD respectively 9.6 ± 4.3 and 7.9 ± 3.7 %; p \ 0.001; Fig. 1). Neither baseline vessel diameter (p = 0.442) nor velocity time integral (p = 0.348) changed significantly between control and noise nights.

The randomization sequence had no impact on the blunting in FMD induced by noise (FMD on the first study night 8.7 ± 4.1 vs. 8.8 ± 4.1 % on the second night; p = 0.980).

Noise exposure was associated with impairment in FMD in both subjects at higher risk (Framingham risk score C22 %) and those at lower risk.

For the lower risk group, FMD changed from 10.1 ± 4.3 to 8.0 ± 3.2 % (p = 0.001) and for the higher risk group FMD was reduced from 9.1 ± 4.4 to 7.8 ± 4.2 % (p = 0.023).

In the linear mixed models, the response of participants' endothelial function was not associated with overall noise sensitivity (NoiSeQ), sleep related noise sensitivity or attitude towards aircraft noise (Fig. 2).

Although subjective sleep quality was markedly impaired by the noise simulation, sleep quality (and sleep quality impairment) did not predict the blunting in endothelial responses on an individual level (Fig. 2).

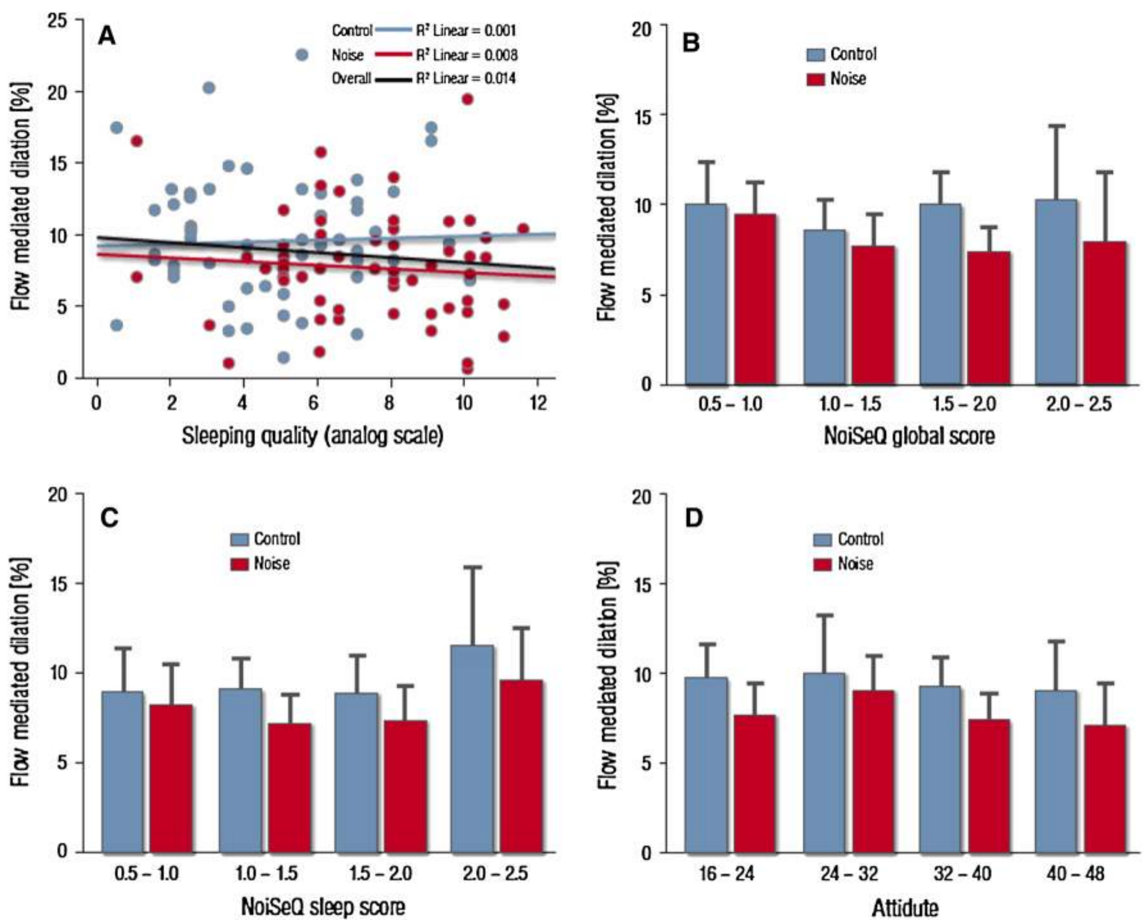

Fig. 2 Influence of patient factors on flow-mediated dilation (FMD). a Subjective sleep quality (in cm as measured in the source data, higher values correspond to worse sleep quality; cumulative transformed data on a 0–10 scale are reported in Table 2) does not exhibit a significant correlation with FMD values. b Global noise sensitivity and c sleep related noise sensitivity as assessed by the Dortmund Noise Sensitivity Questionnaire (NoiSeQ) do not modify the effect of noise exposure on endothelial function (FMD). d Likewise patient attitude towards air traffic and aircraft noise does not predict the effect of noise simulation on the primary endpoint. Data are mean ±2 standard errors. Categories including n \ 5 are not presented

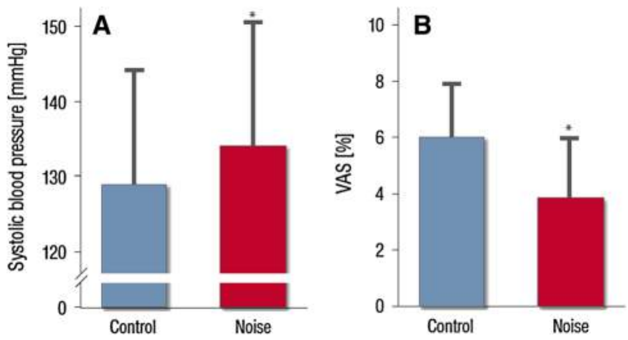

Fig. 3 Effects of nighttime aircraft noise on systolic blood pressure a and sleep quality as expressed by the visual analog scale (VAS) b. Data are mean ± SD in 60 patients. Significance levels are *p = 0.03 (A) and *p \ 0.001 b respectively adjusted for gender, age, night sequence, PSQI, overall noise sensitivity (NoiSeQ), sleep related noise sensitivity, attitude towards aircraft noise, and the results of the Morning Evening Questionnaire

Table 3 Effects of nighttime noise on the activity of coagulation parameters

	Unit	Control	Noise	p value
F V	% activity	127.90 ± 16.10	125.01 ± 13.36	0.418
F VII	% activity	119.77 ± 19.56	117.38 ± 19.82	0.364
F VIII	% activity	122.16 ± 25.52	118.67 ± 26.12	0.527
F IX	% activity	120.60 ± 17.03	116.96 ± 13.15	0.188
F X	% activity	103.40 ± 14.18	100.43 ± 12.58	0.076
F XI	% activity	97.31 ± 17.12	102.96 ± 29.43	0.454
F XII	% activity	96.39 ± 18.49	89.39 ± 16.19	0.004
vWF	% activity	141.45 ± 40.02	128.94 ± 45.07	0.053
D-dimer	ng/ml	482.68 ± 827.18	544.68 ± 863.85	0.251

Bold value indicate statistically significance at the 5 % level

vWF von willebrand factor

Secondary outcomes

Continuously measured systolic blood pressure increased from 129.5 ± 16.5 to 133.6 ± 17.9 mmHg (p = 0.030) (Fig. 3a).

Heart rate was not different between control and noise nights (60.7 ± 7.9 vs. 61.2 ± 7.9; p = 0.320; Table 2). With respect to the index of heart rate accelerations per time interval, there was a trend towards higher heart rate accelerations during noise exposure (8.9 ± 15.3 vs.13.5 ± 25.5; p = 0.059). The pNN50 index of heart rate variability did not change significantly.

The mean pulse transit time did not show any change after noise exposure (p = 0.450). Likewise, there was no evidence for a difference in neurohormonal parameters (adrenaline) and inflammatory markers (CRP, neutrophil count, IL-6) (Table 2).

Subjective sleep quality on a visual analog scale was markedly reduced by simulated aircraft noise from 5.8 ± 2.0 to 3.7 ± 2.2 (p \ 0.001) (Fig. 3b).

Coagulation measures from a subset of study participants (n = 19) demonstrated just with respect Factor XII activity a significant reduction after noise exposure (96.4 ± 18.6 % vs. 89.4 ± 16.2 %; p = 0.004). All other coagulation factors remained unchanged (Table 3).

Discussion

The present data demonstrate for the first time that nighttime aircraft noise markedly attenuates endothelium-dependent vasodilation in patients with established and/or at high risk for CAD. The magnitude of this effect was such that the study was terminated early as the predefined stopping criteria were fulfilled at 60 % of the initially planned recruitment. An increase in blood pressure and a marked decrease in sleep quality were also observed in response to aircraft noise. Collectively, this evidence may concur to explain the reported association between nighttime aircraft noise and arterial hypertension, myocardial infarction and stroke.

Aircraft noise and cardiovascular disease: evidence from epidemiological studies

A growing body of evidence documents that, beyond causing annoyance, aircraft noise should be considered a true cardiovascular risk factor (for review [5]).

In particular, recently published studies clearly substantiate the cardiovascular side effects of aircraft noise. In a multi-airport retrospective study in more than 6 Million people aged [65 years residing near airports, Correia et al. [11] reported a 3.5 % higher admission rate for cardiovascular disease such as ischemic coronary artery disease, cerebrovascular disease and heart failure for each 10 dB(A) increase in noise.

Another study in 3.6 million residents living close to Heathrow airport revealed that aircraft noise increased hospital admissions in a significant linear trend with increased risk with higher levels of both daytime and nighttime aircraft noise [12]. When areas experiencing the highest levels of daytime aircraft noise were compared with those experiencing the lowest levels ([63 dB vs. B51 dB), the relative risk of hospital admissions for stroke was 1.24 for coronary heart disease, 1.21 for cardiovascular disease and it remained 1.14 after adjustment for age, sex, ethnicity, deprivation, and a smoking proxy (lung cancer mortality). The authors concluded that high levels of aircraft noise were associated with increased risks of stroke, coronary heart disease and cardiovascular disease for both hospital admissions and mortality in areas near Heathrow airport in London.

Likewise, Floud et al. [13] reported a significant association between nighttime average aircraft noise and the endpoint 'heart disease and stroke' in the Hypertension and Environmental Noise near Airports (HYENA) study in 4,712 participants (276 cases) who lived near airports in six European countries (UK, Germany, Netherlands, Sweden, Greece, Italy). The result was not changed after adjustment for socio-demographic confounders for participants who had lived in the same place for C20 years. The authors concluded that exposure to aircraft noise over many years may increase risks of heart disease and stroke.

Effects of simulated noise on vascular function

More recently, we provided some insight into potential mechanisms leading to vascular dysfunction and subsequently cardiovascular disease in response to nighttime aircraft noise. In a field study, we showed that nighttime aircraft noise simulation caused endothelial dysfunction and tended to increase blood pressure [6]. This pathophysiological study demonstrated the existence of a dose–response relationship between noise and endothelial function impairment, and the mechanism of noise-induced endothelial dysfunction was demonstrated to be linked with increased oxidative stress within the vasculature, because endothelial dysfunction was partly corrected by the antioxidant vitamin C. We also observed a priming effect, i.e. the impact of noise was larger when subjects had already been exposed to noise, suggesting that the vasculature is rather sensitized than preconditioned. The changes were paralleled and/or caused by increases in circulating adrenaline levels and were strongly associated with impaired sleep quality.

The present studies provide several important new information concerning cardiovascular risk and nighttime aircraft noise.

1. For the first time we demonstrate that nighttime noise substantially reduces FMD in patients with -or at risk for- coronary artery disease despite optimal, guideline conform concomitant cardiovascular medication including ACE-Inhibitors, AT-1 receptor blocker, statins and antiplatelet agents.

Importantly, endothelial dysfunction of forearm vessels has been shown to correlate well with endothelial dysfunction (and with the presence of atherosclerosis) in coronary vessels [14] and it has been shown to be associated with future cardiovascular events in patients with coronary and peripheral artery disease, heart failure, arterial hypertension and stroke (for review [15]).

2. In addition, there was evidence that nighttime aircraft noise simulation increased systolic blood pressure during the night by approximately 4 mmHg in patients with CAD. The observed 4 mmHg increase in systolic blood pressure is considered clinically relevant if sustained in the long-term, since recent studies have demonstrated that every 1 mmHg increase in systolic blood pressure in elderly with isolated systolic hypertension is associated with a 1 % increase new onset heart failure [16].

In the present studies, the increase in blood pressure was not associated with a change in plasma adrenaline concentration, possibly due to the background therapy with beta receptor-blocker or ACE/inhibitors and AT1 receptor blockers, substances that are known to have substantial inhibitory actions on the activity of the adrenergic and the renin angiotensin system [17, 18].

3. These data also demonstrate for the first time that detrimental vascular consequences in response to nighttime aircraft noise occur independently of the conscious perception of noise and the subject's cognitive awareness (Fig. 2).

4. With regard to influence of noise on coagulation we detected a notable reduction in the level of Coagulation Factor XII (Hageman-Factor). While the role of factor XII in vivo remains controversial, associations of mildly reduced levels with increased coronary risk have been reported [19, 20].

The FMD measured in our patient group with cardiovascular disease was just slightly reduced compared to the FMD measured in healthy subjects [6], which may reflect optimal medical therapy.

It is important to note that our previous study clearly demonstrated that vessels are getting sensitized to noise-induced vascular damage rather than getting habituated since the blunting in FMD was in particular evident, when subjects were exposed first to 30 and then to 60 night noise events [6]. With the present studies we can already demonstrate a highly significant reduction in FMD in patients with CAD or being at high risk for CAD being exposed to 60 night noise events alone. Since patients living close to airports experience numerous noise events it seems likely that the degree of deterioration of endothelial function measured in the present study underestimates strongly the vascular damage induced by nighttime aircraft noise in the real world.

As in the previous study, noise exposure had a negative influence on subjective sleep quality of study participants. This finding may be regarded as clinically important, since self reported sleep quality is closely related to vascular calcification [21] and endothelial function [22]. Reduced sleep quality likely increases annoyance, which itself is associated with a higher probability of developing hypertension due to noise [23]. Recent evidence suggests a strong link between sleep duration and cardiovascular risk factors [24], which may explain increased extent of coronary artery disease lesions in persons with daytime sleepiness [25] due to insufficient sleep quality. The blunting in endothelial function and the increase in blood pressure were in our study not associated with impaired sleep quality on a patient level. These two adverse effects were also not prevented by guideline conform cardiovascular therapy.

In the current study, we could not detect changes in measures of immune function like cortisol levels, CRP, IL-6 or neutrophil count.

Limitations of the study

The protocol was designed as a field study. While this limits the confounding influence of environment and equipment, thus creating ecologically valid conditions, ambient conditions, background sound levels and external stimuli could not be controlled for. Further, as only short-term effects of an environmental exposure were investigated here, conclusions on the long-term sequelae of such an exposure cannot be drawn from the present results.

FMD was chosen as surrogate endpoint for several reasons: as a functional measure, it is ideally suited to quantify functional changes of the vasculature to short-term exposure to noxious stimuli and it has shown to be predictive for future cardiovascular events in patients with hypertension, coronary and peripheral artery disease and stroke. FMD of forearm conductance vessels has also been demonstrated in a multicenter trial to have a high reproducibility [7]. In addition, sleep disturbances have just recently been demonstrated to adversely affect FMD [26].

The question whether a threshold of sound pressure levels beyond which the negative effects of noise appear, and what the best indicator of noise is, is often raised. Admittedly, our study setup cannot provide a definite answer to that. Nevertheless, there is now considerable evidence that a mean sound level of about 47 dB(A) such as that achieved in the present study consistently leads to moderate impairment of endothelial function in healthy controls [6] and to a substantial impairment of FMD patients with established or increased risk for coronary artery disease respectively (present study). Future studies will address the question whether mean or peak sound pressure levels are the important determinants leading to vascular dysfunction.

Summary and clinical implications

The presented results demonstrate that nocturnal aircraft noise exposure causes severe endothelial dysfunction, raises systolic blood pressure in patients at high risk for cardiovascular events despite guideline oriented medical therapy. Taking into account the prognostic importance of endothelial function in patients with CAD, it is reasonable to conclude that nighttime aircraft noise-induced deterioration of vascular function may contribute at least in part to the observed increased incidence of arterial hypertension, MI and stroke in nighttime aircraft noise exposed people.

The present studies also stress the fact that more noise effect research has to be implemented and intensified. Important topics for the future may be to determine to what extent nighttime noise is able to modify the amount of circulating progenitor cells [27], whether noise-related stress is able to induce coronary vasomotor abnormalities [28] or to induce changes in biomarker such as nt-proBNP, which has been shown to have prognostic value for risk stratification in primary care [29].

Importantly, when decisions concerning the location and/or activity volume of airports are taken, the impact of aircraft noise on the health of the surrounding population should be considered. While many of the traditional risk factors (e.g. smoking, cholesterol levels, diabetes and hypertension) can be modified by the patientś behavior and attitudes, nighttime aircraft noise can be considered as the only risk factor, which can only be changed by politicians and not by the patient himself.

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FEATURED ARTICLE

Long-term community noise exposure in relation to dementia, cognition, and cognitive decline in older adults

Jennifer Weuve[1] | Jennifer D'Souza[2] | Todd Beck[3] | Denis A. Evans[3] | Joel D. Kaufman[4] | Kumar. B. Rajan[5] | Carlos F. Mendes de Leon[2] | Sara D. Adar[2]

[1] School of Public Health, Boston University, Boston, Massachusetts, USA

[2] School of Public Health, University of Michigan, Ann Arbor, Michigan, USA

[3] Institute for Healthy Aging, Rush University, Chicago, Illinois, USA

[4] School of Public Health, University of Washington, Seattle, Washington, USA

[5] Department of Public Health Sciences, UC Davis, Davis, California, USA

Correspondence
Sara D. Adar, Department of Epidemiology, SPH II M5539, 1415 Washington Heights, Ann Arbor, MI 48109-2029, USA.
E-mail: sadar@umich.edu

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Abstract

Introduction: Exposure to noise might influence risk of Alzheimer's disease (AD) dementia.

Methods: Participants of the Chicago Health and Aging Project (≥65 years) underwent triennial cognitive assessments. For the 5 years preceding each assessment, we estimated 5227 participants' residential level of noise from the community using a spatial prediction model, and estimated associations of noise level with prevalent mild cognitive impairment (MCI) and AD, cognitive performance, and rate of cognitive decline.

Results: Among these participants, an increment of 10 A-weighted decibels (dBA) in noise corresponded to 36% and 29% higher odds of prevalent MCI (odds ratio [OR] = 1.36; 95% confidence interval [CI], 1.15 to 1.62) and AD (OR = 1.29, 95% CI, 1.08 to 1.55). Noise level was associated with worse global cognitive performance, principally in perceptual speed (–0.09 standard deviation per 10 dBA, 95% CI: –0.16 to –0.03), but not consistently associated with cognitive decline.

Discussion: These results join emerging evidence suggesting that noise may influence late-life cognition and risk of dementia.

KEYWORDS
aging, Alzheimer's disease, cognition, cognitive decline, dementia, epidemiology, noise

1 | INTRODUCTION

Alzheimer's disease and related dementias constitute some of the most significant neurodegenerative conditions of our time. An estimated 5.8 million older Americans have Alzheimer's disease (AD) dementia,[1] and 13.8 million AD cases are expected by 2050,[1] a trend that will be echoed globally.[2] There is suggestive evidence that chemical and structural hazards in the environment, such as air pollution and lead, may influence cognitive decline and dementia risk.[3–5] Another environmental exposure that could plausibly affect dementia risk is exposure to community noise—from nearby roadways, railways, air transportation, industry, and construction.[6]

Noise has long been recognized as a hazard to human health. By 1968, when the U.S. Public Health Service co-sponsored a conference on the topic, the effects of noise on hearing loss and physiologic stress responses were already recognized.[7] Since then, dozens of investigations have documented the effects of community noise on children's cognition, their ability to learn, and the benefits of mitigating that noise.[8] The neurotoxicity of noise might extend to older adults, possibly precipitating cognitive decline and dementia through direct effects on AD pathology and inflammatory processes, yet this is a largely understudied area of research.

In animal experiments, noise has been linked to neuropathological changes indicative of AD and in brain regions affected by AD. For example, in rats, noise exposure promoted the production of amyloid beta in hippocampal tissue.[9] Noise-exposed rats also show signs of another neuropathologic hallmark in AD: increases in hyperphosphorylated tau and neurofibrillary tangles in the hippocampus and prefrontal cortex.[10]

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Experimental noise exposures in animals appear to induce a wide range of other effects relevant to AD etiology, including oxidative stress and inflammation, degenerative changes to the ultrastructure of synapses, reduced frequency of neuronal firing, and neuronal apoptosis.[9,11] Furthermore, noise-exposed animals exhibit declines in learning and memory ability.[12–14]

Apart from these neuropathologic effects, the vascular effects of noise also etiologically link it to dementia. These include increased heart rate,[15] peripheral vasoconstriction, peripheral vascular resistance,[16,17] as well as elevated risk of hypertension[18] and myocardial infarction mortality, even after adjusting for air pollution.[19] Noise exposure might also elevate cognitive risk by disrupting hearing and sleep.[20]

In spite of the biologically plausible links of exposure to AD risk, only a handful of epidemiologic studies have investigated community noise and AD-related outcomes[21–24] and none has been set in the United States. The absence of U.S. studies may be important given that, by one rough estimate, more than 100 million persons in 2013 experienced annual noise levels exceeding the U.S. Environmental Protection Agency (EPA) limit ($L_{EQ(24)}$) of 70 A-weighted decibels (dBA), placing them at risk for noise-induced hearing loss.[25] Millions more Americans were likely exposed to the lower noise levels associated with non-auditory health outcomes, such as those potentially relevant to ADRD risk. Notably, community noise is modifiable at both population and individual levels via governmental actions and technological innovations.

We used a novel fine-scale spatial model[26] of community noise developed for the Chicago area to predict long-term residential community noise levels among participants of the Chicago Health and Aging Project (CHAP), a population-based, longitudinal cohort study of cognitive aging in older adults. We then evaluated the relation of these noise levels with prevalent mild cognitive impairment (MCI) and AD, as well as cognitive performance and rate of cognitive decline.

RESEARCH IN CONTEXT

Systematic review: The authors reviewed the literature indexed on PubMed. Exposure to community noise adversely affects learning in children and is associated with cardiovascular disease. Several recent studies have evaluated community noise exposure in relation to dementia and related outcomes; none was in the United States. These relevant studies are appropriately cited.

Interpretation: In a large US metropolitan area, we observed that higher levels of noise were associated with a higher prevalence of MCI and AD and worse cognitive performance after adjustment for other environmental and personal risk factors. Our findings were fairly consistent with findings of previous studies in which participants were exposed to similar levels of community noise. Nonetheless, the small number of studies make it challenging to draw definitive conclusions.

Future directions: In light of the evidence amassed thus far, new research can address our understanding of the role of noise in dementia etiology by (a) using outcome assessments that minimize differential misclassification according to noise exposure, and (b) evaluating different dimensions of exposure, including time of day and indoor and outdoor sources.

2 | METHODS

2.1 | Study population

CHAP is a longitudinal study of residents, 65 years old and older, living in four adjacent neighborhoods on the south side of Chicago, IL, USA.[27,28] From 1993 to 1996, CHAP recruited an original cohort of 6157 participants (79% of all age-eligible persons, established by community census); 4644 newly age-eligible participants were recruited in successive cohorts, for a total study population of 10,802 participants. Until 2003, participants were drawn from three contiguous neighborhoods. Starting in 2003, CHAP also recruited participants from a fourth adjoining neighborhood. Altogether, the study area is ≈15 square miles with participants living throughout.

CHAP participants underwent triennial in-home assessments during which they completed questionnaires and underwent evaluation of their cognitive function; 89% of all survivors, on average, completed follow-up visits subsequent to their baseline evaluations. We limited our analyses to those participants with cognitive assessments that occurred after January 1, 1999 (N = 8245) when our environmental exposure estimates are most reliable.

CHAP was approved by the institutional review board of Rush University Medical Center, and all participants provided written informed consent. This use of CHAP data was also reviewed and approved by the institutional review board at the University of Michigan.

2.2 | Assessment of exposure to noise

We estimated each participant's long-term noise exposure using a universal kriging model developed for the Chicago area. Briefly, this model was derived from 5-minute grab samples of A-weighted noise (the important frequencies for human hearing), collected at 136 unique locations. These samples were collected during daytime, non–rush hour periods between 2006 and 2007.[26] Using geographic covariates such as land use and proximity to roadways, bus stops, and trains, as well as the observed spatial correlation structure for the area, we were able to predict noise levels at any location with an R^2 of 0.7 using 10-fold cross-validation. Using original held-out values as well as a new external dataset collected 10 years later, we found an approximate mean absolute error (MAE) of our model of 3 dBA.

With this model, we first predicted noise levels at each participant's residential address using geographic covariates. We then weighted our predicted noise levels according to their 5-year residential history prior to each interview, accounting for relocation in the 19% of those who moved (including moves to a nursing home) during the course of the study. Estimates of noise from this model tracked closely with noise annoyance from nearly 500 individuals living in the region. Furthermore, replicate sampling in the CHAP neighborhoods in 2016 demonstrated high stability in the spatial distribution of noise levels over time (Pearson correlation for samples at the same locations 10 years apart = 0.8).

2.3 | Assessment of cognitive function

During their home interviews, all participants underwent a brief cognitive assessment that generated four test scores for functions that typically decline with AD. The Symbol Digit Modalities Test[29] measures perceptual speed, a component of executive function; the East Boston Memory Test[30] generates measures of both immediate and delayed episodic memory (two separate scores); and the Mini-Mental State Examination[31] measures several cognitive functions, including orientation, memory, language, and visual construction. For each of the four test scores, we transformed the raw scores to *z*-scores based on the mean and standard deviation of each baseline score. We then constructed three cognitive measures, all scaled to the standard normal distribution to facilitate comparisons across tests. The first, a global cognition score, was created by first averaging the *z*-scores from all four tests into a composite *z*-score and then converting the resulting score to standard normal, using the baseline composite *z*-score's mean and standard deviation.[32–34] This conversion was necessary, because the average of several correlated *z*-scores does not have a standard deviation of 1. The second, the episodic memory score, was the average of the *z*-scores from the two components of the East Boston Memory Test, which we further transformed to standard normal as done for the global score. The third measure, the perceptual speed score, was the *z*-score from the Symbol Digit Modalities Test.

2.4 | Assessment of MCI and AD

As previously described,[27,28,34–36] samples of surviving participants who were AD free in the previous cycle were randomly selected for clinical evaluation of incident AD in cycles 2 to 6 within strata of age, race, sex, and change in cognitive function from the previous home interview. A team of clinicians led by a neurologist conducted these evaluations, which included a structured medical history, neurologic examination, and a battery of 21 cognitive tests, 11 of which encompassed five domains of function.[28] All clinical examiners were blinded to the cognitive scores used for stratification. Diagnosis of AD followed the criteria of the National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease and Related Disorders Association.[37] Also classified as AD cases were persons who met these AD criteria and may have had another condition impairing cognition. Nearly all dementia cases diagnosed in CHAP (93%) met clinical criteria for AD alone or AD mixed with another dementia.

Constraining our dementia assessments to those who were not only in this subsample but also had their assessments in 1999 onward (for compatibility with our environmental exposure estimates) limited the number of participants contributing data to our analyses of MCI and dementia. To circumvent this constraint, we used a previously developed multinomial model to classify each CHAP participant at each visit—whether in the subsample—a probability of having probable AD, MCI, or no cognitive impairment.[38] These scores were developed from the subsample of participants who underwent additional clinical evaluations to diagnose dementia and MCI. The likelihood scores provided a diagnostic accuracy of 0.92 (95% confidence interval [CI], 0.88 to 0.95) for AD and 0.89 (95% CI, 0.82 to 0.94) for MCI.

2.5 | Covariate data

At their in-home interviews, participants provided information on their date of birth, sex, race, education, household income, alcohol intake, smoking status, and physical activity. Interviewers also asked participants about their social connections and interactions; we used these data to form social engagement and network scores.[39] Apolipoprotein E (*APOE*) genotype was measured using the hME Sequenom MassARRAY platform.

We also generated area-level covariates for each participant including neighborhood socioeconomic status (SES), neighborhood disorder scores, and traffic-related air pollution. Neighborhood SES was calculated using a previously published method[40,41] that uses U.S. census block data (eg, median housing value, percentage with managerial occupation) to calculate area socioeconomic scores. Neighborhood disorder[42] was measured using participants' perceptions of safety and neighborhood neglect (eg, vandalism, poor sidewalks, broken curbs). Finally, we used ambient outdoor concentration of nitrogen oxides (NO_x) at the participant's residential location from a spatiotemporal model[43,44] developed for the Multi Ethnic Study of Atherosclerosis as a measure of exposure to traffic-related air pollution.

2.6 | Statistical analyses

To estimate the prevalence odds ratios (ORs) of MCI and AD across community noise levels, we used a multinomial logistic regression model fit with the multgee package in R for correlated nominal outcomes.[45] Our primary associations of interest were the multivariable-adjusted MCI and AD prevalence ORs per 10-dBA of noise. We also compared baseline cognitive performance and longitudinal rate of cognitive decline by levels of residential noise using linear mixed effects regression models, with random intercepts for each participant, using age as the time metric. We fitted separate models for each of the three cognitive scores. The results of interest from these models were the multivariable-adjusted mean difference in baseline cognitive score, as estimated by the regression coefficient for noise,

TABLE 1 Characteristics[a] of participants at baseline, by quartile of exposure to community noise

	All	Quartile of noise level: Lowest (51.1-54.4 dBA)	Second (54.4-55.4 dBA)	Third (55.4-57.0 dBA)	Highest (57.0-78 dBA)
	N = 5227	N = 1306	N = 1307	N = 1307	N = 1307
Follow-up time (years)	4.1 (3.6)	4.1 (3.7)	4.0 (3.6)	4.2 (3.6)	4.0 (3.7)
Number of cognitive assessments	2.3 (1.1)	2.3 (1.2)	2.3 (1.1)	2.3 (1.1)	2.3 (1.1)
Age (years)	73.7 (6.9)	73.1 (6.5)	73.4 (7.0)	74.1 (7.4)	74.1 (6.8)
Male	38%	38%	40%	38%	36%
Race/ethnicity					
Black	63%	70%	59%	54%	68%
Non-Hispanic White	36%	29%	40%	45%	31%
Hispanic White and other race/ethnicity	1.4%	0.6%	0.7%	1.4%	1.9%
Education (years)	12.8 (3.3)	12.7 (3.2)	12.8 (3.3)	13.1 (3.5)	12.6 (3.4)
Neighborhood SES score, SD units[b]	−0.4 (3.3)	−0.6 (2.9)	0.0 (3.4)	0.3 (3.4)	−1.2 (3.2)
Personal income					
Low (<$14,999/year)	21%	20%	21%	19%	24%
Medium ($15,000-$29,999/year)	36%	38%	35%	33%	36%
High (>$30,000/year)	40%	39%	41%	44%	37%
Missing	3%	3%	3%	3%	3%
Social engagement score[c]	2.4 (1.7)	2.4 (1.7)	2.4 (1.7)	2.4 (1.7)	2.3 (1.6)
Social network score[c]	7.1 (6.1)	6.9 (5.6)	7.3 (6.5)	7.3 (6.5)	6.9 (5.8)
Smoking status					
Never	46%	46%	44%	48%	47%
Current	12%	13%	14%	11%	12%
Former	42%	41%	42%	42%	41%
Alcohol consumption					
Low (0 g alcohol/day)	66%	70%	63%	61%	70%
Moderate (>0 g alcohol/day, <2 drinks/day)	6%	5%	6%	8%	5%
High (>0 g alcohol/day, ≥2 drinks/day)	28%	25%	31%	32%	26%
Physical activity (hours/week)	2.9 (4.6)	2.7 (4.3)	3.1 (5.0)	3.0 (4.7)	2.7 (4.3)
Body mass index (kg/m^2)	28.5 (6.1)	28.6 (6.0)	28.6 (6.4)	28.4 (6.2)	28.5 (5.8)
Environmental pollutant exposures					
Noise, dBA	56.2 (2.9)	53.5 (0.7)	54.9 (0.3)	56.1 (0.4)	60.4 (2.6)
NO_x, ppb	40.8 (7.5)	41.8 (6.7)	40.1 (7.1)	39.1 (7.5)	42.2 (8.3)
Outcomes					
Global cognition score	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	-0.1 (1.0)
Episodic memory score	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	-0.1 (1.0)
Perceptual speed score	0.0 (1.0)	0.0 (0.9)	0.1 (1.0)	0.1 (1.0)	-0.1 (1.0)
AD likely	11%	9%	10%	12%	12%
MCI likely	30%	30%	29%	29%	32%

Abbreviations: AD, Alzheimer's disease dementia; dBA, A-weighted decibels; MCI, mild cognitive impairment; NO_x, oxides of nitrogen; SD, standard deviation; SES, socioeconomic status.
[a] Values shown are means (standard deviation) or percentages.
[b] Higher score reflects higher socioeconomic status.
[c] Higher scores reflect more social engagement and larger social networks.

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TABLE 2 Adjusted[a] association of community noise level with the odds of prevalent MCI and AD

Outcome	Prevalence odds ratio (95% CI) of outcome per 10-dBA increment in noise level	
AD	1.29	(1.08, 1.55)
MCI	1.36	(1.15, 1.62)

Abbreviations: AD, Alzheimer's disease dementia; CI, confidence interval; dBA, A-weighted decibels; MCI, mild cognitive impairment; SES, socioeconomic status.
[a]Adjusted for calendar time, baseline age, age at exam, sex, race/ethnicity, income, education, neighborhood SES, smoking, alcohol use, and air pollution (NO_X).

and the mean difference in rate of change in cognitive score, estimated by the regression coefficient for the cross-product of age and noise.

We adjusted all models for calendar time, age at assessment, sex, race/ethnicity (Black, non-Hispanic White, other race/ethnicity), household income (<$14,999; $15,000 to 29,999; >$30,000; missing), years of educational attainment, neighborhood SES, NO_X, smoking (current, former, never), and alcohol intake (high, moderate, none). For cognitive performance, all variables were included as main effects and interactions with assessment age with the exception of smoking and alcohol use as these were only associated with baseline cognitive performance but not cognitive decline. We visually assessed the linearity of all associations with cognitive performance using penalized splines in R. Based on those results, we modeled age at the assessment as a piecewise linear spline with a knot at age 75 years (which included corresponding cross-products with noise). With this model, we estimated effects on change in cognitive score specific to assessment age <75 and ≥75 years. We used SAS 9.4 (Cary, North Carolina, USA) and R (gamm4 package[46]) for our modeling and report all associations per 10-dBA increment in noise level.

2.7 | Sensitive subpopulations

We examined whether associations with noise varied by the following individual- and area-level factors that could convey susceptibility to noise: baseline age (<75 vs ≥75 years), race/ethnicity (Black vs non-Hispanic White), *APOE* ε4 allele carriership (any vs none), and tertiles of both neighborhood SES and disorder.

2.8 | Sensitivity analyses

We assessed the sensitivity of our results to several sources of potential bias. To address potential bias from post-baseline selective attrition, we re-analyzed the data using inverse probability-of-continuation weights.[47] We also explored: whether our results were robust to further adjustment for social engagement and network, chronic diseases (hypertension, heart disease, and cancer), physical activity, and baseline age; averaging exposure over the year (rather than 5 years) prior to interview; and restriction to those who never moved.

3 | RESULTS

We predicted residential noise levels for 7909 participants, of whom 5227 had complete data on outcomes and covariates. This resulted in 11,928 cognitive assessments for our analysis. Estimated levels of noise in the study area varied considerably with participant-specific levels ranging from 51.1 to 78.2 dBA, with a mean of 56.2 dBA (standard deviation, 2.9 dBA). Compared with participants who experienced lower noise levels, those in the highest quartile of noise tended to have fewer years of education and lived in households with lower incomes (Table 1). Neighborhoods with lower SES also had higher noise levels. Of note, NO_X levels were not strongly correlated with noise in our region ($r = 0.08$).

3.1 | Probability of MCI and AD

In unadjusted comparisons, the crude likelihood of AD was slightly higher with progressively greater quartiles of noise (Table 1). After adjustment for potential sources of confounding, community noise was associated with higher odds of both prevalent MCI and AD (Table 2). Specifically, a 10-dBA increment in noise exposure corresponded to a 36% higher odds of MCI (95% CI: 1.15, 1.62) and a 29% higher odds of AD (95% CI: 1.08, 1.55).

3.2 | Cognitive performance and decline

Participants in the highest residential noise quartile had slightly lower cognitive scores at baseline (Table 1). After adjustment for potential confounders (Table 3), we found that a 10-dBA increment in noise was associated with a 0.04 standard deviation (SD) unit lower global cognition score (95% CI −0.11 to 0.03). Underlying this association was the pronounced inverse association of noise with perceptual speed score (−0.09 SD per 10 dBA, 95% CI: −0.16 to −0.03). These associations were similar in magnitude to the difference in scores between participants who were 2 (perceptual speed) and 0.5 (global cognition) years apart in age at baseline. By contrast, there was little association of noise exposure with episodic memory performance (0.005 per 10 dBA; 95% CI: −0.08, 0.10). Noise exposure was also not consistently associated with rate of cognitive decline.

3.3 | Sensitive subpopulations

Associations of noise with higher odds of AD and poorer cognition were most pronounced among participants living in neighborhoods with more neighborhood disorder and lower socioeconomic position (Figure 1). There were no substantial differences in association across levels of other factors.

TABLE 3 Adjusted[a] association of community noise level with baseline and rate of change in cognitive performance

	Mean difference (95% CI) per 10-dBA increment in noise level					
			Rate of change, SD units per year			
	Performance at baseline, SD units		Age < 75 years at examination		Age ≥ 75 years at examination	
Cognitive measure						
Global cognition	−0.04	(−0.11, 0.04)	0.01	(−0.01, 0.02)	0.00	(−0.04, 0.04)
Episodic memory	0.01	(−0.08, 0.10)	0.02	(0.002, 0.04)	0.00	(−0.04, 0.05)
Perceptual speed	−0.09	(−0.16, −0.03)	0.00	(−0.02, 0.01)	0.00	(−0.03, 0.04)

Abbreviations: dBA, A-weighted decibels; CI, confidence interval; NO_x, oxides of nitrogen; SD, standard deviation; SES, socioeconomic status.
[a]Adjusted for calendar time, baseline age, age at exam, sex, race, income, education, neighborhood SES, smoking, alcohol use, and air pollution (NO_x). Rate of change stratified by age at time of examination.

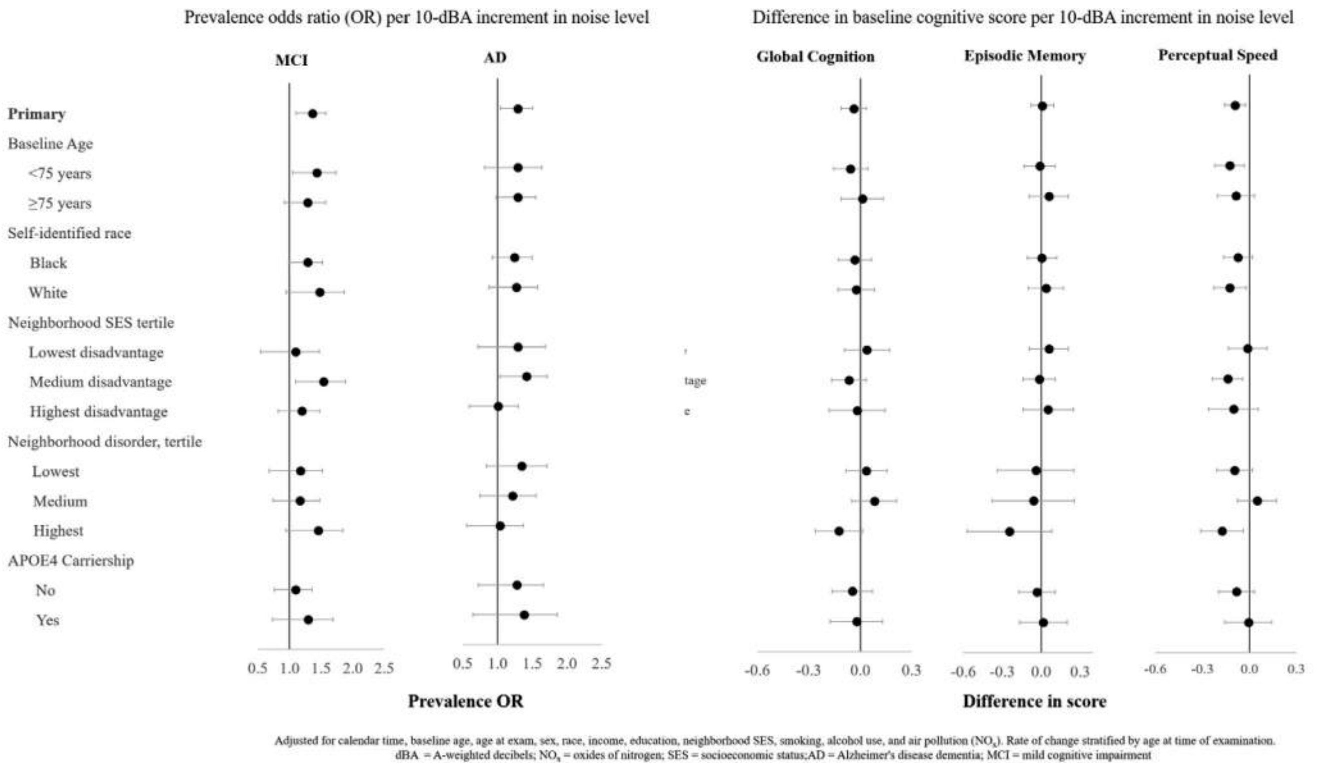

FIGURE 1 Association of community noise level with prevalent mild cognitive impairment and Alzheimer's disease and baseline cognitive performance, by personal and neighborhood factors

3.4 | Sensitivity analyses

All associations were robust to further adjustment for social networks, social engagement, and physical activity. Associations were similarly robust to different averaging times for noise levels and restriction to those who did not move (Figure S1 in supporting information). With adjustment for post-baseline attrition bias with inverse probability-of-continuation weights, most associations with cognitive change over time shifted slightly downward (becoming less positive, more negative, or shifting from positive to negative), although they remained small in magnitude and imprecise. Associations with prevalent MCI and AD were not changed with adjustment for attrition.

4 | DISCUSSION

In this first U.S.-based study of its kind, higher long-term exposure to community noise was associated with higher odds of MCI and AD as well as worse cognitive performance—specifically, perceptual speed—in older adults. These associations were observed across a range of noise levels that are typical in the United States, ranging from a quiet suburb to noisier urban settings near large automotive expressways. These associations were also independent of several measures of socioeconomic status and exposure to traffic-related air pollution, which was only weakly associated with noise exposure.

Although it has been well documented that children exposed to community noise are at heightened risk for developmental delays and deficits in learning and cognitive performance,[20] data pertaining to noise and cognitive risk in older adults is sparse. In this study, we found a strong association between noise and perceptual speed, whereby the decrement in performance corresponding to a 10-dBA higher noise level was similar to the decrement in performance corresponding to being 2 years older at baseline. These findings add to those from the Heinz Nixdorf Recall Study, a cohort of German adults who were 45 to 75 years at baseline. In that investigation, researchers compared cognitive outcomes per 10-dBA increment in noise above thresholds of 60 dBA (for weighted 24-hour mean noise level [L_{DEN}]) and 55 dBA (for nighttime noise). Their results suggested that participants with higher baseline exposure to community noise during the day and at night tended to have worse cognitive performance 5 years later on several tests of cognition.[21] Unlike in our study, however, their estimates were somewhat attenuated with adjustment for long-term exposure to fine particulate matter, which itself was adversely associated with cognitive performance.

In another investigation from the Heinz Nixdorf cohort, higher suprathreshold noise exposure was also associated with higher risk of MCI[22] with a magnitude almost identical to that which we found in CHAP, although exposures in the Heinz Nixdorf cohort were truncated at 60 dB. To our knowledge, only two other studies have reported on the relation of noise to dementia risk. Among London-area adults (50 to 79 years) with clinical data in the Clinical Practice Research Datalink, higher exposure to nighttime noise was associated with elevated dementia risk over the subsequent 9 years.[23] The association was small in magnitude and appeared to be limited to those in the highest quintile of exposure (hazard ratio = 1.09, 95% CI: 0.95 to 1.25, comparing >53.8 dB vs 49.4 dB or lower). In another study set in Umeå, Sweden, community exposure to noise ≥55 dB (versus <55 dB) was not associated with dementia risk, with or without adjustment for NO_X exposure.[24]

One challenge faced by the London and Sweden studies was their reliance on community medical care information on dementia status. Dementia classification based solely on medical records or health insurance claims, in contrast to regular uniform assessments of all persons, is highly prone to misclassification, even in settings with universal health insurance.[48,49] Furthermore, variation in the interval from symptom onset to diagnosis can also introduce differential measurement error. For example, one study found that the time to diagnosis was shorter among those with more formal education.[48] Although little is known about whether dementia misclassification varies by noise exposure, small variations in specificity across exposure level can lead to substantial bias in effect estimates.[50] Another possible issue is that the adverse effects of community noise on cognition and risks of MCI and dementia may be most observable at moderate to high levels. A noise-dementia association in the London study was notably absent except among those with exposures in the highest nighttime noise quintile (53.8 to 75.1 dB [I. Carey, personal communication, September 2, 2019]). In the Swedish study, where no association was observed, <10% of participants in the Swedish study had exposures ≥55 dB and <2% (29) had exposures ≥60 dB, whereas our study and the Heinz Nixdorf Recall cohort both had maximum exposures of about 80 dBA and observed similar associations with noise.

Our study involved repeated uniform measures of cognition as opposed to administrative records. We also had detailed information on potential confounders including individual and neighborhood socioeconomic factors, as well as traffic-related air pollution. In addition, our exposure assessment was unique for research set in the United States, where quality assessments of community noise levels have been rare. Nonetheless, this study is not without limitations. First, we based our noise estimates on daytime measurements. Though nighttime noise may be important because it disrupts sleep, our model predictions track well with overall self-reported noise annoyance in this region.[51] In addition, L_{Den} and L_{Night} appeared to be highly correlated in other areas such as in the Heinz Nixdorf Recall Study.[52] A second potential limitation of this work is that our classification of MCI and AD relied on likelihood scores rather than comprehensive clinical evaluation of every participant. However, these scores were validated against uniform clinical evaluations of a subsample of participants, and using them nearly tripled the available sample size. Our study also evaluated prevalent rather than incident MCI and AD. Considering that prevalence increases with higher incidence and longer survival, our prevalence odds ratios should be a qualitative reflection of the incidence ratios so long as noise does not shorten survival. If noise exposure did shorten survival among those with MCI or AD then our prevalence odds ratios would underestimate the influence of noise on incidence. Finally, in light of the adverse associations we observed between noise exposure and cognitive performance as well as prevalent MCI and AD, it was somewhat unexpected to observe little association with cognitive decline, an outcome that more directly reflects the disease process of neurodegeneration. The duration of follow-up may have been insufficient to capture an effect on cognitive decline, the effects of noise on cognition may have persisted from an earlier period, or the effects may be acute but not progressive.

The estimated associations of noise with the outcomes in our study did not vary substantially by exposure to air pollution, specifically NO_X. By contrast, in the Heinz Nixdorf Recall cohort, weighted 24-hour mean noise level (L_{DEN}) was inversely associated with global cognitive performance among participants with above-median but not below-median exposure to air pollution, especially fine and coarse fraction particulate matter.[53] Effect modification was not reported in other studies. "Mechanistic interactions" between noise and air pollution exposure are of etiologic and policy interest. Nonetheless, apart from the limited statistical power of these interactions, other challenges make it difficult to compare interaction estimates across studies. Heterogeneity across study populations in terms of exposure ranges, exposures assessed, and co-exposures could yield different interaction estimates, even if all estimates are unbiased.[54]

In conclusion, higher long-term exposure to community noise was associated with higher prevalence of MCI and AD and worse cognitive performance, especially perceptual speed. This association was detected in a diverse, urban, U.S.-based population of older adults with noise exposures that are likely to be consistent with exposure levels in other U.S. metropolitan areas.[25] Therefore, if noise exposure does contribute to dementia risk—a question that warrants continued investigation, particularly in U.S. settings—its abatement may be a means for reducing the population burden of dementia.

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CONFLICTS OF INTEREST

The authors have declared no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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NEWS RELEASE 21-OCT-2020

Community noise may affect dementia risk

Peer-Reviewed Publication

WILEY

Results from a new study published in *Alzheimer's & Dementia* support emerging evidence suggesting that noise may influence individuals' risk of developing dementia later in life.

Researchers studied 5,227 participants of the Chicago Health and Aging Project who were aged 65 years or older, of whom 30% had mild cognitive impairment and 11% had Alzheimer's disease. They found that persons living with 10 decibels more noise near their residences during the daytime had a 36% higher odds of having mild cognitive impairment and a 30% higher odds of having Alzheimer's disease.

"These findings suggest that within typical urban communities in the United States, higher levels of noise may impact the brains of older adults and make it harder for them to function without assistance. This is an important finding since millions of Americans are currently impacted by high levels of noise in their communities," said senior author Sara D. Adar, ScD, of the University of Michigan School of Public Health, Ann Arbor. Professor Adar added that "although noise has not received a great deal of attention in the United States to date, there is a public health opportunity here as there are interventions that can reduce exposures both at the individual and population level."

The study was supported by grants from the Alzheimer's Association and the National Institute on Aging.

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Burden of disease from environmental noise

Quantification of healthy life years lost in Europe

Burden of disease from environmental noise

Quantification of healthy life years lost in Europe

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The WHO European Centre for Environment and Health, Bonn Office, WHO Regional Office for Europe coordinated the development of this publication.

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ABSTRACT

The health impacts of environmental noise are a growing concern among both the general publk and policy-makers in Europe. This publication was prepared by experts in working groups convened by the WHO Regional Office for Europe to provide technical supporc to policy-makers and their advisers in the quantitative risk assessment of environmental noise, using evidence and data available in Europe. The chapeers contain the summary of synthesized reviews of evidence on the relationship between environmental noise and specific health effects, including cardiovascular disease, cognitive impairment, sleep disturbance and tinnitus. A chapter 011 annoyance is also included. For each outcome, ·the environmental burden of disease methodology, based on exposure-response relationship, exposure distribution, background prevalence of disease and disability weights of the outcome, is applied to calculate the burden of disease in terms of disability-adjusted life-years {DALYs). With conservative assumptions applied to the calculation. methods, it is estimated that DALYs lost from environmental noise are 61 000 years for ischaemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22 000 years for tinnitus and 587 000 years for annoyance ill the European Union Member States and other western European countries. These results indicate that at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe. Sleep disturbance and annoyance, mostly related to road traffic noise, comprise the main burden of environmental noise. Owing to a lack of exposure data in south-east Europe and the newly independent states, it was not possible to estimate the disease burden in the whole of the WHO European Region. The procedure of estirnating burdens related to environmental noise exposure presented here can be used by international, national and local authorities as long as the assumprions, limitations and uncertainties reported in this publication are carefully taken into account.

LIST OF ACRONYMS AND ABBREVIATIONS

ADL	Activity of daily life
AF	Attributable fraction
AR	Attributable risk
CI	Confidence interval
CLAMES	Classification and Measurement System of Functional Health
DALY	Disability-adjusted life year
DEN	Day-evening-night equivalent level
DW	Disability weight
EBD	Environmental burden of disease
EEA	European Environment Agency
EEG	Electroencephalogram
EMG	Electromyogram
END	Environmental noise directive (2002/49/EC)
EOG	Electrooculogram
ETC LUSI	European Topic Centre on Land Use and Spatial Information
EU	European Union
EUR-A	WHO epidemiological subregion in Europe: Andorra, Austria, Belgium, Croatia, Cyprus, the Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, the Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland and the United Kingdom
GBD	Global burden of disease
HA	Highly annoyed people
HSD	Highly sleep disturbed people
ICD-9	International Statistical Classification of Diseases and Related Health Problems, ninth revision
ICD-10	International Statistical Classification of Diseases and Related Health Problems, tenth revision
LAeq,t or Leq,t	A-weighted equivalent sound pressure level over t hours
Lden	Day-evening-night equivalent sound level
Ldn	Day-night equivalent sound level
Lnight	Night equivalent sound level
NIHL	Noise-induced hearing loss
NOISE	Noise Observation and Information Service for Europe
NYHA	New York Heart Association
OR	Odds ratio
OSAS	Obstructive sleep apnea syndrome
PAR	Population attributable risk
PSG	Polysomnography
REM	Rapid eye movement
SWS	Slow wave sleep
WHO	World Health Organization
YLD	Years lost due to disability
YLL	Years of life lost

FOREWORD

Public health experts agree that environmental risks constitute 25% of the burden of disease. Widespread exposure co environmental noise from road, rail, airports and industrial sites contributes to this burden. One in three individuals is annoyed during the daytime and one in five has disturbed sJeep at night because of traffic noise. Epidemiological evidence indicates that those chronically exposed to high levels of environmental noise have an increased risk of cardiovascular diseases such as myocardial infarction. Thus, noise pollution is considered not only an environmental nuisance but also a threat co public health.

In 1999, WHO sum.marjzed the scientific evidence on the harmful impacts of noise on health and made recommendations on guideline values to protect public health in its *Guidelines for community noise.* The European Union (EU) enacted a directive on the management of environmental noise in 2002 and, accordingly, most EU Member Sraces have produced strategic noise maps and action plans on environmental noise. The WHO European Centre for Environment and Health, Bonn Office, with the financial support of the European Commission, developed *Night noise guidelines for Europe* and provided expertise and scientific advice to policy-makers for future legislation in the area of night noise control and surveillance. Furthermore, a series of projects addressing the health burden of noise was implemented by the WHO Regional Office for Europe in 2005-2009.

At the *Fifth* Ministerial Conference on Environment and Health, in ParJl<I, Italy in March 2010, the Member States urged WHO to develop suitable guidelines on environmental noise policy. This publication, developed by WHO with the support of the Joint Research Centre of the European Com.mission, responds to that request by -assisting policy-makers in quantifying the health impacts of environmental noise. The evidence-base on burden of disease presented here *will* inform the new European health policy, Health 2020, which is being prepared by the WHO Regional Office for Europe for endorsement by the Member States in 2012.

The review of the scientific evidence supporting exposure-response relationships and case studies in calculating burden of disease was performed by a working group composed of outstanding sciencisrs. The contents of this publication have been peer revi.ewed. The Regional Office is thankful ro those who contributed to ics development and presentation of this document and believe that this work will facilitate the implementation of the Parma Declaration and contribute to improving the health of the citizens of Europe.

Dr Gufoael R. M. Rodier
Director, Division of Communicable Diseases, Health Security and Environment
WHO Regional Office for Europe

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Editors

Lin Fritschi

Western Australian Institute for Medical Research, University of Western Australia, Australia

A. Lex Brown

Urban Research Program, Griffith University, Australia

Rokho Kim

WHO Regional Office for Europe, European Centre for Environment and Health (Bonn), Germany

Dietrich Schwela

Stockholm Environment Institute, University of York, United Kingdom

Stelios Kephalopoulos

European Commission Joint Research Centre, Institute for Health & Consumer Protection, Italy

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Peer reviewers

Bernard F Berry (United Kingdom)

Tim Driscoll (Australia)

Gary Evans (USA)

William Hal Martin (USA)

Danny Houthuijs (The Netherlands)

Anne Knol (The Netherlands)

David Michaud (Canada)

Evy Ohrstrom (Sweden)

Annette Priiss-Ostiln (WHO)

Michel Vallet (France)

Martin van den Berg (The Netherlands)

Irene van Kamp (The Netherlands)

G R Watts (United Kingdom)

Meeting participants and authors:

Wolfgang Babisch
Department of Environmental Hygiene
Division of Environment and Health
Federal Environment Agency (UBA)
Germany

Anna Backman
Implementation and Enforcement Department
Swedish Environment Protection Agency
Sweden

Mathias Basner
Unit for Experimental Psychiatry
Division of Sleep and Chronobiology
University of Pennsylvania School of Medicine
USA

Birgitta Berglund
Institute of Environmental Medicine
Karolinska Institute
Sweden

Bernard Berry
Berry Environmental Ltd
United Kingdom

Gosta Bluhm
Institute of Environmental Medicine
Karolinska Institute
Sweden

Hans Boegli
Department of Environment Transport, Energy & Communications
Federal Office for the Environment (FOEN)
Switzerland

Elena Boldo
ISCID-WHO Collaborating Centre for the Epidemiology of Environment Related Diseases
Spain

Xavier Bonnefoy (deceased)
WHO European Centre for Environment and Health (Bonn)
WHO Regional Office for Europe
Germany
(Project leader until 2006}

Dick Botteldooren
Ghent University
Belgium

A. Lex Brown
Urban Research Program
Griffith University
Australia

Thomas Classen
University of Bielefeld
School of Public Health
Germany

Charlotte Clark
Centre for Psychiatry
Barts and London School of Medicine
United Kingdom

Claudia Cote
Institut de readaptation en deficience physique de Quebec
Canada

Pierre Deshaies
Community Medicine
Centre hospitalier affilie universitaire
Hotel-Dieu de Levis
Institut national de sante publique du Quebec and Direction de sante publique Chaudiere-Appalaches
Canada

Franz-Josef Feldmann
Bundesministerium for Umwelt, Naturschutz und Reaktorsicherheit
Germany

Lawrence Finegold
Finegold & So Consultants
USA

Michiko So Finegold
Finegold & So Consultants
USA

Willem Franken
Head of Environmental Protection
Rulemaking Directorate
European Aviation Safety Agency
Germany

Lin Fritschi
Western Australian Institute for
Medical Research
University of Western Australia
Australia

Gabor Gereb
Sol Data SA
Hungary

Balazs Gergely
DG Environment
Unit C3 - Clean air and Transport
European Commission
Belgium

Serge-Andre Girard
Institut national de sante publique du
Quebec
Canada

Truls Gjestland
SINTEF ICT
Norway

Zilma Gonzales
Institut national de sante publique
du Quebec
Canada

Eberhard Greiser
Epi.Consult GmbH
Germany

Barbara Griefahn
Institute for Occupational Physiology
Technical University Dortmund
Germany

Colin Grimwood
Bureau Veritas
Acoustics & Vibration Group
United Kingdom

Rainer Guski
Fakultat fiir Psychologie
AG Umweltpsychologie
Ruhr-Universitat Bochum
Germany

Edward Hawker
Natural Environment Economics
Team
Department for Environment, Food
and Rural Affairs (DEFRA)
United Kingdom

Sylvie Hebert
University of Montreal
Canada

Danny Houthujis
National Institute for Public Health
and the Environment **(RIVM)**
Netherlands

Ken Hume
School of Biology, Chemistry and
Health Science
Faculty of Science and Engineering
Manchester Metropolitan University
United Kingdom

Staffan Hygge
Environmental Psychology
University of Gavle
Sweden

Sabine A. Janssen
TNO Built Environment and
Geosciences Delft
Netherlands

Lars Jarup (deceased)
Department of
Epidemiology and Public Health
Imperial College of Science,
Technology and Medicine
United Kingdom

Snezana Jovanovic
Regierungsprasidium Stuttgart
Gesundheitschutz fiir Arbeit und
Umwelt
Germany

Jenni Keel
Section Air Traffic, Military, Impacts
Federal Office for the Environment
Switzerland

Stelios Kephalopoulos
European Commission
Joint Research Centre
Institute for Health & Consumer
Protection
Italy

Rokho Kim
WHO European Centre for
Environment and Health (Bonn)
WHO Regional Office for Europe
Germany
(Project leader from 2007)

Ronny Klaeboe
Institute of Transport Economics
Norway

Anne Knol
National Institute for Public Health
and the Environment **(RIVM)**
Netherlands

Young Ah Ku
World Health Organization
Switzerland

Tony Leroux
University of Montreal
Canada

Christian Maschke
Forschungs- und Beratungsbiiro
Maschke
Forschungsverbund Larm und
Gesundheit
Germany

Bernadette McKell
Hamilton & McGregor
Acoustics Division
United Kingdom

Odile Mekel
NRW Institute of Health and Work
Germany

David Michaud
Department of Health
Canadian Federal Government
Canada

Henk M.E. Miedema
TNO Built Environment and
Geosciences
Netherlands

Jarlath Molloy
Department of Civil and
Environmental. Engineering
Centre for Transport Studies
Imperial College London
United Kingdom

Nicole Normandin
University of Montreal
Canada

Ruedi Muller-Wenk
Universitat St. Gallen
Switzerland

Colin Nugent
European Environment Agency
Denmark

Sirkka-Liisa Paikkala
Environmental Protection
Department
Ministry of the Environment
Finland

Louise Pare
Centre de readaptation en deficience physique Le Bouclier
Canada

Stefan Plontke
University of Tu.bingen
Germany

Annette Pruss-Ostun
World Health Organization
Switzerland

Dragornira Raeva
Air, Noise and Nanotechnology
European Environmental Bureau
Belgium

Nina Renshaw
European Federation for Transport and Environment
Belgium

Gordana Ristovska
Republic Institute for Health Protection
The former Yugoslav Republic of Macedonia

Jurgita Saulyte
Noise Prevention Division
State Environmental Health Centre
Lithuania

Dietrich Schwela
Stockholm Environment Institute
University of York
United Kingdom

Stephen Stansfeld
Centre for Psychiatry
Wolfson Institute of Preventive Medicine
Barts and London School of Medicine and Dentistry
United Kingdom

Richard Tyler
University of Iowa
USA

Michel Vallet
Institut AEDIFICE
France

Irene Van Kamp
National Institute for Public Health and the Environment **(RIVM)**
Netherlands

Evi Vogel
Bayeriscbes Staatministerium fur Umwelr, Gesundheit und Verbraucherschutz
Germany

Ilse M Zalaman
University of Tu.bingen
Germany

Hans-Peter Zenner
University of Tu.bingen
Germany

EXECUTIVE SUMMARY

Introduction

Urbanization, economic growth and motorized transport are some of the driving forces for environmental noise exposure and health effects. Environmental noise is defined as noise emitted from all sources except industrial workplaces. The EU Directive on the management of environmental noise (END) adds industrial sites as sources of environmental noise.

To estimate the environmental burden of disease (EBD) due to environmental noise, a quantitative risk assessment approach has to be used. Risk assessment refers to the identification of hazards, the assessment of population exposure and the determination of appropriate exposUie-response relationships. The EBD is expressed as disability-adjusted life years (DALYs). DALYs are the sum of the potential years of life lost due to premature death and the equivalent years of "healthy" life lost by virtue of being in states of poor health or disability.

WHO estimated the global burden of disease (GBD) in the second half of the 1990s. The environmental burden of disease due to environmental factors such as lead, outdoor and indoor air pollution and water and sanitation was first published in 2002. The WHO European Centre for Environment and Health, Bonn Office, convened meetings of a working group to estimate the EBD due to exposure to environmental noise. The conclusions and recommendations of these meetings were synthesized to develop this guidance publication on risk assessment of environmental noise using evidence and data available in Europe.

The target audience for this publication is primarily policy-makers, their technical advisers and staff from supporting agencies, and other stakeholders wbo need to estimate the effects of environmental noise. It brings together evidence-based information on health effects of environmental noise and provides exemplary guidance on how to quantify these effects. In summary, the aims of the publication are to provide:

- guidance on the procedure for the health risk assessment of environmental noise;
- reviews of evidence on the relationship between environmental noise and health effects;
- exemplary estimates of the burden of the health impacts of environmental noise; and
- a discussion of the uncertainties and limitations of the EBD procedure.

The health end-points of environmental noise considered by the working group for the EBD estimation included cardiovascular disease, cognitive impairment, sleep disturbance, tinnitus and annoyance. Although annoyance was not addressed as a health outcome of the GBD project, it was selected for the EBD estimation in consideration of WHO's broad definition of health.

£xposure assessment

Assessment of exposure to noise requires consideration of many factors, including:

- the measured or calculated/predicted exposure, described in terms of an appropriate noise metric; and
- the distribution of the exposure of the population to noise.

Population noise exposure in this publication is based on the noise mapping mandated by the END, using the annual average metrics of L_{den} (day-evening-night equivalent level) and L_{night} (night equivalent level) proposed in the Directive.

$$L_{den} - 10 \cdot lg \frac{1}{24} 2 \cdot 10^{10} + 4 \cdot 10^{10} + 8 \cdot 10^{\frac{L_{;p,}+10}{10}})$$

with $L_{day} = L_{eq,12h}$, $L_{evening} \cdot L_{eq,4h}$

and $L_{.\,1} \cdot L_{eq,ah}$

with $L_{Aeq,th}$ the A-weighted equivalent sound pressure level over t hours outside at the most exposed facade.

Methods of environments/ burden of disease assessment

The burden of disease is expressed in DALYs in the general population through the equation

$$DALY = YLL + YLD$$

In this equation, YLL is the number of "years of life lost" calculated by

$$YLL - \sum_i (Nf \cdot Lf + Nf \cdot C_i)$$

where N;"(Nf) is the number of deaths of males (females) in age group i multiplied by the standard life expectancy L';'(Vi) of males (females) at the age at which death occurs. YLD is the number of "years lived with disabiLty" estim<1ted by the equation

$$YLD = I \cdot DW \cdot D$$

where I is the number of incident cases multiplied by a disability weight (DW) and an average duration D of disability in years. DW is associated with each health condition and lies on a scale between O (indicating the health condition is equivalent to full health) and 1 (indicating the health condition is equivalent to death).

The EBD of each end-point was estimated using the following information and data:

- the distribution of environmental noise exposure within the population;
- the exposure-response relationships for the particular health end-point;
- the population-attributable fraction due to environmental noise exposure;
- a population-based estimate of the incidence or prevalence of the health end-point from surveys or routinely reported statistics; and
- the value of DW for each health end-point.

Cardiovascular diseases

The evidence from epidemiological studies on the association between exposure to road traffic and aircraft noise and hypertension and ischaemic heart disease has increased during recent years. Road traffic noise has been shown to increase the risk of ischaernic heart disease, including myocardial infarction. Both road traffic noise and aircraft noise increase the risk of high blood pressure. Very few studies exist regarding the cardiovascular effects of exposure to rail traffic noise.

Exposure-response relationships

Numerical meta-analyses were carried out assessing exposure-response relationships between community noise and cardiovascular risk. A polynomial function was fitted through the data points from the analytic studies within the noise range from 55 to 80 dB(A}:

$$OR - 1.63 - 6.13 \cdot 10^{-4} \cdot L_{day,16h}^{2} + 7.36 \cdot 10^{-6} \cdot L_{day,16h}^{3}$$

Estimated burden In western Europe

Based on the exposure data from the noise maps of EU Member States, it is estimated that the burden of disease from environmental noise is approximately 61 000 years for ischaernic heart disease in high-income European countries.

Cognitive Impairment In children

The case definition of noise-related cognitive impairment is: The Reduction in cognitive ability in school-age children that occurs while the noise exposure persists and will persist for some time after the cessation of the noise exposure. The extent to which noise impairs cognition, particularly in children, has been studied with both experimental and epidemiological studies.

Hypothetical exposure-response relationship

Based on available evidence, a hypothetical exposure-response relationship between noise level (Ldn) and risk of cognitive impairment was formulated: all of the noise-exposed children were cognitively affected at a level as high as 95 dB(A) Ldn, and no children were affected at a relatively low level, such as 50 dB(A) Ldn. A linear relationship in the range of these two limits was assumed as a basis for a conservative approximation of YLD.

Estimated burden In western Europe

If one extrapolates the exposure distribution and population structure of Sweden to western European countries, the estimated DALYs for the EUR-A countries are 45 000 years for children aged 7-19 years.

Sleep disturbance

Sleep disturbance can be measured electro-physiologically or by self-reporting in epidemiological studies using survey questionnaires. In epidemiological studies, "self-reported sleep disturbance" is the most easily measurable outcome indicator, because electro-physiological measurements are costly and difficult to carry out on large samples and may themselves influence sleep.

Exposure-response relationship

The percentage of "highly sleep disturbed" persons (HSD) as a function L_{night} was calculated with the equation:

$$HSD \;] - 20.8 - 1.05 \cdot L_{Dight} + 0.01486 \cdot L_{ibt}$$

£stlmated burden In western £urope

Conservative estimates applied to the calculation using exposure data from noise maps give a total of 903 000 DALYs lost from noise-induced sleep disturbance for the EU population living in towns of> 50 000 inhabitants.

Tinnitus

Tinnitus is defined as the sensation of sound in the absence of an external sound source. Tinnitus caused by excessive noise exposure has long been described; 50% to 90% of patients with chronic noise trauma report tinnitus. In some people, tinnitus can cause sleep disturbance, cognitive effects, anxiety, psychological distress, depression, communication problems, frustration, irritability, tension, inability to work, reduced efficiency and restricted participation in social life.

£xposure-response relationship

For tinnitus due to environmental noise, exposure to social/leisure noise such as personal music players, gun shooting events, music concerts, sporting events and events using firecrackers is most relevant for western Europe and North American countries. Population-based studies associating exposure to leisure noise with the risk of tinnitus are rare. From studies on people with tinnitus, a mean prevalence was calculated of those with slight, moderate and severe tinnitus.

Estimated burden In western'£urope

Applying the mean prevalence data to the EUR-A population of 344 13.1 386 people aged 15 years and over in 2001, the prevalence of slight, moderate and severe tinnitus was estimated. DW of 0.01 was chosen for slight tinnitus and 0.11 for moderate and severe tinnitus. An educated guess of 0.03 was made for the population-attributable fraction of tinnitus caused by environmental noise exposure. DALYs for noise-induced tinnitus were estimated to be 22 000 years for the EUR-A adult population.

Annoyance

WHO defines health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Therefore, a high level of annoyance caused by environmental noise should be considered as one of the environmental health burdens. Standardized questionnaires are used to assess noise-induced annoyance at the population level. The percentage of highly annoyed is the most widely used prevalence indicator for annoyance in a population.

Exposure-response relationship

The percentage of "highly annoyed" persons (HA) due to road traffic noise was calculated with the equation:

$$HA[\%] \bullet 0.5118 \cdot (L_{dn} - 42) - 1.436 \cdot 10^{-2} \cdot (L_{dn} - 42)^2 + 9.868 \cdot 10^{-4} \cdot (L_{dn} - 42)^3$$

Estimated burden In western Europe

Conservative estimates applied to the calculation using exposure data from noise maps give a total of 587 000 DALYs lost from noise-induced annoyance for the EU population living in towns of> 50 000 inhabitants.

Conclusions

There is sufficient evidence from large-scale epidemiological studies linking the population's exposure to environmental noise with adverse health effects. Therefore, environmental noise should be considered not only as a cause of nuisance but also a concern for public health and environmental health.

This publication was produced by the working group convened by the Regional Office to provide policy-makers and their aldvisers in national and local authorities with exemplary practices of using WHO methods of quantifying the burden of disease for selected health end-points. Because of the uncertainties in exposure assessment, exposure-response relationships and health statistics, conservative assumptions were made as far as possible.

It is estimated that DALYs lost from environmental noise in the western European countries are 61 000 years for ischaemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22 000 years for tinnitus and 587 000 years for annoyance. If all of these are considered together, the range of burden would be 1.0-1.6 million DALYs.[1] This means that at least 1 million healthy life years are lost every year from traffic-related noise in the western European countries, including the EU Member States. Sleep disturbance and annoyance related to road traffic noise constitute most of the burden of environmental noise in western Europe. Owing to a lack of exposure data in south-east Europe and the newly independent states, it was not possible to estimate the disease burden in the whole of the WHO European Region.

The procedure of estimating the burden of selected health end-points related to environmental noise exposure presented here can be used by international, national and local authorities as long as the assumptions, limitations and uncertainties reported in this publication are carefully taken into account. This publication also provides an updated review of evidence for the future development of suitable guidelines on noise by WHO, as its urged by Member States in the Parma Declaration adopted at the Fifth Ministerial Conference on Environment and Health in 2010.

1 The extent to which years lost from different effects are additive across different outcomes is unclear. The different health outcomes might have synergistic rather than antagonistic effects when the combined effects occur in a person. Therefore, it would be a prudent approach to add the DALYs of different outcomes without considering synergistic effects.

1. INTRODUCTION

Lin Fritschi
A. Lex Brown
Rokho Kim
Dietrich Schwela
Stelios Kephalopoulos

Noise is a major environmental issue, particularly in urban areas, affecting a large number of people. To date, most assessments of the problem of environmental noise have been based on the annoyance it causes to humans, or the extent to which it disturbs various human activities. Assessment of health outcomes potentially related to noise exposure has so far been limited *(1)*.

According to preliminary results from the Environmental Burden of Disease (EBD) in Europe project in six European countries *(2)* reported at the WHO Ministerial Conference held in Parma in March 2010 *(3)*, traffic noise was ranked second among the selected environmental stressors evaluated in terms of their public health impact in six European countries. Further, the trend is that noise exposure is increasing in Europe compared to ocher stressors (e.g. exposures to second hand smoke, dioxins and benzene), wrucb are declining.

In its *Guidelines for community noise (4)*, the WHO defined environmental noise as "noise emitted from all sources except for noise at the industrial workplace". European Union (EU) Directive 2002/49/EC on the management of environmental noise *(5)* defines environmental noise as "unwanted or harmful outdoor sound created by huinan activities, including noise from road, rail, airports and from industrial sites". The terms community, residential or domestic noise have also been applied to environmental noise, although these terms are not necessarily used consistently. This publication examines health risk assessment for these sources of environmental noise.

In recent years, evidence has accumulated regarding the health effects of environmental noise. For example, well-designed, powerful epidemiological studies have found cardiovascular diseases to be consistently associated with exposure to environmental noise. In order to inform policy and to develop management strategies and action plans for noise control, national and local governments need to understand and consider this new evidence on the health impacts of environmental noise. For this purpose, there should be a risk assessment to evaluate the extent of the potential health effects.

The process of risk assessment of environmental noise requires knowing:

- the nature of the health effects of noise;
- the levels of exposure at which health effects begin to occur and how the extent of the effect changes with increasing noise levels; and
- the number of people exposed to these hazardous levels of noise.

Quantitative risk assessments based on EBD methodology have been developed and used by WHO to help the Member States quantify several environment-related health problems *(6).* The EBD is usually expressed as the number of deaths and the metric disabiliry-adjusted life year {DALY}, which combines the concepts of (a) potential years of life lose due to premarure death and (b) equivalent years of "healthy" life lose by virtue of being in a state of poor health or disability. An estimate for burden of disease due to noise exposure has been made in Germany and other European countries as well as by nongovernmental organizations.

In recent years, the Bonn Office of the WHO European Centre for Environment and Health has organized several meetings of experts to examine the current stare of knowledge and to further develop approaches for quantifying the effect of noise on health. The outcomes of these meetings are summarized in this publication.

Aims of this publication

The target audience for this publication is primarily policy-makers and their technical advisers who need to evaluate the issue of environmental noise in their jurisdictions. Publication brings together information on the evidence base on the health effects of environmental noise and provides guidance on how to quantify these effects. It aims to provide:

- synthesized reviews of evidence on the relationship between environmental noise and health effects in order to inform policy-makers and the public about the health impacts of exposure to noise;

- exemplary estimates of the health impacts of environmental noise based on exposure-response relationships, exposure distribution, population-attributable fraction, background prevalence of disease and disability weights; and

- guidance on the process of health risk assessment of environmental noise consistent with the EBD methodology of WHO.

This publication has been prepared with a European focus in terms of policy, available data and legislation. Nevertheless, as long as the assumptions, limitations and uncertainties described in the various chapters are carefully taken into account, the processes of risk assessment illustrated here can also be applied outside Europe.

Risk assessment

The objective of risk assessment is to support decision-making by assessing risks of adverse effects on human health and the environment from chemicals, physical factors and other environmental stresses. There are several different frameworks available to guide risk assessment. The one used in this publication is the framework outlined in the WHO guideline pubJicarion *Evalt,uition and use of epidemiological evidence for health risk assessme1tt (7).* Other frameworks are used by other organizations *(8,9).*

The WHO model splits health risk assessment into two activities: health hazard characterization and health impact assessment *(7).* The results of risk assessment can be fed into risk management, includjng regulatory options. This publication focuses on health impact assessment aspect of risk assessment; the management of risk from environmental noise is not discussed here.

The process of risk assessment involves the synthesis and interpretation of the evidence from the available data, often across scientific disciplines. There are several limitations, challenges and uncertainties at each step. Tbese include the availability and consistency of the evidence, chance and bias affecting the valid.icy of studies, and the transparency, reproducibility and comprehensiveness of reviews.

Hazard identification (Identification of effects of noise)

After reviewing the available scientific evidence supporting causal association, the following outcomes were selected for inclusion:

- cardiovascular disease
- cognitive impairment
- sleep disturbance
- tinnitus
- annoyance.

While a chapter on hearing impairment due to environmental noise would have been useful, it was found that the data available on the prevalence of leisure noise and the relationship between environmental noise and hearing impairment were not adequate for burden of disease calculations.

On the ocher hand, it was thought to be important to include a chapter on the effect of environmental noise oo annoyance. Although annoyance cannot be classified as a "health effect", it does affect the well-being of many people and therefore may be considered to fall within the WHO definition of health as being "a state of complete physical, mental and social well-being". More importantly, however, it is the effect of noise that most lay people are aware of and concerned about. It was believed that many jurisdictions would be interested in estimating the effects of noise on this outcome.

Exposure assessment

There are many different sources of environmental noise to which people are exposed including, for example:

- transport (road traffic, rail traffic, air traffic);
- construction and industry;
- community sources (neighbours, radio, television, bars and restaurants); and
- social and leisure sources (portable music players, fireworks, toys, rock concerts, firearms, snowmobiles, etc.).

Noise from all sources may be relevant to the assessment of risk, and hence it may be appropriate to assess the exposure of the population of interest to all of these sources. In practice, it is almost impossible to consider exposure to all sources in the risk assessment, because some exposures are difficult to estimate at the population level (for example, leisure noise through attending music concerts or listening to personal music devices). By contrast, considerable work has been done on assessing the exposure of populations to noise sources such as air traffic and road traffic.

Assessment of exposure to noise requires consideration of many factors, including:

- measured exposure or calculated/predicted exposure
- choice of noise indicator
- population distribution
- time-activity patterns of the exposed population
- combined exposures to multiple sources of noise.

The exposure of the population of interest to the noise source can be obtained by measurement or by using models that calculate noise exposure based on information about the source and on information about sound propagation conditions from source to receiver. Such calculation models can also be used to predict levels of noise exposure for some time in the future based on estimated changes in noise sources. Best-practice methods should be adopted for measurement or for calculaci.on in the assessment of exposure, with a full understanding of the assumptions, limitations and potential errors associated with any approach to measurement or estimation. For example, a common approach to assessing the exposure of people to transport noise is to use, as a proxy, the exposure of the most exposed side of the dwelling in which they live. This may not always be a good approximation, however, because the rooms in which people spend most time may not be on the most exposed side of the dwelling.

Noise exposure mapping is a commonly adopted step in the process of estimating the noise exposure of a population. EU Directive 2002/49/EC on the management of environmental noise *(5)* mandated all EU Member States to produce strategic noise maps based on harmonized indicators by 2008 (see Box 1.1).

Box 1.1. EU Directive 2002/49/EC on the management of environmental noise

Noise has high priority on lists of environmental issues in Europe and noise reduction has increasingly become a focus for EU legislation and management. From the 1970s, successive directives have laid down specific noise emission limits for most road vehicles and for many types of outdoor equipment. Despite this increasingly stringent control of emissions, however, and despite the considerable effort and progress made in controlling noise from industry, there has been little improvement in the levels of noise exposure of people across Europe. The European Commission's 1996 Green Paper on future noise policy *(11)* marked the start of an extended "knowledge based" approach to the problem of noise, with a special emphasis on assessing and then managing the exposure of the population to environmental noise.

The European Commission developed a new framework for noise policy based on shared responsibility between the EU and national and local governments. It included a comprehensive set of measures to improve the accuracy and standardization of data to help improve the coherency of different actions:

- **the creation of a Noise Expert Network *(12)*, whose mission is to assist the Commission in the development of its noise policy;**

- **EU Directive 2002/49/EC on the management of environmental noise *(5);* and**

- **the follow-up and further development of existing EU legislation relating to sources of noise such as motor vehicles, aircraft and railway rolling stock, and the provision of financial support to noise-related studies and research projects.**

The European Parliament and Council adopted Directive 2002/49/EC of 25 June 2002, whose main aim is to provide a common basis for tackling noise problems across the EU. The underlying principles of the Directive are similar to those for other environment policy directives:

- **monitoring the environmental problem by requiring competent authorities in Member States to produce strategic noise maps for major roads, railways, civil airports and urban agglomerations, based on harmonized noise indicators;**

- **informing and consulting the public about noise exposure, its effects and the measures considered to address noise, in line with the principles of the Aarhus Convention *(13);***

- **addressing local noise issues by requiring competent authorities to draw up action plans to reduce noise where necessary and maintain environmental noise quality where it is good (the Directive does not set any limit value nor does it prescribe the measures to be used in the action plans, which remain at the discretion of the competent authorities); and**

- **developing a long-term EU strategy, including objectives to reduce the number of people affected by noise and providing a framework for developing existing EU policy on noise reduction from sources.**

Detailed information is available on the authorities responsible for implementing the Directive in Member States and on the agglomerations, major roads, railways and airports to be covered by the noise maps and action plans.

Exposure assessment requires specification of the noise metric that is to be utilized. There is a wide variety of noise indicators and extensive discussion of these can be found in the WHO *Guidelines for community noise (4).* This includes such matters as the type of physical scale and the period of the day over which exposure is to be integrated: for example, "night", "evening" or "day".

The EU has adopted harmonized noise metrics across all of its Member States, suggesting Lden (day-evening-night equivalent level) as an appropriate metric to assess annoyance and Lnight (night equivalenc level) as a metric co assess sleep disturbance *(5).* While noise limits are set individually by each EU Member State, these suggested *metrics* are to be used for strategic mapping of exposure in all countries. They are common across all transport sources and other sources of environmental noise. Definitions of these metrics in Directive 2002/49/EC are paraphrased in Box 1.2 below. Strategic noise maps using these harmonized noise metrics are to be used throughout Europe to assess the number of people exposed to different levels of noise. This information on population exposure can be used in the risk assessment process for envjronmental noise. Directive 2002/49/EC also allows che use of supplementary noise metrics (other than L_{den} and L_{night}) to monitor or control special noise situations.

A key consideration is that risk assessment cannot be carried out (using an exposure-specific approach) unless both the exposure assessment and the exposure-response relationship utilize the matching noise inclicators. This becomes an issue when there is evidence chat the best relationship between a particular health effect and exposure may be based on one indicator, yet data on exposure are only available based on another. While the work required by Directive 2002/49/EC will increase the availability of exposure asscssments using rhe harmonized noise indicators, available exposure-response relationships may be reported using other indicators. These matters are discussed within each of the chapters on the various health outcomes. Exposure-response relationships reported may utilize different noise indicators because the meta-analyses in which these relationships were derived relied on studies using other noise indicators, or because there is evidence that the relationship between a particular health outcome and noise exposure is better described using a different noise indicator.

The quality of exposure data is critical to the accuracy of risk assessment. Some of the difficulties in measuring noise and preparing noise maps are outlined in a good practice guide *(14)*. They include: coverage of all relevant sources; inaccuracies in the process of Linking people to noise levels and thus obtaining exposure distributions; and accounting for the presence of a quiet side or special sound insulation of a house, in particuJar for effects related to sleeping.

Box 1.2. Harmonized noise Indicators in EU Directive 2002/49/EC

The day-evening-night level L_{den} **in decibels is defined by:**

$$L_{den} = 10 \cdot \lg \frac{1}{24} \left(12 \cdot 10^{\frac{L_{day}}{10}} + 4 \cdot 10^{\frac{L_{evening}+5}{10}} + 8 \cdot 10^{\frac{L_{night}+10}{10}} \right)$$

- L_{day}, $L_{evening}$ **and** L_{night} **are the A-weighted** 12, **4, 8 hours average sound levels, respectively, as defined in ISO** 1996-2:1987 *(15)*.
- **The day is** 12 **hours, the evening 4 hours and the night 8 hours. Member States may shorten the evening period by 1 or 2 hours and lengthen the day and/or the night period accordingly (same for all the sources).**
- **The start of the day (and consequently the start of the evening and the start of the night) shall be chosen by the Member State (same for all sources); the default values are** 07:00-19:00, 19:00-23:00 **and** 23:00-07:00 **local time.**
- **The incident sound is considered, which means that no account is taken of the sound that is reflected at the facade of the dwelling under consideration.**

The nighttime noise indicator L_{night} **is the A-weighted long-term average sound level.**

- **The night is 8 hours as defined above.**

Supplementary noise indicators. In some cases, in addition to en and Lnight, and where appropriate ay and Levening, it may be advantageous to use special noise indicators and related limit values. Some examples (consult Directive 2002/49/EC for full advice) are:

- a very low average number of noise events in one or more of the periods (for example, less than one noise event an hour); a noise event could be defined as a noise that lasts less than five minutes, such as the noise from a passing train or aircraft;
- strong low-frequency content of the noise; and
- LAmax or SEL (sound exposure level) for night period protection in the case of **noise peaks.**

Environmental burden of disease assessment

A detailed introduction to the calculation of EBD is available elsewhere *(16,17).* In this section, we describe the majn methods used to calculate EBD that are applied in the following chapters on each health outcome of environmental noise, and discuss some of the strengths and weaknesses of each approach.

In general, the number of deaths and cases of each of the outcomes is estimated in the initial process of EBD calculation. The burden of disease is expressed in deaths and DALYs. The DALY combines in one measure the time lived with disability (YLD) and the time lost due to premature mortality (YLL) in the general population:

$$DALY = YLL + YLD$$

The YLD is the number of incident cases (I) multiplied by a disability weight (DW) and an average duration of disability in years (L):

$$YLD = I \cdot DW \cdot L$$

The YLL essentially corresponds to the number of deaths (N) multiplied by the standard life expectancy at the age at which death occurs (L):

$$YLL = N \cdot L$$

These simple formulae can be further adjusted by discounting for the timing of the health effect (now or in the future) and by the relative value of a year of life lived at different ages using different assumptions (age weighting).

TJle approach to estimating total disease burden can be summarized in the following steps: (a) estimating the exposure distribution in a population; *(b)* selecting one or more appropriate relative risk estimates from the literature, generally from a recent meta-analysis; and (c) estimating the population-attributable fraction with the formula for populatfon-anributable fraction. This is referred to in *this* volume as the exposure-based approach. In certain instances, the number of cases is also directly estimated on che basis of the exposure {outcome-based approach).

Exposure-based approach

This approach uses the distribution of noise exposure within the study population to estimate the fraction of disease in the population that is attributable to noise. This is then applied to the disease estimates. This approach requires the measurement or calculation of:

- the distribution of the exposure to environmental noise within the population (prevalence of noise exposure);
- the exposure-response relationship for the particular outcome;
- a population-based estimate of the incidence or prevalence of the outcome from surveys or routinely reported statistics; and
- a value of DW for each health outcome.

Prevalence of noise exposure

Estimates are required of the distribution of the exposure in the population of interest using the chosen noise metric.

Exposure-response relationship

Exposure-response relationships are usually obtained from epidemiological studies. The validity of any exposure-response relationship depends on the quality of the studies used to derive it, the choice of studies used and the modelling process used to pool the results. It is therefore very important that the process to derive the exposure-response relationships is well defined. In some cases, very well-designed studies can provide this information. In other cases, it is necessary to undertake a meta-analysis to combine a number of different studies. According to the WHO guidelines *(4),* the process of meta-analysis should include, as a minimum:

- a systematic review of the available epidemiological information on exposure-response relationships;
- an inventory of studies that provide quantitative information on exposure or that allow linkage to such information;
- additional selection of studies according to clear inclusion criteria; and
- a meta-analysis of published results or pooling of original data.

The exposure-response relationship may be reported as a regression formula or as a relative risk measure for a given change in noise (or comparing noise-exposed to noise-unexposed). Important issues to consider in the meta-analysis are:

- the quality of studies that have been used in the meta-analysis and the selection criteria used;
- the completeness of the search for studies;
- the quality of the assessment of noise exposure;
- the temporality of the noise exposure (for example, nighttime noise exposure is relevant for sleep disturbance, while daytime noise exposure is important for annoyance and cognitive impairment); and
- the relevance of the published studies to the population for which the risk assessment is being carried out.

In addition, it may be necessary to extrapolate relationships beyond the range of exposure observed in the available epidemiological studies. The arguments for the validity of such an extrapolation must be stated.

Incidence (or prevalence) of outcome

The definition of health outcome in the exposure-response relationship should be consistently used when the incidence data are collected. Some outcomes are easily obtained from national health statistics. For example, deaths from cardiovascular disease in a population per year are routinely collected in most developed countries.

For other outcomes, such routine data may not be available and in these cases prevalence or incidence of outcomes may need to be determined by surveys of the population. The accuracy of the estimates of these outcomes depends on the questions used for each individual survey. Standardized and validated questionnaires are recommended. For example, asking people how often they take medication to overcome sleeping difficulties may differ according to the availability of medication and the definition of sleeping difficulties implicit in the question. The timing of the outcome is important, either reflecting lifetime prevalence ("Have you ever had ... ?"), point prevalence ("Do you currently have ... ?") or incidence ("Since the last survey have you developed new ... ?"). Depending on the condition, severity may be important as different severities of the outcome may have different DWs (e.g. mild, moderate or severe hearing loss).

Attributable fraction

The attributable fraction is the proportion of disease in the population that is estimated to be caused by noise. The accuracy of the fraction of the outcome attributable to environmental noise may also be difficult to specify. If the distribution of exposure and the exposure-response relationship are known, the population-attributable risk percentage can be estimated for a population (see above). The following formulae can be used to calculate the attributable risk percentage (AR%), the population-attributable risk percentage (PAR%), and the population-attributable risk (PAR) for each noise category *(16)*:

AR% $= (RR-1)/RR \cdot 100 [\%]$

PAR% $= P_e/100 \cdot (RR-1) / (P_e/100 \cdot (RR-1) + 1) \cdot 100 [\%]$

PAR $= PAR\%/100 \cdot Nd$

RR = relative risk (odds ratios are estimates of the relative risk)

P_e = percentage of the population exposed [%]

Nd = number of subjects with disease (disease occurrence).

A more generalized formula for the calculation of the population-attributable fraction (PAF) that better accounts for multiple comparisons for large relative risks may also be used:

$$PAF = \{\Sigma(P_i \cdot RR_i) - 1\} / \Sigma (P_i \cdot RR_i)\}$$

Pi = proportion of the population in exposure category ***i***

RRi = relative risk at exposure category *i* compared to reference level

Pi = 1

PAR = PAP · Nd

Disabilityweight

DWs allow non-fatal health states and deaths to be measured under a common unit *(15)*. DWs quantify time lived in various health states to be valued and quantified on a scale that takes account of societal preferences. DWs that are commonly used for calculating DALYs are measured on a scale of 0-1, where 1 represencs death and 0 represents ideal health.

The values of DWs for various disease states have been the subject of considerable discussion and work. They are generally derived from expert panels. This work has been documented extensively *(17)* and will not be summarized further here. WHO has a reasonably comprehensive list of DWs *(17)* and these are recommended for use. If there is no appropriate DW, then an expert committee may be asked to find an appropriate DW by analogy with other known DWs.

Advantagesand disadvantagesof this method

The methods described above are the most common approach used in health risk assessments because the methodology has been established and accepted in comparative risk analysis of WHO's EBD projects *(16)*. They provide standardized estimates of the health risk due to noise that may be understood by workers in the field. However, as described above, these methods require detailed data on noise exposure, the outcome and the exposure-response relationship. Such data are not always easy to obtain and often have significant limitations. For example, the exposure-response relationships may be based on extrapolation from a small number of studies with few subjects and perhaps even a measure of noise exposure that is not available on a population basis. This means that the estimates usually suffer from a considerable degree of uncertainty. This uncertainty is very difficult to quantify, although it is sometimes possible to provide low and high limits using sensitivity analyses *(17)*.

Outcome-based approach

For some noise-related outcomes, such as sleep disturbance and tinnitus, it is possible to estimate the burden directly through national or international surveys. This approach requires:

- an estimate of the prevalence of the outcome attributable to environmental noise; and
- a value of DW corresponding to this outcome.

The choice of questions in the survey needs to be carefully considered so as to be able to differentiate various severities of outcome and be compatible with the DWs. When the data on outcomes are not specific to environmental noise, attributable fractions should be applied to the data. When information on population exposure and/or the exposure-response relationship is not known, expert opinion may be sought on what proportion of cases of an outcome is due to environmental noise. This approach was used for the chapter for tinnitus in this report, because exposure data on leisure noise and exposure-response relationships are not available for tinnitus.

The number of cases can then be multiplied by the DW to obtain the DALYs. When using this method, rhe attribution of the cause of the outcome tends to be more subjective than in exposure-based approaches.

Process of developing this publication

There is currently little information at the international level on the health impact of environmental no-ise in the WHO European Region. The WHO Regional Office for Europe has carried out an assessment study to provide methodological guidance for estimating the burden of disease related to environmental noise by calcularing preliminary estimates of DALYs for the European Region.

The noise EBD project was started in 2005. An expert working group was convened in Stuttgart in June 2005 to review the health effects of noise and the selection of noise-related health outcomes for EBD estimation. Cardiovascular disorders, cognitive impairment, sleep disturbance, hearing loss, tinnitus and annoyance were selected as outcomes to be considered.

A second meeting was held in Bern in December 2005 to review the initial estimates of the burden of disease from environmental noise. Experts provided background documents and made presentations reviewing the detailed methods and preliminary resulrs of EBD assessment for the selected noise-related outcomes. For each topic, a state-of-the-art review was made regarding the exposure data, exposure-response relationships, outcome data, DW and DALY calculation. WHO staff provided the topic-specific experts with methodological guidance based on previous global burden of disease experience. The meeting identified methodological constraints and informational gaps in quantification of DALYs due to environmental noise.

The methods and preliminary estimates were further elaborated in Berlin in April 2006 and in Bonn in December 2006. It was noted cJlat calculation of DALYs is not possible for more than a few countries owing to the limited availability of data in most European cow,tries. Because of this difficulty, the working group had to focus on _providi1 1g methodological guidance on risk assessment rather than on estimating the EBD of environmental noise. Because EU Directive 2002/49/EC provides exposure data in many cow1tries, it was also decided that the exposure metrics should use the Directive indicato.cs as much as possible. With these aims in mind, a meeting of experts was convened in Bonn in May 2008.

Subsequent to the Bonn meeting, the authors of this chapter edited the final document. AU chapters have been peer-reviewed, both within the working group and externally. At the final compilation of the chapters on health outcomes, the chapter on hearing loss was excluded because of a lack of epidemiological data pointed out by the reviewers. All other chapters were revised by the authors, taking into account the comments of the reviewers.

In 2010, exposure data on urban areas of> 250 000 inhabitants in the EU Member States became available through the EEA with the enforcement of EU Directive 2002/49/EC *(18).* Accordingly, the WHO secretariat decided to include dle EBD calculations for the EU population using the available data. In every step of the calculation that involved uncertainties, the working group made conservative assumptions in filling the information gap in order to avoid any possibility of overestimation.

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2. ENVIRONMENTAL NOISE AND CARDIOVASCULAR DISEASE

Wolfgang Babisch
Rokho Kim

This chapter examines the burden of cardiovascular diseases related to environmental noise. It is a common experience that noise is unpleasant and affects the quality of life. It disturbs and interferes with activities of the individual, including concentration, communication, relaxation and sleep *(1,2)*. Besides the psychosocial effects of community noise, there is concern about the impact of noise on public health, particularly regarding cardiovascular outcomes *(3-5)*.

According to the WHO Global Burden of Disease 2000 study, ischaemic heart disease is the leading cause of death in developed and developing countries (22.8% and 9.4% of total deaths, respectively *(6,7)*. Worldwide, 12.6% of deaths are caused by ischaemic heart disease, 9.6% by cerebrovascular disease and 1.6% by hypertensive heart disease *(8)*. High blood pressure and high levels of blood lipids, including cholesterol and triglycerides, are major (biological or endogenous) risk factors for ischaemic heart disease. Endogenous risk factors can be affected by exogenous risk factors (e. g. nutrition, environmental factors). Worldwide, 13.5% of deaths are attributable to high blood pressure (hypertension} and 6.9% to high (total) cholesterol levels. 1.4% of deaths are attributed to urban air pollution according to the WHO Global Burden of Disease 2000 study *(6,8)*.

The auditory system is continuously analysing acoustic information, which is filtered and interpreted by different cortical and sub-cortical brain structures. Arousal of the autonomic nervous system and the endocrine system is associated with repeated temporal changes in bi.ological responses. In the long run, chronic noise stress may affect the homeostasis ofche organism due co dysregulation, incomplete adaptation and/or the physiological costs of the adaptation *(9-17)*. Noise is considered a nonspecific stressor that may cause adverse health effects in the long run. Epidemiological studies suggest a higher risk of cardiovascular di.seases, i.nc,:ludi.ng high_ blood pressure and myocardial infarction, in people chronically exposed to high levels of road or air traffic noise. This chapter collates the available evidence regarding risk estimation for the burden of cardiovascular disease attributable to environmental noise in European regions.

Definition of outcome

Cardiovascular disease includes ischaemic heart disease, hypertension *(high* blood pressure) and strok1. There *is* no evidence available on the relationship between noise and stroke, so it *will* not be considered further here.

lschaemic heart diseases (lCD 10 codes 120-125) include angina (120), acute myocardial infarction (121), subsequent myocardial infarctions and complications of infarctions (122 and 123), other acute forms of ischaemic heart disease (124) and chronic ischaemic heart disease (125). Essential hypertension is classified as I10 with further codes for hypertensive heart failure (111), hypertensive renal disease (112) and hypertensive heart and renal disease (!13).

Summary of evidence linking noise and cardiovascular disease

Epidemiological studies on the relationship between transportation noise (particularly road traffic and aircraft noise) and cardiovascular effects have been carried out on adults and on children, focusing on mean blood pressure, hypertension and ischaemic heart diseases as cardiovascular end-points. The evidence, in general, of a positive association has increased during recent years *(18-20)*. While there is evidence that road traffic noise increases the risk of ischaemic heart disease, including myocardial infarction, there is less evidence for such an association with aircraft noise because of a lack of studies. However, there is increasing evidence that both road traffic noise and aircraft noise increase the risk of hypertension. Very few studies on the cardiovascular effects of other environmental noise sources, including rail traffic, are known. Numerical meta-analyses were carried out assessing exposure-response relationships in quantitative terms *(21,22)* and the issue has been addressed in various WHO projects. The exposure-response curves presented here refer to the data collected for these projects, to illustrate the processes of a quantitative risk assessment.

Blo/oqical model of causation

Non-auditory health effects of noise have been studied in humans and animals for several decades, using laboratory and empirical methods. Biological reaction models have been derived, based on the general stress concept *(17,23-30)*. Noise is a nonspecific stressor that arouses the autonomous nervous system and the endocrine system *(9,11-14,31,32)* (C. Maschke & K. Hecht, unpublished data, 2005}. A neuro-endocrinol.ogical definirion of stress is that it is a srate that threatens homeostatic or adaptable systems in the body *(16,33,34)*. Increased allostatic load is associated with various diseases, including ischaemic heart disease *(35)*. The epidemiological reasoning is based on three facts. First, experimental studies in the laboratory have been carried out for a long time and revealed an increased vegetative and endocrine reactivity during periods of exposure *(1,36-70)*. However, the question regarding long-term effects of chronic noise exposure cannot be answered from short-term experiments. Second, animal studies have shown manifest disorders in species exposed to high levels of noise for a long time *(71-83)*. However, effects in humans and animals cannot be directly compared, particularly because two pathways may be relevant - the direct effect due to nervous innervation and the indirect effect due to the cognitive perception of the sound; the latter is certainly different in humans. Furthermore, noise levels in animal studies were higher than in ambient situations. Third, occupational studies have shown health disorders ill workers chronically exposed to noise for many years *(20,84-98)*. However, noise levels were higher than in the ambient environment. Epidemiological research has therefore been carried out with respect to community noise levels to test the hypothesis and to quantify the risk.

Among other non-auditory health end-points, short-term changes in circulation, including blood pressure, heart rate, cardiac output and vasoconscriction, as well as stress hormones (epinephrine, norepinephrine and corticosteroids), have been studied in experimental settings for many years *(32,99)*. Classical biological risk factors have been shown to be elevated in subjects that were exposed to high levels of noise *(44,54, 79,100-111)*.

From this, the hypothesis emerged that persistent noise stress increases the risk of cardiovascular disorders, including hypertension and ischaemic heart disease. Accordjng to the noise/srress reaction model, the arousal of the endocrine and autonomic nervous sysrem affects classical biological risk factors (e.g. blood pressure, blood lipids, glucose regulation, blood flow, haemostatic factors and cardiac output). Chronic metabolic changes or dysfunction due to noise increase the risk of manifest diseases, including hypertension, arteriosclerosis and myocardial infarction.

Exposure-response relationship

For a quantitative risk assessment and the derivation of guidelines for public health noise policy, a common exposure-response curve is required. The risk estimates obtained from different noise studies can be summarized using the statistical approach of meta-analysis.

Definition of exposure

Energy-based indicators of exposure (L_{eq}) are adequate and sufficient for assessing the relationship between long-term exposure to community noise and chronic diseases such as cardiovascular disorders. While single event noise indicators can be useful predictors (as additional information) for assessing the effects of acute noise (e.g. sleep discurbance) *(112),* integrated noise indicators (e.g. a year's average noise level) are suitable predictors in epidemiological studies for assessing the long-term effects of chronic noise exposure. Such indicators should measure noise during cercain periods of the day. Examples include $L_{day,16h}$ (day-noise indicator 7:00 to 23:00}, $L_{day,12h}$ + $L_{evening,4h}$ (day-noise indicator 7:00 to 19:00 and evening-noise indicator 19:00 to 23:00) and $L_{night,8h}$ (night-noise indicator 23:00 to 7:00). $L_{day,16h}$ is a useful indicator for estimating health impacts according to the method proposed here. When information on noise for the various periods of the day, i.e. day/evening/night, is available, weighted and non-weighted indicators can easily be calculated for use in health studies and related quantitative risk assessment. This includes the indicators L_{den} (weighted day-evening-night noise indicator) and L_{night} according to Directive 2002/49/EC *(113),* which are considered in noise mapping.

If only one figure is anticipated to describe the noise situation, a single noise indicator may be a useful factor to be considered in noise studies (e.g. L_{24h}, L_{dn} or L_{den}). However, since night noise is assessed separately according to Directive 2002/49/EC, it does not appear reasonable when daytime noise and nighttime noise exposures are then combined in a weighted 24-hour indicator. With respect to health effects, it would make much more sense to clearly distinguish between real day and night indicators. An optimal noise study would try to distinguish between the exposure of the living room during the day (L_{day}) and the exposure of the bedroom during the night (L_{night}). Further, the concept of L_{dn} is annoyance-based. From a cardiovascular point of view, tl1ere is no rationale known for weighing factors such as +5 dB(A) or +10 dB(A) for the evening and night periods of the day. It would be a better approach to con:icier day and night exposures separately with respect to its effects, particularly for noise sources other than road traffic 1loise {where the day and night noise levels are usually highly correlated). Studies should also try to distinguish between the exposure of the living room (during daytime) and the exposure of the bedroom (during nighttime}. However, such information is often not available.

When comparing study results for the meta-analyses, problems arise from the fact that different noise indicators (including even more complex national noise indices) have been used in different studies. However, conversion formulas are available for approximation. For example, with respect to road traffic noise the following empirical formula can be used for conversions between Ld_{ay},16h and Lden *(114):*

Lden "' Lday,16h - 2 • ln ((Lda$_{y}$,16h- Lni$_{g}$ht,8h)/22.4))

However, this conversion can, per se, not be applied to other noise sources such as aircraft noise and railway noise. Nevertheless, as long as particular studies referring to Directive 2002/49/EC indicators Ldcn and L_{n}ight are largely missing, exposure-response relationships (regression coefficients) based on ocher noise indicators cou.ld approximately be considered for assessing the relative increase in risk with increasing noise level.

For the meta-analyses, noise exposure was divided into 5-dB(A) categories for the daytime outdoor average A-weighted sound pressure level (Lday,16h)- This was considered in most studies. Information on nighttime exposure {Lnighr,11h} was seldom available. Newer studies used non-weighted or weighted averages of the 24-hour exposure (Lcq, Ldn, Lden) *(113).* Some aircraft noise studies used national calculation methods (e.g. Dutch Kosten Units}. Some of the studies considered subjective ratings of the noise, including noise annoyance, as indicators of noise exposure. Sound levels were converted on the basis of best-guess approximations to Ld_{ay},16h for comparison and pooling.

In urban settings, average nighttime noise levels for road traffic rend to be approximately 7-10 dB(A) lower than average daytime levels and are relatively independent of che traffic volume of the street (except motorways} *(115-117).* Measurements showed that ldcn was approx. 1-3 dB(A) higher than Ldavl6h where rhe difference between Lday,16h and $L_{n}i_{g}$ht,8h ranged from 10 to 5 dB(A)" *(114).*

In the conversion formula given above, if the difference between day and night sound levels *is* of the order of 7-8 dB(A}, then this accounts for approximately 2 dB(A) higher Ld_{c}n values compared to lday,lGh• This is commonly found for road traffic noise in urban streets with the 24-hour noise levels tending to be on.ly slightly lower than dayrime levels *(118).* A conversion factor of 2 dB(A) was also suggested based on Norwegian data (T. Gjestland, personal communication, 2006). Another study found the difference range Lcin - Ldn to be between 0 and 1.5 dB, depending on whether the noise level LAcq dropped in rhe evening *(119).*

To summarize, because the differences between Ld_{en} and Ld_{n} are usually small, in epidemiological studies in which the relative effects of road traffic noise are studied, sound emission during the daytime can be taken as an approximate relative measure of the overall sound emission, including ar night. This is further justified by the fact that existing noise regu.lations usually accept a 10-dB(A) difference between the day and the night. However, this approximation can only be made with respect co road traffic noise. For train and aircraft noise, no such approximation can be made. Approximate formulae for the conversion of different noise indicators are also given in the *Good practice guide for strategic noise mapping (120).*

Meta-analysis - road traffic noise and myocardial Infarction

To determine the most up-to-date and accurate exposure-response relationship between community noise and myocardial infarction, a meta-analysis was carried out *(21,121)*. By 2005, a total of 61 epidemiological studies had been recognized as having either objectively or subjeccively assessed the relationship between transportaci.on noise and myocardial infarction. Nearly all of the studies refer.red to road traffic noise or (commercial) aircraft noise, and a few to military aircraft noise. Most of the studies were of the cross-sectional type (descriptive studies) but observational studies such as case-control and cohort studies (analytical studies) were also available. The study subjecrs were children and adults. Confounding factors were not always adequately considered in some older studies. Not many studies provided information on exposure-response relationships, because only two exposure categories were considered.

All epidemiological noise studies were evaluated with respecc to their feasibility for inclusion in a meta-analysis. The following criteria for the inclusion in the analysis/symhesis process were applied: (a) peer-reviewed in the international literature; (b) reasonable control of possible cottfounding (stratification, model adjustment, marching); (c) objee6ve assessment of exposure (sound level); (d) objective assessment of outcome (clinical assessment); (a) type of study (analytical or descriptive); and (f) multi-level exposure-response assessment (not only dichotomous exposure categories).

Based on the above criteria, five analyrical (prospective case-control and cohort) and two descriptive (cross-sectional.) studies were suitable for derivation of a common exposure-response curve for the association between road tcaffic noise and the risk of myocardial infarction. Two separate meta-ana.lyses were undertaken by considering the analytical studies and descriptive studies separately. The a.naly6cal studies comprised those that were carried out in Caerphilly and Speedwell wfrh a pooled analysis of 6 years follow-up data *(122,123)* and the three Berlin studies *(124,125)*. The descriptive studies comprised the cross-sectional analyses that were carried out on the studies in Caerphilly and Speedwell *(126)*. All studies referred to the road traffic noise Leve! during the day (Lday,16h) and the incidence (analytical studies) or prevalence (descriptive studies) of myocardial infarction as the outcome. The study subjects were men. In all analytical scu.dies the orienrarion of rooms (moderator of the exposure) was considered for the exposure assessment (at least one bedroom or living room facing the street or not). In all descriptive stud.ies the traffic noise level referred to the nearest faeades that were facing the street and did not consider the orientation of rooms/windows (source of exposure misclassification). The individual effect estimates of each study were adjusted for the covariates given in these studies. This means that different sets of covariates were considered in each study. Nevertheless, this pragmatic approach accounts best for possible confounding in each study and provides the most reliable effect estimates derived &om each study.

The common set of covariates considered in the descriptive studtes were age, sex (males only) social class, body mass index, smoking, family history of ischaemic heart diseasc, physical activity during leisure time and prevalence of pre-existing diseases. The common set of covariates considered in the analytical studies were age, sex (males only), social class, school education, employment status, shift work, smoking and body mass index. Some of the analytical srudies also considered physical activity during leisure time, family history of ischaemic heart disease or myocardial infarction, prevalence of pre-existing diseases, work noise and marital status. In one study, the effect estimates were further adjusted for hypertension and diabetes mellitus. This may be a conservative approach owing to over-controlling, because these biological (risk) factors may be mediators along the pathway from exposure (noise stress) to disease.

The odds ratios calculated for the different 5-dB(A) noise categories {Lday,16h} within a single study were then pooled between studies for each noise category. Since higher exposure categories usually consist of smaller numbers of subjects than the lower categories, regression coefficients aeross the whole range of noise levels within a study tend to be largely influenced by the lower categories. This may lead to an underestimation of the risk in higher noise categories. The multi-level approach pooled the effect estimates of single studies within each noise category, thus giving more weight to the higher noise categories and accounting for possible non-linear associations.

The results from the two meta-analyses {descriptive studies and analytical studies) are shown in Table 2.1 *(121)*. For each meta-analysis we include the odds ratios (OR} and 95% confidence intervals (CI) for the original studies (with the weights used in the pooled analysis), the pooled OR and CI and the Laird Q-test of heterogeneity between studies. If the P-value from the Q-test is < 0.05, the studies are too heterogeneous and should not be combined.

The pooled estimates and Cis are shown graphically in Fig. 2.1 (descriptive studies) and Fig. 2.2 {analytical studies). The descriptive (cross-sectional) studies (Fig. 2.1) cover the sound level range of Lday,16h from > *50* to 70 dB(A), while the cohort and case-control studies {Fig. 2.2) cover the range from s *60* to 80 dB(A). The two curves together can serve as a basis for estimating the exposure-response relationship. From Fig. 2.1, it can be seen that below 60 dB(A} for Lday,16h no noticeable increase in myocardial infarction risk is to be detected. For noise levels greater than 60 dB(A), the myocardial infarction risk increases (Fig. 2.1 and 2.2).

A polynomial function was fitted through the data points from the analytical studies (Fig. 2.2), to generate a continuous exposure-response curve that can be applied to categorized noise data and also to continuous noise data. The data points were weighted by the number of subjects (N-weighting) *(21,121)*. Mean category values of the decibel-axis are considered for the calculation. For the reference category "s 60 dB(A)", a value of 55 dB(A) was used because this category also includes a large number of noise levels below 55 dB(A). Using alternative values for this reference category (e.g. 52.5 or 57.5) had only a very marginal effect on the coefficients and the fit statistics. According to the empirical German noise assessment model *(Uirmbelastungsmodell),* daytime noise levels tend to be equally distributed across the categories> 45-50, >50-55 and> 55-60 (127). In urban settings, background levels during the day do not often fall below 50 dB(A).

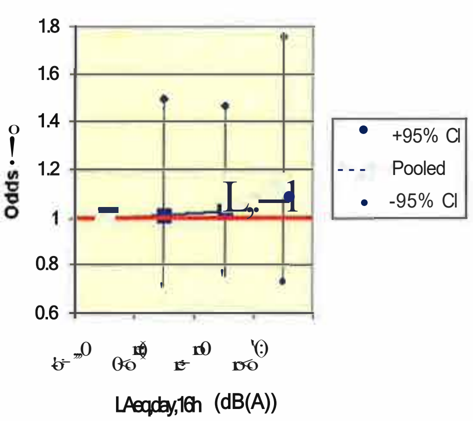
Table 2.1. Odds ratios and 95% confidence intervals from descriptive and analytical studies on the relationship between road traffic noise level and the Incidence/prevalence of myocardial Infarction

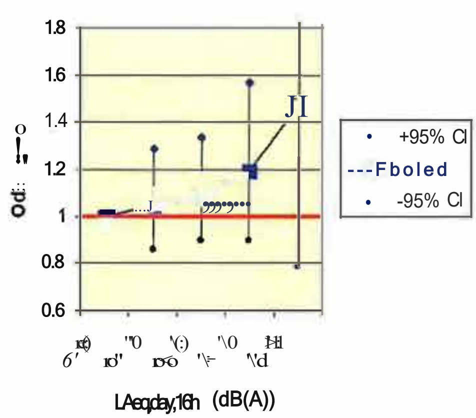
Descriptive studies	Road traffic noise level, Li,,,11h (dB(A))					N
	51-55	56-60	61 5	66-70		
Caerphilly	1.00	1.00 (0.58-1.71) [13.29]	0.90 (0.56-1.44) [17.23]	1.22 (0.63-2.35) [8.98]		2512
Speedwell	1.00	1.02 (0.57-1.83) (11.19)	1.22 (0.70-2.12) (12.62)	1.07 (0.59-1.94) (10.94)		2348
Pooled	1.00	1.01 (0.68-1.50)	1.02 (0.72-1.47)	1.14 (0.73-1.76)		
a-test		P= 0.96	P= 0.41	P= 0.77		
Analytical studies	< 60	61 5	66-70	71-75	76-80	N
Caerphilly& Speedwell	1.00	0.65 (0.27-1.57) [4.95]	1.18(0.74-1.89) [17.48]	—	—	3950
Berlin I	1.00	1.48 (0.57-3.85) [4.21]	1.19 (0.49-2.87) [4.94]	1.25 (0.41-3.81) [3.09]	1.76 (0.11-28.5) [0.50]	243
Berlin I	1.00	1.16 (0.82-1.65) [31.43]	0.94 (0.62-1.42) [22.76]	1.07 (0.68-1.68) [18.92]	1.46 (0.77-2.78) [9.27]	4035
Berlin III	1.00	1.01 (0.77-1.32) (54.42]	1.13 (0.86-s-1.49) (50.8Z]	1.27 (0.88-1.84) (2.8.24]	—	4115
Pooled	1.00	1.05 (0.86-1.29)	1.09 (0.90-1.34)	1.19 (0.90-1.57)	1.47 (0.79-2.76)	
a-test		P= 0.57	P= 0.87	P= 0.84	P=0.90	

Source: Babisch 2006 (121).

Note: *Numbers are odds ratios; 95% confidence inteNals are given in round brackets; weights are given in square brackets; N = sample size; Pooled= pooled estimates from meta-analysis of the studies shown; P =probability of the Q-test for heterogeneity.*

Fig. 2.1 & 2.2. Pooled effect estimates (meta-analysis) of the association between road traffic noise and the prevalence (Fig. 2.1, left) and incidence (fig. 2.2, right) of myocardial infarction (odds ratio+/- 95% confidence interval)





Source: Babisch (21).

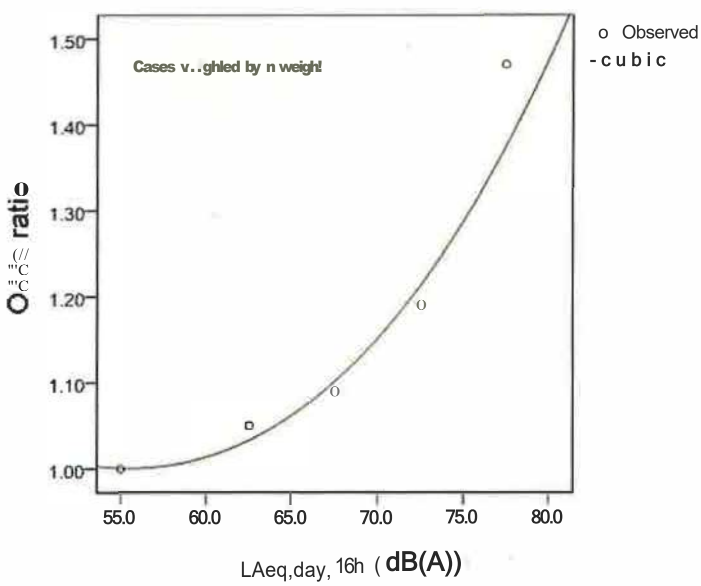
The result is shown graphically in Fig. 2.3 and mathematically below. This polynomial function explains 96% of the variance (R^2) in the meta-analytical results. Because of the data used to derive this function, the exposure-response function refers to road traffic noise and to the daytime noise indicator $L_{day,16h}$. It is defined for noise levels ranging from 55 to approximately 80 dB(A):

$$OR = 1.63 - 0.000613 \cdot (L_{day,16h})^2 + 0.00000736 \cdot (L_{day,16h})^3$$

The analytical studies were chosen for the risk curve because of their generally accepted higher credibility with respect to causal inference. However, when both descriptive and analytical studies were considered together for one polynomial fit, the results were almost identical. This exposure-effect curve will regularly be updated with respect to information from new studies. For practical application, the odds ratios for different noise levels are given in Appendix 1 to this chapter.

Alternatively, a fixed-effect meta-analysis of a linear trend was carried out *(21)*. It revealed an OR of 1.17 (95% CI 0.87-1.57, $P = 0.301$, $P(Q) = 0.943$).

Fig. 2.3. Polynomial fit of the exposure-response relationship for road traffic noise and the Incidence of myocardial infarction



Source: Babisch (21).

Meta-analysis: road traffic noise and hypertension

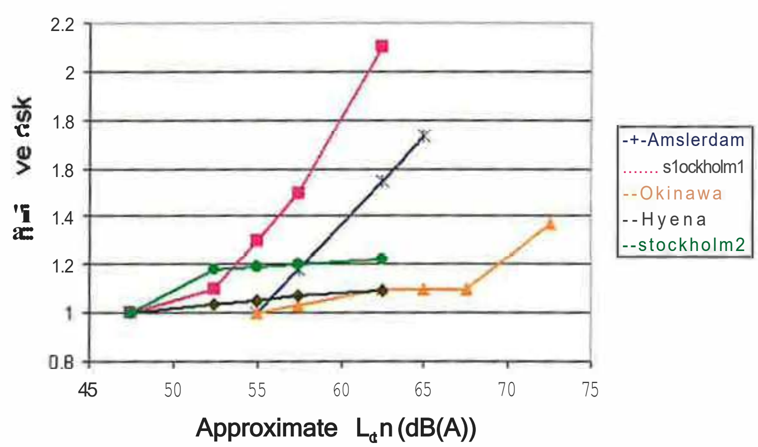
Regarding hypertension, a pooled estimate of the relative risk of 0.95 (95% CI 0.84-1.08) per 5-dB(A) increase in noise level during the day ($L_{day,16h}$ < 55-80 dB(A)) was calculated for the association between road traffic noise and hypertension based on a meta-analysis published in 2002 *(20)*. This estimate was recently updated based on new study results, and a pooled estimate of 1.12 (95% CI 0.97-1.30) was reported *(22)*. Significant results were found in two recently published studies, showing increases in the risk of hypertension of 1.05 (95% CI 1.00-1.10) per 5-

dB(A) increase in noise level (L24h = 45-75 dB(A)) *(128)* and 1.38 (95% CI 1.06-1.80} per 5-dB{A) increase in the 24-hour noise level (L24h,.. 40-70 dB(A)) *(129)*, respectively. In a study looking at the combined effecrs of road traffic noise and air pollution on the prevalence of hypertension, the odds ratios for noise did not wane after adjustment for air pollution *(130)*.

Meta-analysis: aircraft noise and hypertension

The results of five studies on the relationship between aircraft noise and high blood pressure are shown in Fig. 2.4 *(128,131-135)*. The scudy subjects were men and women. A noise-level-related data pooling (categorical approach) was difficult to perform owing co the fact that different (national) exposure indices were used. Furthermore, different definitions of hypertension were applied. Individual odds ratios and confidence intervals were taken from summary reports and the original publications for this purpose to calculate regression coefficients of individual studies and odds ratios with respect to the weighted day/night noise indicator L_{dn}, which is supposed to be very similar to Lden. When the c:oefficients of a linear trend from the five studies were taken together ("regression approach"), the pooled estimate of the relative risk was 1.13 (95% CI 1.00-1.28) per 10 dB(A) for aircraft noise levels ranging between approximately 47 and 67 dB(A) *(136)*. The statistical test for heterogeneity of the studies was significant (P(Q) = 0.002). However, fixed and random effect estimates were the same. Owing co the results of new studies, this pooled effect estimate was smaller than that obtained from an earlier meta-analysis where the estimate of the relative risk was 1.59 (95% CI 1.30-1.93) per 10-dB(A) increase in the noise level *(20)*.

fig. 2.4. Association between aircraft noise and the prevalence or incidence of high blood pressure



Source: Babisch & Van Kamp (136).

Disability weight

Different values of DW are used in the WHO comparative risk assessment reports by the different categories of epidemiological subregion that were defined based on geographical location and the level of infant and adult mortality (7).

The DW for acute myocardial infarction in the WHO EUR-A epidemiological subregion[2] is 0.405 *(7)*. However, disability weights of 0.108 and 0.186 are given for angina pectoris and congestive heart failure. No DW is given for ischaemic heart disease as a group. Hypertensive heart disease for the EUR-A epidemiological subregion is 0.201 but no DW is given for hypertension alone. In the literature, however, disability weights of 0.350 and 0.352 are reported for ischaemic heart disease as a group and for hypertension, and one year was considered for the duration of ischaemic heart disease and hypertension *(137)*.

EBD calculations

Two examples are given for calculating EBD from noise for cardiovascular disease. First, the exposure-specific approach is used to estimate the DALYs from myocardial infarction due to road traffic noise in Germany. Second, different noise exposure prevalence data are used to estimate the attributable fraction of myocardial infarction due to noise in Berlin.

£xposure-based approach for road traffic noise and myocardial infarction in Germany

An example i; given for Germany regarding road traffic noise and myocardial infarction. These £DB calculations use an exposure-based approach. The country-specific population-attributable fraction (impact fraction) and che attributable cases can be calculated based on the distribution of the population in different exposure categories and the respective relative incidence of disease. This approach requires:

- a population-based estimate of the prevalence of the outcome in Germany obtained from surveys or national statistics;
- an estimate of the attributable fraction of the outcome caused by environmental noise, calculated from German estimates of exposure prevalence and Fig. 2.3; and
- a value of DW for each case of the outcome caused by environmental noise.

Prevalence of noise exposure

According to the older German noise exposure model (Liirmbelastimgsmodel/), it was estimated (reference year 1999} that approximately 16% of the German population were exposed to road traffic noise levels (taken at the facades of their houses) exceeding 65 dB(A) during the day (L_{day}, 16h), chat some 15% were exposed to *60-65* dB(A) and chat approximately *69%* were exposed to levels below *60* dB(A) *(138)*. The noise distribution is shown in Table 2.2. During the night, noise levels tend to be 7-10 dB(A} lower.

Attributable fraction calculation

By applying the polynomial equation of the exposure-response function {Fig. 2.3) to che noise exposure distribution of the German population, it is possible to calculate an attributable fraction (AF) for each exposure group, that is, the proportion of cases of myocardial infarction due co noise exposure.

2 l11e WHO EUR-A epidemiological subregion comprises Andorra, A11stria, Belgium, Croatia, Cyprus, chc Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, lsrael, Italy, Luxembourg, Malta, Monaco, rhe Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzcrland and the Unired Kingdom.

The risk ratios attributed to the exposure categories are taken from *Fig.* 2.2. Using the formula of the population-attributable fraction (PAF) provides the following results:

$$PAF = \frac{(1.031 \cdot 0.153 + 1.099 \cdot 0.090 + 1.211 \cdot 0.051 + 1.372 \cdot 0.015 + 1 \cdot 0.691) - 1}{1.031 \cdot 0.153 + 1.099 \cdot 0.090 + 1.211 \cdot 0.051 + 1.372 \cdot 0.015 + 1 \cdot 0.691} = 0\_0291$$

The resulting attributable fraction of myocardial infarction due to road traffic noise for the German population in the year 1999 is therefore 2.9%.

Table 2.2. Example: attributable fraction for myocardial Infarction due to road traffic noise, estimated from the noise exposure pattern In Germany

Road traffic noise 1999, 4-r,1111 (dB(A))	Percentage expoaed	Relative rfsk	Attrfb�ble fraction
<60	69.1	1.000	0.00
60-64	15.3	1.031	3.03
65–69	9.0	1.099	9.03
7 74	5.1	1.211	17.44
>75	1.5	1.372	27.13

Cases of and deaths from myocardial infarction due to noise

According to the nacjonal health statistics, 849 *557* cases of ischaemic heart diseases (ICD 9, No. 410-414), including 133115 cases of acute myocardial infarction (ICD *9,* No. 410), were diagnosed in 1999 *(139).* The number of deaths due to myocardial infarction *in* Germany in 1999 was 76 961. So as not to double count cases when DALYs are calculated, the number of deaths was subtracted from the number of cases, leaving *56* 154 new cases that did not result in death.

To calculate the cases due to traffic noise, the number of cases of myocardial infarction is mul6plied by the attributable risk. Since there is no reason to believe that cases resulting in death should differ from those that do not with respect co noise exposure, the same attributable risk is applied to both groups of myocardial infarction cases.

The number of cases of non-fatal myocardial infarction (56 154) multiplied by 2.9% results in approximately 1629 new cases per year of non-fatal myocardial infarction in Germany attributable to traffic noise.

In *addition,* a proportion of deaths from myocardial infarction may also be attributable to traffic noise. Each of these deaths includes future YLL. Life expectancy at each age in 2002-2004 was used *(139).* For each age group, the number of deaths due to myocardial infarction Was multiplied by the life expectancy at that age separately for males and females. The total YLL for each sex was multiplied by 2.9% to give the YLL attributable to noise. This results in approximately 29 488 YLL.

Calculation of DALYs

To gain a rough estimate of the DALYs lost due to noise-related myocardial infarction for one year, the formulae in the previous chapter can be used:

DALY = YLL + YLD

where YLD = I · DW · L and YLL = number of deaths · average loss of life per death due to myocardial infarction.

Assuming one year of disability for each non-fatal case of myocardial infarction, the total **DALYs** are equal to:

29 488 + (1 629 · 0.405 · 1) = 30 147

This does not include ongoing morbidity after the first year.

Exposure-based approach for road traffic noise and myocardial infarctlon in Berlin

Another example, referring to the city of Berlin, is based on recent noise exposure data (L_{den} and L_{night}) derived from the strategic noise maps according to Directive 2002/49/EC *(113,140).* The noise distribution is shown in Table 2.3 and it can be seen that the prevalences of exposure are lower than those in Table 2.2. Since Berlin is a metropolitan city where the noise exposure is likely to be higher than in smaller communities and rural areas, the data suggest that the traffic noise exposure in Germany, in general, is lower than estimated by the old *Uirmbelastigungsmodell (138).* However, one has to consider that only the primary road network was assessed. On the other hand, traffic volumes of more than about 12 000 vehicles during the day (6:00-22:00) - corresponding to approximately L_{Aeq} = 65 dB(A) - are not very likely for the secondary road network. Applying the formula given above, the attributable fraction for Berlin is 0.0107, meaning that approximately 1.1 % of all myocardial infarctions would be attributable to the road traffic noise in Berlin.

Table 2.3. Estimated road traffic noise exposure for the city of Berlln

Average aound pressure level, L.i.,, (dB(A))	Number of citizens exPOaed•	Percentaf! exposed	Relative rlak of myocardial Infarctlon "
Approx.<55	2683449	80.53	**1.000**
>55-69	**220 200**	**6.61**	**1.000**
60-64	**155 000**	4.65	**1.015**
65-69	**140 200**	**4.21**	**1.067**
70-74	**112 600**	3.38	**1.161**
>75	20800	0.62	1.302

a Numbers refer to the primary road network of Berlin.
b Total population of Berlin: 3 332 249 (2005).
c Odds ratios are derived from lhe polynomial risk equation for lcsay,16h " Lden - 2 dB(A).

Estimation of Ischaemic heart disease burden from road traffic noise In the EU Member States

There is no international database on noise exposure of the European population covering the whole European Region. However, the Noise Observation and Information Service for Europe (NOISE) maintained by the European Environment Agency (EEA) and the European Topic Centre on Land Use and Spatial Information (ETC LUSI) on behalf of the European Commission provide noise exposure data that can be used for calculating disease burden in the western European countries. It contains data related to strategic noise maps delivered in accordance with EU Directive 2002/49/EC relating to the assessment and management of environmental noise (*141*). As for road traffic noise, the dataset covers the exposure distribution in approximately 20% of the total EU population as of January 2010. Bearing in mind that there are uncertainties and assumptions involved in using the exposure data based on strategic noise maps by the Member States (see below), we can use this official data to estimate burden of disease in the EU Member States.[3]

Table 2.4 summarizes the distribution of the population exposed to road traffic noise in agglomerations with more than 250 000 inhabitants, and relative risks and attributable fractions for respective exposure categories. The risk ratios attributed to different L_{den} categories are taken from Appendix 1 of this chapter. Applying the formula given above, the attributable fraction is 0.018, meaning that approximately 1.8% of all myocardial infarctions would be attributable to road traffic noise in these western European countries.

Table 2.4. Road traffic noise exposure for the European countries reporting noise maps

Road traffic nolu within agglomeration t..., (dB(A))	Pen:enta¥9 expoaed	Relative risk[b]	Attributable fraction
<55	60	1.000	0.00
55-69	17	1.000	0.00
6()-64	19	1.015	1.48
65-69	9	1.067	6.29
70-74	4	1.161	13.87

Source: Noise Observation and Information Service for Europe *(141)*.
a The population size is 110 million living in agglomerations with> 250 000 inhabitants.
b The risk ratios attributed to different L_{den} categories are taken from Appendix 1 of this chapter.

3 Austria, Bulgaria, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

In 2008, WHO published an updated report on global burden of disease (142). In this report, the DALYs for disease cluster categories were reported by different subregions based on income levels. High-income European countries[4] correspond to the EUR-A subregion with very low child and adult mortalities in the previous reports. DALYs of cardiovascular diseases are reported in the categories of rheumatic heart disease, hypertensive heart disease, ischaemic heart disease, cerebrovascular disease and inflammatory heart diseases. The total burden of ischaemic heart disease is 16 826 000 DALYs out of 883 million people in the WHO European Region, of which 3 376 000 DALYs are out of 407 million people in the high-income European countries. As DALYs for myocardial infarction were not published, we applied the above attributable fraction to the category of ischaemic heart disease. In other words, for the sake of DALY calculation, we assumed that road traffic noise has the similar impact on all ischaemic heart disease as on myocardial infarction. In high-income European countries, DALYs attributable to transport noise were estimated to be 60 768 years (1.8% of 3 376 000 DALYs) (142).

Uncertainties, limitations and challenges

Blo/oqical plausibility of association

The biological plausibility of the hypothesis of noise effects is well-documented (see previous section summarizing the evidence). Acute noise effects have been studied extensively over the past 50 years, and a general noise reaction model was well-established before research moved from the laboratory to test hypotheses with respect to the long-term effects of noise in epidemiological studies.

The auditory system is continuously analysing acoustic information, which is filtered and interpreted by different cortical and sub-cortical brain structures causing acute responses of the autonomic nervous and the endocrine system, even during sleep. Long-term noise stress can adversely affect biological risk factors due to chronic dysregulation. Considering this pathway, noise must be viewed as an environmental risk factor. In epidemiological noise studies, higher risk estimates were found when length of exposure was considered (years in residence). The same accounts for room orientation and window opening habits (higher risks when rooms were facing the street with windows open). This is in accordance with the noise hypothesis and the effects of chronic noise stress (exposure effect).

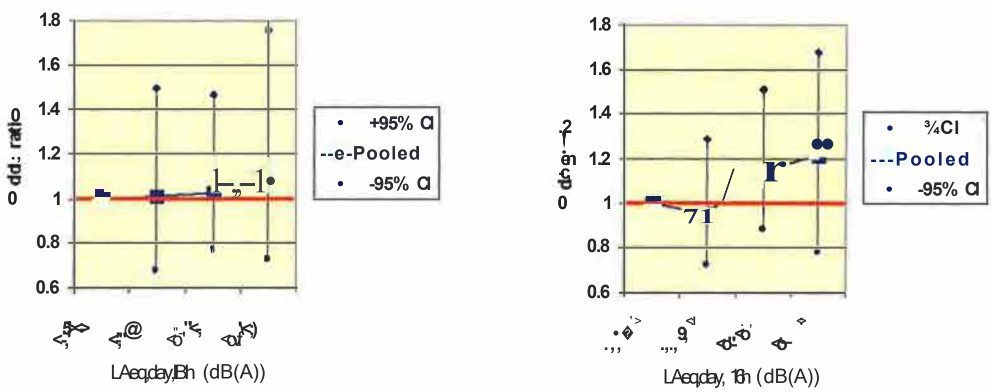
Generalization of myocardial Infarction to other ischaemic heart diseases

Myocardial infarction was considered for the meta-analysis because it was the outcome most commonly assessed in the studies that met the inclusion criteria for the review. The noise impact on myocardial infarction may have been easier to detect by epidemiological studies, because misclassification in the diagnosis of myocardial infarction is less likely than for all ischaemic heart diseases. Ischaemic heart disease comprises: acute myocardial infarction, other acute and sub-acute forms of ischaemic heart disease, old myocardial infarction, ischaemic signs in the electrocardiogram, angina pectoris, coronary atherosclerosis and chronic ischaemic heart disease.

4 High-income European countries are: Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, the Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Because there is no exclusive causal mechanism postulated specifically for myocardial infarction, it has been suggested that the impact fraction of traffic noise could be applied to all types of ischaemic heart disease. Therefore, the exposure-response curve for myocardial infarction could be generalized to all ischaemic heart diseases for the calculation of DALYs. This is supported by Fig. 2.5 and Fig. 2.6, which shows the associati-on between road traffic noise level during rhe day ($L_{day,16h}$) aad the prevalence of myocardial infarction and ischaemic heart diseases based on two studies, where all detailed information was assessed within each study *(126)*. It can be seen that rhe associatioJ;l.S with the noise level look quite similar. The point estimate of pooled effect estimates for noise levels higher than 60 dB(A) are slightly higher for (all} ischaemic heart diseases than for myocardial infarction.

Fig. 2.5 & 2.6. Exposure-response curve for road traffic noise and the prevalence of myocardial Infarctlon (Fig. 2.5, left) and all Ischaemlc heart diseases (Fig. 2.6, right)



Source oflhe data: Babisch et al. 1993 *(126)*

Specificity of hypertension as an outcome

Pooling of data is difficult when different criteria and assessment methods for the disease cnd-po.incs were used in_different studies. For example, with respect to hypertension, some aircraft noise studies refer to the former WHO criterion of a measured blood pressure of 160/100 mmHg, while others refer to the cu_rrent WHO criterion of 140/90 rnmHg. Perhaps more importantly, different determinants of high blood pressure were used, including self-reported doctor-diagnosed hypertension, anti-hypertensive drug medication, actual blood pressure measurements, or combinations of the three. The heterogeneity of the studies may be less of a problem with respect to the slope of the pooled exposure-response curve. However, decisions must be made regarding the onset (tlrreshold) of the increase in risk. For the calculation of the attributable fraction, estimates of different scenarios can be made.

Generalization of evidence to both sexes

The exposure-response curve derived from male study subjects was generalized to women. The subjects in the noise studies were mostly men, owing to considerations of statisrical power in the study design. Cardiovascular diseases are more frequent in middle-aged males *(143)*. For reasons of homogeneity, the relatively small number of females was excluded from the calculation of the pooled effect estimates.

The available results of noise studies do not allow for a distinction between the sexes. There is some indication that males may be more affected by road traffic noise *(125,128,144,145)* but contradictory results have also been found *(129).* Studies on the association between environmental noise and high blood pressure showed no consistent pattern with respect to higher relative risks in either men or women *(18).* In studies where females were considered, the hormonal/menopausal status was not assessed, which could act as a confounder (falsely showing differences between the sexes) *(146).*

In laboratory studies, the focus was primarily on "before-after" effects of noise exposure in the same test subjects rather than on gender differences. In occupational noise studies, gender was often considered as a confounding factor but not as a potentfaliy effect-modifying factor in the statistical analyses. Male blue collar wo.rkers were predominantly found in high-noise workplaces. Scudies on the association between environmental noise and high blood pressure showed no consistent pattern with respect to higher relative risks in either men or women *(121).*

Although there are differences in the absolute risk between males and females, it seems reasonable to assume that, in relative terms, females may be just as affected by noise stress as males. Nevertheless, in future noise studies, potential gender diJferences should be addressed.

Issues of statistical siqnlflcance

The confidence intervals of the effect estimates shown in Fig. 2.1 and 2.2 for the association between traffic noise and myocardial infarction include relative risks of 1.0. The purpose of the meta-analysis was to derive a "best guess" pooled relationship for the cal.culation of population-attributable risks. Individual studies showed significant ($P < 0.05$) or borderline significant ($P < 0.10$) results when the highest exposure categories were combi.n.ed and/or subsets of subjects with long years in residence were considered *(124,125).* When the meta-analysis is carried out for subsamples of subjects that had lived for ac least 10 or 15 years in their dwellings, larger effect estimates were also obtained in the meta-analysis *(21)*. For example, when the upper two noise categories of the exposure-response curve are combined, the pooled effect estimate is OR = 1.25 ($P = 0.068$) in the total sample, and OR = 1.44 ($P = 0.020$) in the sub-sample, the latter being scacisticalJy significant. Regarding linear trend, the odds ratio in the sub-sampl.e of subjects with many years of residence was 1.44 per 10-dB(A) increase in the noise level (CI 0.97-2.12, $P = 0.067$), which was borderline significant. However, for the calculation of population-attributable risk percentages, che weaker effect esti.mates were considered to apply to the entire study populations, because information about modifiers of exposure such as length of residence or window/room orientation will not be available for general populations. Depending on the results of new studies, the current risk curves must be regularly updated.

Lack of exposure data

The lack of accurate exposure data is a major hindrance in estimating actual burden of disease. How can exposure data from countries and subregions be obtained? EU Member States have just started to systematically assess the environmental noise due to road, rail and air traffic and commercial/industrial activities in their communities according to EU Directive 2002/49/EC (113). The noise mapping data for Directive 2002/49/EC can be used as shown above. It should be noted that the application of the exposure data for the urban popu.lation to the total population in the EU may lead ro overestimation of burden. To avoid chis possibility, we extrapolated only to agglomerations with > 50 000 inhabitants (57% of the EU population). Tbe accuracy and representativeness of exposure data will improve when the second round of noise mapping produce data from agglomerations with 100 000-250 000 inhabitants in 2012. Exposure data will be still sparse from the WHO EUR-B[5] and EUR-C[6] epidemiological subregions. Extrapolation of exposure data from EUR-A to the EUR-B and EUR-C epidemiological subregions might be problematic because the level of noise exposure of the population might be quite different between these subregions.

Road traffic is a key environmental noise source. However, results from epidemiological studies with respect to the association of other environmental noise sources (such as air traffic noise, railways *or* even leisure noise) with myocardial infarction are rarely available. For the time being, the exposure-response curve derived for road traffic noise could be used, considering that at the same average noise level, aircraft noise tends co be more annoying and conventional railway noise less annoying than road traffic noise (119,147). Furthermore, exposure misclassification diluting the true effects is less of a problem with respect to aircraft noise because all sides of the house are equally exposed. *(Note.* According to Directive 2002/49/EC, noise levels refer co the most exposed side of a dwelling.) The characteristics of road traffic noise and its effecrs can be quite different from rail and aircraft noise, which is an additional source of uncertainty when applying road noise curves co other noise sources and vice versa.

Confoundinq with air pollution

Air pollutants have also been shown to be associated with cardiovascular end-points *(148-155).* In real life, individuals exposed to road noise are also likely to be exposed co air pollution arising from road traffic. It is not yet clear whether the impact of noise on ischaemic heart disease is independent, additive or synergistic to the impact of outdoor air poUucion. Air pollution studies have not controlled for noise and vice versa. Air pollution epidemiology carried out in the last century focused primarily on respiratory illness, which was not an issue in noise research. However, cardiopulmonary mortality was also identified as a key outcome of acute and chronic exposure to air pollutants.

Most information on hospital admissions due to acute changes (increases) in levels of air pollutants come from time-series studies (150). Studies on short-term exposure to el.evaced concentrations of fine particulate matter are associated with acute changes in cardiopulmonary health. However, since traffic volume does not show

5 llle WHO EUR-B epidemiological subregion comprises Albania, Armenia, Azerbaijan, Bosnia and Herzcgovina,Bulgaria, Georgia, Kyrgyzsmo, Monrencgro, Poland, Romania, Serbia, Slovakia, Tajikistan, the former Yugoslav Republic of Macedonia, Turkey, Turkmenistan and Uzbekistan.

6 11w WHO EUR-C epidemiological subregion comprises Belarus, Estonia, Hungary, Kaz.akhstan, Larvia, 6Lithuania, the Republic of Moldova, the Russi.in Federation and Ukraine.

considerable day•-to-day variations, the changes in air pollution in these studies are due to other factors that affect the concentration of air pollutants, mainly changes in weather conditions. Noise levels in urban environments, on the other hand, are primarily determined by the relatively constant traffic volume per day, and much less by weather conditions when the disranee of houses from the street is short (urban noise). In this respect, confounding between noise and air pollution is not likely with respect to short-term effects in time-series studies.

TJle health effects of noise in general refer co long-term chronic noise stress. Confounding can be an issue in long-term effects observed by cross-sectional, case-control and cohort studjes. Epidemiological studies have shown strong associations of mortality and life expectancy with long-term exposure to fine particulate matter and sulfates *(156)*. However, the study designs of cohort studies on the association between air pollutants and cardiopulmonary mortalicy differ considerably from those of noise exposure. In air pollution studies, the spacial exposure is often considered on an ecological basis. Subjects from djfferent metropolitan areas with different mean (background) concentrations of air pollutants have been compared with respect co disease occurrence. No distinction is usually made between busy streets and side streets *(148,149,152,157)*. In noise studies, the exposure in front of a srudy participant's house was assessed on an individual level with respect to nearby sound sources, along with individual confounding factors. Differences of 1:100 (20 dB(A)) in terms of sound intensicy are common for people living in different streets or even only a few yards away from one another, because shielding is highly effective for noise. The sound level can diminish from the front to the back of a house by 30 dB(A) or more (sound intensity 1:1000). To some extent, one could say that major air pollution studies refer to macro-scale exposures while noise studies refer to micro-scale exposures.

Further, cardiovascular effects of noise (hypertension) were also found for noise sources where air pollutants are less likely to be co-varying factors, e.g. occupational noise *(20)* and aircraft noise *(121)*. It was shown that the relative contribution of airport operations to the emission levels of nitrogen oxides, carbon monoxide, sulfur dioxide, volatile organic compounds and bJack smoke was small compared to the background concentrations in the vicinity of an airport *(158)*. In spite of this obvious co-exposure, there was a lack of .interaction between the scientific community dealing with the health impacts of noise and that dealing with air pollution. However, this has changed in recent years and studies on their combined effects are currently under way *(130,159,160)*. Some studies have used the distance to major roads as a surrogate for exposure to air pollutants. However, noise would be as good an explanation for che observed effects *(161-165)*.

Method of calculating the exposure-response relationship

Different approad,es have been used to calculate pooled effect estimates and exposure-response relationships. These include the "regression approach" and the "categorical approach". In the regression approach, the slopes (regression coefficients) across all noise categories of each noise study are pooled to assess a common regressioncoefficient. In the categorical approach, the relative risks found for the same noise category in each noise study are pooled and considered for the calculation of an exposure-response CUive. The regression approach has the advantage that regression coefficients can be pooled regardless of actual noise levels; only the slope (regression coefficient) of the exposure-response relationship is taken into account. The categorical approach is noise-level oriented. Possible thresholds of effects can be determined, and it *is* less likely co obscure possible non-linear associations, but it requires comparable exposure indicators of the studies considered in the meta-analysis. Often both, trend and categorical contrast analyses are carried out simultaneously (128).

Conclusions

The noise indicators used for noise mapping in the EU can - in principle - be used for a quantitative risk assessment regarding cardiovascular risk if exposure-response relationships are known. Only two end-points - hypertension and ischaemic heart disease - should be considered at this stage. If necessary, different exposure-response curves could be used for different exposures. Some studies showed that associations between noise level and cardiovascular outcomes were stronger with respect to noise exposure at night *(128,166,167).* In this respect, it can be useful co consider different exposure-response relations!tips for day and night noise, particularly if the exposed side of the house is considered for exposure assessment. For practical reasons, attempts should be made to reduce the set of necessary exposure-response curves to a minimum. The noise indicator L_{den} may be useful for assessing and predicting annoyance in the population. However, non-weighted day and night noise indicators may be more appropriate for health-effect-related research and risk quantification. It is a matter for future research to determine how the integrated noise indicator L_{den} performs in noise studies, particularly with respect to noise sources (railways, aircraft) other than road traffic where the differences between day and night noise are less uniform and depend on location and other circumstances (e. g. night noise regulations).

We adopted conservative assumptions whenever necessary. One exception was to extrapolate the exposure data from urban population to the whole population of the EU. This was necessary because of a lack of exposure data for the rural population as of 2010. Considering the advanced level of Uibanizacion in western Europe and the bias toward the null in the estimation of relative risks due to random misclassification of exposure, the overall impact of overestimation due to extrapolation might be minimal. Nevertbeless, it is desirable to use exposure data for the whole population when it is available.

We have to learn to live with uncertainties *(168,169).* Nevertheless, "no exposure data" does not mean "no exposure" and "no scientific evidence" does not mean "no effect" *(170).* Using the precautionary principle, decisions can be made based on best available data *(171,172).* Future epidemiological noise research *will* need co focus on vulnerable groups, effect modifiers, sensitive hours of the day, coping mecharusms, differences between noise sources, possible con.founding with air pollution, differences between objective (noise level) and subjective (noise perception) exposure, and multiple exposures (home, work and leisure environments).

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Appendix 1. Exposure-response curve (polynomial fit) of the association between road traffic noise and incidence of myocardial Infarction

$$OR = 1.629657 - 0.000613 \cdot (L_{day,16h})^2 + 0.000007357 \cdot (L_{day,16h})^3$$

Lciay,18h	l.ian·	O R
55	57	1
55.5	57.5	1
56	58	1
56.5	58.5	1
57	59	1
57.5	59.5	1.002
58	60	1.003
58.5	60.5	1.005
59	61	1.007
59.5	61.5	1.009
60	62	1.012
60.5	62.5	1.015
61	63	1.019
61.5	63.5	1.022
62	64	1.027
62.5	64.5	1.031
63	65	1.036
63.5	65.5	1.042
64	66	1.047
64.5	66.5	1.054
65	67	1.06
65.5	67.5	1.067
66	68	1.074
66.5	68.5	1.082
67	69	1.091

l:<!ay,llIh	La.o·	O R
67.5	69.5	1.099
68	70	1.108
68.5	70.5	1.118
69	71	1.128
69.5	71.5	1.138
70	72	1.149
70.5	72.5	1.161
71	73	1.173
71.5	73.5	1.185
72	74	1.198
72.5	74.5	1.211
73	75	1.225
73.5	75.5	1.239
74	76	1.254
74.5	76.5	1.269
75	77	1.285
75.5	77.5	1.302
76	78	1.318
76.5	78.5	1.336
77	79	1.354
77.5	79.5	1.372
78	80	1.391
78.5	80.5	1.411
79	81	1.431
79.5	81.5	1.452
80	82	1.473

"Approximation: Ld_{an} -' IA_{aq},16h + 2 dB

3. ENVIRONMENTAL NOISE AND COGNITIVE IMPAIRMENT IN CHILDREN

Staffan Hygge
Rokho Kim

It has been suspected for many years that children's learning and memory are negatively affected by noise. Over 20 studies have shown negative effects of noise on reading and memory in children *(1,2):* epidem.iological studies report effects of chronic noise exposure and experimental studies report acute noise exposure. Tasks affected are chose invol.ving central processing and language, such as reading comprehension, memory and attention *(3-6).* Exposure during critical periods of learning at school could potentially impair development and have a lifelong effect on educational attainment.

Evidence from recent well-controlled epidemiological studies with representative samples of children has also made it possible to start to quantify the magnitude of noise-induced impairment on children's cognition and identify the relative contribution of different sources of noise. Children may be exposed to noise for many of their childhood years and the consequences of long-term noise exposure on reading comprehension and further cognitive development remain unknown. Such quantifications, albeit initia!Jy crude, will in the long run help to estimate and quantify how much cognitive development individual children could be expected to lose because of noise, and the econom.ic impact of this for learning in schools. In turn, such estimates will be also of value *for* making projections on the societal level, including political decision about any sociodemographic redistribution of noise exposure. On the other hand, exposure-response curves can also be used for social engineering decisions about llow much of an improvement, and for whom, can be expected from a reduction in noise levels.

This chapter attempts to contribute to this general goal by placing the negative effects of noise on children's cognition into the risk assessment context.

Definition of outcome

Cognitive impairment is not an outcome of a clinical diagnosis; it is therefore not possible to derive a conventional exposure-risk relationship suitable for calculating burden of disease. Lopez et al. *(7)* defined cognitive impairment as "delayed psychomotor development and impaired performance in language *skills,* motor skills, and coordination equivalent to a 5- to 10-point deficit in IQ". Contemporaneous cognitive deficit is defined as "reduction in cognitive ability in school-age children, which occurs only while infection persists".

These definitions are not helpful and not readily applicable to the studies reported on noise and cognition in children. None of the studies has explicitly employed IQ as an end-point and the confining of any reduction in cognitive ability to the duration of the noise exposure is too restrictive. Therefore, our case definition of noise related cognitive impairment is:

> Reduction in cognitive ability in school-age children that occurs while the noise exposure persists and will persist for some time after *the* cessation of *the* noise exposure.

A notable characteristic of this definition is that the cognitive impairment is assumed to show itself during the noise exposure as well as some time after the exposure has stopped.

Summary of evidence linking noise and cognitive impairment in children

The extent co which noise impairs cognition, particuJarly in children, has been studied with both experimental and epidemiological designs. The epidemiological studies report effects of chronic noise exposure and the experimental scudies of acute noise exposure. The srudies relevant to children's cognition are not many and do not always meet strict methodological criteria. Nevertheless• there are three recent studics that meet basic methodological quality criteria and are also comparable with each ocher in terms of the cognitive functions measured.

One of the most compelling studies in this field is the naturally occurring longitudinal quasi-experiment reported by Evans and colleagues, examining the effect of t ie relocation of Munich airport on children's (9-10 years, N::; 326) health and cognition *(8-10).* In 1992, the old Munich airport closed and was relocated. Prior to relocation, high noise exposure was associated with deficits in long-term memory and reading comprehension. Two years after the closure of the airport, these deficits disappeared, indicating that effects of noise on cognition may be reversible if exposure ceases. Most convincing was the finding that deficits in the very same memory and reading comprehension tasks developed over a two-year follow-up in children who became newly exposed to noise near the new airport.

The recent large-scale RANCH study, which compared the effect of road traffic and aircraft noise on children's (9-10 years, N =; 2844) cognitive performance in the Netherlands, Spain and the United Kingdom, found a linear exposure-effect relationship between long-term exposure to aircraft noise and impaired reading comprehension and recognition memory, after taking a range of socioeconomic and confounding factors into account *(JJ).* No associations were observed between long-term road traffic noise exposure and. cognition, with the exception of episodic memory, which surprisingly showed better performance in high road traffic noise areas. Neither aircraft noise nor road traffic noise affected attention or working memory.

A study of ambient noise exposure (predominantly road and rail sources) of fourth-grade children living in the Tyrol mountain region compared three cognitive measures for schoolchildren (mean age 9-7 years, N = 123) exposed to 46 or 62 dB(A) Ld_n-The two sociodemographically homogeneous samples differed only in their noise exposure range (M = 46.1 Ld_n vs M = 62 Lcln). Long-cerm noise exposure was significantly related to both intentional and incidentaJ memory. The improvement in cognitive performance in the quieter group was estimated at 0.5% (recaU prose and recognition) to 1% (free recall) per dB. The authors note that the magnitude of the effects shown was smaller than those uncovered in earlier airport noise studies.

Both the RANCH and Tyrol studies indicate that aircraft noise may be worse for cognition than road traffic noise. For aircraft noise, exposure evidence from the Munich study seems to indicate that LAcq = 60 may be a dividing line, but the RANCH study results suggest more of a linear association between aircraft noise exposure and impairment of reading comprehension. For ambient road and rail noise, the Tyrol study suggests that effects occur around Ldn = 60.

Other field studies of children have had some methodological limitations, which make them less relevant as evidence. For example, the testing of cognitive capacities took place in noisy conditions for the noise-exposed and in quieter conditions for the children in the control groups. Testing in silent conditions would have been preferred, in order to compare the noise effect on memory and learning between exposure and control groups *(12-16)*. Also, for some studies, the sociodemographic variables and different reading curricula between the schools were not fully adjusted or controlled for.

ExperimenraJ studies of the impact of acute noise exposure on reading and memorizing new material are generally not as vulnerable to selection biases as epidemiological studies. Memory tests are made in silence of material that was read in noise. Participants are randomized to exposure and conrrol groups, and children are sampled from sociodemographically comparable schools. To a certain extent, there is comparability between the memory and reading tests employed in the experimental studies and the field studies (the Munich and RANCH studies), even though the field studies concern chronic noise exposure and the second set acute noise exposure.

Exposure-response relationship

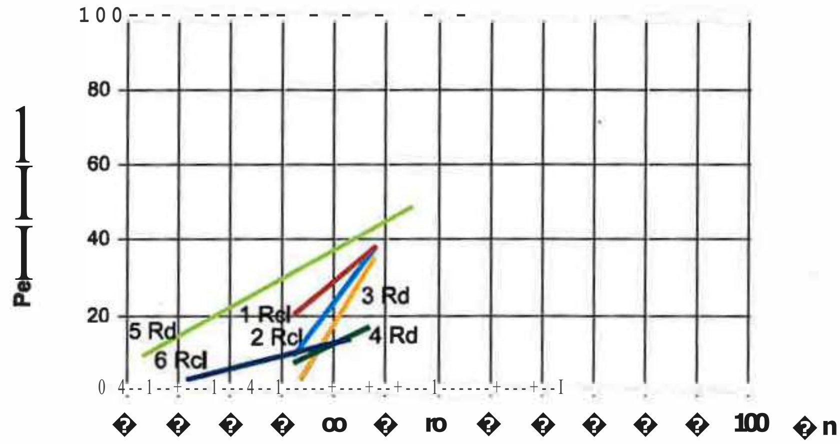
Only the Tyrol study *(17)* has used the noise indicator Ld_n-The Munich study used Leq,24h and the RANCH study predominantly used Lcq,J6h• The Ldn and 4 q metrics are not directly equivalent: Ld_n is always equal to or larger than Lcq, with the following differences between Ldn and Leq (T. Gjestland, personal communication, 2006):

- evenly distributed traffic flow, + 6.4 dB
- evenly distributed 07:00-22:00, no night traffic, + 1.9 dB
- 10% of traffic during 22:00-07:00, + 2.9 dB.

Although it is not clear which noise metric is the most adequate, Ldn may be more appropriate for the measurement ofnoise effects on cognition for some specific noise sources. For example, for aircraft noise exposure, the RANCH study found that both school Lcq,I6h and home Leq,8h (so a ,:omparison of daytime noise exposure at school and nighttime noise exposure at home) had a similar detrimental effect on reading comprehension scores. These findings suggest that a measure such as Ld_n, which combines daytime and nighttime exposure, would be appropriate for examining the effects of aircraft noise on cognition. However, this issue may be more complicated for other noise sources. For cognition, the fact that children spend the daytime at school and the nighttime at home needs to be taken into consideration. Aircraft noise exposure at school and home were highly correlated in the RANCH study, which could account for the similar effect on cognition for the daytime and nighttime measures. Road traffic noise at home and school were less highly correlated, suggesting that exposure measures that cover the 24-hour period may be less reliable in detecting cogn_itive effects and could be associated with error.

Fig. 3.1 shows the exposure-response curves from the different epidemiological studies. This can be summarized in quantitative terms: for the field studies in Fig. 3.1, memory recall and reading have average slopes of around 2% per Ld_n, as calculated by the mean of the slopes of the six lines. Thus, for recall and reading, it is expected chat a reduction of the chronic noise level by 5 Ld_n would result in improved performance by 10%. As noted above, the only available road traffic noise study *(17)* had a less steep slope. The fact that we do not have much data from road traffic noise exposure set a limit to the generality of our conclusion, but the results of studies on aircraft noise, albeit few, are nevertheless consistent.

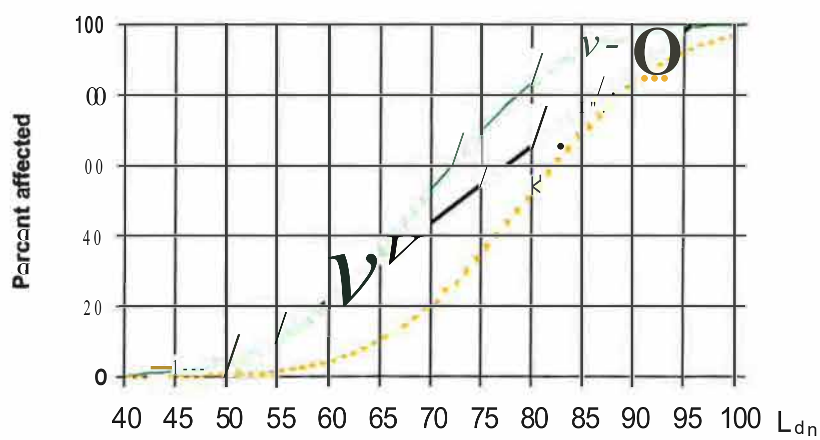
Fig. 3.1. Exposure-response curves from different epidemiological studies



Notes. Rd = reading; Rcl = memory, recall
1 = recall, children, old airport *(10).*
2 = recall, children, new airport *(10).*
3 = reading, children, old airport *(10).*
4 = reading, children, new airport *(10).*
5 = reading, children *(11).*
6 = free recall, children *(17).*

To obtain the exposure-response relationship, we need to use the information above to determine an approximate curve. Assuming that 100% of those exposed to noise are cognitively affected at the very high noise levels, e.g. 95 L_{dn}, and that none are affected at a safely low level, e.g. 50 L_{dn}, a straight line (linear accumulation) connecting these two points, as in Fig. 3.2, can be used a basis for approximations. This scraight line is an underestimation of the real effect, since for theoretical reasons based on an (assumed) underlying normal distribution, the true curve should have the same sigmoidal function form as the two curves in Fig. 3.2. Within the noise exposure bracket 55-65 L_{dn}, the straight line and the solid line sigmoidal distribution agree on approximately 20% impairment. In the bracket 65-75 L_{dn}, the number should be in the range of 45-50% and above 75 L_{dn} in the range of 70-85%.

Fig. 3.2. Hypothetical exposure-risk curves and estimated percentage of affected people



Disability weight

Lopez et al. *(7)* suggested DWs for different cognitive impairments ranging from 0.468 (e.g. Japanese encephalitis) or 0.024 (e.g. as a result of iron deficiency anaemia). Contemporaneous cognitive deficit was given a DW of 0.006. Thus, this is a very conservative choice to go with the definition of co.nremporaneous cognitive deficit and a DW of 0.006 in estimates of the noise-related impairment of children's cognition.

There would be no mortality due to cognitive impairment, so estimation of YLD per year will be sufficient to estimate the total DALYs.

EBO calculations

Two examples are given. First, the exposure-specific approach is used to calculate the burden of disease from cognitive impairment due to noise in children aged 7-19 years in Sweden. And second, the values estimated in the first example are extrapolated to all of the WHO EUR-A epidemiological subregion *(7)*.

Note that the calculations rest on the assumption that the noise effects are there only when people are exposed. There is no assumption made that the inflicted noise-induced disability lasts longer than the noise exposure. It would not be unreasonable to set a case also for lasting cognitive effects of noise after the cessation of exposure, but that has explicitly not been done here.

Exposure-specific approach to environmental noise and coqnitive impairment In Swedish children

For the first example, the exposure-specific approach is used to calculate the burden of cognitive impairment due to environmental noise in children aged 7-19 in Sweden. This approach requires:

- the distribution of the prevalence of exposure to environmental noise within the population from EU data;
- the exposure-response relationship between noise and the outcome from Table 3.1; and
- a value of DW for each case of the outcome caused by environmental noise.

Prevalence of noise exposure

There are no relevant figures for how many children are exposed to different noise levels. What are available are estimates of the percentage of people exposed to noise at different levels in the EU. For instance, Roovers et al. *(18)* stated that around 68% are exposed to Ldn levels< 55, 19% to 55-65, 11 % to 65-75 and 2% to> 75. This is shown in Table 3.1, although statistics for the specific countries within geographical regions such as the EU may vary *(19)*.

The noise exposure distribution shown in Table 3.1 is for adults, but there is no reason to believe that the exposure distribution for children is very different. If there is a difference in noise exposure levels, children are more likely than adults to be exposed to noise.

To calculate the number of children exposed to the noise levels that meet the criterion of cognitive impairment, the age distribution in the population must be considered. In Sweden, 23.9% of the population are aged under 20 years and 16.53% were in the age range of the mandatory school system in 2004. In 2004, there were 1 489 437 school-aged children in Sweden. It can be noted that the proportion of the population up to 19 years (23.95%) fits closely with the 24.2% for the EU in 1998 *(19)*.

Table 3.1. Percentage of the populatlon exposed to various levels of noise (Ldn) and calculated number of exposed children aged 7-19 years

Noise level (Ldn)	Popul11tlon exposed	Number of chlldren expoHd
<55	68%	1 012 817
55-65	19%	282 993
65-75	11%	163 838
>75	2%	29 789
Total	100%	1489437

Source: **Roovers et al.** *(18).*

Number of cases of and YLD from coqnltlve impairment caused by environmental noise

Combining the number of children exposed (Table 3.1) with the likelihood of cognitive impairment *if* exposed (Fig. 3.2), the number of children with noise-induced cognitive impairment can be calculated. To estimate YLD due to the cognitive impairment, this number is multiplied by the DW of 0.006 (Table 3.2).

Table 3.2. Estimated number of children aged 7-19 years in Sweden with noise-induced cognitive Impairment and DALYs per year due to noise-induced cognitive Impairment (NICI)

Age group end noise expo1ure level	No.of children aged7-19 exposed	Percentage ofchlldren whowlll develop NICI	No.of children with NICI	DALYs lost tor NICI
7-19 years,< 55 L.„	1 012 817	0	0	0.0
7-19 years, 55-65 Ldh	282 993	20	56599	339.6
7-19 years, 65-75 Ldh	163 838	50	81 919	491.5
7-19 years.> 75 L,i.	29789	75	22342	134.1
Total	1489437		160 859	965.2

According to our estimates, there are 160 859 Swedish children aged 7-19 (point prevalence) who could be cognitively impaired to the extent of DW 0.006. This can also be considered equivalent to 160 859 years lived with chis disability in 2004. This amounts to 965 YLD for noise-induced cognitive impairment in Swedish children aged 7-19 years. This estimate is based on the conservative assumption chat noise effects on cognitive impairment and childhood learning are temporary.

£xposure•speclflc approach for environmental noise and coqnltlve Impairment In children In the £UR-A epldemloloqlcal subreqlon

The noise exposure figures in Table 3.1 were taken to be representative for Europe, and the distribution of children aged 7-19 years of age in Sweden is close to that reported for Europe as a whole. Therefore, the number of DALYs per million children aged 7-19 in the EUR-A cow1tries can be calculated (Table 3.3). The absolute DALY for the EUR-A countries, with an estimated total population of 420 503 million, is therefore 45 036.

Table 3.3. Estimated DALYs per year per million children aged 7-19 in the EUR-A epidemiological subregion

Age group and noise exposure level	Percentage of population exposed to noise level	Percentage of population whowill develop cognitive Impairment	Number Impaired per mlllon	DALYs lost permllllon
7-19 years,< 55 Ln	11.24	0	0	0.0
7-19 years, 55-65 Ldh	3.14	20	6 281	37.7
7-19 years, 65-75 Ldh	1.82	50	9 090	54.5
7-19 years,> 75 Ldh	0.33	75	2475	14.9
All other age groups	83.47	0	0	0.0
Total	100.00		17 846	107.1

Uncertainties, limitations and challenges

Source of noise

The slopes reported in Fig. 3.1 are for aircraft noise only. In contrast to the Munich study, which focused on aircraft noise, the RANCH study also included road traffic noise. But for road traffic noise, there was no indication of a significant impairment of children's cognition. As an explanation, the authors pointed out that aircraft noise, because of its intensity, the location of the source, and its variability and unpredictability, is likely to have a greater effect on children's reading than road traffic noise, which might be of a more constant intensity. Thus, it is conceivable that aircraft noise is more damaging than road traffic noise for children's cognition. This may also be true when the Ldn level is controlled for, which has been reported for children's memory in an experimental acute noise study *(20)*.

Even though there may be a degree of difference between aircraft and road traffic noise, acting on the safety principle would suggest treating them as equally damaging to children's cognition and to assume that there is approximately the same response effect regardless of noise source. This may, however, tend to overestimate the effects of road traffic noise.

Desiqn of epldemloloqical studies

It should be noted that the RANCH study was a cross-sectional study in contrast to the prospective, longitudinal Munich study. This may make the Munich study more powerful in picking up unconfounded cause-effect relationships between noise exposure and outcomes.

Possibility of lonq-term coqnitive impairment from chronic noise exposure

The DALYs calculated in Table 3.2 have not taken into account any lasting or long-standing impairment of cognitive functioning that could occur as a result of long-term noise exposure. Our calculations are restricted to the period in children's life when they attend primary school, assuming that the impacts of noise are negligible on the cognitive function of adults. This assumption is very conservative, however, because it is more likely that children who have passed through the mandatory school system in a noisy environment would live with a long-term consequence of cognitive impairment. They are also more likely to live in a noisy environment even after the schooling period, which is more likely for children who go co school in areas exposed to aircraft noise. It would be realistic co assume that the impaired cognitive function will carry over to the years after the schooling period. If future studies provide an estimation of the severity and the duration of such chronic effect of noise on cognitive function, the calculation of DALYs should be updated.

Assumption of the duration of the impact

There is some evidence from the Munich study *(10)* that after the cessation of exposure to aircraft noise, children (age 9-11 years) recover within 18 months to the cognitive performance levels of their year-mares who were not exposed to much aircraft noise. Thus, it is possible that, at least for young children, chronic noise effects are reversible and that the DWs will diminish with increasing age. However, we assumed in our calculation that the effects are temporary and recovery is quicker, yielding YLD values that are conservative.

Assumption of the exposure-risk relationship

As pointed out above, with reference to the linear and sigmoidal accumulation of effects in Fig. 3.2, we have most likely not overestimated the fractions of children affected in the noise exposure ranges 65-75 Ldn (50%) and> 75 Ld_n (75%). Further, we might have underestimated the average DW (0.006) for those affected by the higher level of noise. These two conservative assumptions may have led to a significant underestimation of the real DALYs in the EUR-A epidemiological subregion given in Table 3.3. For example, if DW doubles and quadruples to 0.012 and 0.0024 in the exposure brackets 65-75 Ld_n and > 75 Ldn, respectively, the DALYs will be much greater than shown in Table 3.3.

Policy considerations

An alternative to viewing the noise-induced cognitive impairment of children from a burden-of-disease perspective is to analyse the impairment in terms of wasted learning units. The learning units could be given a monetary value in wasted teaching hours in schools - wasted for the teachers, the pupils and society. Therefore, the societal impact will probably be larger than the impact reflected by DALYs, which solely estimate the impact on specific cognitive impairment. A calculation of wasted learning units instead of DALYs is probably a more complicated task, with many more uncertain parameters. For the time being, DALYs from noise-induced impairment of cognition in children, together with DALYs from other environmental risks, may provide evidence for prioritizing policy options, such as lowering recommended noise levels in control guidelines for schools and learning.

Conclusions

Reliable evidence indicates the adverse effects of chronic noise exposure on children's cognition. There is no generally accepted criterion for quantification of the degree of cognitive impairment into a DW. However, it is possible to make a conservative estimate of loss in DALYs using the methods presented in this chapter. It is important to consider the assumptions, uncenainties and limitations in the methods when interpreting the estimated values of EBD.

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4. ENVIRONMENTAL NOISE AND SLEEP DISTURBANCE

Sabine Janssen
Mathias Basner
Barbara Griefahn
Henk Miedema
Rokho Kim

Sleep disturbance is one of the most common complaints raised by noise-exposed populations, and it can have a major impact on health and quality of life. Studies have shown that noise affects sleep in terms of immediate effects (e.g. arousal responses, sleep stage changes, awakenings, body movements, total wake time, autonomic responses), after-effects (e.g. sleepiness, daytime performance, cognitive function deterioration) and long-term effects (e.g. self-reported chronic sleep disturbance).

Sufficient undisturbed sleep is necessary to maintain performance during the day as well as for general good health *(1)*. The human organism recognizes, evaluates and reacts to environmental sounds even while asleep *(2)*. These reactions are part of an imegral activation process of the organism and express themselves as, for example, changes in sleep structure or increases *in* heart race. Although they are natural (and even necessary) reactions to noise, it is assumed that a substantial increase in the number of such effects constitutes a health issue. Environmental noise may reduce the restorative power of sleep by means of repeatedly occurring activations (so-called sleep fragmentation). Acute and chronic sleep restriction or fragmentation has been shown to affect, among other things, waking psychomotor performance *(3)*, memory consolidation *(4)*, creativity *(5)*, risk-taking behaviour *(6)*, signal detection performance *(7)* and risks of accidents *(8,9)*.

There is an ample number of laboratory and field studies that provide sufficient evidence to conclude that traffic noise causaUy and relevantly disturbs sleep and, depending on noise levels, may impair behaviour and well-being during the subsequent period awake *(10-22)*. Although clinical sleep disorders (e.g. obstructive sleep apnoea, which is a sleep disorder characterized by pauses in breathing during sleep) have been shown to be associated with increased risks for cardiovascular disease, little is known about the long-term effects of no,ise-disturbed sleep on health. However, recent epidemiological studies do suggest that nocturnal exposure to traffic noise increases the risk of cardiovascular disease *(23-25)*.

In this chapter, available exposure-response relationships for various sleep disturbance indicators are *dis*cussed. Subsequently, a method forestimating the burden of self-repo.rted sleep disturbance due to noise is proposed and illustrated.

Definition of outcome

Sleep disturbances can be measured electrophysiologically, using so-called polysomnography (PSG), or with self-reporting in epidemiological studies using survey questionnaires. PSG, i.e. the simultaneous recording of the electroencephalogram (EEG), the elecuooculogram (EOG), the electromyogram (EMG) and other physiological variables, remains the gold standard for measuring and evaluating sleep. According to specific conventioDS *(26.27);* the night is usually divided into 30-second epochs. Depending on EEG frequency and amplitude, specific patterns in the EEG, musde cone in the EMG and the occurrence of slow or rapid eye movements in the EOG, different stages of sleep are assigned to each epoch. Wake, superficial sleep stages Sl and $2, deep sleep stages S3 and S4, and REM (rapid eye movement) sleep are differentiated. Current knowledge assumes that sleep stages differ in their function and in their relevance for sleep recuperation, where continuous periods of deep sleep and REM sleep seem to be especially important for sleep recuperation *(4).* Shorter activations in the EEG and EMG, so-called arousals, can also be detected with polysomnography *(26,28).* These arousals are usually accompanied by activations of the autonomic nervous system {e.g. increases in heart rate and blood pressure) and they may contribute to sleep fragmentation *(29,30).* Further, motility (i.e. body movemem during sleep) has been found co be a relatively easy to use and sensitive measure for sleep disturbance, and has been shown to be a predictor of effects such as awakening and self-reported sleep quality *(22).* Depencling on their frequency, acute noise effects on sleep (arousals, awakenings, body movements} cause a general elevation of the organism's arousal level that consequently leads to a redistribution of time spent in the different sleep stages, with an increase of the amounts of wake and stage Sl and a decrease of slow wave sleep (SWS) and REM sleep *(16,31-33).*

In epidemiological studies, "self-reported sleep disturbance" is the most easily measurable outcome indicator, because physiological measurements are costly and difficult to carry out on large samples and may themselves influence sleep. However, since during most of the night the sleeper is not aware of himself or his surroundings, the process of falling asleep and longer wake periods during the night contribute clisproporcionacely to subjective estimates of sleep quality and quantity, which may therefore differ substantially from objective measures *(34).* Nevertheless, self-reported sleep disturbance may have validity in its own right by reflecting the impact on sleep as perceived by the subject over a longer period of time.

In surveys asking about sJeep disturbance, responses can be graded on a scale from 0 to 100. On thls scale, similar to definitions of noise annoyance, cut-off values were chosen of 50 and 72 to determine the percentage of people sleep-disturbed and highly sleep-disturbed by transportation noise, respectively *(35).* In the casc study included in this chapter, high sleep disturbance is used as the sleep disturbance inclicator. Using a lower cur-off value (i.e. sleep-disturbed) would give higher prevalence but would be associated with a lower DW, resulting in either a higher or a lower estimate of the burden caused by sleep disturbance due to noise. *An* Lmporcanc reason for using high sleep disturbance is that this is closer to the case definition used in studies associating a DW to sleep disturbance based on the comparison to other health scates (see below).

Noise exposure

Appropriate exposure Indicator

In the position paper on dose-effect relationships for nighttime noise *(36)*, as well as in the EU's Directive 2002/49/EC *(37)*, L_{night} was proposed as the nighttime noise indicator for sleep disturbances (see Chapter 1). L_{night} is defined as the "A-weighted long-term average sound level as defined in ISO 1996-2: 1987", determined over all night periods of a typical year. Noise events in the period between 23:00 and 7:00 contribute to the calculation of L_{night}. In WHO's *Night noise guidelines for Europe (38)*, several $L_{night,outside}$ exposure categories are linked with sufficient scientific evidence to health and sleep disturbance outcomes, and can accordingly be used to assess the degree of sleep disturbance associated with transportation noise (see Table 4.1). Additionally, it is possible to derive exposure-response relationships between L_{night} and instantaneous reactions to noise (such as the number of additionally induced EEG awakenings or behaviourally confirmed awakenings) to assess the expected degree of sleep fragmentation. However, L_{night} *is* an equivalent continuous sound pressure level summarizing complex time patterns of exposure into a single value. This necessarily leads to information loss: noise scenarios, which differ in number, acoustical properties and placement of noise events, may calculate to the same L_{night} but differ substantially in their effects on sleep. In contrast to daytime traffic, where high traffic densities may lead to more or less constant and continuous noise levels, low traffic densities during the night often go along with intermittent exposure to single noise events. Hence, traffic-noise-induced alterations in sleep structure depend crucially on the number of noise events, the acoustical properties (such as maximum sound pressure levels) of single noise events, the placement of noise events within the night, and noise-free intervals between noise events *(11,19,39)*. Indeed, the *Night noise guidelines for Europe (38)* still support the validity of the recommendation of the WHO *Guidelines for community noise (40)* that, in order to prevent sleep disturbances, one should consider the equivalent sound pressure level and the number and level of sound events. Also, Directive 2002/49/EC *(37)* states that it may be advantageous to use maximum sound pressure level L_{Amax} or sound exposure levels as supplementary noise indicators for night period protection. However, predicting after-effects such as self-reported sleep disturbance or long-term health effects may require information on the long-term average sound level.

Exposure data for estimatinq the burden of sleep disturbance due to noise

Since road traffic noise accounts for the larger proportion of people exposed in most European countries (based on data from France, the Netherlands, Switzerland and the United Kingdom), road traffic noise exposure data are chosen here to estimate the burden of disease. As an example, exposure data from the Netherlands are used (Table 4.2). The exposure assessment was based on most exposed facade at dwellings, not on individuals. The total population was 15.864 million in the Netherlands in 2000. Assuming that household size does not differ between the noise exposure categories, these data may be extrapolated to the whole population. It should be noted that, because of the method of calculation used (25-metre grid), the higher levels tend to be underestimated.

Table 4.1. Ranges for the relationship between nocturnal noise exposure and health effects In the population

$L_{night,outside}$	Health effects observed In the population
<30dB(A)	Although Individual sensitivities and circumstances differ, it appears that up to this level no substantial biological effects are observed.
30-40 dB(A)	A number of effects are observed to increase: body movements, awakenings, self-reported sleep disturbance and arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example, children and chronically ill and elderly people) are more susceptible. However, even in the worst cases, the effects seem modest.
40-55 dB(A)	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected.
> 55 dB(A)	The situation is considered Increasingly dangerous for public health. Adverse health effects occur frequently, and a sizable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

Source: Night noise guidelines for Europe (38).
Note. The guidelines assume an average attenuation of 21 dB(A) between inside and outside noise levels.

Table 4.2. Percentage of dwellings per environmental noise class In the Netherlands, 2000

Ln m 111evels dB(A)- source	<39	40-44	45-49	SD-54	>64
Motorways	70.2	16.2	9.1	3.1	1.4
Regional roads	93.8	3.4	1.6	0.8	0.3
City roads	57.9	17.7	15.2	8.0	1.3
All roads	21.9	37.3	25.9	11.9	3.0
Railways	76.6	12.4	6.3	2.7	1.9
Amsterdam Airport	98.1	1.4	0.5	0.0	0.0
All types of traffic	18.6	24.7	31.3	18.6	6.8

Source: Unpublished data from the Netherlands National Institute for Public Health and the Environment (RIVM), method described in Dassen AGM, Jabben J, Janssen PMH. *[Development of the environmental model for population annoyance and risk analysis. Partial validation and risk analysis.]* (abstract in English). Bilthoven, RIVM, 2001 (RIVM report 2001 725401001/2001).

Exposure-response relationship

£xposure-response relationships from experimental and field studies

Experimental and field studies have shown clear exposure-response relationships between single noise events and instantaneous arousals, EEG awakenings, behavioural awakenings or motility *(12,14,19,22,38,42-44).* Exposure-response relationships between L_{night} or similar integrated measures and instantaneous sleep disturbance are rare *(45,46).* This may in part be attributed to the fact that L_{night} as a whole-night indicator can only be directly related to whole-night sleep parameters. In principle, exposure-response relationships on the single event level can be used to predict the expected degree of sleep fragmentation depending on L_{night}, given the fact that the number and loudness of noise events are positively correlated with L_{night}. However, the variance in the number of noise-induced awakenings, and therefore the imprecision of the prediction, increases with increasing L_{night}, as many different exposure patterns can lead to the same L_{night} in the higher exposure categories. Therefore, it may be advantageous for assessing sleep disturbance to gather information on the number of noise events contributing to L_{night} additional to L_{night}.

Although instantaneous effects such as arousals, EEG awakenings, behavioural awakenings and elevated motility all reflect relevant aspects of the complex concept of sleep disturbance, it is not clear how they could be used to assess the burden of disease. Their occurrence is not pathological per se, as these reactions are also a physiological part of sleep in the absence of noise-induced sleep disturbance. They only reach pathological significance once a certain physiological frequency is exceeded, i.e. once sleep fragmentation reaches a relevant degree. However, interindividual variability in the sensitivity to noise exposure is high, and it is not clear to what extent the exposure-response relationships that were derived from field study subject samples with limited representativeness can be extrapolated to the population. Furthermore, although new research is under way, at the moment relationships are almost exclusively available for aircraft noise, whereas an assessment of the burden of sleep disturbance due to noise requires an assessment of the risk of other main sources as well.

Exposure-response relationships from epidemiological studies

Miedema et al. *(47)* presented synthesis curves for self-reported sleep disturbance from aircraft, road traffic and railway noise. These curves were based on the pooled data from 15 original data sets (more than 12 000 individual observations) obtained from 12 field studies (a) where L_{night} was included in the dataset or there was the possibility to calculate/estimate this metric on the basis of information regarding the included sites; and (b) where questions regarding waking up or being disturbed by transportation noise during the night were answered. Studies using questions that included disturbance of rest were excluded because resting is different from sleeping and does not necessarily take place during the night only. A more extensive analysis was recently completed *(35)*. It was based partly on the same data but included pooled data from 28 original data sets obtained from 24 field studies (23 000 participants) carried out since 1970. This analysis yielded very similar curves and included 95% confidence intervals that took into account the variation between individuals and studies. However, no polynomial approximations were published for these curves, and therefore the functions from Miedema et al. *(47)* were used for the present purpose. The percentage of "highly sleep-disturbed" persons (%HSD) as a function of noise exposure indicated by L_{night} was found to be as follows.

Aircraft: $\%HSD = 18.147 - 0.956 (L_{night}) + 0.01482 (L_{night})^2$

Road traffic: $\%HSD = 20.8 - 1.05 (L_{night}) + 0.01486 (L_{night})^2$

Railways: $\%HSD = 11.3 - 0.55 (L_{night}) + 0.00759 (L_{night})^2$

The curves are based on data in the L_{night} (outside, maximally exposed facade) range 45-65 dB(A). Low exposure levels ($L_{night} < 45$ dB(A)) were excluded from the analyses because the assessment of those noise levels was relatively inaccurate and other sources may be more important in situations with these low levels. High exposure levels ($L_{night} > 65$ dB(A)) were also excluded, because in the areas of very high exposure levels there may also have been self-selection of persons with low sensitivity to noise. Therefore, the extrapolation of the presented functions is expected to give a better indication of sleep disturbance at low and very high levels than using the data at these levels. The polynomial functions are close approximations of the curves in this range and their extrapolations to lower exposure (40-45 dB(A)) and higher exposure (65-70 dB(A)).

Although cumulative effects of simultaneous exposure to noise from different types of traffic should ideally be taken into account, knowledge on the effects of simultaneous exposure to different noise sources is limited *(48)*. A pragmatic way would be to calculate a single Lnight value for all modes of transportation and base the risk assessment on this combined exposure measure, or preferably to use the methodology established earlier for determining the relationship between exposure to multiple noise sources and annoyance *(49)*.

Disability weight

The WHO DW for primary insomnia is 0.100 and is defined *(50)* as:

> *... difficulty falling asleep, remaining asleep, or receiving restorative sleep for a period [of] no less than one month. This disturbance in sleep must cause significant distress or impairment in social, occupational, or other important functions and does not appear exclusive/), during the course of another mental or medical disorder or during the use of alcohol, medication, or other substances.*

This definition of primary insomnia excludes the sleep disturbances that appear during the use of "other substances" or outside factors such as light or noise. When sleep is permanently disturbed by environmental factors and becomes a sleep disorder, it is classified in the International Classification of Sleep Disorders *(51)* as "environmental sleep disorder". Environmental sleep disorder (of which noise-induced sleep disturbance is an example) is a sleep disturbance due to a disturbing environmental factor that causes a complaint of either insomnia or daytime fatigue and somnolence *(38)*. While noise-induced sleep disturbance is not to be considered as a case of primary insomnia, the "burden of disease" of primary insomnia and noise-induced environmental sleep disorder may be similar. Van Kempen, cited in Knol & Staatsen *(41)*, reported a mean DW of 0.100 for severe sleep disturbance due to noise, based on a pilot study among 13 medical experts working according to a protocol by Stouthard *(52)*. De Hollander *(58)* expanded the study to 35 environmental physicians, epidemiologists and public health professionals and also found a mean DW of 0.10 (median DW: 0.08; standard deviation: 0.10; range: 0-0.45) using the same protocol. Although an earlier study published by de Hollander et al. *(53)* used a DW of only 0.010 for the same condition, no DW was available at that time so the weight of the least severe category of the first GBD study by Murray et al. *(59)* was used.

Muller-Wenk *(54)* found a mean DW of 0.055 (median DW: 0.04; range: 0.02-0.31} for those highly sleep-disturbed by nighttime road noise, based on a survey of 42 Swiss physicians who were asked to interpolate this type of sleep disturbance into a list of health states with existing DWs. In 2005, Knoblauch &

Muller-Wenk *(55)* interviewed a sample of 14 general practitioners recently admitting patients with obstructive sleep apnoea syndrome (OSAS) to the sleep clinic in St Gallen in Switzerland. They were asked to compare the relative mean severity of the health state of contacted persons widl OSAS, with primary insomnia or with sleep disturbance due to increased exposure to road noise in the bedroom. This case definition of sleep disturbance is comparable to that of "highly sleep disturbed" on which the exposure-response relationship was based. Based on their own professional experience, 9 of the 14 respondents considered noise-related sleep disturbance to be less serious on average than primary insomnia, and 11 of the 14 considered noise-related sleep disturbance to be less serious on average than OSAS; the mean judgement of the 14 respondents was that noise-related sleep disturbance has a mean severity of 0.9 times the severity of primary insomnia (range: 0-2.1), which resulted in a DW of 0.09 (CI 0.06-0.12). As in the previous studies, the distribution was rather skewed; the median severity ratio was 0.63, which corresponds to a DW of 0.063.

Following the *Night noise guidelines for Europe (38),* 0.07 was chosen as the DW of noise-related sleep disturbance in the calculation of DALYs. This value takes into account both the medians and the means of the DW observed in the above studies. Given the rather skewed distributions of the reported DWs, the median of the study with the lowest DW *(54)* was chosen as a low estimate, whereas the highest observed mean value *(41,58)* was chosen as a high estimate, yielding the uncertainty interval (0.04-0.10). The uncertainty *in* the exposure-response relationship was not factored in for this analysis.

EBD calculations

This section provides methodological guidance to two approaches to calculating the burden of sleep disturbance related to environmental noise. The first method *is* the exposure-based approach using the exposure,-response relationship and exposure data. The second method is the direct estimation of the burden using a population survey.

Exposure-based assessment

The exposure-based approach estimates the prevalence of high sJeep disturbance (reporting 72 or higher on a 100-point scale) due to noise by combining the exposure data with the exposure-response relationships for high sleep disturbance. One year of nighttime exposure to road traffic noise is proposed as the duration causing high sleep disturbance, since people with a bedroom exposed to a road with a high level of night traffic are subject to more or less stationary noise levels at night. Therefore, it can be assumed that their sleep disturbance exists all year round.

DALYs for sleep disturbance were calculated using the road traffic noise exposure distribution in L_{night} as assessed in the Netherlands in 2000 (see Table 4.2), the total population of rhe Netherlands in 2000 (15 864 000), the exposure-response relationships presented above for sleep disturbance due to road traffic noise (using the expected percentage of highly sJeep-disturbed people at the midpoint of rhe category as a function of Lnight in the range 45-65 dB(A)) and the DWs (see Table 4.3). This ca!cu.lation suggests that there are about 24 *669* DALYs lost in the Netherlands due to road traffic noise-induced sleep disturbance. Taking 0.04 and 0.10 as the extremes of the range for the weights, the credible range for the DALYs is from 14 096 to 35 242. This is a very conservative estimate, derived only for the exposure-response and exposure data for road traffic noise and not including the impacts of aircraft and railway noise. However, although the impact at a given exposUie level is expected to be higher for aircraft noise (but slightly lower for railway noise) *(35),* far fewer people are exposed to aircraft (and railway) noise than to road traffic noise.

Table 4.3. Exposure-based approach to estimating DALYs for highly sleep-disturbed people due to environmental noise, using exposure data from the Netherlands

Exposure category Lnight (dB(A))	Percentage of population exposed	Percentage of people highly sleep-disturbed	Number of cases in the Netherlands	DALYa		
				DW= 0.04	DW= 0.07	DW• 0.10
45-49	25.9	4.3	1766n	7068	12367	17668
50-54	11.9	6.4	121 009	4840	8471	12101
>54	3.0	11.5	54730	2188	3831	5473
Total				14096	24669	35242

Source: Unpublished data from the Netherlands National Institute for Public Health and the Environment (RIVM), method described in Dassen AGM, Jabben J, Janssen PMH. **[Development of the environmental model for population annoyance and risk analysis. Partial validation and risk analysis.)** (abstract in English). Bilthoven, RIVM, 2001 (RIVM report 2001 725401001/2001).

Burden of sleep disturbance from road traffic noise in western Europe

As mentioned in Chapter 2, the Noise Observation and Information Service for Europe (NOISE) provides noise exposure data that can be used for calculating disease burden in western European countries. Fo.llowing the same method used in Chapter 2, the percentage of people highly sleep-disturbed can be calculating using the mid-level values of the exposure categories in the NOISE dataset. Because the NOISE dataset does not provide data on the categories of < 45 dB(A) and 45-49 dB(A), the percentages for these two categories were calculated conservatively by assuming the same percentages between the two categories of 45-49 dB(A) and 50-54 dB(A). The mid-level value of the category was used in the application of exposure-response functions specific to the noise sources. Because the Lnighr was the annual average- of exposure level by definition, the duration of effects was also considered to be one year.

Tables 4.4, 4.5 and 4.6 summarize the distribution of population exposed to road, rail and air traffic noise, respectively, during the night in agglomerations with more than 250 000 inhabitants, and exposure-based DALY calculation using the exposure-response function presented above. Owing to a lack of exposure data covering the rural population, it was not possible to estimate DALYs for the whole EU popuJation including rural areas without extrapolation. Assuming that the observed exposure disrributions using che strategic noise maps may apply to approximately 285 million people living in cities or agglomerations with more than 50 000 inhabitanrs (57% of the total EU population), we can cautiously infer that the DALYs are approximately 903 000 years for urban population in the EU assuming DW = 0.07 (Table 4.7). Taking 0.04 and 0.10 as the extremes of the range for DWs, the credible range for the DALYs *is* 0.52-1.29 million. It should be noted that the burden in rural areas or small town with less than *50* 000 inhabitants is not included here, and that we did not count the burden in the exposure range below 45 dB(A).

Table 4.4. DALYs for hlghly sleep-disturbed people due to road traffic noise In the EU

Exposure category L_{night} (dB(A))	Percentage of population exposed•	Percentage of people hlghly aleep-dlaturbed"	Numbs of caanp,r mIlllon"	DALYa lost In the urban population"		
				DW• 0.04	DW• 0.07	DW• 0.10
<45	44[d]	NA	NA	NA	NA	NA
45-49	20d	4.5	8906	101 526	1n610	253 814
50-54	20	6.6	13266	151 230	264652	378 074
55-69	10	9.6	9 556	108 937	190 640	272342
60-64	5	13.2	6611	75365	131 888	188412
65-69	1	17.6	1 763	20099	35174	50248
Total	100		40102	457156	800023	1142890

• The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June **2010.**

• The percentage and number of cases were calculated with the polynomial equation, using the mid-level values of exposure categories.

00ALYs were calculated for the **285** million persons living in agglomerations with> 50 **000** inhabitants.

"Noise maps do not provide data 1or the categories of< **45** dB(A) and **45–49** dB(A) 1or L_{night}. Therefore, the percentages of population in these categories were interpolated using a very conservative assumption: the percentage for the **45–49** dB(A) is the same as that for **50–54** dB(A).

Table 4.5. DALYs for hlghly sleep-disturbed people due to rall traffic noise In the EU

Exposure category L_{night} (dB(A))	Percentage of populatlon exposed•	Percentage of people hlghly &INp-disturbed"	Number of caaea per mllllon"	DALYa lost In the urban population"		
				DW= 0.04	DW= 0.07	OW .. 0.10
<45	93[d]	NA	NA	NA	NA	NA
45-49	3[d]	2.3	690	7866	13765	19664
50-54	3	3.3	1 003	11 440	20019	28599
55-69	1	4.8	477	5437	9 515	13593
60-64	0	6.6	0	0	0	0
65-69	0	8.8	0	0	0	0
Total	100		2170	24743	43300	61 857

• The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June **2010.**

• The percentage and number of cases were calculated with the polynomial equation, using the mid-level values of exposure categories.

00ALYs were calculated for the **285** million persons living in agglomerations with> 50 **000** inhabitants.

"Noise maps do not provide data for the categories of-< **45** dB(A) and **45-49** dB{A) for L_{night}. Therefore, the percentages of population In these categories were interpolated using a very conservative assumption: the percentage for the **45-49** dB(A) Is the same as that for **50–54** dB(A).

Table 4.6. DALYs for hlghly sleep-disturbed people due to air traffic noise In the EU

Exposure category i....... (dB(A))	Percentage of population exposed•	Percentage of people highly sleep-dlaturbed[b]	Number of caaee mlUlon[b]	DALYa lost In the urban population�		
				DW= 0.04	DW= 0.07	DWm: 0.10
<45	968	NA	NA	NA	NA	NA
45-49	2d	6.2	1 235	14078	24637	35195
50-64	2	8.8	1 761	20075	35130	50186
5 9	0	12.2	0	0	0	0
60--64	0	16.3	0	0	0	0
6 9	0	21.1	0	0	0	0
Total	100		2 996	34153	59 767	85382

• The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.
• The percentage and number of cases were calculated with the polynomial equation, using the mid-level values of exposure categories.
•OALYs were calculated for the 285 million persons fivlng in agglomerations with> 50 000 inhabitants.
dNoise maps do not provide data for the categories of< 45 dB{A) and 45-49 dB(A) for ½light- Therefore, the percentages of population in these categories were interpolated using a very conservat.ive assumplfon: the percentage for the 45-49 dB(A) is the same as that for 50–64 dB(A).

Table 4.7. DALYs for highly sleep-disturbed people due to all traffic noise In the EU

Source of traffic noise	DALVs[1]		
	ow .. 0.04	DW=0,07	DW-=0.10
Road	457156	800023	1142 890
Rail	24743	43300	61 857
Air	34153	59767	85 382

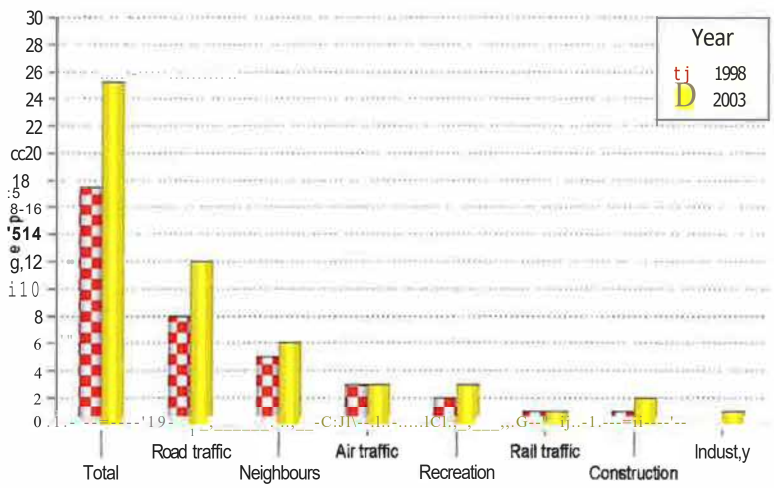
• For the 285 mHlion population living in agglomerations with > 50 000 inhabitants.

Outcome-based assessment

The burden of highly disturbed sleep due to nighttime noise in terms of DALY s may also be directly estimated on the basis of survey data in the population concerned. Survey data from the Netherlands were used as an example in this section. Fig. 4.1 shows the relative contributions to overall sleep disturbance caused by noise from different sources in the Netherlands. These data were derived from surveys in 1998 and 2003 *(56)* in which 4000 and 2000 people, respectively, all of whom were randomly selected, were asked: "To what extent is your sleep disturbed by noise from (source mentioned) ... ?" on a scale from Oto 10 (pertains to noise perceived in the last 12 months). People recording the three highest points on the scale were considered "highly disturbed" according to an international convention that is close to the case definition used in the pooled analysis to define the exposure-response relationship *(46).* About 12% of the general population reported being highly disturbed by road traffic noise during sleep in the Netherlands in 2003. The totals are calculated from the number of people reporting serious sleep disturbance from one or more sources. About 25% of the general population reported being highly disturbed by any source of noise during sleep in the previous 12 months. This approach allows cases from multiple sources to be counted more directly. Since this study is based on a survey conducted in the Netherlands, it is not representative of other Member States in the EU.

Considering that the Necherlands had a population of 16 225 000 in 2003, approximately 1 947 000 and 4 *056* 250 people were highly disturbed during sleep by road traffic noise and any source of t1oise, respectively. The corresponding DALYs calculated with a DW of 0.07 are 136 *290* years and 283 937 years for road traffic noise and any source of noise, respectively (Table 4.8). The uncertainty in che survey estimates was not factored in for this analysis.

Fig. 4.1. Percentages of the population claiming to be highly disturbed by noise during sleep from two surveys in the Netherlands



Source: van den Berg et al. *(36).*

Table 4.8. The estimated DALYs lost due to sleep disturbance using prevalence data from the Netherlands

Noise source	Percentage of population hlghly sleep disturbed	Population of the Netherlands	Number of cases In the Nethertanda	DALYa		
				OW– 0.04	OW• 0.07	OW. 0.10
Road traffic	12	16 225 000	1947000	neeo	136 290	194 700
One or more sources	25	16 225 000	4058250	162104	283937	405625

Uncertainties, limitations and challenges

Comparlnq two approaches

The DALYs based on the second method are significancly greater than those based on the exposure-based estimates. One of the reasons for the difference may be that the exposure-response relationship is not given foe values below 45 dB(A) and above 65 dB(A), where the uncertainties of the relationship are greater. By not counting the people in the exposure range below 45 dB(A), the prevalence of sleep disturbance is underestimated. In addition, the percentage of sleep disturbed above the level of 65 dB(A) may be underestimated, also resulting in an underestimation of the burden of sleep disturbance induced by road traffic noise. This could partly be solved by extrapolating the exposure--response relationship for the range between 40 and 70 dB(A), should exposure data be available in this range.

Uncertainty with respect to the exposure-response relationship

The amount of variance in sleep disturbance scores explained by the exposure-response relationships is intermediate (road traffic, railways) or ar the low end within the range of usual values that are considered meaningful (aircraft), so that they are nor suited to predicting individual reactions. However, in most cases the uncertainty regarding individual reactions is not what matters for noise policy. Most policy, including policy based on estimates of the burden of disease due to environmental noise, *is* made with a view to the overall reaction to exposures in a (reference) population. This means chat it is not the uncertainty with respect to the prediction of an individual or group reaction cliat is important, but that regarding the exact relationship between exposure and response in the (reference) population. The accuracy of the estimation of this relationship is described by the confidence intervals around the curve. If properly established, the confidence interval takes into account the variation between individuals as well as the variation between studies *(57),* which are much smaller than the wide prediction intervals for individuals. The functions can be useful for evaluating the nighttime noise exposure in a particular area by predicting what the response of the reference population would be in that area.

With regard to aircraft noise, it should be noted that the variance in the responses is large compared co the variance fom1d for rail and road traffic, meaning that the uncertainty is 1ligher. One of the reasons for higher uncertainty may be that the time pattern of noise exposures around different airports varies considerably due to specific nighttime regulations. Also, there are indications of a time trend, whereby the most recent studies show the highest sdf-reported sleep disturbance, leading to a possible underestimation of the response at a given aircraft noise exposure level by the current curve.

Appl/cations and /imitations of the exposure-response relationship

According to the EU position paper on dose-effect relationships for nighttime noise *(36),* the exposure-response relationships above represent the current best estimates of the influences of nocturnal traffic noise exposure (conceptualized as Lnighr) on self-reported sleep disturbance for road traffic and for rail traffic, when no other factors are taken into account. As mentioned above, the uncertainty may be higher with respect to aircraft noise, and such responses should be considered as indicative only.

A limitation of the exposure-response relationship is that it does not take into account other (exposure) variables that determine, in addition to average nighttime noise levels outdoors at the most exposed facade, the exposure level in the bedroom. Most important may be the difference in exposure between the most exposed facade and the bedroom facade, as well as the difference between the outdoor exposure at the bedroom facade and the indoor exposure in the bedroom. Also, adding noise exposure descriptors other than the nighttime average, such as noise in the early or late pans of the night, descriptors of peak levels or number of events may improve the prediction of self-reported sleep disturbance.

Also, it must be stressed again that the sleeper is not aware of himself or his surroundings during most parts of the night, and hence subjective estimates of noise-induced sleep disturbance may diHer substantially from objective measures. Indeed, recent laboratory studies indicate that the impact of traffic noise on sleep structure increases in the order air road rail, thus reversing the order observed for self-reported measures such annoyance and sleep disturbance *(19,48)*. Therefore, although the estimated DALYs may correctly reflect the burden of disease in terms of self-reported sleep disturbance, it is questi.onable whether the estimates correctly reflect aspects that would reflect consequences of chronically fragmented sleep in terms of impairment of daytime performance or long-term health effecrs that are not obtainable via self-reporting.

Conclusions

Although self-reported sleep disturbance may not reflect the coral impact of nighttime noise on sleep, it is the only effect for which exposure-response relationships on the basis of L_{night} are available for the most important noise sourccs. Furthermore, while it is hard to weigh self-reported sleep discurbance, it may be even harder to assign a DW to physiological changes indicatil1g a certain degree of sleep fragmentation.

An example using data from 2000 on exposure in the Netherlands indicates a conservative estimate of some 25 000 DALYs lost yearly due to sleep disturbance induced by road traffic noise.

With the increasing effort devoted to noise mapping, more and better data on rhe levels of exposure to nighttime noise will become available in the EU Member Stares, so chat, by combining them with the relationships, the prevalence of self-reported sleep disturbance can be estimated. Our calculatio11 using the noise maps data showed that DALYs assuming DW = 0.07 were 307 959 years for the EU population living in agglomerations with >250 000 inhabitants. Caucious extrapolation indicated that DALYs assuming DW = 0.07 migbt be in the range 0.5-1.0 million years for whole EU population.

We adopted conservative assumptions whenever necessary except for extrapolation of exposure data from larger agglomerations to the population of the agglomerations with > 50 000 inhabitants in the EU Member States. Considering that we did not count cases of high sleep disturbance occurring below 45 dB(A) and milder sleep disturbance at all ranges, we are confident that the above DALY estimation is not an overestimation.

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5. ENVIRONMENTAL NOISE AND TINNITUS [7,8]

Pierre Deshaies
Zilma Gonzales
Hans-Peter Zenner
Stefan Plontke
Louise Pare
Sylvie Hebert
Nicole Normandin
Serge-Andre Girard
Tony Leroux
Richard Tyler
Claudia Cote

Several authors consider tinnitus co be a symptom of the auditory system and not as a disease per se. On the other hand, tinnitus is an entry in the International Classification of Diseases (ICD-9 (388.3) and ICD-10 (H93.1)). Tinnitus is very often found to be present concomitantly with hearing loss. This is also true for noise-induced tinnitus and noise-induced hearing loss (NIHL) *(1,2).* Nevertheless, tinnitus may be experienced by persons exposed to excessive noise without measurable hearing loss (.1). The natural history, the annoyance and disability, the clinical approaches for diagnosis and treatment and the consequences of tinnitus differ significantly from these clements in persons with NIHL. For instance, insomnia reported by tinnitus sufferers is not a consequence of NIHL. Therefore, the authors consider it justified that tinnitus be analysed per se as an independent outcome of environmental noise risk assessment and burden of disease.

Definition of outcome

Tinnitus is the general term for sound perception (for instance, roaring, hissing or ringing) that cannot be attributed to an external sound source. To put it in terms of auditory abilities, tinnirns is the inability to perceive silence *(4).* Tinnitus defined in such broad terms is rather prevalent. It is widely believed that mild, occasional or acute temporary tinnitus is experienced by nearly everybody in their lifetime at some time or another, the majority resolving spontaneously *(5).* There is considerable variation in tinnitus expression, its etiology and its effects on patient's lives *(6).*

Tinnitus may be classified according to its different attributes: duration of a single episode (seconds, minutes; intermittent, continuous), temporal duration (days, months, years) or severity (degree of annoyance, interference with daily living). Dauman & Tyler *(7)* proposed a classification according to five parameters of tinnitus: pathology, severity, duration, site and etiology. Stephens & Hetu *(8)* proposed a clas-

7 This chapter is dedicated to the lure Xavier Bonnefoy, who-was an essential initiator, leader and motivator during its development. P;irt of this work was presented at the Inremoise2006, 3-6 December 2006, Honolulu, Hawaii, USA.

8 Collaborators (In alplmbetical order): Jcan-Mnrie Berthelot (formerly Statistics Canada); France D6silers (lnstitut Haymond-Dewar); l'auline fortier (lnstitut national de 5.lntc publique du Quebec); Mnrtin forrin (privnre audio! gist pr ctitioner); Susan Griest (Oregon Health and Sdcnccs University); Mathieu Hotton (Insritut de Rendoptarion on Deficience phi•siquc de Quebec); Rokho Kim (WHO £uwpcnn Centre for Environment and Health, Bonn Office); Chantal Laroche (University of Orrawa); Rlchard Larocque (lnstitut national de Sante publique du Quebec); Marie Leblanc (Lmitut de Rfudapr.ation en Delicicncc physique de Quebec); Krist.el LcPctit (formerly Suuistic:s C1l111da); M:irtin Hal Manin (Oregon Health nnd Sciences University); Colin J). Madms (World Health Organization, Geneva); Michel Jijcard (Universily of Monrreal); Annette J'ri.iss-Ostiin (World Health Organiz.ation, Geneva); Mireille Tardif (lnscitut Raymond-Dewar); and Ilse Maria Zalaman (University of Tiibingen, Germany).

sification according to the patient's abilities and quality of life. In fact, there is no unique internationally recognized classification.

Tinnitus can cause in some patients one or several of the following consequences:

- sleep disturbance (difficulty in falling asleep or going back to sleep)
- cognitive effects (difficulty with attention and concentration)
- anxiety
- psychological distress
- depression (case reports of suicide)
- communication and listening problems (hearing problems)
- frustration
- irritability
- tension
- inability to work
- reduced efficiency
- restricted participation in social life.

Tinnitus annoyance and experienced handicap can be measured in clinical or research settings on an individual basis by several valid questionnaires. The severity grading classification (grade I to grade IV) as measured by the Tinnitus Severity Questionnaire developed by Goebel et al. is probably one of the most frequently used tinnitus questionnaires in Germany *(9)*. Other countries use different questionnaires that have good psychometric properties (i.e. good .internal consistency and test-retest reliability), such as the Tinnitus Reaction Questionnaire *(J0)*, which measures emotional tinn.itus-related distress, the Tlnnitus Handicap Questionnaire *(11)*, wh.ich measures the self-reported severity of tinnitus as a handicap, and the Tinnitus Handicap Inventory *(I2)*, which quantifies the impact of tinnitus on everyday life. Psychoacoustical measuremeots of tinnitus can also be made. Typically, however, these measurements do not predict the psychological distress reported by patients **(13)**.

In population-based survey studies, simple questions about duration and the degree of annoyance caused by tinnitus are usually used, rather than the tools described above to assess the individual status. According to Davis *(6)*, at least two elements should be included into any epidemiological study: tinnitus that lasts for five minutes or more (additionally whether it is present for some or all the time); and an assessment of the impact of tinnitus (for example, severity or annoyance}. The general agreement of the authors and contributors to this chapter is to focus, for burden of disease purposes, on the degree of severity of disabling tinnitus rather than on its duration.

The proposed operational case definition of tinnitus is a sound perception (for instance roaring, hissing, ringing, noise in the ears or the like} at the time of the survey or during the past year that cannot be attributed co an external sound source, and having disabling consequences in terms of constant disturbance of the emotional, cognitive, psychological or physical state of the patient. The term "constant" implies rhac the person has tinnitus that causes an impact on his or her functional life most of the time in at least one of these spheres.

Summary of evidence linking noise and tinnitus

A very small proportion of tinnitus cases signal the presence of an underlying treatable medical condition, such as a tumour or chronic partial opening of the Eustachian tube, but the majority of cases have no apparent or treatable cause. Tinnitus caused by excessive exposure to noise has long been described ***(14-16).*** Fifty to 90% of patients with chronic noise trauma report tinnitus ***(17).***

Between 12% and 50% of persons with noise-induced hearing loss report having tinnitus ***(18-21).*** Nevertheless, as stated before, tinnitus *may* be experienced by persons exposed to excessive noise who do not have measurable hearing loss ***(3).***

There is no single path.ophysiological pathway to explain the occurrence of tinnitus. All structures of the auditory system have been suggested as possible sites of generation for tinnitus, from the periphery to the auditory cortex. Many explanatory models have been proposed, based on either anatomical, physiological, clinical or neuropsychological approaches. The underlying mechanisms responsible for transient and chronic tinnitus are most likely also different ***(2).*** Despite chose limitations in understanding the pathophysiology, however, there is no doubt that acute and chronic noise exposure can cause incapacitating ciun.i.ms ***(2,22).*** In noise-induced hearing loss and noise-induced tinnitus, it can be assumed that genesis is based on the same pathophysiological pathway ***(23-27).***

Hearing impairment is not expected to occur at LAcq,&h levels of 75 dB(A) or below, even for prolonged occupational noise exposure. It is *also* expected that environmental noise exposure with a LAcq24h of 70 dB(A) or below will not cause headng impairment in the large majority of people, even aiter a lifetime of exposure ***(28).*** Although, to our knowledge, there are no empirical data to propose a no observed adverse effect level (NOAEL) for noise-induced tinnitus, it is reasonable and plausible to use the same protective NOAELs for tinnitus as those for noise-induced hearing loss. Therefore, for this burden of disease calculation, social/leisure noise is the most relevant source of exposure and concern for the EUR-A epidemiological sabregion and North American countries, as these sources may typically exceed these thresholds. It is worth noting that traffic noise exceeds 85 dB(A) in some urban settings of developing countries ***(29-31).***

Exposure-response relationship

The exposure of interest in this context is leisure exposure, such as personal music players, gun shooting events, music concerts, sporting events and the use of firecrackers. To develop an exposure-response relationship, it woul.d be necessary to find studies that linked these leisure noise exposures with the relative risk of occurrence of moderat.e to severe tinnitus. Although there are some studies based on this approach ***(32-36),*** few could be identified and these did not cover all exposure settings. It was therefore not possible to develop an exposure-response relationship.

An alternative would be to estimate the relationship between noise and tinnitus derived from the risk curve relating noise exposure co hearing loss. This theoretical approach would be based on the existence of a valid quantitative relationship between noise-induced hearing loss levels and cinnitus risk. Should such a curve exist or be derived from existing data, the ISO 1999:1990 standard could be used to derive the risk of tinnitus per noise exposure level and duration. Although we know that the prevalence of tinnitus increases with the prevalence of noise-induced hearing loss, according to a recent literature review by Tyler *(37)* we are still not aware of any valid quantified relationship per hearing level between tinnitus prevalence and noise-induced hearing loss. Some authors do preseut data about this relationship, but we are not aware of any valid curves that could be used for burden of disease calculation.

Both these approaches also require population exposure data regarding the prevalence of exposure to leisure noise, which are not readily available at present.

Disability weight

There were no DWs readily available for tinnitus for burden of disease calculations. Three different approaches have been used to estimate DWs.

A first approach was for the authors to propose DWs by analogy with comparable diseases for which WHO already had DWs from the Global Burden of Disease Project. The best comparison proposed by dle experts was with chronic pain, as this health problem shares several characteristics with tinnirus, such as: ongoing w1-wanted incernal (centrally located) stimulus; causing or inducing co-morbidity (secondary symptoms) in terms of constant disturbance of the emotional, cognitive, psychological or physical state; not so well-underscood pathophysiology; a lack of valid objective clinical findings or confirmatory laboratory tests; aod possible response to cognitive therapy. Cnronic pelvic pain has a DW of 0.122, whereas low back pain caused by chronic imervertebral disc protrusion has a DW of 0.121 (range 0.103-0.125). Ocher plausible comparisons are with cases of primary insomnia, which have a DW of 0.100 while a mild depressive episode has a DW of 0.140. As tinnirus may induce in some cases any of these two consequences, an interpolation in those ranges seemed reasonable. Thus, a DW of 0.120 was suggested *(38)*.

As this first approach was not considered to be very robust, a second approach was developed, based on the Canadian Population Health Impact of Disease Project, as an alternative to this first approach *(39)*. The preference scores (conceptually corresponding to one minus DW) were based on rating by heal.th professionals and university experts using the Classification and Measurement System of Functional Health (CLAMES) *(40)* (see Appendix 1). This attempt did not give the expected results owing to unresolved methodological issues, and thus was not pursued.

Finally, an expert panel approach was trndertaken. Based on all the available data, former proposals and an expert portrait of functional Limitations caused by tinnitus (see Appendix 2), a third approach was proposed by the WHO expert on the Global Burden of Disease Prqject, Dr Colin D. Mathers, together with the WHO expert responsible for the Environmental Noise Burden of Disease Project, Dr Rokho Kim and the first author. This approach was based on die concept of "affecting ability co lead a normal life" (or affecting quality of life in terms of dlsabling consequeuces) within the definition of disabling tinnitus. Two different DWs for different levels of severity of disabling tinnitus were proposed: 0.01 for mildly (slightly) disabling tinnitus and 0.11 for an aggregate moderate and severely disabling tinnitus. These two severity weights are for limitations in leading a normal life. These provisional proposals, pending a more formal valuation exercise, are based on approximate correspondence to the following conditions in a Durch DW study that used the same methodology as rhe Global Burden of Disease Project {41). This study estimated the following DWs for activities of daily living (ADL) Limitations in the elderly:

- no to mild ADL limitations in the elderly, 0.01 (range 0.006-0.012)
- moderate to severe ADL limitations in the elderly, 0.11 (range 0.056-0.174).

For comparison, this study gave low back pain an average weight of 0.06, mild to moderate agoraphobia and epilepsy both a weight of 0.11, and mild stable angina (NYHA class 1-2) a weight of 0.08. Some comparable weights used in the GBD 2001 update of the Global Burden of Disease Study include:

- primary insomnia (causing problems with usual activities), 0.10
- dysthymia, 0.14
- moderate iron deficiency (80-109 g/l haemoglobin in women), 0.011.

It is worth mentioning that the DW of 0.11 for moderate to severely disabling tinnitus is very close to the proposed DW of 0.120 cllat emerged from the first approach. Therefore, DWs of 0.01 for slightly disabling tinnitus and of 0.11 for moderate to severely disabling tinnitus are used for the burden of disease calculations in this chapter.

EBD calculations

Outcome-based approach for leisure-noise-Induced tinnitus In the £UR-A epidemioloqlcal subregion

The approach chosen for this chapter uses survey-based studies to estimate the prevalence of tinnitus on a population basis. With this approach, it is necessary to estimate the attributable portion of tinnitus caused by environmental noise exposure.

Prevalence of the outcome

A comprehensive review of the literature was made using published documents as identified by PubMed's internet resource through Laval University's Ariane search tool (http://ariane.ulaval.ca/web2/tramp2.exe/log_in?setting_key=french), references cited in selected articles, the authors and contributors of unpublished documents, and experts' opinions. When more than one published article was based on the same study population and design, the later or updated version was used.

The three research strategies retrieved more than 400 studies in English, French, Spanish or German. From that first extraction, 99 were selected as being potentially of interest. A global quality assessment of the studies was done independently by two reviewers, who classified each study as pass or fail based on criteria including external validity, internal validity and data analysis. Disagreements on the inclusion/exclusion of articles were resolved by consensus among the reviewers. Once studies were selected, a data extraction form was used. This process led to the identification of 23 epidemiological studies of interest that met minimal specified quality criteria and these were presented in a background paper *(38).*

To select the studies that are to be used for burden of disease calculations, the authors identified those that estimated point prevalence. Also, sampling had to be random and population-based. The authors analysed, when available, the wording of the questions. There is no internationally recognized standard definition of disabling tinnitus. None of the questions used in these studies answered specifically and in a standardized manner all the consequences of chronically disabling tinnitus. The selected studies estimated the prevalence of tinnitus through various concepts such as annoyance, difficulty falling asleep, and tinnitus moderately or very bothersome. Table 5.1 gives a summary of the six selected studies, with specification of the potential disability concept that could be used in each one. All six are cross-sectional descriptive prevalence studies estimating a point or yearly prevalence, based on random samples of the study population.

Table 5.1. Summary of studies selected for burden of disease calculations for tinnitus

Reference (age group In years, country) [sample size]	Question	Selected potential dlaablllty concept
Axelsson & Ringdahl *(42)* (20-80, Sweden) [3600]	Do you suffer from tinnitus?	Question 6. Severity of tinnitus (mark the most appropriate alternative) Tinnitus does not bother me particularly Tinnitus bothers me only In quiet surroundings Tinnitus disturbs my sleep [...] Tinnitus plagues me all day
Davis *(43)* (17+, England) [48 313]	Nowadays do you get noises In your head or ears?	Tinnitus affecting quality of life
Hannaford et al. *(44)* 2005 (14+, Scotland) [15 788]	(missing exact question) ["Most questions related to current or recent (within the previous twelve months) symptoms ... "]	Tinnitus problems "affected their ability to lead a normal life"
Nondahl et al. *(21)* 2002 (48-92, USA) [3737]	In the past year, have you had buzzing, ringing, or noise in your ears?	"Significant tinnitus" if at least moderate tinnitus or tinnitus causing difficulty in falling asleep
Pare & Levasseur *(45)* (15+, Canada) [20 773]	Do you hear ringing, buzzing or whistling noises in your ears or head that last 5 minutes or more at a time?	Do these noises [tinnitus] bother you? (moderately or a lot)
Sindhusake et al. *(18)* (55-99, Australia) [2015]	Have you experienced any prolonged ringing, buzzing or other sounds in your ears or head within the past year, that Is, lasting for 5 minutes or longer?	Tinnitus "gets you down"

As the most common complaint from tinnitus sufferers is sleep disturbance, a first proposal by the experts was to use these data foI burden of disease purposes. Although this was appealing, these results give only a partial picture of all the possible consequences of tinnitus. Of all the concepts used in the selected studies, chose used by Davis *(43)* and by Hannaford *(44),* as presented in Table 5.1, match more closely the global concept of disabling tinnitus and the sirnilar concepts used for burden of disease calculations for other health problems. Therefore, the results of these two studies were used for burden of disease calcularions of tinnitus induced by environmental noise. Despite the fact that the concepts used in these two studies do not correspond exactly to the wording of the operational case definition, the authors consider that these concepts match in an acceptable and reasonable way our definition of disabling tinnitus for calculating DALYs. Studies using similar concepts for disabling tinnitus could eventually be used for burden of disease calculations.

Based on the two selected studies, the authors calculated a weighted prevalence (with weights based on sample size) of tinnitus according to severity level (Table 5.2).

Table 5.2. Weighted population prevalence calculation for disabling tinnitus

Reference	Sample size (age group)	No. of caaaa of disabling tinnitus		
		Sllght	Moderate	Severe
Davis *(43)*	19 023 (17+)	634 (3.3%)	228 (1.2%)	83 (0.4%)
Hannaford et al. *(44)*	15 788 (14+)	564 (3.6%)	189 (1.2%)	59 (0.4%)
Weighted mean prevalence	—	3.4	1.2	0.4

The general trend for the relationship between tinnitus prevalence and age generally shows that tinnitus prevalence increases with age and decreases after 60-70 years of age *(6).* Hannaford et al. *(44)* do not present the results by age group for disabling tinnitus. Davis *(6)* reports an increasing prevalence with age for disabling tinnitus (see Table 5.3). For burden of disease calculations, the crude prevalence rate was used, as both studies cover almost the same age range (14 years and over or 17 years and over) and were done in two countries that have similar age distributions. For countries with different age distributions than European countries, the prevalence data by age group presented in chapter 9, Tables: section 1 page 901 under "Tinnitus affecting quality of life" of reference 43 can be used.

There are no clinically or statistically significant gender differences for noise-induced tinnitus *(6,38).* Therefore, the authors suggest not taking gender into account for burden of disease calculations of tinnitus induced by environmental noise.

Prevalent cases in EUR-A countries were calculated based on population data extracted from the European health for all database *(46)* (Table 5.3). There is some evidence that noise-induced tinnitus is present in children *(47).* To our knowledge, there are no population data on the prevalence of tinnitus· in children. As the available prevalence data are based on two population studies of young people aged 14 years and over and 17 years and over, respectively, prevalent cases in EUR-A countries were calculated for age 15 years and over. The year 2001 was used for this example of calculation for comparison with *The world health report 2002 (48).*

Table 5.3. Population and prevalent cases of dlsabllng tinnitus per severity level for the WHO EUR-A epidemiological subregion, 15 years old and over, 2001

Total population	Populatlon aged 15 years and over	Weighted prevalence per severity level	Prevalent cases of disabling tinnitus by seventy level
413 967 744	3441313B6	Sllght:3.4%	11845523
		Moderate: 1.2%	4122166
		Severe: 0.4%	1 407670
		Total	17 375 359

Attributable fraction of the outcome

As mentioned above, the prevalence approach involves proposing an attributable fraction of tinnitus specifically caused by environmental noise exposure in order to be able to calculate environmental noise burden of disease. Most studies reviewed, including the two selected ones, report the prevalence of tinnitus in the study population with no direct reference to cause. The few that do address cause do not specifically address environmental noise as a causal factor. There is no particular clinical presentation of tinnitus induced by environmental noise compared to tinnitus from other causes.

For burden of disease purposes, a case of environmental-noise-induced tinnitus is one that corresponds to the exclusive case definition. Cases due to mixed causes such as occupational and environmental noise exposures should be excluded from the attributable fraction. This choice will tend to give a conservative estimate of burden of disease due to tinnitus induced by environmental noise.

Only two data sources were readily available to estimate the population-attributable fraction for environmental noise. One is based on a large study in which 1535 patients attending the Tinnitus Clinic at the Oregon Health & Science University answered a standardized questionnaire. Among the 1406 patients with a valid noise exposure history, 16.2% (228/1406) reported having been exposed to recreational noise without any occupational or military exposures. Of these patients, 199 (14.2%) reported having usually or always at least one of 15 disability items. To the question "Were illness, accident or other special circumstances associated with the onset of your present tinnitus?", 26 (1.8%) reported that the onset of tinnitus was associated with exclusive recreational noise exposure. This last figure should be considered as an absolute minimum for this population, as people often do not relate the onset of their tinnitus with noise exposure unless it began suddenly following a brief, intense exposure (S.E. Griest & W.H. Martin, unpublished data, 2008).

The other available estimation is from Girard & Simard, who produced preliminary results based on a large medical surveillance database of over 88 320 workers' audiometric examinations carried out between 1983 and 1996 (S.A. Girard & M. Simard, unpublished data, 2005). After adjustment for occupational noise exposure level and duration, hearing level and age, the estimated attributable fraction of tinnitus caused exclusively by hobby or leisure noise exposure was 4.6% for this cohort *(38).*

A third source of information was used. The authors asked 14 audiology experts (clinicians, rehabilitation centre professionals and university professors), one specialized psychologist and two ear, nose and throat medical specialists for their opinion on their estimation of the attributable portion of tmnitus caused exclusively by environmental noise exposure. The experts first gave an individual estimate of the attributable fraction with figures ranging from 1% to 15%. After discussing this issue during a meeting with a subgroup of the same experts, based on the three available data sources, the consensus was for an estimated attributable fraction of 3% as a conservative but plausible and reasonable figure;

Calculation of DALYs

According to current knowledge and the data presented, the authors consider that there is no premature mortality caused by environmental-noise-induced tinnitus and therefore no YLL. Even though there are some reports of tinnitus sufferers committing suicide *(49),* these are likely to be already accounted for in calculations of burden of disease attributed to suicide.

Table 5.4 presents the calculations of DALYs for disabling tinnitus, without reference to cause, for the WHO EUR-A epidemiological subregion in 2001.

Table 5.4. DALY calculation for disabling tinnitus per severity level for WHO EUR-A epidemiological subregion, 15 years of age and over, 2001

Severity	Prevalent cases	Disability weight	DALYs
Slight	11845523	0.01	118 455
Moderate	4122166	0.11	453438
Severe	1407670	0.11	154 844
Total	17375359	—	726 737

As a comparison, the burden of non-cause-specific disabling tinnitus in EUR-A countries is higher than that of lower respiratory infections and several other well-recognized health problems (Table 5.5}.

Table 5.5. Comparison of burden of disease for disabling tinnitus with some other common health problems, EUR-A epidemiological subregion, 2001

Health problem	DALYs
Unipolar depressive disorders	4 091 000
Hearing loss, adult onset	1 857000
Diabetes mellitus	1083000
Disabling tinnitus	726000
Lower respiratory infections	614000
Oral diseases	353000
Prostate cancer	335000
Hypertensive heart disease	317 000
HIV/AIDS	208000
Sexually transmitted diseases, excluding HIV	79000

Source: World Health Organization *(48)* (except for disabling tinnitus).

DALYs for environmental-noise-induced disabling tinnitus for the WHO EUR-A epidemiological region in 2001 are presented in Table 5.6 by introducing the 3% population-attributable fraction into the calculations.

Table 5.6. Calculation of DALYs for environmental noise Induced tinnitus by severity level for the WHO EUR-A epidemiological subregion, 15 years of age and over, 2001

Severtty	Prevalent cases	Disability weight	Population• attrtbutable fraction	DALYa
Slight	11 845523	0.01	0.03	3 554
Moderate	4122166	0.11	0.03	13603
Severe	1407670	0.11	0.03	4 645
Total	17 375 359	—	—	21802

As a comparison, tlle burden of disease for environmental-noise-induced disabling tinnitus is higher cban that for cataracts or hepatitis Bin EUR-A countries (Table 5.7).

Table 5.7. Comparisons of burden of disease for envlronmental-nolse-induced disabling tinnitus with some other common health problems, WHO EUR-A epidemiological subregion, 2001

Health problem (from all causes unless mentioned)	DALYa
Mlid mental retardation caused by lead"	55000
Hepa_titis C[b]	30000
Upper respiratory infections [b]	26000
Environmental-noise-induced disabling tinnitus	22000
Cataracts [b]	19000
Hepatitis B[b]	18 000
Appendicltls [b]	16000
Period.ontal dlsease [b]	16000
Gonorrhoea [b]	15 000

• *Source:* Fewtrell Let al. *(50).*
• *Source:* World Health Organization *(48).*

These calculations are likely to be valid for the WHO EUR-A epidemiological subregion. They are based on valid population prevalence data corresponding reasonably to the case definition and with DWs matching tliis case defirtition, using a rather conservative but plausible impact fraction. Although several aspects of the calculation method are based on expert opinion, all the best available data were integrated into a systematic logical reproducible analysis.

Uncertainties, limitations and challenges

Accuracy of estimates of tinnitus prevalence

The approach chosen for this chapter uses survey-based studies to estimate the prevalence of tinnitus on a population basis. Depending on the questions used for each individual survey, the results may represent anything from lifetime to point prevalence of tinnitus, with or without considerations of duration or severity. In a recent review of the literature *(38),* prevalence of tinnitus varied from 3% to 36%.

Burden of disease calculations being based on an annual occurrence of the event of interest multiplied by duration, the prevalence data used must reflect a yearly prevalence. Therefore, only poinc prevalence data, or at the most the previous year's data on disabJing cinnitus should be considered.

This approach has some limits for calculating global burden of disease: the prevalence of tinnitus may be different from one country to another, and the survey questions vary from one study to another as there is no standardization of questionnaires. Also, cross-sectional studies have some limitations as they cannot assess the evolution of the problem in terms of fluctuations in duration and severity.

Clinical studies reveal that some individual cases of tinnitus do fluctuate over time from more to less disabling and vice versa *(6)*. Nevertheless, it is assumed that, on average, the overall prevalence will remain stable all year round on a population level.

Lack of exposure data

To our knowledge, there are no valid population data available at present on the prevalence of exposure to leisure-time noise sufficient to induce tinnitus.

Calculatlnq burden of disease in countries other than those in Europe

The authors were unable to identify population data on disabling tinnitus outside the Organisation for Economic Co-operation and Development (OECD) countries. As tinnitus is by essence a subjective experience, its natural history may differ in different cultural settings. The authors consider that it may be risky to infer similar prevalences for economically developing countries as those found in the selected studies. For instance, as stated above, traffic noise in some urban settings is above the levels that can produce tinnitus, thus likely adding to the number of noise sources that induce disabling tinnitus and therefore to the attributable fraction of environmental-noise-induced tinnitus. Should national burden of disease calculations for environmental-noise-induced tinnitus be estimated, calculations should adjust for the age distribution of the target population.

Some experts arc convinced that the burden of tinnitus is influenced by the cultural situation. For instance, given tJlat moderate tinnitus can impair cognitive functions such as auditory working memory and visual attention span *(51,52)*, the burden may be higher in cultures with frequent highly demanding professional work, where tinnitus may contribute co unacceptable mistakes.

Conclusions

To our knowledge, the global burden of disease for disabling tinnitus or environmental-noise-induced tinnitus has never been estimated before. The epidemiology of functional limitations caused by tinnitus is rather scarce and even more so for environmental-noise-induced tinnitus.

Although the proposed approach is in some aspects based on expert opinion, hopefully it will be useful as a starting place from which to better ascertain the burden of s ffecing caused by tinnitus. One oft-he fundamental goals in constructing summary measures of health is to identify the relative magnitude of different health problems, including diseases, injuries and dsk factors *(53)*. The estimate of environmental-noise-induced tinnicus presented in this chapter is based on the best available science and may e u on the conservative side, according to the authors. Therefore, it is our hope that this work will help to better understand and value the importance of diseases such as 6nnitus, which are often not very well known or understood outside specific expert circles, and therefore not a very high priority in the political agenda.

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Appendix 1. Classification and Measurement System of Functional Health (CLAMES)

Core attributes

Pain or discomfort	1. Generally free of pain and discomfort 2. Mild pain or discomfort 3. Moderate pain or discomfort 4. Severe pain or discomfort
Physical functioning	1. Generally no limitations in physical functioning 2. Mild limitations in physical functioning 3. Moderate limitations in physical functioning 4. Severe limitations in physical functioning
Emotional state	1. Happy and interested in life 2. Somewhat happy 3. Somewhat unhappy 4. Very unhappy 5. So unhappy that life is not worth while
Fatigue	1. Generally no feelings of tiredness, no lack of energy 2. Sometimes feel tired, and have little energy 3. Most of the time feel tired, and have little energy 4. Always feel tired, and have no energy
Memory and thinking	1. Able to remember most things, think clearly and solve day-to-day problems 2. Able to remember most things but have some difficulty when trying to think and solve day-to-day problems 3. Somewhat forgetful, but able to think clear1y and solve day-to-day problems 4. Somewhat forgetful. and have some difficulty when trying to think or solve day-to-day problems 5. Very forgetful, and have great difficulty when trvlni;i to think or solve dav-to-dav problems
Social relationships	1. No limitations in capacity to sustain social relationships 2. Mild limitations in capacity to sustain social relationships 3. Moderate limitations in capacity to sustain social relationships 4. Severe limitations in capacity to sustain social relationships 5. No capacity or unable to relate to other people socially

Supplementary attributes

Anxiety	1. Generally not anxious 2. Mild levels of anxiety experienced occasionally 3. Moderate levels of anxiety experienced regularly 4. Severe levels of amdety experienced most of the time
Speech	1. Able to be understood completely when speaking with strangers or friends 2. Able to be understood partially when speaking with strangers but able to be understood completely when speakIng with people who know you well 3. Able to be understood partially when speaking with strangers and people who know you well 4. Unable to be understood when speaking to other people
Hearing	1. Able to hear what is said in a group conversation, without a hearing aid, with at least three other people 2. Able to hear what is said in a conversation with one other person In a quiet room, with or without a hearing aid, but require a hearing aid to hear what Is said in a group conversation with at least three other people 3. Able to hear what Is said In a conversation with one other person in a quiet room, with or without a hearing aid, but unable to hear what Is said in a group conversation with at least three other people 4. Unable to hear what others say, even with a hearing aid
Vision	1. Able to see well enough, with or without glasses or contact lenses, lo read ordinary newsprint and recognize a friend on the other side of the street 2. Unable to see well enough, even with glasses or contact lenses, to recognize a friend on the other side of the street but can see well enough to read ordinary newsprint 3. Unable lo see well enough, even with glasses or contact lenses, to read ordinary newsprint but can see well enough to recognize a friend on the other side of the street 4. Unable to see well enough, even with glasses or contact lenses, to read ordinary newsprint or to recognize a friend on the other side of the street
Use of hands and fingers	1. No limitations in the use of hands and fingers 2. Limitations in the use of hands and fingers: but do not require special tools or the help of another person 3. Limitations in the use of hands and fingers, independent with special tools and do not require the help of another person 4. Limitations In the use of hands and fingers, and require the help of another person for some tasks 5. limitations in the use of hands and fingers, and require the help of another person for most tasks

Source: **Public Health Agency of Canada (http:l/www.phac-aspc.gc.ca/phi-isp/state_preference-eng.php#clames).**

Appendix 2. CLAMES description of a typical (median or average) case of disabling tinnitus causing some consequences

Cl.AMES attribute	Experts' description of consequence of tinnitus	Corresponding Cl.AMES descriptor"	Cl.AMES score
Pain or discomfort	Moderate physical discomfort as the persoh hears the sound in a lot of day-to-day circumstanoes (discomfort refers to an unpleasant sensation that Is not pain, such as nausea or itching)	Moderate pain or discomfort	3
Physical functioning	Generally no limitations in physical functioning	Generally no limitations in physical functioning	1
Emotional state	More unhappy or sad than happy during waking hours (more than 50% of the time unhappy), (...]	Somewhat unhappy (you are not completely unhappy, but you are more unhappy than happy)	3
Fatigue	(...] with little energy and feeling Ured most of the time	Most of the time feel tired, and have little energy (most of your waking hours are spent feeling tired or fatigued)	3
Memory and thinking	No problems with memory or thinking clearly, but will have some difficulty in solving day-to-day problems (tinnitus Influence on cognition. on thinking capacity and on attention)	Able to remember most things but have some difficulty when trying to think and solve day-to-day problems	2
Social relation-ships	Induces mild limitations in the capacity to sustain social relationships (will limit the number of people and of groups or people they relate to)	Mild limitations In the capacity to sustain social relationships (you have an inhibited capacity for social relationships: you do not always have the abOity to maintain the full range of usual social relationships)	2
Anxiety	Anxiety is a hallmark or tinnitus causing consequences (sequelae): there is a high level of anxiety experienced most of the time; there is a reefing of loss of control and helplessness	Severe levels of anxiety experienced most of the time (you experience excessive uneasiness. worry or fear most of the time)	4
Speech	No effect on speech	Able to be understood completely when speaking with strangers or friends	1

CLAMES attribute	Experts' description of consequence of tinnitus	Corresponding CLAMES descriptor"	CLAMES score
Hearing	The independent effect of tinnitus on communication is rather difficult to pinpoin♦ as a majority of tinnll!Js sufferers do have some hearing Impairment (lhese are two concomitant health problems that *may* both affect communication capacities); hearing impairment affects particularly communication in a group conversation; Zenner states that the communication problems do not have the same origin for hearing loss and tinnitus; for tinnitus patients with hyperacusls without hearing loss, often hyperac;usls is the source of difficulties communicating in groups or 3 or more people; better descriptor for tinnitus is that ii causes more of a discomfort or intolerance in situations of group conversations, rather than an impossibility to hear a conversation; nevertheless, the experts consider lhat, on average, tinnitus does cause some communication problems in groups	Able to hear what is said in a conveisation with 1 other person in a quiet room, with or without a hearing aid, but require a hearing aid to hear what is said in a group conversation with at least 3 other people Able to hear what is said in a conversation with 1 other person in a quiet room, with or without a hearing aid, but unable to hear what is said in a group conversation with at least 3 other people	3 (2)
Vision	No effect on vision	Able to see well enough, with or without glasses or contact lenses, to read ordinary newsprint and recognize a friend on Ille other side of the street	1
Use of hands and fingers		No limitations in the use of hands and fingers	1

6. ENVIRONMENTAL NOISE AND ANNOYANCE

Henk Miedema
Sabine Janssen
Rokho Kim

Noise annoyance is widely accepted as an end-point of environmental noise that can be taken as a basis for evaluating the impact of noise on the exposed popularion. As a consequence, EU Directive 2002/49/EC *(1)* recommends evaluating environmental noise exposures on the basis of estimated noise annoyance.

As discussed in Chapter 1, WHO defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" *(2)*. This implies that noise-induced annoyance may be considered an adverse effect on health. People annoyed by noise may experience a variety of negative responses, such as anger, disappoinonent, dissatisfaction, w:ithdrawal, helplessness, depression, anxiety, distraction, agitation or ex.haustion *(3-5)*. Furthermore, stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress have been found to be associated with noise exposure as well as noise annoyance *(6, 7)*. Some public health experts feel chat severe forms of noise-related annoyance should be considered a legitimate environmental issue affecting the well-being and quality of life of the population exposed to environmental noise. The most important issue in the present context is to what extent health (according to the broad definition given above) is reduced by noise and whether a DW that ex.presses this reduction, when combined with the prevalence of annoyance, leads to a significant burden of "disease". The other possibilicy would be that noise annoyance does not significantly contribute to disability and, hence, should noc be taken into accow1t when considering the noise-induced burden of disease.

In chis chapter, a method for estimating the burden of annoyance due to noise is proposed and illusrrated, and rel.ated issues are discussed. The method was developed by rhe Netherlands National Institute for Public Health (RNM) *(8)* and initially applied to the Netherlands. First, a closer look is taken at noise annoyance in the context of burden of disease calculations.

Definition of outcome

Noise annoyance is assessed at the level of populations by means of a questionnaire. Efforts have been made by the International Commission on Biological Effects of Noise and the International Organization for Standardization *(9)* towards the use of standardized questions asking for the degree of annoyance, and introducing an 11-point numerical scale and a 5-point semantic scale. Recoding scales into a 0-100 annoyance response scale, cut-off values of 50 and 72 have been used to determine the percentage of people annoyed and highly annoyed, respectively. For the 5-point scale, however, cut-off values of 40 and 60 are also in use, matching the three highest categories for annoyance and the two highest categories for high annoyance. The percentage highly annoyed, .i.e. the percentage of persons with a response exceeding 72, is the most widely used indicator of the prevalence of annoyance in a population, although percentages using other cut-offs or the mean annoyance may also be used *(J0)*. In the case study included in this chapter, high annoyance is used as the annoyance indicator. Using a lower cut-off value would give higher prevalence but would be associated with a lower DW, resulting in either a higher or a lower estimate of the burden caused by noise annoyance. An important reason for using highly annoyed as the cut-off is the expectancy that only for rather severe annoyance may it be possible to gain consensus on a DW that can be meaningfully distinguished from zero.

Provided it contributes significantly, annoyance due to environmental noise can be included in estimares of the burden related to environmental noise when (a) the noise exposure of the population is known, (b) exposure-response relationships are available for estimating the annoyance on the basis of the exposures, and (c) a DW is attached to noise annoyance. In principle, it is also possible to replace steps *(a)* and (b) by direct estimates of annoyance pr:evalence through an annoyance survey in the population concerned (outcome-based approach).

Traffic noise exposure

Within the framewo.rk of Directive 2002/49/EC *(])*, exposure data have been provided by agglomerations with more than 250 000 inhabitants, as reported by the Noise Observation and Information Service for Europe (NOISE) of the European Environment Agency (EEA) *(11)*. While not all Member States have reported yet, and some differences between Member Srates may be attributed to methodological differences rather than differences in exposure, these data provide an indication of the exposure distribution within large urban areas in the EU. The distribution of exposure to road traffic noise in Member States was used based on 110 million people, the total number of inhabitants in the agglomerations for which a report had been provided up to June 2010 *(11)*. It is assumed here that the observed exposure d.istribution may apply to the total urban population within the EU living in cities or agglomerations with more than 50 000 inhabitants, which is estimated to be around 285 million people (57% of the total EU population).

Exposure-response relationship

The EU Position Paper on dose-response relationships between transportation noise and annoyance *(12)* presented synthesis curves for noise annoyance from aircraft, road traffic and railway noise, with their 95% confidence intervals taking into account rhe variation between individuals and studies. These curves were based on all studies examined by Schultz *(13)* and Fidell et al. *(14)* for which Ld_{en} (and Ldn), and the percentage of "highly annoyed" persons (%HA) meeting certain minimal requirements could be derived, augmented by a number of additional studies *(J0)*. The raw data from a total of 54 studies from Europe, North America and Australia investigating noise annoyance from road traffic, aircraft and railways were analysed. The percentage of "highly am1oyed' persons (%HA) as a function of noise exposure indicated by Ldn was found to be the following.

Aircraft:
$\%HA = -9.199 \cdot 10^{-5} (L_{den} - 42)^3 + 3.932 \cdot 10^{-2} (L_{den} - 42)^2 + 0.2939 (L_{den} - 42)$

Road traffic:
$\%HA = 9.868 \cdot 10^{-4} (L_{den} - 42)^3 - 1.436 \cdot 10^{-2} (L_{den} - 42)^2 + 0.5118 (L_{den} - 42)$

Railways:
$\%HA = 7.239 \cdot 10^{-4} (L_{den} - 42)^3 - 7.851 \cdot 10^{-3} (L_{den} - 42)^2 + 0.1695 (L_{den} - 42)$

Data below 45dB and above 75dB (L_{den}) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels. The confidence intervals found were narrow, indicating that, even though there is considerable variation between individuals and between studies, the uncertainty regarding the relationships between noise exposure and annoyance is rather limited.

In the same way, and based on the same data, Miedema & Oudshoorn *(10)* established the following relationships for L_{dn},

Aircraft:
$\%HA = -1.395 \cdot 10^{-4} (L_{dn} - 42)^3 + 4.081 \cdot 10^{-2} (L_{dn} - 42)^2 + 0.342 (L_{dn} - 42)$

Road traffic:
$\%HA = 9.994 \cdot 10^{-4} (L_{dn} - 42)^3 - 1.523 \cdot 10^{-2} (L_{dn} - 42)^2 + 0.538 (L_{dn} - 42)$

Railways:
$\%HA = 7.158 \cdot 10^{-4} (L_{dn} - 42)^3 - 7.774 \cdot 10^{-3} (L_{dn} - 42)2 + 0.163 (L_{dn} - 42)$

Disability weight

Given the limited number of studies on a DW for annoyance, and the sensitivity of the environmental burden attributed to noise annoyance for small changes in DW, a tentative DW of 0.02 is proposed with a relatively large uncertainty interval (0.01-0.12). The minimum value (0.01) is based on the value used by de Hollander et al. *(15)* and by Stassen et al. *(16)* in environmental burden of disease calculations. The maximum value (0.12) is based on the mean DW found for severe annoyance by Van Kempen (cited in Knol & Staatsen) ***(17),*** who did a pilot study among 13 medical experts, working according to a protocol by Stouthard et al. ***(18).*** De Hollander ***(19)*** expanded this study to 35 environmental physicians, epidemiologists and public health professionals and also assessed a mean DW of 0.12 (median: 0.07; standard deviation: 0.16; range 0-0.35) using the same protocol. The relatively high DW for annoyance in these studies may be explained by the presentation of the definition of annoyance with the description that annoyance could lead to various symptoms such as being not (95%) or mildly (5%) anxious or depressed, and having no (95%) to some (5%) cognitive impairment. In addition, Muller-Wenk *(20)* found a mean DW of 0.033 (median: 0.03; range: 0.01-0.12) for communication disturbance based on a survey of 42 Swiss physicians, which may apply to annoyance related to daytime noise exposure. Based on these data and taking a "conservative approach", here only severe cases of annoyance (highly annoyed) are given DW 0.02 for estimation of burden in terms of DALYs.

EBD calculations

Here we provide a method for estimating the environmental burden of disease for noise, estimating the prevalence of noise annoyance by combining exposure data with the exposure-response relationships for noise annoyance. One year is proposed as the duration for exposure causing severe annoyance, as annoyance is an effect that disappears when the noise stops. Age was not considered, assuming that children are annoyed in the same way as adults. While this assumption seems justified, since children showed similar patterns of annoyance to those of their parents *(21),* it may lead to a slight overestimation since annoyance does not appear to be a relevant concept for infants.

We calculated the DALYs for noise annoyance using the exposure distribution in Lden presented by EEA *(11)* for large agglomerations(> 250 000 inhabitants), the exposure-response relationships for annoyance (with expected percentage of highly annoyed people at the midpoint of the category, as a function of L_{den} in the range 42-80 dB(A)) and a range of DWs. This calculation suggests that there are about 587 000 DALYs lost due to noise-induced annoyance within the EU population living in urban areas. Taking 0.01 and 0.12 as the extremes of the range for DWs, the credible range for the DALYs is 0.29-3.52 million (Tables 6.1-6.4). It should be noted that the burden in rural areas or small town with less than 50 000 inhabitants is not included here, and that we took a very conservative assumption about the exposure distribution below 50 dB(A).

Table 6.1. DALYs for highly annoyed people due to road traffic noise In the EU

Exposure category Ltn (dB(A))	Percentage of population exposed[a]	Percentage of people highly annoyed[b]	Number of cases per mlllIon[b]	DALVs lost In the urban population[c]		
				DW= 0.01	DW= 0.02	OW= 0.12
<55	50	2.n	13 835	39430	78859	473155
55-59	17	8.16	13868	39524	79 047	474285
60-64	19	12.96	24621	70170	140341	842044
65--69	9	20.08	18068	51494	102 989	617 933
70-74	4	30.25	12100	34485	68 969	413815
>75	1	30.25[d]	3025	8621	17 242	103 454
Total	100		85517	243 724	487448	2924686

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.

[b] The percentage and number of cases were calculated using the micl-level value of each exposure category. For the category of < 55 dB(A), the mid-level value was conservatively set to 48 dB(A).

[c] DALYs were calculated for the 285 million persons living in agglomerations with> 50 000 inhabitants.

[d] As the exposure-response function does not apply to the range over 75 dB(A), the percentage of people highly annoyed in this exposure category was assumed to be the same as in the 70-74 dB(A) category.

Table 6.2. DALYs for highly annoyed people due to rall traffic noise in the EU

Exposure category L_{den} (dB(A))	Percentage of population exposed[a]	Pen:enlage of people highly annoyed[b]	Number of caaes per m1Dion[b]	DALVs lost In lhe urban population[c]		
				DW= 0.01	DW= 0.02	DW= 0.12
<55	95	0.89	8462	24 116	48233	289397
55-69	3	3.44	1 031	2938	5877	35261
60-64	1	6.41	641	1 827	3655	21929
65-69	1	11.22	1122	3198	6396	38374
70-74	0	18.41	0	0	0	0
>75	0	18.41[d]	0	0	0	0
Total	100		11 256	32080	64160	384960

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.

[b] The percentage and number of cases were calculated using the mid-level value of each exposure category. For the category of < 55 dB(A), the mid-level value was conservatively set to 48 dB(A).

[c] DALYs were calculated for the 285 million persons living in agglomerations with> 50 000 inhabitants.

[d] As the exposure-response function does not apply to the range over 75 dB(A), the percentage of people highly annoyed h this exposure category was assumed to be the same as in the 70-74 dB(A) category.

Table 6.3. DALYs for highly annoyed people due to air traffic noise In the EU

Exposure category L_{den} (dB(A))	Percentage of population exposed[a]	Perc:Mta_ge of people highly annoyed[b]	Number ofcaaea per mIllIon[b]	OALYa lost In the urban population[c]		
				DW= 0.01	OW= 0.02	DW• 0.12
<55	96	3.16	30327	33360	66719	400315
55-69	3	13.66	4098	11 679	23358	140147
60-64	1	21.76	2176	6201	12401	74408
65-69	0	31.54	0	0	0	0
70-74	0	42.93	0	0	0	0
>75	0	42,93[d]	0	0	0	0
Total	100		36601	17880	35759	214555

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.

[b] The percentage and number of cases were calculated using the mid-level value of each exposure category. For the category of < 55 dB(A), the mid-level value was conservatively set to 48 dB(A).

[c] DALYs were calculated for the 285 million persons living in agglomerations with> 50 000 inhabitants.

[d] As the exposur�sponse function does not apply to the range over 75 dB(A), the percentage of people highly annoyed in this exposure category was assumed to be the same as in the 70-74 dB(A) category.

Table 6.4. DALYs for highly annoyed people due to all traffic noise In the EU-

Source of traffic nolae	DALVa		
	ow.o.o,	DW•0.02	ow.0.12
Road	243 724	487448	2924 686
RaU	32080	64160	384960
Air	17880	35759	214555
Total	293684	587 367	3524201

• For the 285 million population IMng in agglomerations with > 50 000 inhabitants.

Uncertainties, limitations and challenges

Alternative approaches

The burden in terms of DALYs may also be directly estimated on the basis of noise annoyance smvey data in the population concerned, if available. However, we expect that the approach starting with the noise exposure levels will be most feasible in the future with the increase of the noise exposure mapping effort. Moreover, it is less sensitive to the idios>•ncrasies of the different surveys conducted in different populations and the differences in the processing of the data obtained with the surveys, and it is less sensitive to temporary factors affecting the response of a population surveyed. Therefore, provided char the noise exposure assessment is sufficiently harmonized, the approach that estimates the prevalence of noise annoyance by combining exposure data with the exposure-response relationships for noise annoyance appears to be most promising.

Choice of the exposure-response relationship for annoyance

Various authors have synthesized existing data from community annoyance surveys co develop an exposure-response relationship for use io environmental impact analyses and related community planning efforts, such as Schultz *(13),* Fidell et al. *{14)* and Miedema & Oudshoorn *(JO)*. SchuJtz recognized the preliminary nature of his original synthesis curve, and did not expect it to remain the final word for long *(19).* The most comprehensive of these meta-analyses is dearly that published in 2001 by Miedema & Ou.dshoorn *(JO)*. There are, however, two types of qualification chat have to be made, which are not elaborated on here:

- the relationships can be refined by taking into account non-acoustical factors and, probably more relevant, acoustical factors that can be affected by policy other than the exposure at the most exposed side, such as sound insulation of the dwelling or the presence or absence of a quiet side *(7);* and

- there are strong indications that the exposure-response relationships for aircraft noise have changed, so that the curves presented here probably underestimate the annoyance at a given aircraft noise exposure level *(20).*

Uncertainty with respect to the exposure-response relationship

One cause of doubt regarding the predictability of noise annoyance is that the studies show a large variation in individual annoyance reactions to the same noise exposure level. The other cause of doubt is that attempts co integrate the results from different studies show that there is a large variation in the relationships found in different studies. The large individual variation and the large study variation suggest that it is difficult to predict annoyance with sufficient accuracy. Indeed, the annoyance response of a particular individual or group of individuals can be predicted on the basis of the exposure only with a large amount of uncertainty. This uncertainty can be described by the prediction interval for individuals or groups around the exposure-response curves.

Nevertheless, in most cases, the uncertainty regarding individual or group reactions is not what matters for noise policy. Most policy, including that based on estimates of the burden of disease due to environmental noise, is made with a view to the overall reaction to exposures in a (reference) population. This means that it is not the uncertainty with respect to the prediction of an individual or group reaction that is important, but the uncercainry regarding the exact relationship between exposure and response in the (reference) population. The accuracy of the estimation of this relationship is described by the confidence interval around the curve. [f properly established, the confidence interval takes into account the variation between individuals as well as the variation between studies. As found by Miedema & Oudshoorn *(10),* this results in relatively narrow confidence intervals (as opposed to the wide prediction intervals for individuals or groups).

Applications and /lmitations of the exposure-response relationship

According to the EU Position Paper, which also recommends the exposure-response relationships presented here, they are only to be used for aircraft, road traffic and railway noise and for assessing long-term, stable situations *(12)*. They can be utilized for strategic assessments, in order to estimate the effects of noise on populations in terms of annoyance. They are not applicable to local, complaint-type situations or to the assessment of the short-term effects of a change of noise climate. The curves have been derived for *adults.* The curves are not recommended for specific sources such as helicopters, low-flying military aircraft, train shunting, shipping, or aircraft on the ground (taxiing) *(12)*.

Conclusions

Compared to other effects of environmental noise and also compared to effects of environmental factors in general, there are relatively many data directly obtained from exposed humans in the field from which exposure-response relationships for noise annoyance could be derived. It appears that, with the increasing effort on noise mapping, more and better noise exposure data will become available so that, by combining them with the relationships, the prevalence of annoyance can be estimated. The third ingredient for estimating the burden due to environmental noise appears the most difficult. It is hard to weigh "annoyance" and it is difficult to relate it to existing weighted outcomes. We used the limited data on the weights available, giving the indication that about 0.5 million DALYs are lost yearly among the urban population in EU countries owing to the occurrence of noise annoyance.

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7. CONCLUSIONS

Lin Fritschi
A. Lex Brown
Rokho Kim
Dietrich Schwela
Stelios Kephalopoulos

Environmental noise: a public health problem

Environmental noise, also known as noise pollution, is among the most frequent sources of complaint regardjng environmental issues in Europe, especially in densely populated urban areas and residential areas near highways, railways and airports. ti, comparison to other pollutants, the control of environmental noise has been hampered by insufficient knowledge of its effects on hwnans and of exposure-response relationships, as well as a lack of defined criteria. In 1999, WHO pub}jshed its *Guidelines for community noise (1).*

The European Parliament and Council adopted Directive 2002/49/EC of 25 June 2002 *(2)* with the main aim of providing a common basis for cackling noise problems across the EU. This Directive defines environmental noise as unwanted or harmful outdoor sound created by human activities, including uojse from road traffic, railway traffic airports and industrial sites, and focuses on three action areas: the determination of exposure to environmental noise dirough noise mapping, based on common assessment methods; the adoption of action plans *by* the Member States based on noise-mapping results; and public access to information on environmental noise and its effects.

Among the various effects of environmental noise, health effects are a growing concern of both the general public and policy-makers *in* the Membei; Status in Europe. Most of the assessments performed so far to evaluate the impact of environmental noise have been based on the annoyance it causes. Its consideration as a public health problem with measurable health outcomes has been limited *(3).*

In 2009, WHO published the *Night noise guidelines.for Europe (4).* Thjs publication presented new evidence of the health damage of nighttime noise exposure and recommend rhreshold values that, if breached at night, would threaten health. An annual average night exposure not exceeding 40 dB outdoors is recommended in the guidelines.

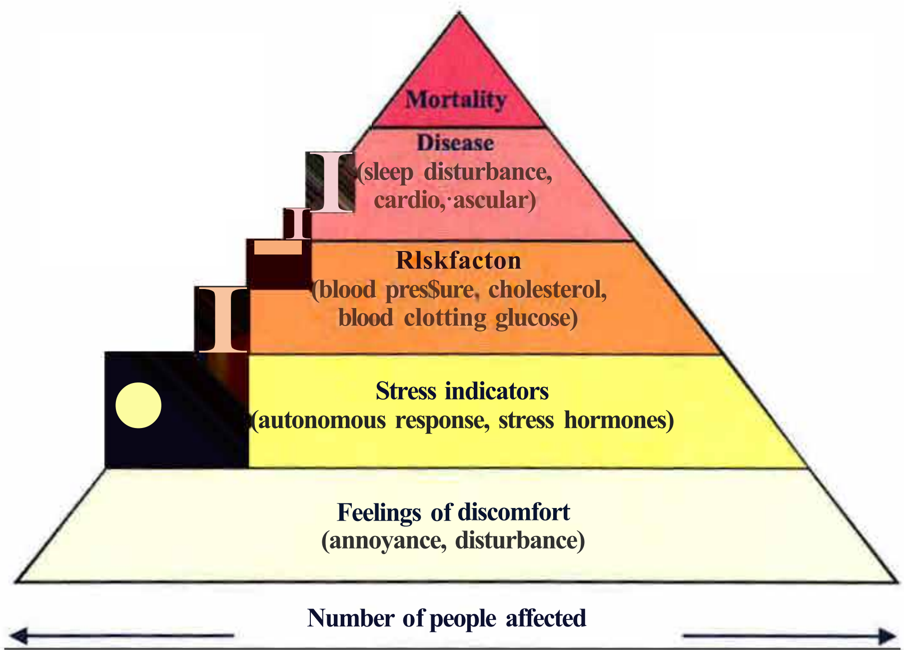
Considering the scientific evjdence on the threshold of night noise exposure indicated by Lnight as defined in Directive 2002/49/EC, a Lnight value 0€ 40 dB should be the target of the night noise gwdelines to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly. A Lnight value of 55 dB is recommended as an interim target for countries that cannot follow night noise guidelines in the short term for various reasons and where policy-makers choose to adopt a stepwise approach. These guidelines can be considered an extension to the previous WHO *Gui.defines for community noise (I).*

Over the past few years, the working group of experts convened by the European Centre for Environment and Health, Bonn Office and supported by the Joint Research Centre of the European Commission, has collaborated to estimate the burden of disease from environmental noise, using available evidence and data to inform policy-makers and the public about the health impacts of noise exposure in Europe. The chapters in this publication contain the summary of synthesized reviews of evidence on the relationship between environmental noise and specific health effects. Following the EBD methodology of WHO, the health impacts of environmental noise were estimated using exposure-response relationships, exposure distribution, background prevalence of disease and DWs. For each chapter on specific health outcome, a case study is provided. Policy-makers and their advisers can use these chapters as good practice guidance for the process of quantifying specific health risks of environmental noise.

Effects of environmental noise on selected health outcomes

The severity of health effects due to noise versus the number of people affected is schernatically presemed by Fig. 7.1. Annoyance, sleep disturbance, cardiovascular disease, cognitive impairment, hearing impairment and tinnitus were initially selected by the working group as health outcomes related to environmental noise.

Fig. 7.1. Severity of health effects of noise and number of people affected



Source: Babisch *(3).*

Sufficient evidence was available to perform calculations of burdens of such outcomes as annoyance, sleep disturbance and cardiovascular disease. The epidemiological evidence was not as sufficient but was still enough for assuming the relationship of environmental noise to cognitive impairment and tinnitus. The epidemiological studies linking hearing impairment to environmental noise exposure are so sparse that any generalization can be considered exploratory and speculative. Therefore, following the recommendations of the peer-reviewers, the chapter on hearing impairment was not included in this publication.

Cardiovascular disorders

The noise indicators used for noise mapping in the EU can - in principle - be used for a quantitative risk assessment regarding cardiovascular risk if exposure-response relationships are known. Only two end-points - hypertension and ischaemic heart disease - should be considered at this stage. If necessary, different exposure-response curves could be used for different exposures. The noise indicator L_{den} may be useful for assessing and predicting annoyance in the population. However, non-weighted day and night noise indicators may be more appropriate for health-effect-related research and risk quantification.

Coqnltive Impairment

Scientific evidence indicates the adverse effects of chronic noise exposure on children's cognition. There is no generally accepted criterion for quantification of the degree of cognitive impairment into a **DW.** However, it is possible to make a conservative estimate of loss in **DALYs** using the methods presented in this chapter. It is important to consider the assumptions, uncertainties and limitations of the methods when interpreting the estimated values of EBD.

Sleep disturbance

Although self-reported sleep disturbance may not reflect the total impact of night-time noise on sleep, it is the effect for which exposure-response relationships on the basis of L_{night} are available for the most important noise sources. Furthermore, while it is hard to weigh self-reported sleep disturbance, it may be even harder to assign a **DW** to physiological changes indicating a certain degree of sleep fragmentation. Now that exposure data from noise mapping will become available as well as the exposure-response relationships, the prevalence of self-reported sleep disturbance can be estimated.

Tinnitus

There is a method to estimate burden of tinnitus from environmental noise based on expert opinion, which will be useful as a starting point using conservative assumptions and approaches.

Annoyance

There are relatively many data directly obtained from exposed humans in the field from which exposure-response relationships for noise annoyance could be derived. It is hard to weigh "annoyance" and it is difficult to relate it to existing DW values. However, if the national and local authorities are willing to take into account the most common complaints of environmental noise, they could assign an acceptable **DW** value to annoyance, and estimate EBD accordingly.

£st/mated DALYs for western European countries

It is estimated that DALYs lost from environmental noise in the EU countries are 60 000 years for ischaemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 21 000 years for tinnitus and 587 000 years for annoyance. Sleep disturbance and annoyance mostly related to road traffic noise comprise the main burdens of environmental noise in western Europe. If all of these impacts are considered together, the interval estimate would be 1.0-1.6 million DALYs.[9] The total burden of health effects from environmental noise would be greater than one million years in western Europe, even with the most conservative assumptions that avoid any possible duplication.

Uncertainties, limitations and challenges

The process of risk assessment involves the gathering, synthesizing and interpretation of available evidence. The EBO process, as applied by WHO, is one way of synthesizing this evidence in a standardized manner. EBO methods depend on the availability of data, information, and specific assumptions. To obtain valid and reliable estimates of EBO, good data are needed on the distribution of exposure, on outcomes and on the exposure-response relationship. In the European region, more and better data are available on the distribution of environmental noise, and it is expected that the process of ongoing implementation of EU Directive 2002/49/EC will provide higher quality data in standardized formats comparable between the countries. Regarding outcomes, high-quality data are available for some (e.g. cardiovascular disease) but not for others (e.g. tinnitus). Established exposure-response relationships exist for annoyance, sleep disturbance (subjective), cognitive impairment (children) and cardiovascular disease.

Selection of health effects

Unfortunately, the quality and the quantity of the evidence and data are not the same across the different health outcomes. Other than for cardiovascular disease, obtaining prevalence estimations for the conditions discussed in this publication posed some difficulties. Most of the subclinical conditions are not recorded in routine mortality and morbidity statistics. For tinnitus, the proportion caused by leisure noise rather than occupational noise was difficult to estimate. And conditions such as cognitive impairment in children, sleep disturbance and annoyance are difficult to characterize, let alone estimate the proportion caused by environmental noise. Nevertheless, this publication brings together the best literature and available data and provides transparent justifications of the estimates using conservative assumptions.

Some other outcomes have been suggested as being associated with environmental noise, including hearing impairment, psychiatric conditions such as depression and anxiety, next-day effects of sleep disturbance such as motor accidents. As more evidence accumulates on whether these conditions are indeed associated with environmental noise, further refinements of the estimates in this volume can be made.

Noise exposure Indicators

The EU adopted harmonized noise metrics across its Member States: L_{den} to assess annoyance and L_{night} to assess sleep disturbance *(1)*. These metrics are used for strategic mapping of exposure in the EU Member States and are common across all transport sources and other sources of environmental noise. The quality of the exposure data produced through the first round of strategic noise maps in EU may not be.optimal in terms of validity and reliability. This will have an unavoidable impact

9 The extent to which years lost from different effects are additive across different outcomes is unclear. The different health outcomes might have synergistic rather than antagonistic when the combined effects occur in a person. Therefore, it would be a conservative approach to add the DALYs of different outcomes not considering synergistic effects.

on the accuracy and precision of any risk assessment using these exposure data. With the full implementation of Directive 2002/49/EC, L_{den} and L_{night} are widely accepted as standard indicators of noise exposure in Europe *(6)*. Many previous studies used other metrics that can be converted to L_{den} and L_{night} with some assumptions. However, this conversion from old to new indicators will contribute to the uncertainties of the estimate.

Exposure-response relationships

Although the exposure-response relationships presented in this publication are based on the available evidence at the time of the working group meetings, there are uncertainties especially when they are derived from limited numbers of studies. It should be noted that the exposure-response relationships will need to be updated using the results of future studies.

Confoundlnq factors and effect modifiers

Most epidemiological studies are prone to bias if confounding factors are not properly controlled by design or statistical methods. Confounding factors include age, gender, smoking, obesity, alcohol use, socioeconomic status, occupation, education, family status, military service, hereditary disease, medication, medical status, race and ethnicity, physical activity, noisy leisure activities, stress-reducing activities, diet and nutrition, housing conditions (crowding) and residential status. Future epidemiological research will have to consider effect modifiers (vulnerable groups, sensitive hours of the day, coping mechanisms, different noise sources, etc.) as well as potential confounding factors.

Combined exposure to noise, air pollution and chemicals

The health impacts of the combined exposure to noise, air pollutants and chemicals are rarely considered in epidemiological studies. Combined exposures occur, for example, when people are exposed to road traffic where noise and air pollution co-exist. The stressors that might be considered in the context of combined exposure with noise include: indoor air pollutants (environmental tobacco smoke, volatile organic compounds), outdoor air pollutants (particulate matter, carbon monoxide, sulphur dioxide, nitrogen dioxide), asphyxiants (carbon monoxide, hydrogen cyanide), solvents (xylene, styrene, toluene, benzene, etc.), heavy metals (lead, mercury), pesticides (organophosphates), variables related to housing (biological agents), and vibration.

An international workshop organized by the Joint Research Centre of the European Commission in cooperation with EEA and WHO in 2007 *(7)* concluded that the best knowledge on the health effects due to combined exposure to noise and solvents or heavy metals exists in occupational environments. However, there are few studies showing combined effects of noise and air pollutants in urban environments. Some data exist only on respiratory disorders caused by combined effects of noise and outdoor air pollutants, balance disorders caused by occupational exposure to noise and solvents, and effects on human growth caused by combined effects of noise and heavy metals. The workshop concluded that a substantial amount of research is needed to determine the health effects of combined exposure to environmental noise and other environmental pollutants.

Total burden from environments/ noise

In general, care should be taken to avoid "double counting" when DALYs from different outcomes are totalled to estimate an overall burden of disease from an environmental risk factor. In the case of environmental noise, this should not be a big problem. For example, the burdens of annoyance during the daytime and sleep disturbances at night can be safely added up. Nevertheless, because of the different qualities of the evidence underlying the different EBD calculations, special care should be taken when making direct comparisons between DALYs for different outcomes.

If DALYs caused by environmental noise are compared with those from other pollutants, it is important to take into account the approximations and assumptions made in the calculation process. More information on these issues has been summarized in documents on the methodology of EBD *(8)*.

Health Inequality and vulnerable qroups

Some noise exposures may be worse for some subgroups than for others. Issues such as the lower housing prices near noisy roads mean that the effect of noise is not uniformly distributed throughout the population. Except for a chapter on cognitive impairment in children, this publication did not explore the additional burdens in potentially vulnerable subgroups such as older people and lower socioeconomic groups.

Uses of this publication

The evidence and methods for quantifying the health impacts of environmental noise presented and iJlustrated in this volume can be used by policy-makers, planners and engineers to measure the magnitude of health problems related to noise pollution in society today. Because many European countries have already produced strategic noise maps and action plans on noise control according to Directive 2002/49/EC *(2)*, the good practices of risk assessment presented in this volume can be readily applied to the national and local situations in many countries. In countries where all the required data for a complete calculation of burden of disease may nor be available, this publication demonstrates a range of options that can be used to make estimations according to which components of the risk assessment are accessible.

Although this publication has been prepared with a European focus in terms of policy, available data and legislation, the processes of risk assessment illustrated here can also be used outside Europe as long as the assumptions, limitations and uncertainties described in the various chapters are carefully taken into account.

The effects of neighbourhood noise were not addressed in this publication as they need to be better characterized and measured in future studies. In addition, the effects of leisure noise were not considered because there is very little information available on the prevalence of voluntary exposure to leisure noise through amplified music at concerts and other public events and through personal music players.

Noise and the Parma Declaration on Environment and Health

There is overwhelming evidence that exposure to environmental noise has adverse effects on the health of the population. Recognizing the special need to protect children from the harmful effects of noise, the Parma Declaration adopted at the Fifth Ministerial Conference on Environment and Health *(9)* called on all stakeholders to work together to reduce the exposure of children to noise, including that from personal electronic devices, from recreation and traffic (especially in residential areas), at child care centres, kindergartens and schools and in public recreational settings. This publication provides an evidence base for the future development of suitable guidelines on noise by WHO, as was urged by the Member States in the Parma Declaration. The evidence on burden of disease presented here will inform the new European health policy, Health 2020, which will be presented for endorsement at the WHO Regional Committee for Europe in 2012.

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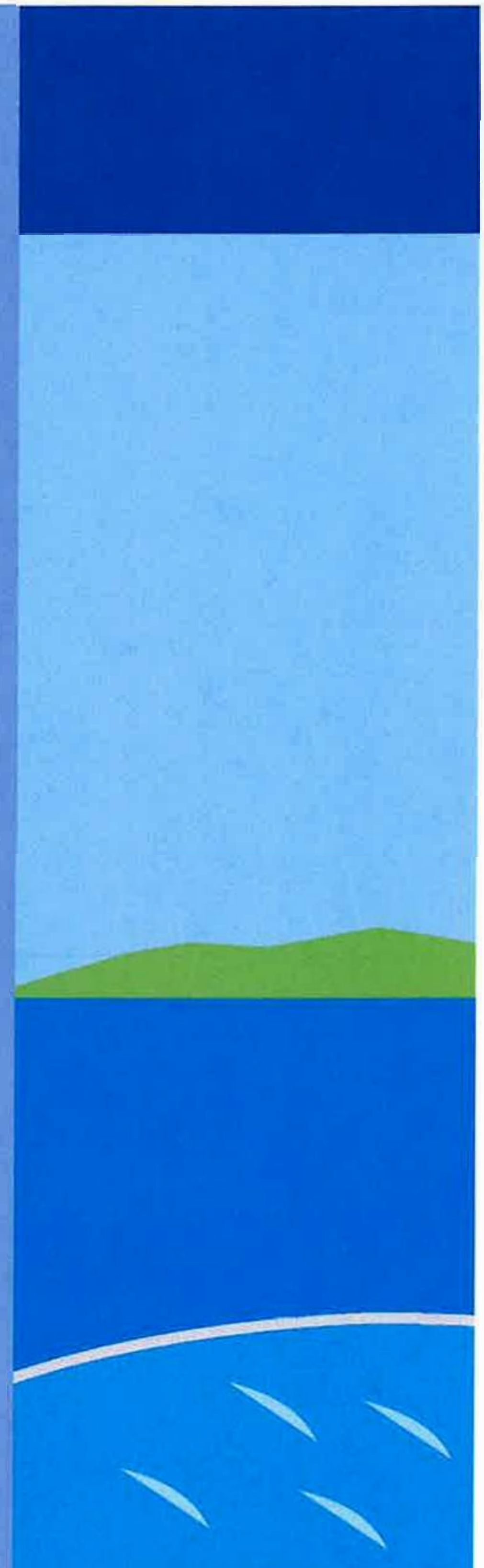
Burden of Disease from Environmental Noise

The health impacts 0f envirenmental noise are a growing dtone:zem among both the general public and palicy makers in Eurepe. This publication provides technical support fo policy-makers and their advfs rs in the quantitative risk assessment of environmental noise, using evidence and data available in Europe. It contains the summary G>fsynthesized reviews of evidence on the relationship between environmental noise and specific health effects, including e::ardiovasc1,1laf disease, cognitive impairment, steeri) disturbanc;e, tinnitus, and annoyance. F0r each outcome, the environmental burden of disease methgdology, based on exposure-r:esponse relationship, exposure distribution, l!>ackgreund prevalence of diseas and disability wei!!lhts of the outcame, is applied to calculate the burden of disease in terms of disability-adj1.1sted life-years. The r,esults indit:ate that at least one million healthy life years are lost every year frem traffic-related n@ise in the western part ef Eurepe. Owing to a lack pf e_xposure data in seuth-east Europe and the newly independent states, it was not possible to estimate the disease burden in the whole of the WHO European Region. The procedure 0f estimating burdens presented in this publiEati<m Gan be used by intematienal, natienal and lecal authorities h prioritizing and planning erivir0nmental and public health policies.

World Health Organization
Regional Office for Europe
Sche!!Ogsve.j 8. DK 2JOO €opeuhagen 0„ Dentn!U'k
Tel.; +'5 39 11 P 17. Fn;,: +'if> JI} 17 18 18. E-mail: eontm:L@euM.who.int
\Veh sit|l : ww\,•.eul'o,who.int



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DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 25 June 2002
relating to the assessment and management of environmental noise

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof,

Having regard to the proposal from the Commission [1],

Having regard to the opinion of the Economic and Social Committee [2],

Having regard to the opinion of the Committee of the Regions [3],

Acting in accordance with the procedure laid down in Article 251 of the Treaty [4], and in the light of the joint text approved by the Conciliation Committee on 8 April 2002,

Whereas:

(1) It is part of Community policy to achieve a high level of health and environmental protection, and one of the objectives to be pursued is protection against noise. In the Green Paper on Future Noise Policy, the Commission addressed noise in the environment as one of the main environmental problems in Europe.

(2) In its Resolution of 10 June 1997 [5] on the Commission Green Paper, the European Parliament expressed its support for that Green Paper, urged that specific measures and initiatives should be laid down in a Directive on the reduction of environmental noise, and noted the lack of reliable, comparable data regarding the situation of the various noise sources.

(3) A common noise indicator and a common methodology for noise calculation and measurement around airports were identified in the Commission Communication of 1 December 1999 on Air Transport and the Environment. This communication has been taken into account in the provisions of this Directive.

(4) Certain categories of noise emissions from products are already covered by Community legislation, such as Council Directive 70/157/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles [6], Council Directive 77/311/EEC of 29 March 1977 on the approximation of the laws of the Member States relating to the driver-perceived noise level of wheeled agricultural or forestry tractors [7], Council Directive 80/51/EEC of 20 December 1979 on the limitation of noise emissions from subsonic aircraft [8] and its complementary directives, Council Directive 92/61/EEC of 30 June 1992 relating to the type-approval of two or three-wheel motor vehicles [9] and Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000 on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors [10].

(5) This Directive should *inter alia* provide a basis for developing and completing the existing set of Community measures concerning noise emitted by the major sources, in particular road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery, and for developing additional measures, in the short, medium and long term.

(6) Certain categories of noise such as noise created inside means of transport and noise from domestic activities should not be subject to this Directive.

(7) In accordance with the principle of subsidiarity as set out in Article 5 of the Treaty, the Treaty objectives of achieving a high level of protection of the environment and of health will be better reached by complementing the action of the Member States by a Community action achieving a common understanding of the noise problem. Data about environmental noise levels should therefore be collected, collated or reported in accordance with comparable criteria. This implies the use of harmonised indicators and evaluation methods, as well as criteria for the alignment of noise-mapping. Such criteria and methods can best be established by the Community.

(1) OJ C 337 E, 28.11.2000, p. 251.
(2) OJ C 116, 20.4.2001, p. 48.
(3) OJ C 148, 18.5.2001, p. 7.
(4) Opinion of the European Parliament of 14 December 2000 (OJ C 232, 17.8.2001, p. 305), Council Common Position of 7 June 2001 (OJ C 297, 23.10.2001, p. 49) and Decision of the European Parliament of 3 October 2001 (OJ C 87 E, 11.4.2002, p. 118). Decision of the European Parliament of 15 May 2002 and Decision of the Council of 21 May 2002.
(5) OJ C 200, 30.6.1997, p. 28.
(6) OJ L 42, 23.2.1970, p. 16. Directive as last amended by Commission Directive 1999/101/EC (OJ L 334, 28.12.1999, p. 41).
(7) OJ L 105, 28.4.1977, p. 1. Directive as last amended by Directive 97/54/EC (OJ L 277, 10.10.1997, p. 24).
(8) OJ L 18, 24.1.1980, p. 26. Directive as last amended by Directive 83/206/EEC (OJ L 117, 4.5.1983, p. 15).
(9) OJ L 225, 10.8.1992, p. 72. Directive as last amended by Directive 2000/7/EC (OJ L 106, 3.5.2000, p. 1).
(10) OJ L 162, 3.7.2000, p. 1.

(8) It is also necessary to establish common assessment methods for 'environmental noise' and a definition for 'limit values', in terms of harmonised indicators for the determination of noise levels. The concrete figures of any limit values are to be determined by the Member States, taking into account, *inter alia*, the need to apply the principle of prevention in order to preserve quiet areas in agglomerations.

(9) The selected common noise indicators are L_{den}, to assess annoyance, and L_{night}, to assess sleep disturbance. It is also useful to allow Member States to use supplementary indicators in order to monitor or control special noise situations.

(10) Strategic noise mapping should be imposed in certain areas of interest as it can capture the data needed to provide a representation of the noise levels perceived within that area.

(11) Action plans should address priorities in those areas of interest and should be drawn up by the competent authorities in consultation with the public.

(12) In order to have a wide spread of information to the public, the most appropriate information channels should be selected.

(13) Data collection and the consolidation of suitable Community-wide reports are required as a basis for future Community policy and for further information of the public.

(14) An evaluation of the implementation of this Directive should be carried out regularly by the Commission.

(15) The technical provisions governing the assessment methods should be supplemented and adapted as necessary to technical and scientific progress and to progress in European standardisation.

(16) The measures necessary for the implementation of this Directive should be adopted in accordance with Council Decision 1999/468/EC of 28 June 1999 laying down the procedures for the exercise of implementing powers conferred on the Commission [1],

HAVE ADOPTED THIS DIRECTIVE:

Article 1

Objectives

1. The aim of this Directive shall be to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise. To that end the following actions shall be implemented progressively:

(a) the determination of exposure to environmental noise, through noise mapping, by methods of assessment common to the Member States;

(b) ensuring that information on environmental noise and its effects is made available to the public;

(c) adoption of action plans by the Member States, based upon noise-mapping results, with a view to preventing and reducing environmental noise where necessary and particularly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality where it is good.

2. This Directive shall also aim at providing a basis for developing Community measures to reduce noise emitted by the major sources, in particular road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery. To this end, the Commission shall submit to the European Parliament and the Council, no later than 18 July 2006, appropriate legislative proposals. Those proposals should take into account the results of the report referred to in Article 10(1).

Article 2

Scope

1. This Directive shall apply to environmental noise to which humans are exposed in particular in built-up areas, in public parks or other quiet areas in an agglomeration, in quiet areas in open country, near schools, hospitals and other noise-sensitive buildings and areas.

2. This Directive shall not apply to noise that is caused by the exposed person himself, noise from domestic activities, noise created by neighbours, noise at work places or noise inside means of transport or due to military activities in military areas.

Article 3

Definitions

For the purposes of this Directive:

(a) 'environmental noise' shall mean unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity such as those defined in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control [2];

(b) 'harmful effects' shall mean negative effects on human health;

[1] OJ L 184, 17.7.1999, p. 23.

[2] OJ L 257, 10.10.1996, p. 26.

(c) 'annoyance' shall mean the degree of community noise annoyance as determined by means of field surveys;

(d) 'noise indicator' shall mean a physical scale for the description of environmental noise, which has a relationship with a harmful effect;

(e) 'assessment' shall mean any method used to calculate, predict, estimate or measure the value of a noise indicator or the related harmful effects;

(f) 'L_{den}' (day-evening-night noise indicator) shall mean the noise indicator for overall annoyance, as further defined in Annex I;

(g) 'L_{day}' (day-noise indicator) shall mean the noise indicator for annoyance during the day period, as further defined in Annex I;

(h) '$L_{evening}$' (evening-noise indicator) shall mean the noise indicator for annoyance during the evening period, as further defined in Annex I;

(i) 'L_{night}' (night-time noise indicator) shall mean the noise indicator for sleep disturbance, as further defined in Annex I;

(j) 'dose-effect relation' shall mean the relationship between the value of a noise indicator and a harmful effect;

(k) 'agglomeration' shall mean part of a territory, delimited by the Member State, having a population in excess of 100 000 persons and a population density such that the Member State considers it to be an urbanised area;

(l) 'quiet area in an agglomeration' shall mean an area, delimited by the competent authority, for instance which is not exposed to a value of L_{den} or of another appropriate noise indicator greater than a certain value set by the Member State, from any noise source;

(m) 'quiet area in open country' shall mean an area, delimited by the competent authority, that is undisturbed by noise from traffic, industry or recreational activities;

(n) 'major road' shall mean a regional, national or international road, designated by the Member State, which has more than three million vehicle passages a year;

(o) 'major railway' shall mean a railway, designated by the Member State, which has more than 30 000 train passages per year;

(p) 'major airport' shall mean a civil airport, designated by the Member State, which has more than 50 000 movements per year (a movement being a take-off or a landing), excluding those purely for training purposes on light aircraft;

(q) 'noise mapping' shall mean the presentation of data on an existing or predicted noise situation in terms of a noise indicator, indicating breaches of any relevant limit value in force, the number of people affected in a certain area, or the number of dwellings exposed to certain values of a noise indicator in a certain area;

(r) 'strategic noise map' shall mean a map designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area;

(s) 'limit value' shall mean a value of L_{den} or L_{night}, and where appropriate L_{day} and $L_{evening}$, as determined by the Member State, the exceeding of which causes competent authorities to consider or enforce mitigation measures; limit values may be different for different types of noise (road-, rail-, air-traffic noise, industrial noise, etc.), different surroundings and different noise sensitiveness of the populations; they may also be different for existing situations and for new situations (where there is a change in the situation regarding the noise source or the use of the surrounding);

(t) 'action plans' shall mean plans designed to manage noise issues and effects, including noise reduction if necessary;

(u) 'acoustical planning' shall mean controlling future noise by planned measures, such as land-use planning, systems engineering for traffic, traffic planning, abatement by sound-insulation measures and noise control of sources;

(v) 'the public' shall mean one or more natural or legal persons and, in accordance with national legislation or practice, their associations, organisations or groups.

Article 4

Implementation and responsibilities

1. Member States shall designate at the appropriate levels the competent authorities and bodies responsible for implementing this Directive, including the authorities responsible for:

(a) making and, where relevant, approving noise maps and action plans for agglomerations, major roads, major railways and major airports;

(b) collecting noise maps and action plans.

2. The Member States shall make the information referred to in paragraph 1 available to the Commission and to the public no later than 18 July 2005.

Article 5

Noise indicators and their application

1. Member States shall apply the noise indicators L_{den} and L_{night} as referred to in Annex I for the preparation and revision of strategic noise mapping in accordance with Article 7.

Until the use of common assessment methods for the determination of L_{den} and L_{night} is made obligatory, existing national noise indicators and related data may be used by Member States for this purpose and should be converted into the indicators mentioned above. These data must not be more than three years old.

2. Member States may use supplementary noise indicators for special cases such as those listed in Annex I(3).

3. For acoustical planning and noise zoning, Member States may use other noise indicators than L_{den} and L_{night}.

4. No later than 18 July 2005, Member States shall communicate information to the Commission on any relevant limit values in force within their territories or under preparation, expressed in terms of L_{den} and L_{night} and where appropriate, L_{day} and $L_{evening}$, for road-traffic noise, rail-traffic noise, aircraft noise around airports and noise on industrial activity sites, together with explanations about the implementation of the limit values.

Article 6

Assessment methods

1. The values of L_{den} and L_{night} shall be determined by means of the assessment methods defined in Annex II.

2. Common assessment methods for the determination of L_{den} and L_{night} shall be established by the Commission in accordance with the procedure laid down in Article 13(2) through a revision of Annex II. Until these methods are adopted, Member States may use assessment methods adapted in accordance with Annex II and based upon the methods laid down in their own legislation. In such case, they must demonstrate that those methods give equivalent results to the results obtained with the methods set out in paragraph 2.2 of Annex II.

3. Harmful effects may be assessed by means of the dose-effect relations referred to in Annex III.

Article 7

Strategic noise mapping

1. Member States shall ensure that no later than 30 June 2007 strategic noise maps showing the situation in the preceding calendar year have been made and, where relevant, approved by the competent authorities, for all agglomerations with more than 250 000 inhabitants and for all major roads which have more than six million vehicle passages a year, major railways which have more than 60 000 train passages per year and major airports within their territories.

No later than 30 June 2005, and thereafter every five years, Member States shall inform the Commission of the major roads which have more than six million vehicle passages a year, major railways which have more than 60 000 train passages per year, major airports and the agglomerations with more than 250 000 inhabitants within their territories.

2. Member States shall adopt the measures necessary to ensure that no later than 30 June 2012, and thereafter every five years, strategic noise maps showing the situation in the preceding calendar year have been made and, where relevant, approved by the competent authorities for all agglomerations and for all major roads and major railways within their territories.

No later than 31 December 2008, Member States shall inform the Commission of all the agglomerations and of all the major roads and major railways within their territories.

3. The strategic noise maps shall satisfy the minimum requirements laid down in Annex IV.

4. Neighbouring Member States shall cooperate on strategic noise mapping near borders.

5. The strategic noise maps shall be reviewed, and revised if necessary, at least every five years after the date of their preparation.

Article 8

Action plans

1. Member States shall ensure that no later than 18 July 2008 the competent authorities have drawn up action plans designed to manage, within their territories, noise issues and effects, including noise reduction if necessary for:

(a) places near the major roads which have more than six million vehicle passages a year, major railways which have more than 60 000 train passages per year and major airports;

(b) agglomerations with more than 250 000 inhabitants. Such plans shall also aim to protect quiet areas against an increase in noise.

The measures within the plans are at the discretion of the competent authorities, but should notably address priorities which may be identified by the exceeding of any relevant limit value or by other criteria chosen by the Member States and apply in particular to the most important areas as established by strategic noise mapping.

2. Member States shall ensure that, no later than 18 July 2013, the competent authorities have drawn up action plans notably to address priorities which may be identified by the exceeding of any relevant limit value or by other criteria chosen by the Member States for the agglomerations and for the major roads as well as the major railways within their territories.

3. Member States shall inform the Commission of the other relevant criteria referred to in paragraphs 1 and 2.

4. The action plans shall meet the minimum requirements of Annex V.

5. The action plans shall be reviewed, and revised if necessary, when a major development occurs affecting the existing noise situation, and at least every five years after the date of their approval.

6. Neighbouring Member States shall cooperate on the action plans for border regions.

7. Member States shall ensure that the public is consulted about proposals for action plans, given early and effective opportunities to participate in the preparation and review of the action plans, that the results of that participation are taken into account and that the public is informed on the decisions taken. Reasonable time-frames shall be provided allowing sufficient time for each stage of public participation.

If the obligation to carry out a public participation procedure arises simultaneously from this Directive and any other Community legislation, Member States may provide for joint procedures in order to avoid duplication.

Article 9

Information to the public

1. Member States shall ensure that the strategic noise maps they have made, and where appropriate adopted, and the action plans they have drawn up are made available and disseminated to the public in accordance with relevant Community legislation, in particular Council Directive 90/313/EEC of 7 June 1990 on the freedom of access to information on the environment [1], and in conformity with Annexes IV and V to this Directive, including by means of available information technologies.

2. This information shall be clear, comprehensible and accessible. A summary setting out the most important points shall be provided.

Article 10

Collection and publication of data by Member States and the Commission

1. No later than 18 January 2004, the Commission will submit a report to the European Parliament and the Council containing a review of existing Community measures relating to sources of environmental noise.

2. The Member States shall ensure that the information from strategic noise maps and summaries of the action plans as referred to in Annex VI are sent to the Commission within six months of the dates laid down in Articles 7 and 8 respectively.

3. The Commission shall set up a database of information on strategic noise maps in order to facilitate the compilation of the report referred to in Article 11 and other technical and informative work.

4. Every five years the Commission shall publish a summary report of data from strategic noise maps and action plans. The first report shall be submitted by 18 July 2009.

(1) OJ L 158, 23.6.1990, p. 56.

Article 11

Review and reporting

1. No later than 18 July 2009, the Commission shall submit to the European Parliament and the Council a report on the implementation of this Directive.

2. That report shall in particular assess the need for further Community actions on environmental noise and, if appropriate, propose implementing strategies on aspects such as:

(a) long-term and medium-term goals for the reduction of the number of persons harmfully affected by environmental noise, taking particularly into account the different climates and different cultures;

(b) additional measures for a reduction of the environmental noise emitted by specific sources, in particular outdoor equipment, means and infrastructures of transport and certain categories of industrial activity, building on those measures already implemented or under discussion for adoption;

(c) the protection of quiet areas in open country.

3. The report shall include a review of the acoustic environment quality in the Community based on the data referred to in Article 10 and shall take account of scientific and technical progress and any other relevant information. The reduction of harmful effects and the cost-effectiveness ratio shall be the main criteria for the selection of the strategies and measures proposed.

4. When the Commission has received the first set of strategic noise maps, it shall reconsider:

— the possibility for a 1,5 metre measurement height in Annex I, paragraph 1, in respect of areas having houses of one storey,

— the lower limit for the estimated number of people exposed to different bands of L_{den} and L_{night} in Annex VI.

5. The report shall be reviewed every five years or more often if appropriate. It shall contain an assessment of the implementation of this Directive.

6. The report shall, if appropriate, be accompanied by proposals for the amendment of this Directive.

Article 12

Adaptation

The Commission shall adapt Annex I, point 3, Annex II and Annex III hereto to technical and scientific progress in accordance with the procedure provided for in Article 13(2).

Article 13

Committee

1. The Commission shall be assisted by the committee set up by Article 18 of Directive 2000/14/EC.

2. Where reference is made to this paragraph, Articles 5 and 7 of Decision 1999/468/EC shall apply, having regard to the provisions of Article 8 thereof.

The period laid down in Article 5(6) of Decision 1999/468/EC shall be set at three months.

3. The Committee shall adopt its rules of procedure.

Article 14

Transposition

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive no later than 18 July 2004. They shall inform the Commission thereof.

When the Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such a reference on the occasion of their official publication. The methods of making such a reference shall be laid down by the Member States.

2. The Member States shall communicate to the Commission the texts of the provisions of national law that they adopt in the field governed by this Directive.

Article 15

Entry into force

This Directive shall enter into force on the day of its publication in the *Official Journal of the European Communities*.

Article 16

Addressees

This Directive is addressed to the Member States.

Done at Luxembourg, 25 June 2002.

For the European Parliament	For the Council
The President	*The President*
P. COX	J. MATAS I PALOU

ANNEX I

NOISE INDICATORS

referred to in Article 5

1. Definition of the day-evening-night level L_{den}

The day-evening-night level L_{den} in decibels (dB) is defined by the following formula:

$$L_{den} = 10 \lg \frac{1}{24}\left(12 * 10^{\frac{L_{day}}{10}} + 4 * 10^{\frac{L_{evening}+5}{10}} + 8 * 10^{\frac{L_{night}+10}{10}}\right)$$

in which:

— L_{day} is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the day periods of a year,

— $L_{evening}$ is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the evening periods of a year,

— L_{night} is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year;

in which:

— the day is 12 hours, the evening four hours and the night eight hours. The Member States may shorten the evening period by one or two hours and lengthen the day and/or the night period accordingly, provided that this choice is the same for all the sources and that they provide the Commission with information on any systematic difference from the default option,

— the start of the day (and consequently the start of the evening and the start of the night) shall be chosen by the Member State (that choice shall be the same for noise from all sources); the default values are 07.00 to 19.00, 19.00 to 23.00 and 23.00 to 07.00 local time,

— a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances;

and in which:

— the incident sound is considered, which means that no account is taken of the sound that is reflected at the façade of the dwelling under consideration (as a general rule, this implies a 3 dB correction in case of measurement).

The height of the L_{den} assessment point depends on the application:

— in the case of computation for the purpose of strategic noise mapping in relation to noise exposure in and near buildings, the assessment points must be 4,0 ± 0,2 m (3,8 to 4,2 m) above the ground and at the most exposed façade; for this purpose, the most exposed façade will be the external wall facing onto and nearest to the specific noise source; for other purposes other choices may be made,

— in the case of measurement for the purpose of strategic noise mapping in relation to noise exposure in and near buildings, other heights may be chosen, but they must never be less than 1,5 m above the ground, and results should be corrected in accordance with an equivalent height of 4 m,

— for other purposes such as acoustical planning and noise zoning other heights may be chosen, but they must never be less than 1,5 m above the ground, for example for:

  — rural areas with one-storey houses,

  — the design of local measures meant to reduce the noise impact on specific dwellings,

  — the detailed noise mapping of a limited area, showing the noise exposure of individual dwellings.

2. Definition of the night-time noise indicator

The night-time noise indicator L_{night} is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year;

in which:

— the night is eight hours as defined in paragraph 1,

— a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances, as defined in paragraph 1,

— the incident sound is considered, as laid down in paragraph 1,

— the assessment point is the same as for L_{den}.

3. **Supplementary noise indicators**

In some cases, in addition to L_{den} and L_{night}, and where appropriate L_{day} and $L_{evening}$, it may be advantageous to use special noise indicators and related limit values. Some examples are given below:

— the noise source under consideration operates only for a small proportion of the time (for example, less than 20 % of the time over the total of the day periods in a year, the total of the evening periods in a year, or the total of the night periods in a year),

— the average number of noise events in one or more of the periods is very low (for example, less than one noise event an hour; a noise event could be defined as a noise that lasts less than five minutes; examples are the noise from a passing train or a passing aircraft),

— the low-frequency content of the noise is strong,

— L_{Amax}, or SEL (sound exposure level) for night period protection in the case of noise peaks,

— extra protection at the weekend or a specific part of the year,

— extra protection of the day period,

— extra protection of the evening period,

— a combination of noises from different sources,

— quiet areas in open country,

— the noise contains strong tonal components,

— the noise has an impulsive character.

ANNEX II

ASSESSMENT METHODS FOR THE NOISE INDICATORS

referred to in Article 6

1. **Introduction**

The values of L_{den} and L_{night} can be determined either by computation or by measurement (at the assessment position). For predictions only computation is applicable.

Provisional computation and measurement methods are set out in paragraphs 2 and 3.

2. **Interim computation methods for L_{den} and L_{night}**

2.1. *Adaptation of existing national computation methods*

If a Member State has national methods for the determination of long-term indicators those methods may be applied, provided that they are adapted to the definitions of the indicators set out in Annex I. For most national methods this implies the introduction of the evening as a separate period and the introduction of the average over a year. Some existing methods will also have to be adapted as regards the exclusion of the façade reflection, the incorporation of the night and/or the assessment position.

The establishment of the average over a year requires special attention. Variations in emission and transmission can contribute to fluctuations over a year.

2.2. *Recommended interim computation methods*

For Member States that have no national computation methods or Member States that wish to change computation method, the following methods are recommended:

For INDUSTRIAL NOISE: ISO 9613-2: 'Acoustics — Abatement of sound propagation outdoors, Part 2: General method of calculation'.

Suitable noise-emission data (input data) for this method can be obtained from measurements carried out in accordance with one of the following methods:

— ISO 8297: 1994 'Acoustics — Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment — Engineering method',

— EN ISO 3744: 1995 'Acoustics — Determination of sound power levels of noise using sound pressure — Engineering method in an essentially free field over a reflecting plane',

— EN ISO 3746: 1995 'Acoustics — Determination of sound power levels of noise sources using an enveloping measurement surface over a reflecting plane'.

For AIRCRAFT NOISE: ECAC.CEAC Doc. 29 'Report on Standard Method of Computing Noise Contours around Civil Airports', 1997. Of the different approaches to the modelling of flight paths, the segmentation technique referred to in section 7.5 of ECAC.CEAC Doc. 29 will be used.

For ROAD TRAFFIC NOISE: The French national computation method 'NMPB-Routes-96 (SETRA-CERTU-LCPC-CSTB)', referred to in 'Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Officiel du 10 mai 1995, Article 6' and in the French standard 'XPS 31-133'. For input data concerning emission, these documents refer to the 'Guide du bruit des transports terrestres, fascicule prévision des niveaux sonores, CETUR 1980'.

For RAILWAY NOISE: The Netherlands national computation method published in 'Reken- en Meetvoorschrift Railverkeerslawaai '96, Ministerie Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 20 November 1996'.

Those methods must be adapted to the definitions of L_{den} and L_{night}. No later than 1 July 2003 the Commission will publish guidelines in accordance with Article 13(2) on the revised methods and provide emission data for aircraft noise, road traffic noise and railway noise on the basis of existing data.

3. **Interim measurement methods for L_{den} and L_{night}**

If a Member State wishes to use its own official measurement method, that method shall be adapted in accordance with the definitions of the indicators set out in Annex I and in accordance with the principles governing long-term average measurements stated in ISO 1996-2: 1987 and ISO 1996-1: 1982.

If a Member State has no measurement method or if it prefers to apply another method, a method may be defined on the basis of the definition of the indicator and the principles stated in ISO 1996-2: 1987 and ISO 1996-1: 1982.

Measurement data in front of a façade or another reflecting element must be corrected to exclude the reflected contribution of this façade or element (as a general rule, this implies a 3 dB correction in case of measurement).

ANNEX III

ASSESSMENT METHODS FOR HARMFUL EFFECTS

referred to in Article 6(3)

Dose-effect relations should be used to assess the effect of noise on populations. The dose-effect relations introduced by future revisions of this Annex in accordance with Article 13(2) will concern in particular:

— the relation between annoyance and L_{den} for road, rail and air traffic noise, and for industrial noise,

— the relation between sleep disturbance and L_{night} for road, rail and air traffic noise, and for industrial noise.

If necessary, specific dose-effect relations could be presented for:

— dwellings with special insulation against noise as defined in Annex VI,

— dwellings with a quiet façade as defined in Annex VI,

— different climates/different cultures,

— vulnerable groups of the population,

— tonal industrial noise,

— impulsive industrial noise and other special cases.

ANNEX IV

MINIMUM REQUIREMENTS FOR STRATEGIC NOISE MAPPING

referred to in Article 7

1. A strategic noise map is the presentation of data on one of the following aspects:
   - — an existing, a previous or a predicted noise situation in terms of a noise indicator,
   - — the exceeding of a limit value,
   - — the estimated number of dwellings, schools and hospitals in a certain area that are exposed to specific values of a noise indicator,
   - — the estimated number of people located in an area exposed to noise.
2. Strategic noise maps may be presented to the public as:
   - — graphical plots,
   - — numerical data in tables,
   - — numerical data in electronic form.
3. Strategic noise maps for agglomerations shall put a special emphasis on the noise emitted by:
   - — road traffic,
   - — rail traffic,
   - — airports,
   - — industrial activity sites, including ports.
4. Strategic noise mapping will be used for the following purposes:
   - — the provision of the data to be sent to the Commission in accordance with Article 10(2) and Annex VI,
   - — a source of information for citizens in accordance with Article 9,
   - — a basis for action plans in accordance with Article 8.

   Each of those applications requires a different type of strategic noise map.
5. Minimum requirements for the strategic noise maps concerning the data to be sent to the Commission are set out in paragraphs 1.5, 1.6, 2.5, 2.6 and 2.7 of Annex VI.
6. For the purposes of informing the citizen in accordance with Article 9 and the development of action plans in accordance with Article 8, additional and more detailed information must be given, such as:
   - — a graphical presentation,
   - — maps disclosing the exceeding of a limit value,
   - — difference maps, in which the existing situation is compared with various possible future situations,
   - — maps showing the value of a noise indicator at a height other than 4 m where appropriate.

   The Member States may lay down rules on the types and formats of these noise maps.
7. Strategic noise maps for local or national application must be made for an assessment height of 4 m and the 5 dB ranges of L_{den} and L_{night} as defined in Annex VI.
8. For agglomerations separate strategic noise maps must be made for road-traffic noise, rail-traffic noise, aircraft noise and industrial noise. Maps for other sources may be added.
9. The Commission may develop guidelines providing further guidance on noise maps, noise mapping and mapping softwares in accordance with Article 13(2).

ANNEX V

MINIMUM REQUIREMENTS FOR ACTION PLANS

referred to in Article 8

1. An action plan must at least include the following elements:
   - a description of the agglomeration, the major roads, the major railways or major airports and other noise sources taken into account,
   - the authority responsible,
   - the legal context,
   - any limit values in place in accordance with Article 5,
   - a summary of the results of the noise mapping,
   - an evaluation of the estimated number of people exposed to noise, identification of problems and situations that need to be improved,
   - a record of the public consultations organised in accordance with Article 8(7),
   - any noise-reduction measures already in force and any projects in preparation,
   - actions which the competent authorities intend to take in the next five years, including any measures to preserve quiet areas,
   - long-term strategy,
   - financial information (if available): budgets, cost-effectiveness assessment, cost-benefit assessment,
   - provisions envisaged for evaluating the implementation and the results of the action plan.
2. The actions which the competent authorities intend to take in the fields within their competence may for example include:
   - traffic planning,
   - land-use planning,
   - technical measures at noise sources,
   - selection of quieter sources,
   - reduction of sound transmission,
   - regulatory or economic measures or incentives.
3. Each action plan should contain estimates in terms of the reduction of the number of people affected (annoyed, sleep disturbed, or other).
4. The Commission may develop guidelines providing further guidance on the action plans in accordance with Article 13(2).

ANNEX VI

DATA TO BE SENT TO THE COMMISSION

referred to in Article 10

The data to be sent to the Commission are as follows:

1. **For agglomerations**

1.1. A concise description of the agglomeration: location, size, number of inhabitants.

1.2. The responsible authority.

1.3. Noise-control programmes that have been carried out in the past and noise-measures in place.

1.4. The computation or measurement methods that have been used.

1.5. The estimated number of people (in hundreds) living in dwellings that are exposed to each of the following bands of values of L_{den} in dB 4 m above the ground on the most exposed façade: 55-59, 60-64, 65-69, 70-74, > 75, separately for noise from road, rail and air traffic, and from industrial sources. The figures must be rounded to the nearest hundred (e.g. 5 200 = between 5 150 and 5 249; 100 = between 50 and 149; 0 = less than 50).

In addition it should be stated, where appropriate and where such information is available, how many persons in the above categories live in dwellings that have:

— special insulation against the noise in question, meaning special insulation of a building against one or more types of environmental noise, combined with such ventilation or air conditioning facilities that high values of insulation against environmental noise can be maintained,

— a quiet façade, meaning the façade of a dwelling at which the value of L_{den} four metres above the ground and two metres in front of the façade, for the noise emitted from a specific source, is more than 20 dB lower than at the façade having the highest value of L_{den}.

An indication should also be given on how major roads, major railways and major airports as defined in Article 3 contribute to the above.

1.6. The estimated total number of people (in hundreds) living in dwellings that are exposed to each of the following bands of values of L_{night} in dB 4 m above the ground on the most exposed façade: 50-54, 55-59, 60-64, 65-69, > 70, separately for road, rail and air traffic and for industrial sources. These data may also be assessed for value band 45-49 before the date laid down in Article 11(1).

In addition it should be stated, where appropriate and where such information is available, how many persons in the above categories live in dwellings that have:

— special insulation against the noise in question, as defined in paragraph 1.5,

— a quiet façade, as defined in paragraph 1.5.

It must also be indicated how major roads, major railways and major airports contribute to the above.

1.7. In case of graphical presentation, strategic maps must at least show the 60, 65, 70 and 75 dB contours.

1.8. A summary of the action plan covering all the important aspects referred to in Annex V, not exceeding ten pages in length.

2. **For major roads, major railways and major airports**

2.1. A general description of the roads, railways or airports: location, size, and data on the traffic.

2.2. A characterisation of their surroundings: agglomerations, villages, countryside or otherwise, information on land use, other major noise sources.

2.3. Noise-control programmes that have been carried out in the past and noise-measures in place.

2.4. The computation or measurement methods that have been used.

2.5. The estimated total number of people (in hundreds) living outside agglomerations in dwellings that are exposed to each of the following bands of values of L_{den} in dB 4 m above the ground and on the most exposed façade: 55-59, 60-64, 65-69, 70-74, > 75.

In addition it should be stated, where appropriate and where such information is available, how many persons in the above categories live in dwellings that have:

— special insulation against the noise in question, as defined in paragraph 1.5,

— a quiet façade, as defined in paragraph 1.5.

2.6. The estimated total number of people (in hundreds) living outside agglomerations in dwellings that are exposed to each of the following bands of values of L_{night} in dB 4 m above the ground and on the most exposed façade: 50-54, 55-59, 60-64, 65-69, > 70. These data may also be assessed for value band 45-49 before the date laid down in Article 11(1).

In addition it should be stated, where appropriate and where such information is available, how many persons in the above categories live in dwellings that have:

— special insulation against the noise in question, as defined in paragraph 1.5,

— a quiet façade, as defined in paragraph 1.5.

2.7. The total area (in km^2) exposed to values of L_{den} higher than 55, 65 and 75 dB respectively. The estimated total number of dwellings (in hundreds) and the estimated total number of people (in hundreds) living in each of these areas must also be given. Those figures must include agglomerations.

The 55 and 65 dB contours must also be shown on one or more maps that give information on the location of villages, towns and agglomerations within those contours.

2.8. A summary of the action plan covering all the important aspects referred to in Annex V, not exceeding ten pages in length.

3. **Guidelines**

The Commission may develop guidelines to provide further guidance on the above provision of information, in accordance with Article 13(2).

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CLINICAL REVIEW

Environmental noise, sleep and health

Alain Muzet*

FORENAP, BP 27, Rouffach, France

KEYWORDS
Noise;
Sleep disturbance;
Subjective evaluation;
Health effects;
Habituation;
Age

Summary Unlike other physical ambient factors (i.e. electromagnetic fields or air pollutants), noise is perceived by a specific system (auditory system) in humans. It is therefore a phenomenon that is sensed and evaluated by everybody, and this is why exposure to noise is one of the most, if not the most, frequent complaints of populations living in large cities. In these areas and their surroundings, the sources of noise most frequently cited are traffic, followed by neighbourhood noises and aircraft noises. Sleep is a physiological state that needs its integrity to allow the living organism to recuperate normally. It seems to be sensitive to environmental factors that can interrupt it or reduce its amount. Ambient noise, for example, is external stimuli that are still processed by the sleeper sensory functions, despite a non-conscious perception of their presence. Over the past 30 years, research into environmental noise and sleep has focused on different situations and environments, and therefore the findings are variable. However, it still seems necessary for some fundamental questions to be answered on whether environmental noise has long-term detrimental effects on health and quality of life and, if so, what these effects are for night-time, noise-exposed populations.

Sound and noise

Sound is produced by any mechanical movement and is propagated as a motion wave through the air or any other material. Therefore, sound is defined by its mechanical energy and is measured in energy-related units. Sound pressure proportional to the square of sound intensity (W/m^2) is expressed in Pascal units (Pa), whereas sound pressure level is expressed in decibel units (dB) on a logarithmic scale, owing to the wide range covered.

Sound evokes physiological signals in the auditory system constituted by the ear and the auditory pathways. However, some sounds do not evoke those signals as they are out of the auditory perception range in humans,- which theoretically ranges from 20 to 20,000 Hz.

Noise is generally defined as an unwanted sound or set of sounds. This definition means that it is not possible to classify sounds as noise on the unique basis of their physical characteristics. The general agreement is that noise is an audible acoustic phenomenon that adversely affects, or may affect, people. The effects of noise can be appreciated physiologically but also psychologically (annoyance and disturbed well-being).

*Tel.: +33 3 89787370; fax: +33 3 89787371.
E-mail address: alain.muzet@forenap.com.

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Noise in the environment

Noise is a phenomenon that affects everybody. We are constantly exposed to noise during our everyday life. Within our environment, there are different sources of noise, but they generally depend on our activity, location, and the time of day.

Transportation noise represents a large majority of external noise affecting people in large cities and their surroundings. Road traffic noise is mostly noise generated by the engine of the vehicle, but noise produced by frictional contact between the vehicle and the air, as between tyres and the road surface, exceeds engine noise at speeds higher than 50 km/h for passenger cars and at speeds higher than 80 km/h for lorries. Railway noise mainly depends on the speed of the train and the quality of the track. High-speed trains, for instance, might produce high-frequency noise, which is fairly similar to those generated by jet aircrafts. The expected development of this high-speed freight transport system in the next few years should be regarded as potentially disturbing for people living alongside the rail tracks, especially at night. Air traffic noise has been given much research attention during the past 30 years. Noise from a single aircraft, however, has considerably diminished during this period, as the concept of engines and flying machines has changed. However, increasing volume of traffic, and specifically night-time traffic, has often created conflict between populations living around large airports and the airport authorities.

Industrial plants can also be a source of excessive noise for the surroundings. This type of noice can be complex in nature, owing to the wide variety of sources. It can be spontaneous or more or less continuous, with large variations in intensity. Low-frequency noises are not so well attenuated by surrounding structures, and they can be transmitted across large distances. Building construction and ground work (e.g. hammering, crane, or heavy trucks) can generate high noise emissions. Military activities, although generally limited to specific areas, may also cause large noise disturbances for the surrounding populations.

Inside buildings, several different types of noises can be found: mechanical devices (e.g. lift, ventilation, pumps, water pipes) or domestic noises (e.g. neighbour's voices, Hi Fi, TV set, pets, and musical instruments). Ventilation noise can be quite disturbing in residential areas because of its low-frequency characteristics, even at low A-weighted sound pressure levels.[1] Domestic noises are among the most frequently reported causes of annoyance and the most difficult to characterize and quantify.[2] This is mainly due to the general attitude of the exposed people towards the source of noise and who is responsible for it. Neighbourhood noises (e.g. voices, music or footsteps) have high information content, which may catch the attention of the listener, independent of their intensity. Thus, independent of the noise exposure characteristics, the psychological dimension of the expressed annoyance is highly related to the specific relationship that exists between the noise producer and the noise receiver ("the bark of your neighbour's dog is much louder than the bark of your dog"). Therefore, in the domestic setting, the physical characteristics of the noise are often less important than the resultant attitude towards the source of the noise.[3]

Noise from leisure activities is clearly increasing with the invasion of more powered machines on the ground as well as in air and water (e.g. off-road vehicles, motorboats, and sporting airplanes). They are often limited to more or less specific areas, but they tend to increase at the periphery of large cities. Outdoor shooting activities, as well as outdoor concerts, have to be avoided in residential areas, but less noisy activities are often programmed almost everywhere and are, in addition, often accompanied by increased motor traffic.

The exposure to noise

As discussed previously, complaints about global noise exposure are one of the most, if not the most, frequent complaints among populations living in large cities.[4] Surveys show that frequency of complaints from noise increases with the size of cities, and that exposure to noise is inversely related to family income, with those on lower levels of income being the most exposed to ambient noise.[2] The most frequently cited sources are traffic noises, followed by noises from the neighbourhood and then aircraft noises.

Ten years ago in France, the number of people living in a "noisy environment" was estimated to be 10% of the total population or 6 million individuals, compnsmg 2 million (including 450,000 children) exposed to high levels of noise above 70dB Leq 8h-20h (Leq or equivalent noise level: constant noise level having an equivalent energy to the total energy of the actual noises occurring between 08:00 and 20:00).[5] Unfortunately, there is no reason to believe that this picture has much improved, and these days the numbers are certainly higher. However, the extent of the noise problem is large, and the case given above can be applied to many more industrialized countries. Thus, annoyance to community noise is widespread among citizens in the European Union, and the number of people exposed to moderately high levels (55-65 dB Leq) still increases in those countries. This is mainly due to the increasing sources of noise and their wider dispersion, along with greater individual mobility and growing leisure activities.

Sleep disturbance due to noise

Sleep disturbance is part of the extra-auditory effects of noise (Fig. 1). The input to the auditory area of the brain through the auditory pathways is prolonged by inputs reaching both the brain cortical area and the descending pathways of the autonomic functions. Thus, the sleeping body still responds to stimuli coming from the environment, although the noise sensitivity of the sleeper depends on several factors. Some of these factors are noise dependent, such as the type of noise (e.g. continuous, intermittent, impulsive), noise intensity, noise frequency, noise spectrum, noise interval (e.g. duration, regularity, expected), noise signification and the difference between the background noise level and the maximum amplitude of the occurring noise stimulus. Other factors are related to the sleeper, such as age, **sex,** personality characteristics and self-estimated sensitivity to noise.

The effects of noise on sleep can be immediate or secondary to the noise exposure. The first category corresponds to responses occurring simultaneously or immediately after the noise emission, whereas the latter corresponds to effects visible the next day or after a few days.

Immediate effects: objective measures of sleep disturbance

Sleep disturbance may be quantified by number and duration of nocturnal awakenings, number of sleep stage changes, and modifications in their amount. Proper rhythms of particular sleep stages (i.e. slow wave sleep [SWS] or stages 3 and 4, and rapid eye movement [REM] sleep [Fig. 2]), also characterize sleep disturbance, together with modifications in the autonomic functions (heart rate, blood pressure, vasoconstriction and respiratory rate).

Shortening of the sleep period

Total sleep time can be reduced by both longer time to fall asleep and premature final awakening. It has been reported that intermittent noises with peak noise levels of 45 dB(A) and above, can increase the time to fall asleep by a few minutes to 20 min.[6] On the other hand, sleep pressure is significantly reduced after the first 5 h. Therefore, in the morning hours, noise events can more easily awake and prevent the sleeper of going back to sleep. The main problem, however, is to determine whether

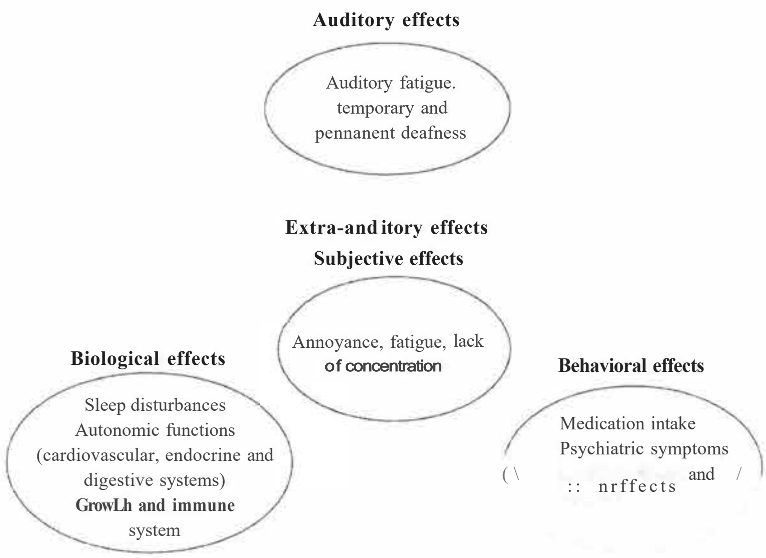

Figure 1 Auditory and extra-auditory effects of noise.

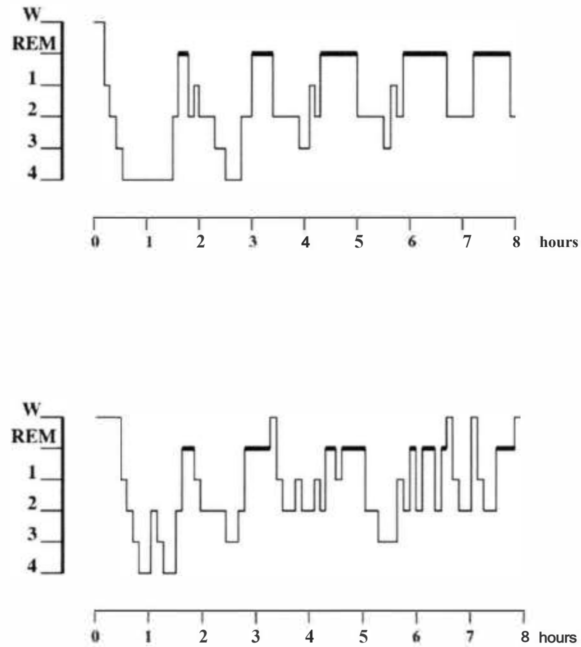

Figure 2 Hypnograms of a young adult. Top: during non-disturbed sleep. Sleep onset occurs within 10 min after light out time (0). Sleep begins by NREM sleep stages and the first REM episode occurs some 90 min after sleep onset. SWS (stages 3 and 4) occurs mainly during the first 3 h of the night. REM sleep episodes appear at very regular intervals. No awakening is seen during the entire night. Bottom: during a noise-disturbed night. Sleep onset is slightly delayed. The first episode of stage 4 is partly interrupted. A significant amount of SWS does occur during the fifth hour (possibly as a compensatory mechanism of the disturbed first episode). REM sleep still shows clear rhythmic occurrence but some of the episodes are fragmented. Significant awakenings occur throughout the sleep process. Sleep efficiency is reduced.

a significant part of sleep can be chronically reduced with no detrimental effect in the long term.

Sleep awakenings

It seems obvious that noise occurring during sleep may cause awakenings. The awakening threshold observed with noise (the sleeper is asked to push a button when awake) depends on several factors. In the sleeper's current stage of sleep, the threshold is particularly high in deep slow wave sleep (stages 3 and 4), whereas it is much lower in shallower sleep stages (stages 1 and 2).[7] The awakening threshold also depends on physical characteristics of the noisy environment (intermittent or sharp rising noise occurring above a low background noise will be particularly disturbing), as well as noise signification. Thus, whispering the sleeper's name can awake the person more easily than a much louder but neutral acoustic stimulus.[8] Similarly, and with a similar intensity, the noise of an alarm will awaken the sleeper more easily than a noise without any particular signification.

Sleep stage modifications

If nocturnal awakenings can be provoked for peak noise level of 55 dB(A) and above, disturbance of normal sleep sequence can be observed for peak noise levels between 45 and 55 dB(A). In order to protect noise-sensitive people, The World Health Organization recommended a maximal level (LA-max) inside the bedroom at night of 45 dB, whereas, for the same period, the mean recommended level (integrated noise level over the 8 nocturnal hours: Lnight) was of 30dB.[9]

SWS and REM sleep are both considered to be important stages of sleep, which should be well protected. SWS seems to be an energy restoration state of the sleeping body, whereas REM sleep seems to be more related to mental and memory processes. Carter[10] reported that SWS could be reduced in young sleepers exposed to intermittent noises. We previously reported that REM sleep rhythmicity could also be affected by environmental noise exposure.[11] It is a common observation in all noise-disturbed sleep studies to see an increase in sleep stage changes resulting in a reduced amount of SWS and REM sleep to the benefit of shallower sleep stages. This instability of the sleep process might be detrimental if it becomes chronic. Its picture is close to that observed in chronic insomniacs, and exploring the long-term evolution of such sleep disturbance could be important.

Autonomic responses

Awakenings and sleep-stage modifications are not the only possible acute effects of noise on the sleep process itself. The limit values given above do not mean that for lower noise levels there are no more effects on the sleeper. Autonomic responses, such as heart rate changes and vasoconstrictions, can be obtained for much lower peak noise intensities, indicating that the sleeping body still perceives the external stimuli even if there is no consciousness or memory about these events the next day.[7] Although these effects are considered to be minimal, they have been found not to habituate over long exposure times compared with clear subjective habituation over successive noise-exposed nights.[11–13] These autonomic responses represent reflex responses of the sleeping body to the external stimuli, which can already be observed at quite a low intensity. The health effects of long-term repetition of such responses should be discussed, especially in the case of multi-exposure (e.g. air and surface traffic). In this situation, there could be a cumulative effect of these cardio-vascular responses over a few thousands stimuli per night.

Secondary effects of the sleep disturbance due to noise

The secondary effects of night-time noise exposure can be separated into subjective reports of sleep disturbances and objective effects on daytime functioning.

Subjective evaluation of sleep disturbance

Objective recordings of sleep disturbance data are too costly and too difficult to use with large samples of the population or when funding is limited. Next-day subjective evaluation of sleep quality is a much easier and less costly way of collecting data, especially in the field. Sleep disturbance *per se* can be assessed from complaints about bad sleep quality, delayed sleep onset, nocturnal awakenings, and early morning waking up. These sleep disturbances are often accompanied by impaired quality of the subsequent daytime period with increased tiredness, daytime sleepiness and need for compensatory resting periods.[2]

However, the actual value of subjective complaints might be quite different from assessments based on instrumental measures. In fact, many factors influence people's subjective evaluations of their own sleep quality. Several studies show that subjective self-reports on sleep quality or on nocturnal awakenings do not correlate well with more objective measures of sleep disturbance.[14] When the number of noise events increases, the number of sleep modifications or awakenings also increases, although not proportionally. As indicated by Porter et al.[15] noise heard at night will be more intrusive and noticeable than during the day. This is caused by reduced outside and inside background noises at night and to the circadian fluctuation of biological rhythms. The night-time period may also be a time of higher noise sensitivity, especially if awakenings related to aircrafts flying over occur. Therefore, use of self-reports of movement, awakenings, or other sleep-related effects, needs serious reconsideration because of their questionable validity.

However, if the number of noise events is important and the noise level is high, nocturnal awakening can be excessively prolonged and even constitute a premature final awakening of the night. Sleep disturbance occurring during the early part of the night and during the time just preceding usual awakening seems to be most annoying.[6,16] In this case, sleep disturbances will lead to excessive daytime fatigue, often accompanied by daytime sleepiness, with its specific effects being low work capacity and increased accident rate.

Fear of living under aircraft routes is often a major reason of protesting against aircraft noise even if the measured noise levels are relatively low. This largely accounts for the difficulty in trying to find a clear relationship between subjective complaints and actual noise exposure.

Other secondary effects

In addition to subjective evaluations of sleep quality, after-effects of nocturnal noise exposure can be measured the following morning by objective biochemical data (i.e. increase in levels of stress hormones, including noradrenalin, adrenalin and cortisol),[10,17,18] or by cognitive performance deterioration during the next day.[19,20]

Physiological sensitivity to noise

The noise physiological sensitivity depends also on the age of the sleeper. Although electroencephalogram (EEG) modifications and awakening thresholds are, on average, 10dB(A) higher in children than in adults, their cardiovascular sensitivity to noise is similar to, if not higher than, older people.[21] Elderly people complain much more than younger adults about environmental noise. However, their spontaneous awakenings during sleep are also much more numerous. Therefore, it is difficult to conclude if elderly people are more sensitive to noise or if they hear noise because they are often awake during the night. This natural fragmentation of their night sleep tends also to lengthen their return to the sleeping state, and this accounts for a significant part in their subjective complaints. The main question about possible sensitive groups remains almost entirely unanswered. Most of the studies (in laboratories as well as in the home) have been carried out on groups of "normal" people or, at least, populations where some pathologies have been systematically excluded.

The particular case of shift workers

The sleep of shift workers is often disturbed by combined influences of ambient factors (noise is one of them) and chronobiological factors (sleeping at an unusual time of the day). Thus, noise was considered as the first cause of sleep interruptions in a group of female shift workers.[22] It is also considered a major cause of sleep shortening during daytime.[23] Some investigators comparing daytime to night-time sleep disturbance due to noise in shift workers, have found that the percentage of noise-induced EEG effects was significantly higher during the day than during the night-time REM sleep.[24] These investigators also stated that the inversion of the sleep-wake cycle did not markedly influence the average cardiovascular reactivity to noise, and they concluded that daytime sleep disturbance by noise was as important and harmful as night-time disturbance. Carter et al.[25] underlined the effects of noise on the cardiovascular side and, particularly, the modifications in blood pressure due to suddenly occurring noises.

Possible health effects of noise-disturbed sleep

From a public health perspective, it is necessary to be able to link sleep disturbance from noise exposure with long-term health effects. Of course, these effects depend on the magnitude and the repetition of sleep disturbance. To be awakened when engaged in a quiet and comfortable universe full of sweet dreams is, *per se,* a real aggression that only few sleepers may appreciate. However, it is much more through the reduction of daytime quality of life that sleep disturbance can be evaluated. Chronic partial sleep deprivation induces marked tiredness, increases a low vigilance state, and reduces both daytime performance and the overall quality of life.[26] Excessive daytime fatigue accompanied by sleepiness, deterioration of normal behaviour, expression of anger, lack of concentration and reduced work ability are often associated with chronic sleep deprivation. In this case, the need for additional resting period during the daytime is not always satisfied. In fact, the subtle equilibrium between waking and sleeping states is deteriorated to the detriment of the quality of both states.

More generally, some health effects, such as increased prescription of drugs around major airports[27] or increased rate of psychiatric hospital admission[28] could also be related to night-time noise exposure. However, many confounding factors cannot be eliminated in these epidemiological studies and, therefore, it remains difficult to confirm such results. The perception by the exposed population of possible factors affecting their health is often reported by the airport services in charge of communication with the public. Most of the complaints refer to sleep disturbance, general fatigue and anxiety. Noise is then clearly identified as a factor of stress and stress may be considered as the possible mechanism through which mental and physical health can be affected by noise.[29]

Of particular interest is the possible relationship between noise and the stress responses it produces, as they have the potential to be linked to hypertension, cardiovascular disease and other severe medical problems.[30-37] As mentioned previously, there is also a need to protect sensitive groups and shift workers who sleep during the day.[25]

Conclusion

Sleep is a physiological state that needs its integrity to allow for normal recuperation of the living organism. Its reduction or disruption is detrimental in the long term, as chronic partial sleep deprivation induces marked tiredness, increases low vigilance state and reduces daytime performance and quality of life. Sleep seems to be fairly sensitive to environmental factors, and, specifically, to ambient noise, as external stimuli are still processed by the sleeper sensory functions, despite a non-conscious perception of their presence.

The large amount of research developed in the laboratory during the past 30 years has produced variable results, and some of them seem quite controversial. In fact, the effects of noise exposure depend on several factors, and the absence of a clear dose-effect relationship is certainly due to the complex interactions of these factors, including the noise characteristics, the individual sensitivity and the context of the explored living environment. However, the amplitude of the subjective complaints about sleep disturbance seems to have been increasing during recent years. Unfortunately, only a few epidemiological studies have considered the possible effect of noise exposure (considered globally), together with other environmental factors, on the health of exposed populations. To our knowledge, no large-scale epidemiological study focusing on the effect of night-time noise exposure on health has yet been undertaken. Therefore, it is necessary to answer some fundamental questions in order to understand the detrimental effects on health and quality of life in the long term, for night-time, noise-exposed populations. Continuous high-level exposure can lead to aggression in a hostile, angry, and helpless population. It is often the population with the least income that suffers the most from noise in general. Also, annoyance due to ambient noise may be often seen as the visible part of a greater problem. Therefore, it should be an everyday concern to protect these populations against this major environmental aggression.

Practice points

Immediate and secondary effects of sleep disturbance due to noise are as follows:

Immediate effects:

- Delayed sleep onset, earlier final awakening or nocturnal awakenings.
- Sleep stage changes or sleep structure changes.
- Arousals and body movements.
- Vegetative or hormonal responses to noise.

Secondary effects:

- Subjective estimation of sleep quality.
- Performance decrement.
- Change in daytime behaviour.

Research agenda

Future research should focus on:

- Long term effects of night-time noise exposure of different populations.
- The study of specific sub-groups that can be considered to be "at risk" (e.g. children, elderly people, self-estimated sensitive people, insomniacs, sleep disorder patients, night and shift workers).
- Combined effects of noise exposure and other physical agents or stressors during sleep.

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ARTICLE

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Review of the effect of aircraft noise on sleep disturbance in adults

Stéphane Perron[1], Louis-François Tétreault[2], Norman King[3], Céline Plante[3], Audrey Smargiassi[4]
[1] Departement of Social and Preventive Medicine, University of Montreal; Public Health of the Montreal Agency for Health and Social Serv
[2] Public Health of the Montreal Agency for Health and Social Services; Department of Environmental and Occupational Health, University Canada
[3] Public Health of the Montreal Agency for Health and Social Services, Canada
[4] Department of Environmental and Occupational Health, University of Montreal; Environmental Health and Toxicology, Quebec Institute c Canada

Click **here** for **correspondence address** and email

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Abstract

Noise exposure generated by air traffic has been linked with sleep disturbances. The purpose of this systematic review is to clarify whether t link between aircraft noise exposure and sleep disturbances. Only complete, peer-reviewed articles published in scientific journals were exa published until December 2010 were considered. To be included, articles had to focus on subjects aged 18 or over and include an objective e levels. Studies were classified according to quality. Given the paucity of studies with comparable outcome measures, we performed a narrati a best-evidence synthesis approach. The primary study findings were tabulated. Similarities and differences between studies were investigat studies surveyed that dealt with sleep disturbances, four were considered to be of high quality, five were considered to be of moderate qualit considered to be of low quality. All moderate- to high-quality studies showed a link between aircraft noise events and sleep disturbances suc decreased slow wave sleep time or the use of sleep medication. This review suggests that there is a causal relation between exposure to aircr disturbances. However, the evidence comes mostly from experimental studies focusing on healthy adults. Further studies are necessary to de of aircraft noise on sleep disturbance for individuals more than 65 years old and for those with chronic diseases.

Keywords: *Aircraft, noise, sleep disturbance, systematic review*

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Introduction

Noise produced by aircrafts has led to conflict between airports and citizens living in their vicinity that can be traced back to the 1960s. [1] F increase of air traffic and the rapid expansion of cities have accentuated this problem. Several studies have been conducted to assess the effe on sleep.

According to the World Health Organisation (WHO), disturbance of sleep is not only a health concern in itself, it has also been reported to b other health problems. [2] Even though there are many uncertainties regarding the chronic health effects of minor sleep disturbances, decrea: is associated with obesity, [3],[4] hypertension, [5] diabetes [6] and increased mortality. [7]

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At least two other reviews have focused on the effects of aircraft noise on sleep disturbance. [2],[8] However, these two reviews did not expli search strategies and did not evaluate the quality of the revised studies. Standards and guidelines of systematic reviews have highlighted the study quality should be considered in systematic reviews in order to obtain the best estimates of study results. [9],[10],[11],[12]

This systematic review focuses on the association between aircraft noise and sleep disturbances. We considered noise emitted by aircraft tak and by any flight trajectories that expose the population to the noise of their engine. Both field and experimental laboratory data were consic systematic review is the first to focus exclusively on aircraft noise and sleep disturbance using study design and bias assessment to evaluate and select studies.

Methods

Only original, peer-reviewed articles published in scientific journals in English or French were examined. To be included, articles had to foc 18 or over and had to report an objective evaluation of noise levels. Studies had to focus on aircraft noise to be included in our review. Studi distinguish aircraft noise from other types of noise were excluded. Studies with no measurable sleep outcomes were also excluded from this parts of studies focusing on sleep disturbances were considered for inclusion. Studies focusing on morning-after effects were excluded.

The Pubmed, Medline, embase and psychinfo search engines were consulted using *aircraft or airport and noise* as keywords. Studies publis December 2010 were considered. We employed a search strategy that was not particularly sensitive, yet highly specific at the same time. In "snowball" strategy, consulting the references included in all of the studies on noise and sleep patterns (including available review articles) t relevant studies were selected. Lastly, we consulted experts in the field and colleagues at the Institut National de Santé Publique du Québec published studies that we may have missed for inclusion in our review. Abstracts were independently analyzed by two authors (LFT and SP opinions were resolved by discussion.

Study quality

In order to consider quality, we assessed both study design and presence of biases (systematic error) of the studies retrieved.

We considered that experimental studies were of greater quality than cross-sectional studies, that cross-sectional studies could only be of mc quality and that studies attempting to measure individual-level effects with complete ecological designs were only of low quality. [13],[14] N were included in the experimental studies category. [14] These studies include those where noise levels were not controlled by the researcher field settings and were recorded and were correlated to the subjects' responses. All experimental studies were of the repeated-treatment desi and outcome covary over time. In general, this design is strong for internal validity. [15]

We defined minor biases as those likely to affect the relationships between the variables studied but unlikely to compromise the results of th biases are those that by themselves could invalidate the results of a study. The quality of the studies was assessed using the following biases Selection bias refers to populations studied (those exposed to noise and those not exposed to it) that were not comparable, classification bias noise exposure or on health effects that were measured inaccurately or were not properly validated and confounding bias refers to the preser confounding variables associated with noise exposure and sleep disturbance that were not accounted for. [16]

[Table 1] presents how study quality was ranked based on both design and biases. For example, experimental studies had to have no major b considered of high quality, whereas cross-sectional studies with no major bias were considered of moderate quality. All ecological studies us data were classified as being of low quality.

Table 1: Ranking of study quality

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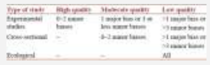

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[Table 2] presents the various biases present within studies. Response rates lower than 30% were considered major biases. Response rates be 60% were considered minor biases. The use of methods other than polysomnography to assess sleep disturbance were considered major clas These methods included the use of questionnaire, push buttons, actigraphy or seismosomnography (see [Table 3] for a description). Still, we there was a minor classification bias in one study (Basner), where sleep disturbance was assessed by polysomnography because sleep disturl the most sensitive sleep stages.

Table 2: Biases and quality ranking of studies on aircraft noise and sleep disturbances

Click here to view

Table 3: Comparison of methods used to detect awakenings

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Regarding noise exposure, we considered that when modelled or measured residential noise exposure levels were not available, there were r cross-sectional studies, individual exposure estimates based on modelling were considered to induce minor biases.

We decided to use a best-synthesis approach as described by Slavin, 1995. [32] Hence, of all studies reviewed, we present only the results of or high quality.

Noise exposure

Sound levels are measured in decibels (dB). Average sound levels (L_{Aeq}) are calculated based both on the variations of sound pressure ove duration of the noise. A weighted average is therefore used to measure exposure. In the studies reviewed, it was seen that the average can re period or be divided into different periods (typically daytime, evening and night time). L_{Aeq} values can refer to various other durations (e.g $_{night}$ is an L_{Aeq} used for night time noise of an 8-h duration. L_{den} (day, evening, night) is an equivalent sound level over 24 h in which sour evening (19h00 to 23h00) are increased by 5 dB(A) and those during the night (23h00-07h00) by 10 dB(A).

Maximum sound levels are also used to measure exposure when the sound fluctuates over time; examples include aircraft noise on take-offs $_{Amax}$ measures the average maximum A-weighted sound level, in dB, over a given time interval, usually 0.125 ms or 1 s. In some studies, so (SEL) is also used. SEL is a metric used to describe the noise energy produced from a single noise event. It is computed from measured dB(and integrates all the acoustic energy contained within the event and integrated over 1 s.

As previously mentioned, for a study to be included in our review, it had to include an objective estimate of noise exposure. Such estimates measurements (inside subjects' homes-which is ideal-or outside) or modelled noise levels (generated noise exposure contours for given geog Studies using subjects exposed to recorded aircraft noises played back in a laboratory setting during the night were also included in our revie analyzed noise from various sources had to specifically distinguish aircraft noise from other noise sources in our analysis to be included in c

Measurement of sleep disturbances

Possible effects of noise on sleep are generally grouped into three categories: the immediate effects of noise on sleep (sleep disturbance and effects), the secondary effects of the sleep disturbances (morning-after effects) and the long-term health effects. [33] Sleep disturbance is def deviation, measurable or subjectively perceived, from an individual's habitual or desired sleep behavior. [34] Categories of sleep disturbance our review include awakenings, sleep quality, medication taken to control sleep, total sleep time, time spent in slow wave sleep (SWS) (prev stage three and four sleep), [35] sleep stage changes and arousals as defined in Basner *et al*. 2008 [19] and time spent in rapid eye movement (REM).

Polysomnography is the only valid method to evaluate and measure sleep stages. Polysomnography is also the gold standard for many types including awakenings and total sleep time. Polysomnography comprises electroencephalogram (EEG) measurements of brain activity, electr measurements of eye activity and electromyogram (EMG) measurements of muscle activity. [18] In the reviewed studies, different methods measure awakenings. [Table 2] compares these methods. The individual's body movements (motility) during sleep can be linked to awakeni methods such as actigraphy and seismosomnography. Actigraphy measures movements of the wrist and seismosomnography measures smal body and a change of heart rate or breathing rate. Actigraphy has a positive predictive value of 50% or less compared with detection of awal by the gold standard polysomnography, which limits its validity. [26],[30] Seismosomnography was designed to have better sensibility and sp

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actigraphy and to have a greater ease of analysis and of use than polysomnography. [21] However, seismosomnography is subject to the sam actigraphy as it is also based on body movement. [36] Seismosomnography has yet to be validated against polysomnography.

Methods that depend on the subject reporting any spontaneous awakenings during the night by pressing a button on a device (defined as beh awakenings), or completing a sleep quality questionnaire the next morning, lack positive predictive value because many awakenings are not recalled or to induce the pressing of a button. In fact, subjective evaluations of awakenings by questionnaire do not correlate well with objec by polysomnography for individuals with sleep disorders. [31] Actigraphy and questionnaires are the least-expensive methods and are easier analyze than the other methods. Polysomnography and seismosomnography are more expensive and result in a complex set of data, giving t sensitivity and specificity but low ease of analysis and usability. [21]

Data analysis

Given the paucity of studies with comparable outcome measures, we did not perform a metaanalysis. For this reason **,** we undertook a narrat Narrative synthesis is a method to synthesize research results in the context of systematic reviews **,** where the summary of the findings of th narrative (as opposed to a statistical summary). Usually, a narrative synthesis is used when there is too much study heterogeneity that preclu statistical summary, as is the case for this review. [**37**] The primary study findings were tabulated. Similarities and differences between stud investigated.

Results

We identified 2652 articles with our first-stage search strategy. An expert identified three further articles on the subject. The majority of stuc because they did not focus on sleep, but on other health aspects related to aircraft noise. Two studies were excluded because the focus of the compare rail, road and aircraft noise and the authors did not provide independent analysis of each type of noise and sleep disturbance. [38],[3 were excluded because they focused on morning-after effects rather than sleep disturbances. [39],[40],[41] Four studies were excluded becaus specifically on the cardiovascular effects of aircraft noise and not on sleep *per se*. [36],[42],[43],[44] One study by Basner *et al*. 2008 [19] used another published study by Basner *et al*. 2005. [17] However, the research question was different and hence both studies were presented in th

Twelve studies evaluating the relationship between aircraft noise and sleep disturbance met our inclusion criterion. Of those articles, eight w studies, three were cross-sectional studies and one was an ecological study. All experimental studies involved within-subject comparison.

[Table 3] presents the biases in each of the studies of high, moderate and low quality. Four of 12 studies were classified as high quality. [17], considered to be of moderate quality. [21],[22],[23],[24],[25] Three of the studies were classified as being of low quality because of important b The three studies of lower quality were not evaluated further.

Two studies specifically focused on the impact of aircraft noise on sleep structure (total sleep time, SWS stage sleep time, REM stage sleep etc.) [17],[19] Six studies evaluated the impact of aircraft noise levels on awakenings. [18],[19],[20],[21],[22],[23] Four studies used polysomnogr awakenings. [17],[18],[19],[20] Awakenings were also measured using actigraphy [23] and push buttons. [22],[23] One study measured motility a awakenings using a seismosomnograph. [21] Sleep disturbances were evaluated by the use of sleep medication in two studies. [24],[25] Sleep evaluated in one study, but the study did not indicate whether and how the two questionnaires used had been validated. [22] Hence, it was im categorize biases arising from these questionnaires and the results were not considered reliable and will not be considered in this review. Th studies for our analysis that follows.

[Table 4] presents the cities, study period, recruitment process and study objectives and [Table 5] presents noise events characteristics, meas outcomes and findings. All high-quality studies were conducted in Germany by the same group of researchers. [17],[18],[19],[20] All studies w since the 1990s. The participants in the experimental studies were generally young and healthy, with no study participant being more than 6 experimental studies that described the recruitment process used volunteers. [17],[18],[19],[20],[21] Three experimental studies were conducted with pre-recorded aircraft noise events (ANE) that were played back. [17],[19],[20] One experimental study was conducted in the subject's ho recorded ANE that were played back, [21] and in three studies the noise was monitored indoor from outside noise events. [18],[22],[23] In add those studies, noise was also monitored outdoors. [23]

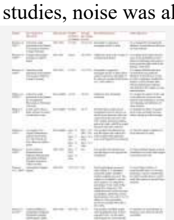

Table 4: Characteristics of moderate- and high-quality studies: Cities, study period, recruitment process and

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Table 5: Description of high- and moderate-quality studies: Noise events, measurement of sleep outcomes a

Click here to view

In the two cross-sectional studies, noise contours were used to estimate noise exposure. [24],[25] Those two studies used stratification to max various noise levels in their recruitment process. [24],[25] One study used a postal questionnaire and reminder letters for non-responders. [24]

Concerning the objectives of the studies, five studies aimed to specifically study the impact of aircraft noise on sleep disturbance. [17],[18],[1 study focused on the impact of noise on sleep, but did not specify in its objectives that aircraft noise constituted the only significant noise so study compared the impact of the impact of noise, rail and aircraft noise on sleep parameters. [20] The two cross-sectional studies focused o aircraft noise on the use of medication, including sleep medication. [24],[25]

One study focusing on sleep structure demonstrated that increasing the number of noise events or increases in L_{Amax} result in decreased SV increased awakening frequency. [17] For example, eight ANE of 80 dB(A), 32 ANE of 70 dB(A) or 64 ANE of 65 dB(A) resulted in close to in SWS time. They also resulted in an increase in awakenings, up to eight-times, for 64 ANE of 65 dB(A). The other study focusing on slee demonstrated that ANE of 45 dB(A) and 65 dB(A) result in change in sleep structure. [19] Indeed, the number of awakenings, sleep stage ch as observed by polysomnography caused by ANE increases significantly when compared with baseline nights with no noise events.

Basner *et al*. 2006 demonstrated that aircraft noise was associated with increased probability of awakenings. In this study, no increase in pro awakenings was observed up to aircraft noise levels of 32.7 dB(A). [18] However, at 70 dB(A), there was a 9% increase in awakenings. The corroborated by two studies using polysomnography where increases in aircraft noise also resulted in increased probability of awakenings. [events were correlated with behavioural awakenings that occurred within 5 min after the noise event. [22],[23] All studies using motility mea actigraphy and seismonosomnography as a proxy to awakenings had similar results. [21],[23] In one study, it was shown that every 1 dB incr increased the probability of motility by 1.2%. [23] In Brink *et al*. 2008, motility was more important when subjects were exposed to 60 dB(A compared with 50 dB(A) [OR 1.03 (95% CI 1.02-1.05)]. [21] Increased ambient noise levels had effects that were opposite to those of spora each 1 dB increase in ambient noise level reduced the odds of awakening in the presence of a noise event by 5%. [22]

Franssen *et al*. 2004 showed that ANE occurring between 22 h and 23 h were strongly associated with the use of over-the-counter sedative c [24] In Floud *et al*. 2010, the use of anxiolytics was associated with the aircraft noise level during the night (L_{night}). [25] However, no associ between aircraft noise and use of hypnotics. [25]

Discussion

Our systematic review demonstrates that ANE have impacts on sleep disturbances. All studies of moderate to high quality performed to date association between increases in aircraft noise exposure and the deterioration of sleep outcomes. As the sound levels increase, the probabilit increases [17],[18],[20],[22],[23] and awakening times last for longer periods. [18] Individuals exposed to higher levels of noise have been show periods of SWS. [17] The use of over-the-counter sedative or sleep medication increased in the presence of ANE occurring in the evening. [2 events were linked to sleep disturbance in all moderate- to high-quality studies using different designs and measures.

The night noise guidelines published by the WHO comprised a literature review that concluded that there is sufficient evidence to indicate t noise exposure during sleep results in arousals, sleep stage changes, awakening, self-reported sleep disturbance and increase of medication u our review complements the WHO review with an assessment of study quality. Furthermore, because the assessment of the quality of the stu noise and sleep disturbances has never been performed before, this evaluation will be informative for the design of future studies of high qu noise and sleep disturbances.

On the other hand, Michaud *et al*. 2007 in their review of field studies of aircraft noise-induced sleep disturbance concluded that the method differences between the studies renders the interpretation of results of the studies between aircraft noise and sleep disturbances difficult. [8] Michaud *et al*. 2007 included five studies, two of which are included in our review, and three studies that were not included in our review b not peer reviewed. The two studies were graded as moderate quality in our review. In addition, all of the studies reviewed by Michaud *et al*. awakenings with actigraphy, questionnaires or push button. None of the studies reviewed used polysomnography to measure awakenings. H studies reviewed used sleep measurement methods with a low positive-predictive value to measure awakenings, leading to non-differential r

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biases. If there is a true effect of noise on awakenings, such non-differential misclassification biases would lead to an underestimation of the is possibly why Michaud *et al*.'s 2007 results are difficult to interpret. Our review is more comprehensive as it attempted to cover different t disturbances, to include studies that used polysomnography and to include more high-quality studies. However, even with our results, risk q difficult given that different methods were used in each study.

In our methodology, we assessed the quality of studies and then only reviewed those of the high- and moderate-quality studies. This review limitations. First, in the high-quality studies reviewed, individuals were individuals with no chronic diseases and were aged between 18 and the results of this systematic review cannot be generalized to children or to the elderly. All high quality studies were derived from one group would give further credence to these findings if similar results were found by a different team of independent researchers. Only articles writ English were reviewed; there is some literature on aircraft noise and sleep that was written in German and hence some important findings m missed. Of course, as in any systematic review, there is the possibility of "publication bias," namely that studies with inconclusive or null re published. Another limitation pertains to the fact that, using the best-synthesis approach, we only reviewed studies of high and moderate qua there were only three studies that, according to our criteria, were of poor quality and were excluded. Their inclusion would not have change Finally, we classified study quality in high, moderate and low quality. Our classification is subjected to debate, especially for studies categor There are no gold standards for the rating of studies. Hence, it is possible that other authors will not rate studies like we did. However, we ar our approach is useful in discerning what constitutes good, moderate or poor evidence.

There are many gaps in our knowledge that need to be further investigated. Most of the high-quality studies were experimental studies perfo young individuals. Further research is thus necessary to better characterize the impact of aircraft noise on total sleep time, awakenings, SWS and REM stage sleep time using L_{Night} noise metrics in older individuals or individuals with chronic diseases. The role played by annoyanc disturbances should also be better characterized. Indeed, the studies by Floud *et al*. 2010 indicated that there might be differential sensitivity result from annoyance. [25] Morning-after effects should be systematically reviewed. New evidence is also emerging from recent and ongoi link sleep disturbance with cardiovascular health. [36],[43],[44] There is still a lot of uncertainty regarding the threshold noise levels at which awaken. Furthermore, there is a need to document the influence of background noise on aircraft noise effects. Based on high-quality eviden available estimation of the dose-response curve is presented in the Basner *et al*. 2006 study and could be used for modelling the impact of ai sleep. [18] However, some uncertainty persists for the exact dose-response curve, both for awakenings and for the duration of awakenings, e individuals older than 65 years and for individuals with chronic diseases. Research is also needed to better identify which sound level and d the duration of awakenings and have acute or chronic impacts on health.

Conclusion

There is evidence of a causal association between exposure to night time aircraft noise and the following sleep disturbances: increased awak motility, decreased SWS time and non-prescribed sleep medication. However, there are many research gaps that were identified. There is a r research on the effect of aircraft noise on sleep disturbance for individuals aged more than 65 years and for individuals with chronic disease sleep disorders.

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Correspondence Address:
Stéphane Perron
Montreal Public Health Department, 1301 Sherbrooke Est Montreal, Québec, H2L 1M3
Canada
Login to access the email ID

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RESEARCH ARTICLE Open Access

The effect of aircraft noise on sleep disturbance among the residents near a civilian airport: a cross-sectional study

Kyeong Min Kwak[1,2], Young-Su Ju[1*], Young-Jun Kwon[1], Yun Kyung Chung[1], Bong Kyu Kim[1,2], Hyunjoo Kim[3] and Kanwoo Youn[4]

Abstract

Background: Aircraft noise is a major environmental noise problem. This study was conducted in order to investigate the relationship between sleep disturbance and exposure to aircraft noise on the residents who are living near an airport.

Methods: There were 3308 residents (1403 in the high exposure group, 1428 in the low exposure group, and 477 in the non-exposure group) selected as the subjects for this study. The Insomnia severity Index (ISI) and Epworth Sleepiness Scale (ESS) questionnaires were used to evaluate sleep disturbance.

Results: The mean ISI and ESS scores were 6.9 ± 6.4 and 5.5 ± 3.7, respectively, and the average scores were significantly greater in the aircraft noise exposure group, as compared to the non-exposure group. The percentage of the abnormal subjects, which were classified according to the results of the ISI and ESS, was also significantly greater in the noise exposure group, as compared to the control group. The odd ratios for insomnia and daytime hypersomnia were approximately 3 times higher in the noise exposure group, as compared to the control group.

Conclusions: The prevalence of insomnia and daytime hypersomnia was higher in the aircraft noise exposure group, as compared to the control group. Further study is deemed necessary in order to clarify the causal relationship.

Keywords: Aircraft, Noise, Sleep disturbance, Insomnia, Daytime hypersomnia

Background

Noise is defined as any unwanted, or mentally or physically harmful sound [1]. As described in its definition, noise involves psychological factors as well as physiological features. As a result, it may unfavorably affect a person's hearing ability or cause various health problems, such as hypertension [2], myocardial infarction [3], psychological disease [4], and sleep disturbance [5].

With the rapid growth of air traffic, aircraft noise has recently become a major environmental noise problem. The aircraft noise can affect a person's hearing ability [6], blood pressure [7], mental health [8], and sleep quality [9, 10]. A continuous exposure to aircraft noise increases the frequency of waking up during sleep and decreases slow-wave sleep, sometimes called deep sleep. This condition can cause a decreased quality of sleep and sleep disturbance [9]. Sleep disturbance is an important health issue and it has been associated with other health problems [10]. Sleep deprivation, which is caused by sleep disturbance, is related to obesity, hypertension, diabetes, cardiovascular disease, depression, and increased risk of mortality [11–15]. Many studies have been conducted on the effect of aircraft noise on sleep [16, 17]; however, the population sizes of most studies are insufficient. There are only a few studies conducted in the large populations of more than 1000 subjects [18, 19]. Large population studies that directly evaluate sleep disturbance have not sufficiently supported the clear correlation between noises and sleep disturbance.

* Correspondence: zorro@hallym.ac.kr
[1]Department of Occupational and Environmental Medicine, Hallym University Sacred Heart Hospital, Anyang, South Korea
Full list of author information is available at the end of the article

This study conducted a survey on more than 3000 subjects by using a structured questionnaire. The purpose of this study is to investigate the relationship between sleep disturbance and exposure to aircraft noise on residents who are living near an airport.

Methods

Noise measurement

This study did not measure the aircraft noise level directly, but instead, we used the result of the aircraft noise measurement in the official announcement of the Seoul Regional Aviation Administration (SRAA) [20] that was issued on October 8, 2010. This announcement was based on the noise measurement of the areas near the Gimpo International Airport that was performed by noise specialists in 2008. For this measurement, 50 sites were chosen to measure the aircraft noise, and the Weighted Equivalent Continuous Perceived Noise Level (WECPNL) was used as the noise metric. The WECPNL was recommended by the International Civil Aviation Organization (ICAO) for measuring the aircraft noise [21]. The WECPNL used in Korea is defined as follows [22]:

$$\mathrm{WECPNL} = \overline{L}_A + 10\log\left(N_2 + 3N_3 + 10(N_1 + N_4)\right) - 27,$$

where $\overline{L}_A$ is the energy mean of all maximum aircraft noise level during daytime. N_1 is the number of flight events during midnight from 00:00 to 07:00, N_2 is the number of events during daytime from 07:00 to 19:00, N_3 is the number of flight events during nighttime from 19:00 to 22:00, and N_4 is the number of flight events during late nighttime from 22:00 to 24:00.

Study subjects

This study has chosen the aircraft noise exposure areas based on the official announcement of SRAA. This announcement divided the areas near the Gimpo International Airport into 3 districts (type 1 [95+ WECPNL]), type 2 [90–95 WECPNL], and type 3 [75–90 WECPNL]) based on the aircraft noise level. There were no residents living in type 1 and 2 districts. The type 3 district was divided again into 3 subdistricts ('Ga' [85–90 WECPNL], 'Na' [80–85 WECPNL], and 'Da' [75–80 WECPNL]).

According to this official announcement by SRAA, the areas in Seoul City near the Gimpo International Airport, which required measurement for noise monitoring, were selected for this study. This study classified 'Ga' and 'Na' into a high noise exposure group (80-90 WECPNL) and 'Da' into a low noise exposure group (75-80 WECPNL) (Fig. 1). 'A'-dong was selected as the control area with similar demographic, socioeconomic, and geologic characteristics, and without aircraft noise, as it is far from the airport. However, the control area did not have a noise measurement result.

This study was conducted as a door-to-door visit by the researchers from March to April 2015 in order to investigate the effect of aircraft noise on the health of the residents living near the Gimpo International Airport. Adults, who are 20 years old and above, were included in the study, but those who are older than 75 years old were excluded. A total of 3531 residents (1516 in the high exposure group, 1515 in the low exposure group, and 500 in the non-exposure group) participated in this survey. The 166 residents (61 in the high exposure group, 90 in the low exposure group, and 15 in the non-exposure group), who had been treated for depression within 1 year, were excluded from the study. In addition, 57 residents (27 in the high exposure group, 22 in the low exposure group, and 8 in the non-exposure group), whose questionnaire missed a significant amount of information, were also excluded from the study. Finally, 3308 residents (1428 in the high exposure group, 1403 in the low exposure group, and 477 in the non-exposure group) were selected as subjects for the analysis.

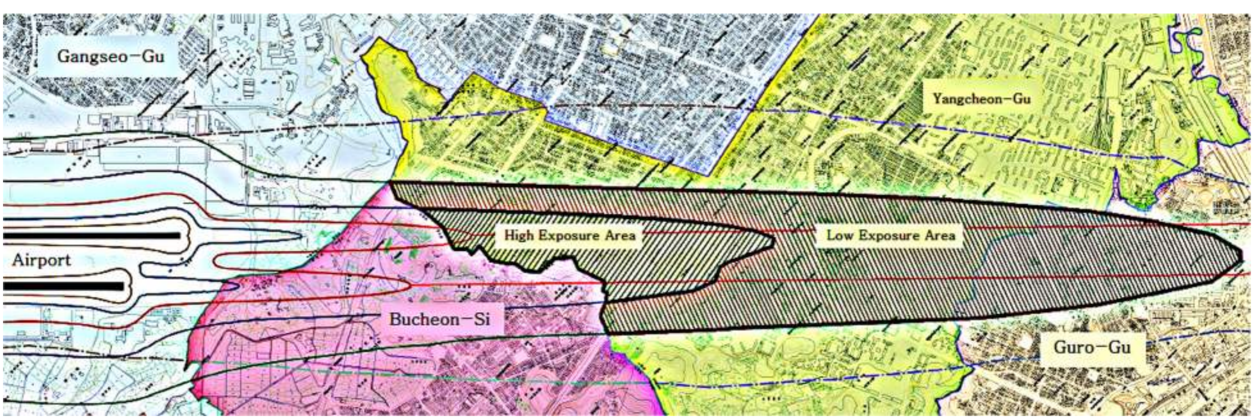

Fig. 1 Aircraft noise map in the vicinity of Gimpo International Airport

Table 1 General characteristics and Insomnia Severity Index (ISI)/Epworth Sleepiness Scale (ESS) results by noise exposure groups

Characteristics		All groups	Control	Low-exposure (75-80 WECPNL)	High-exposure (80-90 WECPNL)	*p*-value
		n = 3308(%)	*n* = 477(%)	*n* = 1403(%)	*N* = 1428(%)	
Sex[a)]	Male	1111(33.6)	153(32.1)	443(31.6)	515(36.1)	0.0308
	Female	2197(66.4)	324(67.9)	960(68.4)	913(63.9)	
Mean age(years)[b)]		50.5 ± 14.2	50.5 ± 14.4	50.6 ± 14.1	50.4 ± 14.2	0.9116
Age(years)[a)]	20-29	268(8.1)	44(9.2)	110(7.8)	114(8.0)	0.4197
	30-39	585(17.7)	81(17.0)	240(17.1)	264(18.5)	
	40-49	656(19.8)	77(16.1)	300(21.4)	279(19.5)	
	50-59	739(22.3)	121(25.4)	297(21.2)	321(22.5)	
	60-69	764(23.1)	108(22.6)	330(23.5)	326(22.8)	
	70-74	296(9.0)	46(9.6)	126(9.0)	124(8.7)	
Education[a)]	Never	77(2.3)	4(0.8)	26(1.8)	47(3.3)	<0.0001
	Elementary school	343(10.4)	28(5.9)	134(9.6)	181(12.7)	
	Middle school	512(15.5)	57(11.9)	242(17.3)	213(14.9)	
	High school	1407(42.5)	225(47.2)	552(39.3)	630(44.1)	
	College or more	969(29.3)	163(34.2)	449(32.0)	357(25.0)	
Residency period(year)[a)]	≥15	826(28.7)	86(20.3)	382(31.4)	358(29.0)	<0.0001
	10-14	655(22.8)	120(28.4)	287(23.6)	248(20.1)	
	5-9	679(23.6)	101(23.9)	260(21.4)	318(25.7)	
	<5	716(24.9)	116(27.4)	288(23.7)	312(25.2)	
Drinking[a)]	No	2055(62.1)	284(59.5)	906(64.6)	865(60.6)	0.0408
	Yes	1253(37.9)	193(40.5)	497(35.4)	563(39.4)	
Smoking[a)]	Never	2546(77.4)	369(77.4)	1102(78.5)	1075(75.3)	0.2182
	Past smoker	273(8.2)	43(9.0)	101(7.2)	129(9.0)	
	Current smoker	489(14.8)	65(13.6)	200(14.3)	224(15.7)	
Regular Exercise[a)]	No	1793(54.2)	234(49.1)	782(55.7)	777(54.4)	0.0398
	Yes	1515(45.8)	243(50.9)	621(44.3)	651(45.6)	
Operation or hospitalization within 1 year[a)]	No	3025(91.4)	446(93.5)	1296(92.4)	1283(89.9)	0.0123
	Yes	283(8.6)	31(6.5)	107(7.6)	145(10.1)	
ISI[c)]	Mean[b)]	6.9 ± 6.4	4.1 ± 5.1	7.2 ± 6.5	7.6 ± 6.4	<0.0001
	Normal	1956(59.1)	376(78.8)	782(55.7)	798(55.9)	<0.0001
	Sub-threshold insomnia	897(27.1)	75(15.7)	426(30.4)	396(27.7)	
	Moderate insomnia	382(11.6)	25(5.2)	155(11.1)	202(14.2)	
	Severe insomnia	73(2.2)	1(0.2)	40(2.8)	32(2.2)	
ESS[c)]	Mean[b)]	5.5 ± 3.7	4.1 ± 3.0	5.4 ± 3.7	6.0 ± 3.8	<0.0001
	Normal	2853(86.2)	451(94.5)	1214(86.5)	1188(83.2)	<0.0001
	Daytime hypersomnia	455(13.8)	26(5.5)	189(13.5)	240(16.8)	

[a)]By Chi-square test
[b)]By ANOVA
[c)]By Mantel-Haenszel Chi-square test

Survey tool

Survey tools for insomnia and daytime hypersomnia were used to evaluate sleep disturbance. The Insomnia Severity Index (ISI) [23, 24] was used to measure insomnia. The ISI is a self-reported questionnaire that consists of 7 questions for evaluating the difficulties of sleep onset and sleep maintenance, satisfaction with current sleep pattern, interference with daily functioning, noticeability of impairment attributed to the sleep problem, and degree of distress or concern caused by the sleep problem. Each question is scored between 0 and 4, and a higher score means a more severe status. The

Table 2 Insomnia Severity Index (ISI)/Epworth Sleepiness Scale (ESS) according to subject characteristics

Characteristics		ISI				ESS	
		Normal	Sub-threshold insomnia	Moderated insomnia	Severe insomnia	Normal	Daytime hypersomnia
Sex	Male	726(65.4)	267(24.0)	106(9.5)	12(1.1)c)***	972(87.5)	139(12.5)a)
	Female	1230(56.0)	630(28.7)	276(12.6)	61(2.8)	1881(85.6)	316(14.4)
Mean age(years)b)		48.7 ± 14.3	52.0 ± 13.6	54.6 ± 13.2	57.7 ± 11.9**	49.9 ± 14.2	54.2 ± 13.1**
Age(years)c)	20-29	200(74.6)	56(20.9)	11(4.1)	1(0.4)****	250(93.3)	18(6.7)****
	30-39	389(66.5)	140(23.9)	52(8.9)	4(0.7)	527(90.1)	58(9.9)
	40-49	409(62.3)	164(25.0)	70(10.7)	13(2.0)	570(86.9)	86(13.1)
	50-59	420(56.8)	218(29.5)	85(11.5)	16(2.2)	631(85.4)	108(14.6)
	60-69	394(51.6)	229(30.0)	112(14.7)	29(3.8)	637(83.4)	127(16.6)
	70-74	144(48.7)	90(30.4)	52(17.6)	10(3.4)	238(80.4)	58(19.6)
Educationc)	Never	41(53.2)	22(28.6)	12(15.6)	2(2.6)****	63(81.8)	14(18.2)****
	Elementary School	174(50.7)	104(30.3)	58(16.9)	7(2.1)	279(81.3)	64(18.7)
	Middle school	267(52.1)	150(29.3)	74(14.5)	21(4.1)	434(84.8)	78(15.2)
	High school	849(60.3)	365(25.9)	160(11.4)	33(2.4)	1199(85.2)	208(14.8)
	College or more	625(64.5)	256(26.4)	78(8.1)	10(1.0)	878(90.6)	91(9.4)
Residency period(year)c)	≥15	446(54.0)	253(30.6)	108(13.1)	19(2.3)****	685(82.9)	141(17.1)***
	10-14	381(58.2)	179(27.3)	76(11.6)	19(2.9)	571(87.2)	84(12.8)
	5-9	418(61.6)	165(24.3)	80(11.8)	16(2.4)	592(87.2)	87(12.8)
	<5	442(61.7)	195(27.2)	68(9.5)	11(1.5)	625(87.3)	91(12.7)
Drinking	No	1164(56.6)	573(27.9)	265(12.9)	53(2.6)c)****	1776(86.4)	279(13.6)a)
	Yes	792(63.2)	324(25.9)	117(9.3)	20(1.6)	1077(86.0)	176(14.0)
Smokingc)	Never	1474(57.9)	708(27.8)	300(11.8)	64(2.5)***	2190(86.0)	356(14.0)
	Past smoker	180(65.9)	68(24.9)	24(8.8)	1(0.4)	229(83.9)	44(16.1)
	Current smoker	302(61.8)	121(24.7)	58(11.9)	8(1.6)	434(88.8)	55(11.2)
Regular Exercise	No	1111(62.0)	454(25.3)	199(11.1)	29(1.6)c)****	1532(85.4)	261(14.6)a)
	Yes	845(55.8)	443(29.2)	183(12.1)	44(2.9)	1321(87.2)	194(12.8)
Operation or hospitalization within 1 year	No	1830(60.5)	801(26.5)	329(10.9)	65(2.2)c)****	2625(86.8)	400(13.2)a)*
	Yes	126(44.5)	96(33.9)	53(18.7)	8(2.8)	228(80.6)	55(19.4)
Noise exposure Groupc)	Control	376(78.8)	75(15.7)	25(5.2)	1(0.2)****	451(94.6)	26(5.4)****
	Low-exposure	782(55.7)	426(30.4)	155(11.1)	40(2.8)	1214(86.5)	189(13.5)
	High-exposure	798(55.9)	396(27.7)	202(14.2)	32(2.2)	1188(83.2)	240(16.8)

a)By Chi-square test
b)By ANOVA
c)By Mantel-Haeszel Chi-square test
*$p < 0.05$, **$p < 0.001$, ***p for trend < 0.05, ****p for trend < 0.001

total score is ranged between 0 and 28. A score of 0-7 is considered as normal, 8-14 is considered as sub-threshold insomnia, 15–21 is considered as moderate insomnia, and 22–28 is considered as severe insomnia. The Epworth Sleep Scale (ESS) [25] was used in order to measure daytime hypersomnia. ESS uses a scoring system from 0 to 3 to indicate the degree of drowsiness in 8 different situations. A score of 3 indicates that a person feels sleepy the most. The total score is ranged from 0 to 24 and a score above 10 is considered as daytime hypersomnia.

Analysis method

A technical analysis was performed in order to investigate the demographic and sociological characteristics, as well as the degree of sleep disturbance of the subjects. ANOVA and Chi-square test were used to investigate if there was any difference in the demographic and

Table 3 Multiple logistic regression model for Insomnia Severity Index (ISI) according to subject characteristics

Characteristics		Model 1		Model 2	
		OR	95 % CI	OR	95 % CI
Sex	Male	1.0		1.0	
	Female	1.54	1.31-1.81	1.57	1.24-1.97
Age(years)	20-29	1.0		1.0	
	30-39	1.39	0.95-2.04	1.40	0.95-2.06
	40-49	1.74	1.22-2.50	1.73	1.21-2.49
	50-59	2.27	1.59-3.25	2.17	1.51-3.12
	60-69	2.97	2.05-4.30	2.76	1.89-4.02
	70-74	3.88	2.52-5.98	3.64	2.35-5.65
Education	Never	1.0		1.0	
	Elementary school	1.07	0.64-1.77	1.09	0.65-1.81
	Middle school	1.22	0.74-2.01	1.25	0.76-2.07
	High school	1.15	0.70-1.89	1.19	0.73-1.96
	College or more	1.17	0.69-1.96	1.18	0.73-1.98
Residency period(year)	<5	1.0		1.0	
	5-9	0.93	0.75-1.16	0.93	0.75-1.16
	10-14	1.02	0.82-1.27	1.01	0.81-1.26
	≥15	0.96	0.77-1.19	0.96	0.77-1.19
Noise exposure group	Control	1.0		1.0	
	Low-exposure	3.45	2.64-4.50	3.41	2.61-4.46
	High-exposure	3.24	2.48-4.22	3.26	2.50-4.25
Drinking	No			1.0	
	Yes			0.98	0.82-1.16
Smoking	Never			1.0	
	Past smoker			0.86	0.62-1.21
	Current smoker			1.16	0.88-1.53
Regular Exercise	No			1.0	
	Yes			1.25	1.07-1.45
Operation or hospitalization within 1 year	No			1.0	
	Yes			1.75	1.37-2.25

Table 4 Multiple logistic regression model for Epworth Sleepiness Scale (ESS) according to subject characteristics

Characteristics		Model 1		Model 2	
		OR	95 % CI	OR	95 % CI
Sex	Male	1.0		1.0	
	Female	1.22	0.97-1.55	1.22	0.97-1.55
Age(years)	20-29	1.0		1.0	
	30-39	2.22	1.07-4.58	2.20	1.06-4.54
	40-49	3.04	1.53-6.03	3.03	1.53-6.01
	50-59	3.25	1.65-6.41	3.19	1.62-6.30
	60-69	3.77	1.89-7.53	3.65	1.83-7.29
	70-74	4.53	2.13-9.62	4.39	2.06-9.33
Education	Never	1.0		1.0	
	Elementary school	1.02	0.52-1.99	1.04	0.53-2.05
	Middle school	0.90	0.46-1.77	0.93	0.47-1.82
	High school	1.16	0.60-2.24	1.20	0.62-2.32
	College or more	0.73	0.36-1.50	0.75	0.37-1.54
Residency period(year)	<5	1.0		1.0	
	5-9	0.88	0.64-1.22	0.89	0.64-1.22
	10-14	0.86	0.63-1.19	0.86	0.62-1.20
	≥15	1.05	0.77-1.43	1.05	0.77-1.43
Noise exposure group	Control	1.0		1.0	
	Low-exposure	2.58	1.65-4.04	2.57	1.64-4.03
	High-exposure	3.43	2.20-5.34	3.39	2.17-5.28
Operation or hospitalization within 1 year	No			1.0	
	Yes			1.41	1.00-1.97

sociological characteristics between the groups. The Mantel-Haenszel Chi-square test was performed to investigate if the demographic and sociological characteristics, as well as the degree of noise exposure, were related to insomnia or daytime hypersomnia. In addition, the results that showed a significance in the univariate analysis (age, sex, education level, residency period, smoking, drinking, exercise, and medical history) were corrected by using a multiple logistic regression model. The odds ratio and 95 % confidence interval were obtained for the effect of the exposure degree on insomnia and daytime hypersomnia.

Results

General characteristics of the subjects

There were 3308 subjects, and their characteristics were analyzed by using a frequency analysis. The female subjects accounted for 66.4 % among the entire subjects, which were twice the number of the male subjects. The mean age of the subjects was 50.5 years old. Based on the age groups, 764 (23.1 %) subjects aged 60–69 years old accounted for the majority of the subjects, closely followed by the group with 739 (22.3 %) subjects aged 50–59 years old. For the education level, high school drop-out or graduate took up the greatest portion with a total of 1407 subjects (42.5 %). For the residency period, the greatest number of subjects, which was 826 (28.7 %), had lived for over 15 years in their residences.

Table 5 Daily average number of flight events in Gimpo International Airport (2015. 3. ~ 2015. 4.)

Time	Daily average number of flight events		
	Arrival	Departure	Total
0:00-6:00	0	0	0
6:00-7:00	0	6.0	6.0
07:00-12:00	46.7	68.0	114.7
12:00-18:00	77.1	78.0	155.1
18:00-22:00	51.6	43.2	94.8
22:00-23:00	19.3	0.1	19.4
23:00-24:00	0.1	0	0.1
Total	194.8	195.3	390.1

A total of 1253 (37.9 %) subjects answered that they drink, while 489 (14.8 %) subjects answered that they are current smokers. A great number of subjects (1515, 45.8 %) answered that they exercise regularly. There were 283 (8.6 %) subjects who had been hospitalized or had undergone operations in the previous year.

Comparison of general characteristics by noise exposure groups

For sex, the male subjects accounted for a significantly greater portion in the high exposure group (36.1 %) than the low exposure group (31.4 %) and the control group (32.1 %). The mean age and age distribution did not show any significant difference between the groups.

The education level results showed that the subjects, who received a high school education level or an even higher education, were smaller in numbers in the high exposure group and low exposure group, as compared to the control group (69.1 % vs 71.3 % vs 81.4 %), and the difference was statistically significant. For the residency period, 29.0 % of the subjects in the high exposure group and 31.4 % in the low exposure group lived in the area for 15 years or longer, which was significantly higher than that of the control group (20.3 %). For the drinking factor, 39.4 % of the subjects in the high exposure group and 40.5 % in the control group answered that they drink, which was significantly higher than that of the low exposure group (35.4 %). There was no significant difference in the results for the smoking factor between the groups. The 45.6 % of the subjects in the high exposure group and 44.3 % of the subjects in the low exposure group answered that they exercise regularly, which was significantly lower than that of the control group (50.9 %). The 10.1 % of the subjects in the high exposure group had been hospitalized or had undergone operations in the previous year, which was significantly higher than that of the low exposure group (7.6 %) and the control group (6.5 %).

Comparison of ISI and ESS results by the noise exposure groups

The mean score of the ISI in all subjects was 6.9 ± 6.4. There were 1956 (59.1 %) subjects in the normal group, 897 (27.1 %) subjects in the sub-threshold insomnia group, 382 (11.6 %) subjects in the moderate insomnia group, and 73 (2.2 %) subjects in the severe insomnia group. The mean score of ESS was 5.5 ± 3.7. There were 2853 (86.2 %) subjects in the normal group, and 455 (13.8 %) subjects in the daytime hypersomnia group.

The ISI scores of the three groups were compared, and the results showed that the mean score increased from the control group to the high exposure group, thereby showing 4.1 ± 5.1 in the control group, 7.2 ± 6.5 in the low exposure group, and 7.6 ± 6.4 in the high exposure group. The post-hoc results showed that the difference of the scores between the control group and low exposure group, and between the control group and high exposure group were statistically significant. The percentage of the subjects with moderate or severe insomnia increased from the control group to high exposure group, thereby showing 26 (5.4 %) for the control group, 195 (13.9 %) for the low exposure group, and 234 (16.4 %) for the high exposure group. The Mantel-Haenszel Chi-square test results showed that the percentage of the subjects with insomnia had a statistically significant difference among the groups.

Likewise, the ESS scores of the three groups were compared, and the results showed that the mean score also increased from the control group to the high exposure group, thereby showing 4.1 ± 3.0 in the control group, 5.4 ± 3.7 in the low exposure group, and 6.0 ± 3.8 in the high exposure group. The post-hoc analysis results showed that the difference between all groups were statistically significant. The percentage of the subjects with daytime hypersomnia increased from the control group to high exposure group, thereby showing 26 (5.5 %) for the control group, 189 (13.5 %) for the low exposure group, and 240 (16.8 %) for the high exposure group. The Mantel-Haenszel Chi-square test results showed that the percentage of the subjects with daytime hypersomnia had a statistically significant difference among the groups (Table 1).

Comparison of ISI and ESS results by the characteristics of the subjects

The percentages of the subjects, who were considered as having sub-threshold insomnia, moderate insomnia, and severe insomnia based on ISI, were significantly higher in females (28.7 %, 12.6 %, and 2.8 %, respectively) than in males. The subjects with more severe insomnia showed greater mean age. Likewise, the percentages of the older subjects, who were considered as having sub-threshold insomnia, moderate insomnia, and severe insomnia, were higher than the younger subjects. The lower education level was associated with a high percentage of the subjects with insomnia, thereby disregarding the subjects with no education. The subjects, who have lived longer in the area, showed more insomnia. Meanwhile, the subjects, who had been hospitalized or had undergone operations in the previous year, had more insomnia. The subjects who are non-smokers and non-drinkers, as well as the subjects who exercise regularly, had more insomnia.

Based on the ESS, the percentage of the subjects suffering from daytime hypersomnia was 14.4 % in females, which was significantly higher than in males. The subjects with daytime hypersomnia showed greater mean age. The older subjects also showed more daytime hypersomnia. The lower education level was associated with a high percentage of subjects with daytime hypersomnia. The subjects, who have lived longer in the area, showed more daytime hypersomnia. Meanwhile, the subjects, who had been hospitalized or had undergone an operation in the previous year, showed more insomnia. No statistically significant relationship between smoking, drinking, exercise, and daytime hypersomnia was confirmed (Table 2).

Multiple logistic regression for insomnia and daytime hypersomnia

The variables that showed significance in the univariate analysis were corrected by using the multiple logistic regression model. The odds ratio and 95 % confidence interval for the degree of noise exposure and sleep disturbance were obtained. For insomnia, the variables, including sex, age, education level, and residency period, were corrected in the first regression model. The other variables, including operation and hospitalization history for the previous year, smoking, drinking, and regular exercise performance, were additionally corrected in the second model.

The risk of insomnia was 3.45 times (95 % CI 2.64-4.50) higher in the low exposure group and 3.24 times (95 % CI 2.48-4.22) higher in the high exposure group, as compared to that of the control group. The risk of insomnia was 3.41 times (95 % CI 2.61-4.46) higher in the low exposure group and 3.26 times (95 % CI 2.50-4.25) in the high exposure group after additionally correcting the factors of operation and hospitalization history, smoking, drinking, and regular exercise (Model 2), as compared to that of the control group. The female subjects showed a significantly greater risk of insomnia than the males in both Model 1 (OR 1.51, 95 % CI 1.30-1.77) and Model 2 (OR 1.55, 95 % CI 1.24-1.94). The older aged group had a greater risk of insomnia than the younger aged group, and the odds ratio increased with age. However, the risk of insomnia was not significantly different according to the education level and residency period in both Models 1 and 2. The risk of insomnia was 1.71 times (95 % CI 1.35-2.17) greater in the subjects, who had been hospitalized or had undergone operations in the previous year, than the subjects who had not. For the lifestyle habits, the risk of insomnia was not significantly different according to smoking or drinking factors. However, the subjects who regularly exercised had 1.3 times (1.12-1.50) greater risk of insomnia than those who do not (Table 3).

For daytime hypersomnia, the variables that showed significance in the univariate analysis were also corrected by using a multiple logistic regression model. The variables, including sex, age, education level, and residency period, were corrected in the first regression model. Another variable of operation and hospitalization history for the previous year was additionally corrected in the second model. The results showed a similar pattern as those in the multivariate analysis of insomnia. The risk of daytime hypersomnia was 2.58 times greater (95 % 1.65-4.04) in the low exposure group and 3.43 times greater (95 % CI 2.20-5.34) in the high exposure group, as compared to the control group. In Model 2, the risk of daytime hypersomnia was still greater in the low and high exposure groups, 2.57 times (95 % CI 1.64-4.03) and 3.39 times (95 % CI 2.17-5.28), respectively, as compared to the control group even after the additional variable of the operation and hospitalization history in the previous year has been corrected. The odds ratio of Model 2 was similar to that of Model 1. The female subjects showed a greater risk of daytime hypersomnia than the males in both Model 1 (OR 1.30, 95 % CI 1.03-1.63) and Model 2 (OR 1.29, 95 % CI 1.03-1.62). The older subjects had a greater risk of daytime hypersomnia, as shown in the results for insomnia. The odds ratio increased with age. The risk of daytime hypersomnia was 1.41 times greater (95 % CI 1.02-1.93) in the subjects, who had been hospitalized or had undergone operations in the previous year, than those who had not (Table 4).

Discussion

The subjects within the exposed area showed a significantly higher mean of ISI than the subjects within the non-exposed area. The ESS mean also showed significantly higher results in the subjects within the exposed area than the subjects within the non-exposed area. The percentage of insomnia and daytime hypersomnia, which were classified according to the results of the ISI and ESS, was also significantly greater in the subjects within the exposed area than the subjects within the non-exposed area. The multiple logistic regression model reflecting the corrected variables, including sex, age, education level, residency period, lifestyle habits, operation, and hospitalization history, showed approximately 3 times higher risk of insomnia and daytime hypersomnia in the subjects within the exposed area than the subjects within the non-exposed area. In summary, the degree of noise exposure and sleep disturbance showed significant association based on the results.

The number of aircraft arrivals and departures by time from Gimpo International Airport can be found from the Airport Statistics [26] that was published by the Korea Airports Corporation. The average number of flight events daily was 51.6 in the evening from 18:00 to 22:00, and 19.5 after 22:00 during this study period between March and April of 2015. The air services during the evening and nighttime change the depth of sleep, maintain wakefulness, and disturb the process of falling into sleep [27]. This study used WECPNL as the noise metric. The WECPNL is an appropriate metric for reflecting the impact on sleep because the flight events during the evening and nighttime are weighted in this metric. As a result, it can be assumed that the air traffic has a direct impact on the sleep pattern of the residents in the area, where the survey was performed, thereby increasing the risk of sleep disturbance (Table 5).

The previous studies have confirmed that continuous exposure to noise can increase the risk of sleep disturbance [28–31]. There are a few studies that evaluated the relationship between aircraft noise and sleep disturbance, including a community-based cross-sectional study, which is similar to this study, that was conducted by Kim et al. [9]. The sleep quality of the residents adjacent to the airport was evaluated by using the Pittsburgh Sleep Quality Index (PSQI) [32]. The results showed that the quality of sleep was poor in the residents, who were exposed to the aircraft noise, and there was a greater risk of sleep disturbance.

Sleep is also influenced by the sex and age of a person [33]. In this study, female and older subjects showed significant results in terms of their association with sleep disturbance. The prevalence of sleep disturbance showed a difference according to the education level and residency period of the subjects in the univariate analysis. However, the multiple logistic regression model results did not show a statistical significance after the adjustment of such variables.

The subjects, who had been hospitalized or had undergone operations in the previous year, also showed a higher prevalence of sleep disturbance. The chronic comorbidities and health status that may affect the sleep quality [34] and the reverse effect of sleep disturbance can also be considered. Patients with sleep disturbance are more likely to develop affective disorders [35, 36]. Likewise, the prevalence of the hospitalizations or operations was greater in the noise exposure group than that in the control group. It could be considered as a health effect of the aircraft noise [6–10].

For the lifestyle habits, there was no variable that showed a significant association with the occurrence of daytime hypersomnia. In the univariate analysis, the prevalence of insomnia showed some difference based on the lifestyle habits, but only regular exercise performance showed a significance in the multivariate analysis. The subjects, who exercised regularly, showed a higher prevalence of insomnia, which was different from the general understanding that regular exercise improves the quality of sleep [37, 38]. However, exercise near bedtime changes the circardian phase [39], increases the core body temperature [40], and increases the physiological arousal [41], which would disturb sleep. However, this study did not collect the information on the exercise time, so the relationship could not be confirmed. On the contrary, this is a cross-sectional study and a reverse causation can be suspected. It is possible that people, who experience sleep disturbance, tend to exercise more than others.

There are some limitations to this study. First, the subjects of the exposure group were selected based on the official announcement of the Seoul Regional Aviation Administration 5 years earlier without using a direct noise measurement. As it used the past noise level, the current exposure to the noise could not be accurately reflected, and the possibility of a misclassification could not be ruled out. Second, a subjective method was used to evaluate sleep disturbance rather than objective methods, such as EEG and polysomnography. There was a study that evaluated sleep disturbance by using EEG and polysomnography [42], but these objective methods are practically difficult to use in a large-scale epidemiological study. Third, other factors that might have an impact on sleep, such as drinking coffee and watching television at night, were not taken into consideration.

Despite such limitations, this was a large-scale epidemiological study that enrolled more than 3000 subjects. It was the largest scale study among those on aircraft noise conducted in South Korea. This study was significant, as it was conducted on the residents, who live in city areas near the airport, whereas the previous studies on aircraft noise were conducted in the suburbs or towns located outside the city.

Sleep disturbance caused by aircraft noise is an important public health issue. In particular, the airport, on which this study was conducted, was located near the city with residents living in the area, and this might lead to more serious problems. The air services during the evening or nighttime also have a direct impact on the sleep pattern of the residents. For this reason, appropriate measures need to be considered.

Conclusion

In conclusion, the prevalence of insomnia and daytime hypersomnia was higher in the residents, who are exposed to aircraft noise, as compared to the control group. This study was significant, as it was a large-scale epidemiological study. Further research needs to be conducted by using a direct measurement of the noise and objective sleep evaluation methods in order to clarify the cause-effect relationship.

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Authors' contributions
KMK analyzed the data and drafted the manuscript. YSJ suggested the study design, analyzed the data, and revised the manuscript. YJKwon collected and interpreted the data. YKC participated to analyze the data. BKK helped to draft the manuscript. HJK participated in the study design. KWY participated to collect the data. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Occupational and Environmental Medicine, Hallym University Sacred Heart Hospital, Anyang, South Korea. [2]Department of Occupational and Environmental Health, Graduate School of Public Health, Seoul National University, Seoul, South Korea. [3]Department of Occupational and Environmental Medicine, Ewha Womans University Mokdong Hospital, Seoul, South Korea. [4]Department of Occupational and Environmental Medicine, Wonjin Institute for Occupational and Environmental Health Green Hospital, Seoul, South Korea.

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Aircraft noise effects on health

Prepared for the Airports Commission

Dr Charlotte Clark
Centre for Psychiatry
Barts & the London School of Medicine
Queen Mary University of London

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Table of Contents

1. Introduction

Recent years have seen an increase in the strength of the evidence linking environmental noise exposure (road, rail, airport and industrial noise) to health. The World Health Organization (WHO, 2011) recently estimated that between 1 and 1.6 million healthy life years (Disability-Adjusted Life Years) are lost annually because of environmental noise exposure[1], such as road traffic noise and aircraft noise, in high income western European Countries. The WHO estimated that each year 903,000 DALYS are lost due to sleep disturbance; 654,000 DALYS due to noise annoyance; 61,000 DALYS due to heart disease; and 45,000 DALYS due to cognitive impairment in children.

Aircraft noise negatively influences health if the exposure is long-term and exceeds certain levels (Basner et al., 2014). This review briefly summarizes the strength of the evidence for aircraft noise effects on cardiovascular health, sleep disturbance, annoyance, psychological well-being, and effects on children's cognition and learning, as well as briefly discussing guidelines for environment noise exposure. This evidence is related to the three shortlisted schemes for the new runway.

This is a selective review focusing on reviews assessing the strength of the evidence, as well as high quality, robust, large-scale epidemiological field studies of aircraft noise exposure, highlighting studies that have been conducted within the United Kingdom, where possible. It represents key studies within the field but should not be considered an exhaustive review. Studies of road traffic noise, as opposed to aircraft noise, have only been included where evidence for aircraft noise exposure is unavailable.

2. Aircraft noise effects on health: a review of recent evidence

2.1. Cardiovascular health

Over the past 10 years, evidence that aircraft noise exposure leads to increased risk for poorer cardiovascular health has increased considerably. A recent review, suggested that risk for cardiovascular outcomes such as high blood pressure (hypertension), heart attack, and stroke, increases by 7 to 17% for a 10dB increase in aircraft or road traffic noise exposure (Basner et al., 2014). A review of the evidence for children concluded that there were associations between aircraft noise and high blood pressure (Paunović et al., 2011), which may have implications for adult health (Stansfeld & Clark, 2015).

The HYENA study (HYpertension and Exposure to Noise near Airports) examined noise effects on the blood pressure (hypertension) of 4,861 people, aged 45-70 years, who had lived for over 5 years near 7 major European airports including London Heathrow; Amsterdam Schiphol; Stockholm Arlanda & Bromma; Berlin Tegel, Milan Malpensa; and Athens Eleftherios Venizelos (Jarup et al., 2008). High blood pressure was

[1] The range 1 to 1.6 million is given as it is not known if the effects for the different health outcomes are additive or if they might interact/co-occur.

assessed via measurements and medication use. The HYENA study found that a 10dB increase in aircraft noise at night (L_{night}) was associated with a 14% increase in odds for high blood pressure but day-time aircraft noise ($L_{Aeq\ 16\ hour}$) did not increase the odds for high blood pressure (Jarup et al., 2008). The HYENA study did not find an association between day-time aircraft noise and high blood pressure which might be because many residents work away from home during the day-time, leading to potential mis-classification of their day-time aircraft noise exposure. The HYENA study also found that a 10dB increase in night-time aircraft noise was associated with a 34% increase in the use of medication for high blood pressure in the UK (Floud et al., 2011). The HYENA study is a high quality large-scale study of aircraft noise exposure effects on blood pressure, which includes a population sample around London Heathrow airport. One short-coming of the study is that it assesses noise and health at the same point in time, meaning that we cannot be sure whether noise exposure occurred before the poorer health outcomes, or whether the poorer health outcomes may have preceded the noise exposure.

A recent study around London Heathrow airport examined risks for hospital admission and mortality for stroke, coronary heart disease and cardiovascular disease for around 3.6 million people living near London Heathrow airport (Hansell et al., 2013). Both day-time ($L_{Aeq\ 16\ hour}$) and night-time (L_{night}) aircraft noise exposure were related to increased risk for a cardiovascular hospital admission. Compared to those exposed to aircraft noise levels below 51dB in the day-time, those exposed to aircraft noise levels over 63dB in the day-time had a 24% higher chance of a hospital admission for stroke; a 21% higher chance of a hospital admission for coronary heart disease; and a 14% higher chance of a hospital admission for cardiovascular disease. These estimates took into account age, sex, ethnicity, deprivation and lung cancer mortality as a proxy for smoking. These results were also not accounted for by air pollution, which was adjusted for in the analyses. Similar effects were also found between aircraft noise exposure and mortality for stroke, coronary heart disease, and cardiovascular disease. The study concluded that high levels of aircraft noise were associated with increased risks of stroke, coronary heart disease, and cardiovascular disease for both hospital admissions and mortality in areas near Heathrow airport.

Further longitudinal evidence for an association between aircraft noise exposure and mortality from heart attacks comes from a large-scale Swiss study of 4.6 million residents over 30 years of age (Huss et al., 2010). This study found that mortality from heart attacks increased with increasing level and duration of aircraft noise exposure (over 15 years), but there were no associations between aircraft noise exposure and other cardiovascular outcomes including stroke or circulatory disease. The lack of association between aircraft noise and stroke differs from the findings of the similar study conducted around Heathrow airport, which did find an association of aircraft noise on stroke mortality (Hansell et al., 2013).

It is not uncommon for studies in this field to demonstrate some inconsistencies in the specific cardiovascular outcomes for which significant effects of aircraft noise associations are found. There are several explanations for this. Firstly, demonstrating environmental noise effects on cardiovascular disease requires very large samples.

Even in large samples effects may not be statistically significant, as the confidence intervals for the estimate of the effect can be wide, if the cardiovascular outcome does not have a high prevalence, e.g. incidence of stroke. Thus, studies vary in their sample size and in their ability to examine a range of cardiovascular outcomes. Secondly, with epidemiological studies, there is always the potential for residual confounding: the analyses may still not be taking into account all factors, which might be influencing the association between aircraft noise and cardiovascular disease. Thirdly, there is always the possibility of exposure mis-classification: the estimated aircraft noise exposure may be incorrect for some of the sample, which could influence the findings. For example, there is a limitation to using day-time aircraft noise exposure at home for adult samples, when they may work away from their home environment. Fourthly, there is variation in the level and range of aircraft noise exposures examined, which could explain differences between the studies. Despite these differences between the aircraft noise studies, the most recent meta-analysis of the field (Babisch, 2014) concluded that aircraft noise exposure was associated with increased risk for cardiovascular outcomes such as high blood pressure, heart attack and stroke.

It is biologically plausible that long-term exposure to environmental noise might influence cardiovascular health (Babisch, 2014). Figure 2.1. shows a model of proposed pathways between environmental noise exposure and cardiovascular diseases (Babisch, 2014). In brief, increased stress associated with noise exposure might cause physiological stress reactions in an individual, which in turn can lead to increases in established cardiovascular disease risk factors such as blood pressure, blood glucose concentrations, and blood lipids (blood fats). These risk factors lead to increased risk of high blood pressure (hypertension) and arteriosclerosis (e.g. narrowing of arteries due to fat deposits) and are related to serious events such as heart attacks and strokes (Babisch, 2014; Basner et al., 2014). The stress that triggers this pathway can operate directly via sleep disturbance or indirectly via interference with activities and annoyance.

To date, few studies have examined whether aircraft noise exposure influences metabolic risk factors for cardiovascular health, such as Type II diabetes, body mass index, and waist circumference. Such factors would lie on the proposed pathway between aircraft noise exposure and cardiovascular diseases. A recent study of long-term exposure to aircraft noise in Sweden found that exposure was associated with a larger waist circumference but less clearly with Type II diabetes and body mass index (Eriksson et al., 2014). This is an area of research where further evidence should be forthcoming in the next few years.

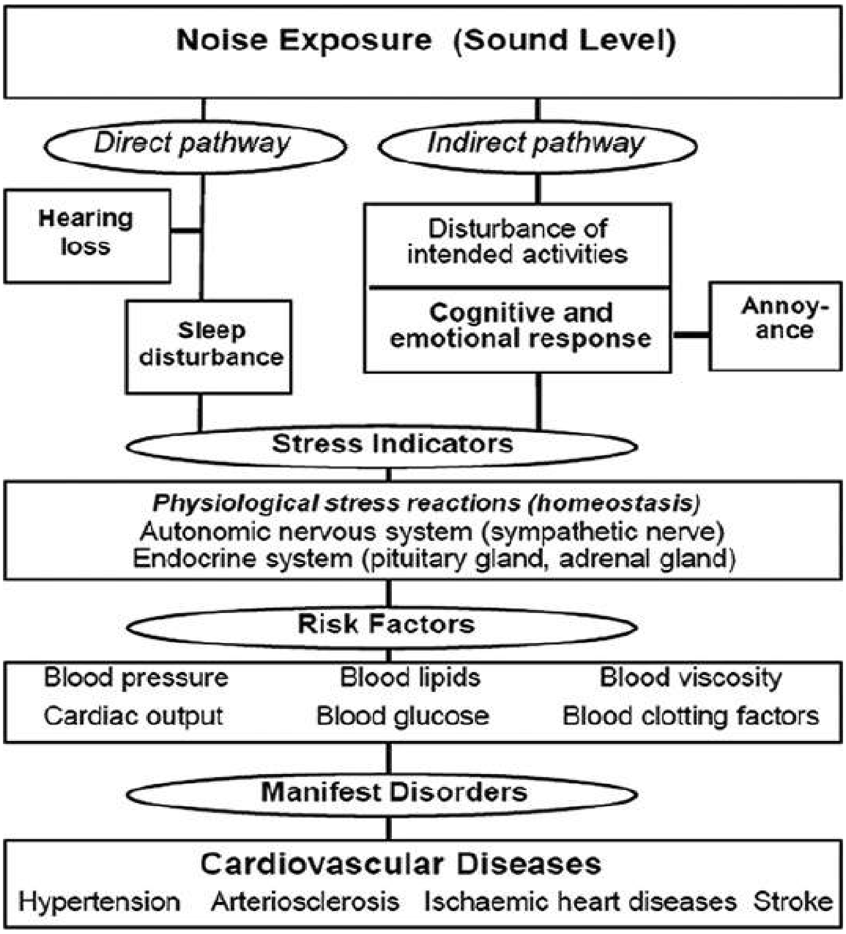

Figure 2.1. Pathways from environmental noise exposure to cardiovascular disease (Babisch, 2014).

2.2. Sleep disturbance

The WHO estimated sleep disturbance to be the most adverse non-auditory effect of environmental noise exposure (Basner et al., 2014; WHO, 2011). Undisturbed sleep of a sufficient number of hours is needed for alertness and performance during the day, for quality of life, and for health (Basner et al., 2014). Humans exposed to sound whilst asleep still have physiological reactions to the noise which do not adapt over time including changes in breathing, body movements, heart rate, as well as awakenings (Basner et al., 2014). The elderly, shift-workers, children and those with poor health are thought to be at risk for sleep disturbance by noise (Muzet, 2007).

The effect of night-time aircraft noise exposure has been explored for a range of sleep outcomes ranging from subjective self-reported sleep disturbance and perceived sleep quality, to more objective measures of interference with ability to fall asleep, shortened sleep duration, awakenings, and increased bodily movements as assessed by polysomnography[2] (Michaud et al., 2007). Most evidence comes from studies of self-reported sleep disturbance. However, self-reported sleep disturbance outcomes are vulnerable to bias, as such measures are likely to be influenced by noise annoyance and other demographic factors (Clark & Stansfeld, 2011).

Reviews have concluded that there is evidence for an effect of night-time aircraft noise exposure on sleep disturbance from community based studies (Hume et al., 2012; Miedema & Vos, 2007). However, some reviews have concluded that the evidence is contradictory and inconclusive (Jones, 2009; Michaud et al., 2007), which might be explained by methodological differences between studies of noise effects on sleep disturbance. A meta-analysis of 24 studies, including nearly 23,000 individuals exposed to night-time noise levels ranging from 45-65dBA, found that aircraft noise was associated with greater self-reported sleep disturbance than road traffic noise (Miedema & Vos, 2007). However, another study, whilst confirming that aircraft noise was associated with greater self-reported sleep disturbance than road traffic noise, found that when polysomnography measures of sleep disturbance were analysed that road traffic noise was associated with greater disturbance than aircraft noise (Basner et al., 2011).

Polysomnography enables the assessment of noise effects on different stages of the sleep cycle. The average sleep cycle last between 90 to 110 minutes, and an individual experiences between four to six sleep cycles per night (Michaud et al., 2007). Figure 2.2. describes the duration and characteristics of each stage of the sleep cycle (Clark & Stansfeld, 2011) from wake, through non-rapid eye movement (NREM) stages 1 to 4, and rapid eye movement (REM) sleep. It is usual for people to move between NREM sleep stages several times before undergoing REM sleep. Slow-wave sleep (NREM stage 3 and 4) occurs more frequently in the first half of the night, and REM sleep propensity is greater in the second half of the night. Sleep disturbance is indicated by less stage 3, stage 4 and REM sleep, and by more wake and stage 1 sleep, as well as more frequent changes in sleep stage (Basner & Siebert, 2010).

There is evidence that aircraft noise influences the time spent in different sleep stages, with aircraft noise reducing slow-wave sleep (NREM Stage 4) and REM sleep and increasing NREM Stages 1, 2 & 3 (Basner et al., 2008; Swift, 2010). This evidence, taken with the increase in REM sleep in the later stages of the night might have implications for early morning (04.00-06.30 hours) flight operations at airports.

A laboratory study compared the potential effects of changes in the night-time curfew at Frankfurt airport on sleep disruption (Basner & Siebert, 2010), using polysomnography on 128 subjects over 13 nights. Three different operational scenarios were compared: scenario 1 was based on 2005 air traffic at Frankfurt airport which included night flights; scenario 2 was as scenario 1 but cancelled flights between 23.00-05.00 hours; scenario 3 was as scenario 1 but with flights between 23.00-05.00

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[2] Polysomnography records biophysiological changes that occur during sleep, including brain waves using electroencephalography (EEG), eye movements using electroculography (EOG), muscle activity using electromyography (EMG), and heart rhythm using electrocardiography (ECG).

hours rescheduled to the day-time and evening periods. The study found that compared to the night without a curfew on night flights (scenario 1), small improvements were observed in sleep structure for the nights with curfew, even when the flights were rescheduled to periods before and after the curfew period. However, the change in the amount of time spent in the different sleep stages for the different scenarios was small, which might be explained by the small number of night-flights (on average 4 take-offs per hour) in the Frankfurt airport scenarios examined: larger effects may be observed for airports with a greater number of night-flights. The authors concluded that the benefits for sleep seen in the scenario involving rescheduling of flights rather than cancellation may be offset by the expected increase in air traffic during the late evening and early morning hours for those who go to bed before 22.30 or after 01.00 hours.

Wake	
Non-rapid eye movement (NREM)	
Stage 1	Light stage of sleep Lasts 5-10 minutes Bridge between wakefulness and sleep
Stage 2	Light stage of sleep Lasts around 20 minutes Brain waves of increased frequency Increased heart rate variability
Stage 3	Transition to deeper stages of sleep Increased amount of delta waves of lower frequency
Stage 4	Deepest stage of sleep Characterised by a greater number of delta waves
Rapid Eye Movement (REM) sleep	Typically starts 70-90 minutes after falling asleep Characterised by rapid eye movements Increases in brain activity Greater variability in respiration rate, blood pressure and heart rate

Figure 2.2. Stages of sleep, adapted from (Clark & Stansfeld, 2011).

The WHO Europe Night Noise Guidelines (WHO, 2009) were based on expert-consensus that there was sufficient evidence that nocturnal environmental noise exposure was related to self-reported sleep disturbance and medication use, and that there was some evidence for effects of nocturnal noise exposure on high blood pressure (hypertension) and heart attacks. The WHO Europe Night Noise Guidelines state that the target for nocturnal noise exposure should be 40 dB $L_{night,\ outside}$, which should protect the public as well as vulnerable groups such as the elderly, children, and the chronically ill from the effects of nocturnal noise exposure on health. The Night Noise Guidelines also recommend the level of 55 dB $L_{night,\ outside}$, as an interim target for countries wishing to adopt a step-wise approach to the guidelines. It is worth noting that the 40dB $L_{night\ outside}$ guideline represents a very low level of noise exposure, e.g. a refrigerator humming.

There have been fewer studies on aircraft noise exposure and sleep in children (Stansfeld & Clark, 2015), even though children are a group thought to be vulnerable to the effects of sleep disturbance (Pirrera et al., 2010). Drawing on studies of road traffic noise exposure in children, studies have suggested associations with sleeping problems (Tiesler et al., 2013), sleep quality (Ohrstrom et al., 2006) and sleepiness during the day (Ohrstrom et al., 2006) but not with difficulties falling asleep (Ohrstrom et al., 2006). However, these studies are limited by small samples and self-reports of sleep. Children sleep outside the typical hours used to denote night-time noise exposure around airports (e.g. L_{night} is typically 23.00 hours to 07.00 hours), so exposures during the hours of the evening and morning, which would fall within day-time exposure metrics may also be relevant when considering sleep disturbance effects for children.

2.3. Annoyance

Annoyance is the most prevalent community response in a population exposed to environmental noise. The term annoyance is used to describe negative reactions to noise such as disturbance, irritation, dissatisfaction and nuisance (Guski, 1999). Annoyance can also be accompanied by stress-related symptoms, leading to changes in heart rate and blood pressure, as described above. Acoustic factors, such as the noise source and sound level, account for only a small to moderate amount of annoyance responses: other factors such as the fear associated with the noise source, interference with activities, ability to cope, noise sensitivity, expectations, anger, attitudes to the source – both positive or negative, and beliefs about whether noise could be reduced by those responsible influence annoyance responses (WHO, 2000).

Annoyance scales are commonly used within European policy to measure the quality of life impact of environmental noise exposure on communities around airports. An International Standard is in place governing the measurement of annoyance in community surveys (Fields et al., 2001; ISO/TS, 2003), with questions typically taking the format "Thinking about the last year when you are at home, how much does the noise from aircraft bother, disturb or annoy you?" with responses ideally given on a 10 point scale with 0 being 'not at all annoyed' and 10 being "extremely annoyed". This question is often reported as the % of the population "highly annoyed" or "annoyed", where "highly annoyed" is 72% or more on the scale and "annoyed" is 50% or more on the scale.

Exposure to aircraft noise at 60dB L_{den} is estimated to be associated with 38% of the population reporting being "annoyed" and 17% being "highly annoyed" (EC, 2002). Exposure to aircraft noise at 65dB L_{den} is estimated to be associated with 48% of the population reporting being "annoyed" and 26% being "highly annoyed" (EC, 2002). However, in recent years, several studies have suggested that aircraft noise annoyance around major airports in Europe has increased (Babisch et al., 2009; Janssen et al., 2011; Schreckenberg et al., 2010), so the percentage of the population reporting being "annoyed" or "highly annoyed" at each noise exposure level may have increased since these figures were put forward by the European Commission in 2002 (EC, 2002).

Annoyance responses can also increase in relation to a change in airport operations. A study around Zurich airport found that residents who experienced a significant increase in aircraft noise exposure due to an increase in early morning and late evening flight operations had a pronounced over-reaction of annoyance i.e. the annoyance reaction was greater than that which would be predicted by the level of noise exposure (Brink et al., 2008).

Children also report annoyance responses, although it is not known at what age children being to exhibit annoyance responses. The RANCH (Road traffic and Aircraft Noise exposure and children's Cognition and Health) study found that children aged 9-11 years of age living near London Heathrow, Amsterdam Schiphol, and Madrid Barajas airports, reported annoyance for aircraft noise exposure at school and at home (van Kempen et al., 2009). For school exposure the percentage of "highly annoyed" children increased from about 5.1% at 50dB $L_{Aeq\ 16\ hour}$, to 12.1% at 60dB $L_{Aeq\ 16\ hour}$.

2.4. Psychological health

Following on from annoyance, it has been suggested that long-term noise exposure might influence psychological health. However, overall the evidence for aircraft noise exposure being linked to poorer well-being, lower quality of life, and psychological ill-health is not as strong or consistent as for other health outcomes, such as cardiovascular disease. A recent study of 2300 residents near Frankfurt airport found that annoyance but not aircraft noise levels per se ($L_{Aeq16\ hour}$, L_{night}, L_{den}) was associated with self-reported lower quality of life (Schreckenberg et al., 2010).

Several studies of children around London Heathrow airport have shown no effect of aircraft noise at school on children's psychological health or cortisol levels (Haines et al., 2001a; Haines et al., 2001b; Stansfeld et al., 2009): we would expect cortisol levels to be raised in children with depression. However, there may be a small effect of aircraft noise on hyperactivity symptoms. The West London Schools Study of 451 children around Heathrow airport, aged 8-11 years found higher rates of hyperactivity symptoms for children attending schools exposed to aircraft noise exposure >63dB $L_{Aeq\ 16\ hour}$ compared with <57dB $L_{Aeq\ 16\ hour}$ (Haines et al., 2001a). A similar effect was observed in the RANCH study where 10dB $L_{Aeq\ 16\ hour}$ increase in aircraft noise exposure at school was associated with 0.13 increase in hyperactivity symptoms (Stansfeld et al., 2009). However, these increases in hyperactivity symptoms, whilst statistically significant, are extremely small and most likely not of clinical relevance. Aircraft noise exposure does not appear to be causing children to develop hyperactivity problems.

There have been fewer studies of aircraft noise effects on adult psychological health. The HYENA study, found that a 10dB increase in day-time ($L_{Aeq\ 16\ hour}$) was associated with a 28% increase in anxiety medication use: similarly, a 10dB increase in night-time (L_{night}) aircraft noise was associated with a 27% increase in anxiety medication use. However, day-time and night-time aircraft noise exposure were not associated with sleep medication or anti-depressant medication use (Floud et al., 2011). Anxiety medication is prescribed for individuals experiencing levels of anxiety and worry that interfere with their ability to function effectively: they can also be prescribed for sleeping problems. A sub-study of the HYENA study found that salivary cortisol (a stress hormone which is higher in people with depression) was 34% higher for women exposed to aircraft noise > 60dB $L_{Aeq\ 24\ hour}$, compared to women exposed to less than 50dB $L_{Aeq\ 24\ hour}$ (Selander et al., 2009). However, no association between aircraft noise and salivary cortisol was found for men.

2.5. Implications of the evidence for aircraft noise effects on health for the shortlisted options for a new runway

2.5.1. Populations exposed for each shortlisted option

This section considers the implications of the current evidence for aircraft noise effects on cardiovascular health, sleep disturbance, annoyance, and psychological health for the three shortlisted options for a new runway:

- Gatwick 2-R promoted by Gatwick Airport Limited (GAL).
- Heathrow-NWR promoted by Heathrow Airport Limited (HAL).
- Heathrow-ENR promoted by Heathrow Hub (HH).

Information relating to each of these options is taken from the “Noise: Baseline”, the “Noise: Local Assessment” and the “Noise: Local Assessment Addendum” reports prepared by Jacobs for the Airport Commission (all available on https://www.gov.uk/government/organisations/airports-commission).

The Commission has evaluated these shortlisted options in terms of populations exposed to several noise metrics including $L_{Aeq\ 16\ hour}$, $L_{Aeq\ 8\ hour}$, L_{den}, N70 & N60. Most of the evidence for aircraft noise effects on health has made use of average noise metrics such as $L_{Aeq\ 16\ hour}$ and $L_{Aeq\ 8\ hour}$. This section relates key messages from the evidence to the estimated populations exposed to $L_{Aeq\ 16\ hour}$ and $L_{Aeq\ 8\ hour}$ for each of the shortlisted options using the predefined exposure categories used by the Commission of >54, >57, >60, >63, >66, >69, and >72dB for $L_{Aeq\ 16\ hour}$ and >48, >51, >54, >57, >60, >63, >66, >69, and >72dB for $L_{Aeq\ 8\ hour}$.

The magnitude of the populations exposed to aircraft noise varies between the shortlisted options for each scheme and is nearly always greater in terms of the net population exposed in the Do-Something scenario compared with the Do-Minimum scenario.

2.5.1.1. Gatwick 2-R

For Gatwick-2-R, the estimated population exposed to day-time noise levels greater than 54dB $L_{Aeq\ 16\ hour}$ is 17,600 in 2030, 19,400 in 2040, and 24,600 in 2050. The estimated population exposed to night-time noise levels greater than 48dB $L_{Aeq\ 8\ hour}$ is 22,300 in 2030, 17,400 in 2040 and 18,600 in 2050.

Table 2.1. Estimated population exposed to levels greater than 54dB $L_{Aeq\ 16\ hour}$ and $L_{Aeq\ 8\ hour}$ in 2030, 2040, & 2050 for Gatwick 2-R.

	Gatwick 2-R		
	2030	**2040**	**2050**
Day-time			
54dB $L_{Aeq\ 16\ hour}$	17,600	19,400	24,600
57dB $L_{Aeq\ 16\ hour}$	4,900	5,300	7,200
60dB $L_{Aeq\ 16\ hour}$	1,700	1,900	2,800
63dB $L_{Aeq\ 16\ hour}$	400	500	800
66dB $L_{Aeq\ 16\ hour}$	<50	<50	200
69dB $L_{Aeq\ 16\ hour}$	<50	<50	<50
72dB $L_{Aeq\ 16\ hour}$	<50	<50	<50
Night-time			
48dB $L_{Aeq\ 8\ hour}$	22,300	17,400	18,600
51dB $L_{Aeq\ 8\ hour}$	6,500	5,200	5,400
54 dB $L_{Aeq\ 8\ hour}$	2,900	2,300	2,400
57dB $L_{Aeq\ 8\ hour}$	800	500	700
60dB $L_{Aeq\ 8\ hour}$	200	100	100
63dB $L_{Aeq\ 8\ hour}$	<50	<50	<50
66dB $L_{Aeq\ 8\ hour}$	<50	<50	<50
69dB $L_{Aeq\ 8\ hour}$	<50	<50	<50
72dB $L_{Aeq\ 8\ hour}$	<50	<50	<50

These estimates for the population exposed in the Do-Something scenario for Gatwick 2-R are higher than the estimates for the Do-Minimum scenario in 2030, 2040 and 2050. The differences in the 2030, 2040, and 2050 Do-Something scenario compared with the 2030, 2040, and 2050 Do-Minimum scenario are summarized below for day-time and night-time exposure:

2030 $L_{Aeq\ 16\ hour}$

- >54 dB: An increase of 9,600 (from 8,000 to 17,600)
- >57 dB: An increase of 2,700 (from 2,200 to 4,900)
- >60 dB: An increase of 600 (from 1,100 to 1,700)
- >63 dB: No discernible difference from (from 400 to 400)
- >66 dB: A reduction from 300 to <50
- >69 dB: A reduction from 200 to <50
- >72 dB: No discernible difference (from <50 to <50)

2040 $L_{Aeq\ 16\ hour}$
• >54 dB: An increase of 12,000 (from 7,400 to 19,400)
• >57 dB: An increase of 3,100 (from 2,200 to 5,300)
• >60 dB: An increase of 1,000 (from 900 to 1,900)
• >63 dB: No discernible difference (from 500 to 500)
• >66 dB: A reduction from 300 to <50
• >69 dB: A reduction from 200 to <50
• >72 dB: No discernible difference (<50 to <50)

2050 $L_{Aeq\ 16\ hour}$
• >54 dB: An increase of 17,000 (from 7,600 to 24,600)
• >57 dB: An increase of 4,400 (from 2,800 to 7,200)
• >60 dB: An increase of 1,600 (from 1,200 to 2,800)
• >63 dB: An increase of 300 (from 500 to 800)
• >66 dB: A reduction of 100 (from 300 to 200)
• >69 dB: A reduction from 200 to <50
• >72 dB: No discernible difference (from <50 to <50)

2030 $L_{Aeq\ 8\ hour}$
• >48 dB: An increase of 10,600 (from 11,700 to 22,300)
• >51 dB: An increase of 900 (from 5,600 to 6,500)
• >54 dB: An increase of 1,200 (from 1,700 to 2,900)
• >57 dB: An increase of 200 (from 600 to 800)
• >60 dB: A reduction of 200 (from 400 to 200)
• >63 dB: A reduction from 300 to <50
• >66 dB: No discernible difference (from <50 to <50)
• >69 dB: No discernible difference (from <50 to <50)
• >72 dB: No discernible difference (from <50 to <50)

2040 $L_{Aeq\ 8\ hour}$
• >48 dB: An increase of 6,300 (from 11,100 to 17,400)
• >51 dB: A reduction of 300 (from 5,500 to 5,200)
• >54 dB: An increase of 600 (from 1,700 to 2,300)
• >57 dB: A reduction of 100 (from 600 to 500)
• >60 dB: A reduction of 300 (from 400 to 100)
• >63 dB: A reduction from 300 to <50
• >66 dB: No discernible difference (from <50 to <50)
• >69 dB: No discernible difference (from <50 to <50)
• >72 dB: No discernible difference (from <50 to <50)

2050 $L_{Aeq\ 8\ hour}$
• >48 dB: An increase of 7,400 (from 11,200 to 18,600)
• >51 dB: A reduction of 200 (from 5,600 to 5,400)
• >54 dB: An increase of 700 (from 1,700 to 2,400)
• >57 dB: An increase of 100 (from 600 to 700)
• >60 dB: A reduction of 300 (from 400 to 100)

• >63 dB: A reduction from 300 to <50
• >66 dB: No discernible difference (from <50 to <50)
• >69 dB: No discernible difference (from <50 to <50)
• >72 dB: No discernible difference (from <50 to <50)

2.5.1.2. Heathrow-NWR

For Heathrow-NWR-T, the estimated population exposed to day-time noise levels greater than 54dB $L_{Aeq\ 16\ hour}$ is 456,200 in 2030, 488,600 in 2040, and 491,900 in 2050. The estimated population exposed to night-time noise levels greater than 48dB $L_{Aeq\ 8\ hour}$ is 266,800 in 2030, 308,500 in 2040 and 295,800 in 2050.

Table 2.2. Estimated population exposed to levels greater than 54dB $L_{Aeq\ 16\ hour}$ and $L_{Aeq\ 8\ hour}$ in 2030, 2040, & 2050 for Heathrow-NWR-T.

	Heathrow-NWR-T		
	2030	**2040**	**2050**
Day-time			
54dB $L_{Aeq\ 16\ hour}$	456,200	488,600	491,900
57dB $L_{Aeq\ 16\ hour}$	237,100	249,900	249,300
60dB $L_{Aeq\ 16\ hour}$	128,200	137,000	140,600
63dB $L_{Aeq\ 16\ hour}$	38,300	41,300	42,900
66dB $L_{Aeq\ 16\ hour}$	1,200	11,800	10,900
69dB $L_{Aeq\ 16\ hour}$	900	900	800
72dB $L_{Aeq\ 16\ hour}$	<50	<50	<50
Night-time			
48dB $L_{Aeq\ 8\ hour}$	266,800	308,500	295,800
51dB $L_{Aeq\ 8\ hour}$	167,200	188,800	185,600
54 dB $L_{Aeq\ 8\ hour}$	72,200	95,700	88,600
57dB $L_{Aeq\ 8\ hour}$	11,600	18,100	12,100
60dB $L_{Aeq\ 8\ hour}$	900	2,400	900
63dB $L_{Aeq\ 8\ hour}$	200	200	200
66dB $L_{Aeq\ 8\ hour}$	<50	<50	<50
69dB $L_{Aeq\ 8\ hour}$	<50	<50	<50
72dB $L_{Aeq\ 8\ hour}$	<50	<50	<50

The differences in the 2030, 2040, and 2050 Do-Something scenarios compared with the 2030, 2040, and 2050 Do-Minimum scenarios are summarized below for day-time and night-time exposure. Generally, the estimates for the population exposed in the Do-Something scenarios for Heathrow-NWR-T in the day-time are higher than the estimates for the Do-Minimum scenarios in 2030, 2040 and 2050: there is an increase in the population exposed at the lower contour levels for $L_{Aeq\ 16\ hour}$ along with a slight reduction in the population exposed at the higher contour levels. For night-noise the population exposed to >48dB $L_{Aeq\ 8\ hour}$ is reduced for the Do-Something scenarios compared with the Do-Minimum scenarios at 2030, 2040 and 2050. In 2030 and 2040, there is an increase in the population exposed to >51dB and >54dB $L_{Aeq\ 8\ hour}$ but reductions are estimated for all the other $L_{Aeq\ 8\ hour}$ exposure contours. For the 2050 scenario the number of the population exposed at night-time is reduced across all the contours.

2030 $L_{Aeq\ 16\ hour}$
• >54 dB a decrease of 37,400 (from 493,600 to 456,200)
• >57 dB an increase of 15,900 (from 221,200 to 237,100)
• >60 dB an increase of 19,200 (from 109,000 to 128,200)
• >63 dB an increase of 3,100 (from 35,200 to 38,300)
• >66 dB an increase of 4,100 (from 7,900 to 12,000)
• >69dB a reduction of 1,200 (from 2,100 to 900)
• >72 dB no discernible difference (from <50 to <50)

2040 $L_{Aeq\ 16\ hour}$
• >54 dB an increase of 28,000 (from 460,600 to 488,600)
• >57 dB an increase of 30,500 (from 219,400 to 249,900)
• >60 dB an increase of 33,200 (from 103,800 to 137,000)
• >63 dB an increase of 7,400 (from 33,900 to 41,300)
• >66 dB an increase of 4,700 (from 7,100 to 11,800)
• >69 dB a reduction of 1,200 (from 2,100 to 900)
• >72 dB no discernible difference (from <50 to <50)

2050 $L_{Aeq\ 16\ hour}$
• >54 dB an increase of 56,100 (from 435,800 to 491,900)
• >57 dB an increase of 29,700 (from 219,600 to 249,300)
• >60 dB an increase of 36,800 (from 103,800 to 140,600)
• >63 dB an increase of 8,000 (from 34,900 to 42,900)
• >66 dB an increase of 3,200 (from 77,00 to 10,900)
• >69 dB a reduction of 1,300 (from 2,100 to 800)
• >72 dB no discernible difference (from <50 to <50)

2030 $L_{Aeq\ 8\ hour}$
• >48 dB a reduction of 4,400 (from 271,200 to 266,800)
• >51 dB an increase of 15,900 (from 151,300 to 167,200)
• >54 dB an increase of 11,100 (from 61,100 to 72,200)
• >57 dB a reduction of 10,300 (from 21,900 to 11,600)
• >60 dB a reduction 3,000 (from 3,900 to 900)
• >63 dB a reduction of 1,100 (from 1,300 to 200)
• >66 – 72 dB no discernible differences (all remain at <50 in both scenarios)

2040 $L_{Aeq\ 8\ hour}$
• >48 dB a reduction of 28,500 (from 337,000 to 308,500)
• >51 dB an increase of 4,200 (from 184,600 to 188,800)
• >54 dB an increase of 14,400 (from 813,00 to 95,700)
• >57 dB a reduction of 13,300 (from 31,400 to 18,100)
• >60 dB a reduction of 4,000 (from 6,400 to 2,400)

• >63 dB a reduction of 2,200 (from 2,400 to 200)
• >66 – 72 dB no discernible differences (all remain at <50 in both scenarios)

2050 $L_{Aeq\ 8\ hour}$
• >48 dB a reduction of 7,730 (from 373,100 to 295,800)
• >51 dB a reduction of 11,800 (from 197,400 to 185,600)
• >54 dB a reduction of 600 (from 89,200 to 88,600)
• >57 dB a reduction of 21,800 (from 33,900 to 12,100)
• >60 dB a reduction of 6,200 (from 7,100 to 900)
• >63 dB a reduction of 2,400 (from 2,600 to 200)
• >66 – 72 dB no discernible differences (all remain at <50 in both scenarios)

2.5.1.3. Heathrow-ENR

For Heathrow-ENR-O (using the offset flight path results), the estimated population exposed to day-time noise levels greater than 54dB $L_{Aeq\ 16\ hour}$ is 480,300 in 2030, 488,900 in 2040 and 462,900 in 2050. The estimated population exposed to night-time noise levels greater than 48dB $L_{Aeq\ 8\ hour}$ is 263,800 in 2030, 298,900 in 2040 and 306,700 in 2050.

Table 2.3. Estimated population exposed to levels greater than 54dB $L_{Aeq\ 16\ hour}$ and $L_{Aeq\ 8\ hour}$ in 2030, 2040, & 2050 for Heathrow-ENR-O.

	Heathrow-ENR-O		
	2030	**2040**	**2050**
Day-time			
54dB $L_{Aeq\ 16\ hour}$	480,300	488,900	462,900
57dB $L_{Aeq\ 16\ hour}$	257,900	264,700	261,200
60dB $L_{Aeq\ 16\ hour}$	157,500	164,400	165,500
63dB $L_{Aeq\ 16\ hour}$	63,700	67,500	67,100
66dB $L_{Aeq\ 16\ hour}$	17,100	17,700	17,800
69dB $L_{Aeq\ 16\ hour}$	3,900	4,000	3,900
72dB $L_{Aeq\ 16\ hour}$	600	700	600
Night-time			
48dB $L_{Aeq\ 8\ hour}$	263,800	298,900	306,700
51dB $L_{Aeq\ 8\ hour}$	177,400	193,800	197,200
54 dB $L_{Aeq\ 8\ hour}$	87,800	107,300	110,300
57dB $L_{Aeq\ 8\ hour}$	31,000	36,900	36,400
60dB $L_{Aeq\ 8\ hour}$	4,900	6,800	6,200
63dB $L_{Aeq\ 8\ hour}$	800	1,600	1,600
66dB $L_{Aeq\ 8\ hour}$	200	300	200
69dB $L_{Aeq\ 8\ hour}$	<50	100	<50
72dB $L_{Aeq\ 8\ hour}$	<50	<50	<50

The number of people within the day-time $L_{Aeq\ 16\ hour}$ noise contours are greater in the Heathrow-ENR-O Do-Something scenarios, when compared to the Do-Minimum scenarios, for all of the assessment years considered. For night-noise the population exposed to >48dB $L_{Aeq\ 8\ hour}$ and >63 $L_{Aeq\ 8\ hour}$ is reduced for the Do-Something scenario compared with the Do-Minimum scenario at 2030, 2040 and 2050, however, within the other exposure contours there are increases in the population exposed to night-noise.

2030 $L_{Aeq\ 16\ hour}$

- >54 dB: A reduction of 13,300 (from 493,600 to 480,300)
- >57 dB: An increase of 36,700 (from 221,200 to 257,900)
- >60 dB: An increase of 48,500 (from 109,000 to 157,500)
- >63 dB: An increase of 28,500 (from 35,200 to 63,700)
- >66 dB: An increase of 9,200 (from 7,900 to 17,100)
- >69 dB: An increase of 1,800 (from 2,100 to 3,900)
- >72 dB: An increase from <50 to 600

2040 $L_{Aeq\ 16\ hour}$

- >54 dB: An increase of 28,300 (from 460,600 to 488,900)
- >57 dB: An increase of 45,300 (from 219,400 to 264,700)
- >60 dB: An increase of 60,600 (from 103,800 to 164,400)
- >63 dB: An increase of 33,600 (from 33,900 to 67,500)
- >66 dB: An increase of 10,600 (from 7,100 to 17,700)
- >69 dB: An increase of 1,900 (from 2,100 to 4,000)
- >72 dB: A change from <50 to 700

2050 $L_{Aeq\ 16\ hour}$

- >54 dB: An increase of 27,100 (from 435,800 to 462,900)
- >57 dB: An increase of 41,600 (from 219,600 to 261,200)
- >60 dB: An increase of 61,700 (from 103,800 to 165,500)
- >63 dB: An increase of 32,200 (from 34,900 to 67,100)
- >66 dB: An increase of 10,100 (from 7,700 to 17,800)
- >69 dB: An increase of 1,800 (from 2,100 to 3,900)
- >72 dB: A change from <50 to 600

2030 $L_{Aeq\ 8\ hour}$

- >48 dB: A reduction of 7,400 (from 271,200 to 263,800)
- >51 dB: An increase of 26,100 (from 151,300 to 177,400)
- >54 dB: An increase of 26,700 (from 61,100 to 87,800)
- >57 dB: An increase of 9,100 (from 21,900 to 31,000)
- >60 dB: An increase of 1,000 (from 3,900 to 4,900)
- >63 dB: A reduction of 500 (from 1,300 to 800)
- >66 dB: An increase from <50 to 200
- >69 dB: No discernible change (from <50 to <50)
- >72 dB: No discernible change (from <50 to <50)

2040 $L_{Aeq\ 8\ hour}$

- >48 dB: A reduction of 38,100 (from 337,000 to 298,900)
- >51 dB: An increase of 9,200 (from 184,600 to 193,800)
- >54 dB: An increase of 26,000 (from 81,300 to 107,300)
- >57 dB: An increase of 5,500 (from 31,400 to 36,900)
- >60 dB: An increase of 400 (from 6,400 to 6,800)
- >63 dB: A reduction of 800 (from 2,400 to 1,600)
- >66 dB: An increase from <50 to 300
- >69 dB: An increase from <50 to 100
- >72 dB: No discernible change (from <50 to <50)

2050 $L_{Aeq\ 8\ hour}$

- >48 dB: A reduction of 66,400 (from 373,100 to 306,700)
- >51 dB: A reduction of 200 (from 197,400 to 197,200)
- >54 dB: An increase of 21,100 (from 89,200 to 110,300)
- >57 dB: An increase of 2,500 (from 33,900 to 36,400)
- >60 dB: A reduction of 900 (from 7,100 to 6,200)
- >63 dB: A reduction of 1,000 (from 2,600 to 1,600)
- >66 dB: An increase from <50 to 200
- >69 dB: An increase from <50 to <50
- >72 dB: No discernible change (from <50 to <50)

2.5.2. Mitigation

All the schemes suggest mitigation activities for their schemes. Aspects to note are as follows:

- Gatwick 2-R: houses within the 60 $L_{Aeq\ 16\ hour}$ contour will be offered £3,000 towards double glazing and loft insulation for newly affected homes. Residents with a home within the 57dB $L_{Aeq\ 16\ hour}$ contour will be offered £1000 per annum – to qualify residents must have been living in the house before 1st January 2015.
- Heathrow-NWR: runway operations allow respite for local populations. Residents in the 60dB $L_{Aeq\ 16\ hour}$ contour will be offered full-costs for insulation; residents exposed to 55dB L_{den} will be offered a £3,000 contribution towards insulation.
- Heathrow ENR: the promoter is not advocating night-time operation of the extended runway and is also planning to reduce day-time exposure by use of noise preferential routing. This scheme will also offer full-costs for home insulation for residents in the 60dB $L_{Aeq\ 16\ hour}$ contour, with residents in the 55dB L_{den} contour offered a £3,000 contribution towards insulation.

In terms of mitigation, very little is understood in terms of how monetary payments or respite from exposure might influence the associations between aircraft noise and health. The health-benefits associated with many of these activities should not be assumed and need to be empirically tested. The impact of any mitigation scheme would ideally be evaluated to assess efficacy and cost-effectiveness.

2.5.3. Implications of the noise effects on health evidence for the proposed schemes

A brief consideration of the evidence for noise effects on health in relation to the three schemes is provided below:

- Aircraft noise exposure is associated with small increases in risk for poor cardiovascular health outcomes such as high blood pressure, heart attacks, and stroke, as well as with cardiovascular hospital admission and cardiovascular mortality, with effects observed for day-time ($L_{Aeq\ 16\ hour}$) and night-time ($L_{Aeq\ 8\ hour}$) exposure.

- Whilst the increase in risk observed between aircraft noise exposure and cardiovascular health is considered moderate, such increases in risk become important if a large population is exposed to aircraft noise.

- Night-noise is associated with self-reported sleep disturbance and with changes in sleep structure. Night-noise might also be particularly important for cardiovascular effects. Populations exposed to night-time noise could benefit from insulation of their home. It may also be beneficial to consider the use of curfews for night-noise flights: respite may also be effective but needs empirically evaluating.

- Aircraft noise exposure during the evening and early morning (outside the typical 23.00 to 07.00 8 hour night exposure metric) also has relevance for the health and sleep quality of the local population, and may be particularly relevant for children, the physically ill, and shift-workers. Therefore the impact of aircraft noise on the sleep of the local population may not be restricted only to the night-time period and insulation to the homes of populations exposed to day-time noise levels might also be beneficial.

- Consideration should be given to health monitoring of cardiovascular risk factors in the exposed population: for example, high blood pressure and cholesterol can be treated with medication to avoid more serious cardiovascular disease progression. This can probably be achieved through existing NHS Health Checks offered to individuals aged 40-74 by their GPs, which checks vascular and circulatory health.

- Aircraft noise annoyance responses are to be expected for children and adults and it should be borne in mind that annoyance responses in relation to exposure may be higher than predicted by the traditional annoyance curves. In particular, annoyance can increase in relation to operational changes; where populations become newly exposed to noise; where populations experience a step-change in exposure; and in response to early morning and evening flights. Monitoring of annoyance responses over the long-term using survey methods in the exposed population would be advisable. In particular, annoyance responses at different times of the day should be examined. Surveys assessing baseline annoyance, in terms of annoyance responses prior to the development of the new runway would be useful for comparative purposes. Such monitoring would help the airport to identify any increases in annoyance related to operational decisions.

- Based on current evidence aircraft noise might be associated with decreased quality of life but is unlikely to be causing psychological ill-health. The increases in hyperactivity symptoms observed for children are small and unlikely to be of clinical significance in the population exposed. The evidence relating to aircraft noise effects on psychological health should be re-reviewed throughout the planning process, as further evidence becomes available.

3. Aircraft noise effects on children's cognition and learning

3.1. Reading and memory

Many studies have found effects of aircraft noise exposure at school or at home on children's reading comprehension or memory skills (Evans & Hygge, 2007). The RANCH study (Road traffic and Aircraft Noise and children's Cognition & Health) of 2844 9-10 year old children from 89 schools around London Heathrow, Amsterdam Schiphol, and Madrid Barajas airports found that aircraft noise was associated with poorer reading comprehension and poorer recognition memory, after taking social position and road traffic noise, into account (Stansfeld et al., 2005).

Figure 3.1 shows the exposure-effect relationship between aircraft noise at school and reading comprehension from the RANCH study (Clark et al., 2006), indicating that as aircraft noise exposure increased, performance on the reading test decreased. Reading began to fall below average at around 55dB $L_{Aeq\ 16\ hour}$ at school but as the association is linear, (thus there is no specific threshold above which noise effects begin) any reduction in aircraft noise exposure at schools should lead to an improvement in reading comprehension, supporting a policy to not only insulate schools exposed to the highest levels of aircraft noise. The development of cognitive skills such as reading and memory is important not only in terms of educational achievement but also for subsequent life chances and adult health (Kuh & Ben-Shlomo, 2004). In the UK, reading age was delayed by up to 2 months for a 5dB increase in aircraft noise exposure (Clark et al., 2006). The UK primary schools in the RANCH study ranged in aircraft noise exposure from 34dB $L_{Aeq\ 16\ hour}$ to 68 dB $L_{Aeq\ 16\ hour}$. If we take a 20dB difference in aircraft noise exposure between schools, the study would estimate an 8-month difference in reading age.

For primary school children, aircraft noise exposure at school and at home are very highly correlated: in the RANCH UK sample, this correlation was r=0.91 (Clark et al., 2006). Such a high correlation can make estimating the impact of aircraft noise exposure in both environments difficult. The RANCH study found that night-time aircraft noise at the child's home was also associated with impaired reading comprehension and recognition memory, but night-noise was not having an additional effect to that of day-time noise exposure on reading comprehension or recognition memory (Clark et al., 2006; Stansfeld et al., 2010). These findings suggest that indices of aircraft noise exposure in the day-time in the school environment should be sufficient to capture effects. Further analyses of the UK RANCH sample found that these associations for aircraft noise exposure remained after taking co-occurring air pollution levels into account (Clark et al., 2012).

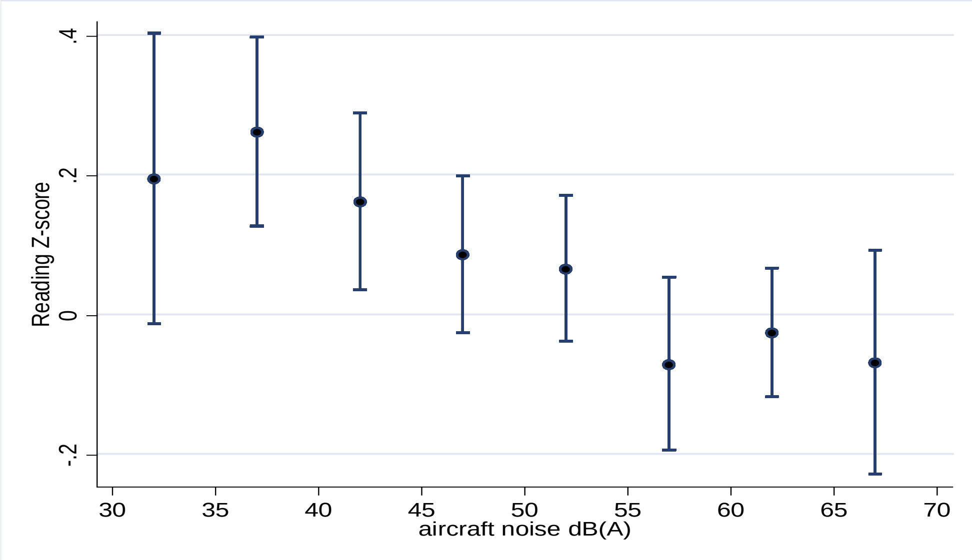

Figure 3.1. Exposure-effect relationship between aircraft noise exposure at school and reading comprehension in the RANCH study (Clark et al., 2006).

There are several ways in which aircraft noise could influence children's cognition: lost teaching time - as a teacher may have to stop teaching whilst noise events occur; teacher and pupil frustration; annoyance and stress responses; reduced morale; impaired attention; children might tune out the aircraft noise and over-generalise this response to other sounds in their environment missing out on information; and sleep disturbance from home exposure which might cause performance effects the next day (Stansfeld & Clark, 2015).

Children spend a considerable amount of time at school in the playground. Play is thought to be important for children's social, cognitive, emotional and physical development, as well as enabling relaxation between more formal teaching activities. Unfortunately, at this time, there is no empirical evidence upon which to draw conclusions about how aircraft noise exposure might impact upon children's use of playground settings.

3.2. School intervention studies

Two studies of interventions to reduce or remove aircraft noise exposure at school are worth noting. The longitudinal Munich Airport study (Hygge et al., 2002) found that prior to the relocation of the airport in Munich, high noise exposure was associated with poorer long-term memory and reading comprehension in children aged 10 years. Two years after the airport closed these cognitive impairments were no longer present, suggesting that the effects of aircraft noise on cognitive performance may be reversible if the noise stops. In the cohort of children living near the newly opened Munich airport impairments in memory and reading developed over the following two years.

A recent study of 6,000 schools exposed between the years 2000-2009 at the top 46 United States airports, (exposed to Day-Night-Average Sound Level of 55dB or higher) found significant associations between aircraft noise and standardised tests of mathematics and reading, after taking demographic and school factors into account (Sharp et al., 2014). In a sub-sample of 119 schools, they found that the effect of aircraft noise on children's learning disappeared once the school had sound insulation installed. This study supports a policy for insulating schools that may be exposed to high levels of aircraft noise associated with a new runway.

3.3. Implications of the evidence for aircraft noise effects on children's cognition and learning for the proposed schemes

It is clear from the research studies that aircraft noise exposure at school is associated with children' having poorer reading and memory skills. Further, evidence is emerging that confirms the use of insulation to mitigate against these effects, and which ever scheme is undertaken, there should be a commitment to insulate schools exposed to high levels of aircraft noise in the day-time.

Schools located near airports often also experience high levels of road traffic noise but it is important to appreciate that aircraft noise exposure still influences children's learning, even if road traffic noise exposure is high. The results presented for the RANCH study are the association for aircraft noise exposure, after taking road traffic noise into account (Clark et al., 2006).

For each of the shortlisted options an estimate of the change in the number of sensitive buildings, including schools, within each contour between the Do-Minimum and the Do-Something scenarios has been made. Below a summary is given of the difference in the number of schools in the Do-Minimum scenario and the Do-Something scenario for each scheme, focusing on day-time noise exposure which best represents exposure during the school day. It should be noted that these figures do not represent the total number of schools impacted by the schemes: the figures are restricted to schools whose exposure is changed by the scheme.

3.3.1. Gatwick 2-R

Gatwick Airport Limited (GAL) states that it hopes that no new noise sensitive buildings would be given planning consent in the areas with the highest noise contours. It is estimated that in 2030, compared with the Do-Minimum scenario, that there will be 5 additional schools exposed to >54dB $L_{Aeq\ 16\ hour}$; in 2040 there will be 7 additional schools exposed to >54dB $L_{Aeq\ 16\ hour}$; and in 2050 14 additional schools exposed to >54dB $L_{Aeq\ 16\ hour}$. There will also be a small reduction in the number of schools exposed to >60dB and 63dB $L_{Aeq\ 16\ hour}$ in 2030, 2040, and 2050: in 2030 there will also be a small reduction in the number of schools exposed to 57dB $L_{Aeq\ 16\ hour}$.

The N70 metrics for the schools are at the lower end for all years, with schools mostly exposed to N70>20. These school exposed to aircraft noise associated with Gatwick 2-R would be at the lower-end of the N70 contours, but should be insulated to protect again effects on children's learning. There is a small reduction in the number of schools exposed to N70>200 in 2030, 2040, and 2050: small reductions are also seen for the number of schools exposed to N70>100 in 2030 and 2040, and for N70>50 in 2030.

Table 3.1. Number of schools in the Do-Something Scenarios for Gatwick 2-R compared with the Do-Minimum scenarios.

	Gatwick 2-R		
	2030	**2040**	**2050**
Day-time			
54dB $L_{Aeq\ 16\ hour}$	5	7	14
57dB $L_{Aeq\ 16\ hour}$	(1)	(1)	2
60dB $L_{Aeq\ 16\ hour}$	(1)	(1)	(1)
63dB $L_{Aeq\ 16\ hour}$	(2)	(2)	(1)
66dB $L_{Aeq\ 16\ hour}$	0	0	0
69dB $L_{Aeq\ 16\ hour}$	0	0	0
72dB $L_{Aeq\ 16\ hour}$	0	0	0
N70			
N70>20	7	6	8
N70>50	(1)	2	2
N70>100	(1)	(1)	0
N70>200	(1)	(1)	(1)
N70>500	0	0	0

Numbers in parentheses indicate a reduction in the number of schools within that noise contour.

3.3.2. Heathrow-NWR

It is estimated that in 2030, compared with the Do-Minimum scenario, that there will be 49 fewer schools exposed to 54dB $L_{Aeq\ 16\ hour}$. In 2040 it is estimated that there will be 12 additional schools exposed to >54dB $L_{Aeq\ 16\ hour}$ and in 2050 24 additional schools exposed to >54dB $L_{Aeq\ 16\ hour}$.

In 2030 there is a reduction of 2 in the number of schools exposed to N70>20. However, there are increases in the number of schools exposed to N70>20 in 2040 and 2050, and for N70>50, N70>100 and N70>200 in 2030, 2040 and 2050. There is also a small increase (n=2) in the number of schools exposed to N70>500 in 2040 and 2050. Schools experiencing a high number of events over 70dB would benefit from being included in insulation schemes.

Table 3.2. Number of schools in the Do-Something Scenarios for Heathrow-NWR-T compared with the Do-Minimum scenarios.

	Heathrow-NWR-T		
	2030	**2040**	**2050**
Day-time			
54dB $L_{Aeq\ 16\ hour}$	(49)	12	24
57dB $L_{Aeq\ 16\ hour}$	15	22	15
60dB $L_{Aeq\ 16\ hour}$	17	22	23
63dB $L_{Aeq\ 16\ hour}$	1	1	1
66dB $L_{Aeq\ 16\ hour}$	2	3	4
69dB $L_{Aeq\ 16\ hour}$	1	1	1
72dB $L_{Aeq\ 16\ hour}$	0	0	0
N70			
N70>20	(2)	11	12
N70>50	6	11	9
N70>100	8	16	13
N70>200	4	10	14
N70>500	0	2	2

Numbers in parentheses indicate a reduction in the number of schools within that noise contour.

3.3.3. Heathrow-ENR

Using the offset flight path results, it is estimated that in 2030, compared with the Do-Minimum scenario, that there would be a reduction of 22 schools exposed to >54dB $L_{Aeq\ 16\ hour}$ in 2030. In 2040 it is estimated that there will be 25 additional schools exposed to >54dB $L_{Aeq\ 16\ hour}$ and in 2050 13 additional schools exposed to >54dB $L_{Aeq\ 16\ hour}$.

Compared with the Do-Minimum scenario, there would be increase in the number of schools exposed to N70>20, with 16 additional schools exposed in 2030, 29 additional schools in 2040, and 19 additional schools in 2050. For the Heathrow-ENR-O scheme there is also an increase in the number of additional schools exposed to N70>50, N70>100, and N70>200 in 2030, 2040 and 2050. Schools experiencing a high number of events over 70dB would benefit from being included in insulation schemes.

Table 3.3. Number of schools in the Do-Something Scenarios for Heathrow-ENR-O compared with the Do-Minimum scenarios.

	Heathrow-ENR-O		
	2030	**2040**	**2050**
Day-time			
54dB $L_{Aeq\ 16\ hour}$	(22)	25	13
57dB $L_{Aeq\ 16\ hour}$	22	34	32

60dB $L_{Aeq\ 16\ hour}$	36	40	39
63dB $L_{Aeq\ 16\ hour}$	11	12	12
66dB $L_{Aeq\ 16\ hour}$	3	2	3
69dB $L_{Aeq\ 16\ hour}$	2	2	2
72dB $L_{Aeq\ 16\ hour}$	0	0	0
N70			
N70>20	16	29	19
N70>50	19	25	24
N70>100	12	17	19
N70>200	23	27	27
N70>500	0	0	0

Numbers in parentheses indicate a reduction in the number of schools within that noise contour.

3.4. Discussion

The Gatwick 2-R scheme results in a small number of additional schools being exposed to >54dB $L_{Aeq\ 16\ hour}$ in each year. Both of the Heathrow schemes are initially associated with a reduction in the number of schools exposed to 54dB $L_{Aeq\ 16\ hour}$ (49 fewer schools for Heathrow-NWR and 22 fewer schools for Heathrow-ENR), but in subsequent years (2040 & 2050) both schemes would result in additional schools being exposed to 54dB $L_{Aeq\ 16\ hour}$. The number of schools additionally exposed to 54dB $L_{Aeq\ 16\ hour}$ in 2040 is 12 for Heathrow-NWR and 29 for Heathrow-ENR. The number of schools additionally exposed to 54dB $L_{Aeq\ 16\ hour}$ in 2050 is 24 for Heathrow-NWR and 13 for Heathrow-ENR. Over-time both of the Heathrow schemes would result in a considerable increase in the number of schools in the surrounding area being exposed to aircraft noise. Both schemes also result in a small number of additional schools being exposed at the higher ends of the contours.

Whilst Gatwick impacts on fewer additional schools, funding for the insulation of schools additionally exposed to aircraft noise over the process of extending the airport operation (whether it be Gatwick 2R, Heathrow-NWR, or Heathrow-ENR) would need to be found. For example, at present the Heathrow-NWR scheme has £19 million included to insulate schools. Schools exposed would be insulated as they fell into the noise contours. Currently, schools around Heathrow airport are insulated if they are exposed to 63dB $L_{Aeq\ 16\ hour}$. Consideration should be given, particularly for schools experiencing an increase in their average noise exposure and therefore subject to a step-change in exposure, to insulating schools exposed to a high level of aircraft noise. Consideration should also be given to including schools experiencing a high number of events over 70dB in the insulation programme. It is important that any insulation programme for schools is fully-funded and managed over the decades, as the number of schools affected by aircraft noise increases with the operation of some of the schemes, despite initially decreasing the number of schools exposed. Such a large-scale insulation plan of schools should also be evaluated empirically to ensure its effectiveness.

It is important to note that the figures in relation to the number of schools exposed to aircraft noise discussed in this section, do not include schools that may already be exposed to levels above 54dB $L_{Aeq\ 16\ hour}$ or N70>20 prior to the additional runway being commissioned, and/or which may already have been insulated via existing mitigation schemes. It is advisable that all schools within the contours identified as eligible for mitigation, whether newly exposed or already exposed to aircraft noise be offered access to the same insulation programme.

4. Guidelines for Environmental Noise Exposure

4.1. The WHO Community Noise Guidelines

There are recommended guidelines for environmental noise exposure levels. The most influential set of guidelines are those proposed by the World Health Organisation Europe back in 2000 (WHO, 2000), which were determined by expert panels evaluating the strength of the evidence and suggesting guideline values for thresholds for exposure in specific dwellings and for specific health effects. Below is a summary of the guideline levels suggested for dwellings, schools & pre-schools, hospitals, and parkland:

DWELLINGS

Day-time

- Indoors the dwelling during the day/evening – 35 dB $L_{Aeq\ 16\ hour}$
- Outdoor living areas - 55 dB $L_{Aeq\ 16\ hour}$ to protect the majority of people from being 'seriously annoyed' during the day-time.
- Outdoor living areas – 50 dB $L_{Aeq\ 16\ hour}$ to protect the majority of people from being 'moderately annoyed' during the day-time

Night-time

- Outside façades of the living spaces should not exceed 45 dB $L_{Aeq\ 8\ hour}$ and 60 dB L_{Amax} to protect from sleep disturbance.
- Inside bedrooms - 30 dB $L_{Aeq\ 8\ hour}$ and 45 dB L_{Amax} for single sound events to protect from sleep disturbance.

SCHOOLS & PRE-SCHOOL

- School playgrounds outdoors should not exceed 55 dB L_{Aeq} during play to protect from annoyance.
- School classrooms should not exceed 35 dB L_{Aeq} during class to protect from speech intelligibility and, disturbance of information extraction.
- The reverberation time in the classroom should be about 0.6 s.
- Pre-school bedrooms – 30 dB during sleeping time & 45 dB L_{Amax} for single sound events to protect from sleep disturbance.

HOSPITALS

Day-time

- Hospital ward rooms indoor values during the day-time/evening - 30 dB $L_{Aeq\ 16\ hour}$ to protect from sleep disturbance and interference with rest and recovery.

Night-time

- Hospital ward rooms indoor values at night - 30 dB $L_{Aeq\ 8\ hour}$, together with 40 dB L_{Amax} to protect from sleep disturbance and interference with rest and recovery.

PARKLAND AND CONSERVATION AREAS

- Existing large quiet outdoor areas should be preserved and the signal-to-noise ratio kept low.

Below these noise levels, it is thought there are no detrimental effects on health.

The WHO Community Guidelines represent a 'precautionary principle' approach to environmental noise effects on health and the WHO Community Guidelines are often thought by policy makers and acousticians to be very difficult to achieve in practice. It is also worth noting that when these guidelines were established in the late 1990s the evidence-base for noise effects on cardiovascular health and children's cognition was much weaker and that these effects per se, did not inform the guidelines. The WHO plans to publish a revision of these guidelines in 2015, so it is worth stipulating that the revised guidelines should be considered in relation to school, home, hospital and any other settings affected by the new runway.

The number of hospitals identified as being impacted by aircraft noise is low for Gatwick-2R, Heathrow-NWR, and Heathrow-ENR, falling at the lower ends of the noise exposure contours. However, efforts to insulate these hospitals should be included in the planning consent for the successful scheme.

4.2. WHO Night Noise Guidelines

The WHO Europe Night Noise Guidelines (WHO, 2009) state that the target for nocturnal noise exposure should be 40 dB $L_{night, outside}$, which should protect the public as well as vulnerable groups such as the elderly, children, and the chronically ill from the effects of nocturnal noise exposure on health. The Night Noise Guidelines also recommend the level of 55 dB $L_{night, outside}$, as an interim target for countries wishing to adopt a step-wise approach to the guidelines.

4.3. Building Bulletin 93: Acoustic Design of Schools in the UK

For schools, it is also worth noting the requirements of recently updated Building Bulletin 93: Acoustic Design of Schools in the UK (DfE, 2015), which recommends external noise levels for new school buildings or refurbished school buildings should not exceed <60 dB $LA,_{30 \text{ minutes}}$.

5. Conclusion

The health effects of environmental noise are diverse, serious, and because of widespread exposure, very prevalent (Basner et al, 2014). For populations around airports, aircraft noise exposure can be chronic. Evidence is increasing to support preventive measures such as insulation, policy, guidelines, & limit values. Efforts to reduce exposure should primarily reduce annoyance, improve learning environments for children, and lower the prevalence of cardiovascular risk factors and cardiovascular disease (Basner et al, 2014).

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Aircraft and road traffic noise and children's cognition and health: a cross-national study

*S A Stansfeld, B Berglund, C Clark, I Lopez-Barrio, P Fischer, E Öhrström, M M Haines, J Head, S Hygge, I van Kamp, B F Berry, on behalf of the RANCH study team**

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*Study team listed at end of article

Barts and the London, Queen Mary's School of Medicine and Dentistry, University of London, London E1 4NS, UK (Prof S A Stansfeld PhD, C Clark PhD, M M Haines PhD, J Head MSc); **Karolinska Institute, Stockholm, Sweden** (Prof B Berglund PhD); **Consejo Superior De Investigaciones Científicas (CSIC), Madrid, Spain** (I Lopez-Barrio PhD); **National Institute for Public Health and Environment (RIVM), Bilthoven, Netherlands** (P Fischer MSc, I van Kamp PhD); **Göteborg University, Göteborg, Sweden** (Prof E Öhrström PhD); **University of Gavle, Gavle, Sweden** (Prof S Hygge PhD); **and Berry Environmental, London, UK** (B F Berry MSc)

Correspondence to: Prof Stephen Stansfeld **S.A.Stansfeld@qmul.ac.uk**

Summary

Background Exposure to environmental stressors can impair children's health and their cognitive development. The effects of air pollution, lead, and chemicals have been studied, but there has been less emphasis on the effects of noise. Our aim, therefore, was to assess the effect of exposure to aircraft and road traffic noise on cognitive performance and health in children.

Methods We did a cross-national, cross-sectional study in which we assessed 2844 of 3207 children aged 9–10 years who were attending 89 schools of 77 approached in the Netherlands, 27 in Spain, and 30 in the UK located in local authority areas around three major airports. We selected children by extent of exposure to external aircraft and road traffic noise at school as predicted from noise contour maps, modelling, and on-site measurements, and matched schools within countries for socioeconomic status. We measured cognitive and health outcomes with standardised tests and questionnaires administered in the classroom. We also used a questionnaire to obtain information from parents about socioeconomic status, their education, and ethnic origin.

Findings We identified linear exposure-effect associations between exposure to chronic aircraft noise and impairment of reading comprehension ($p=0\cdot0097$) and recognition memory ($p=0\cdot0141$), and a non-linear association with annoyance ($p<0\cdot0001$) maintained after adjustment for mother's education, socioeconomic status, longstanding illness, and extent of classroom insulation against noise. Exposure to road traffic noise was linearly associated with increases in episodic memory (conceptual recall: $p=0\cdot0066$; information recall: $p=0\cdot0489$), but also with annoyance ($p=0\cdot0047$). Neither aircraft noise nor traffic noise affected sustained attention, self-reported health, or overall mental health.

Interpretation Our findings indicate that a chronic environmental stressor—aircraft noise—could impair cognitive development in children, specifically reading comprehension. Schools exposed to high levels of aircraft noise are not healthy educational environments.

Introduction

An understanding of the way the environment affects children's health and development is central to sustainable living and to the prevention of illness.[1] The effects of air pollution and lead are well known, but less attention has been paid to environmental noise.[2,3] Noise, an ubiquitous environmental pollutant, is a public-health issue because it leads to annoyance, reduces environmental quality, and might affect health and cognition.[4] Children could be particularly vulnerable to the effects of noise because of its potential to interfere with learning at a critical developmental stage, and because they have less capacity than adults do to anticipate, understand, and cope with stressors.[5]

Attention, memory, and reading are all involved in cognitive development at primary school age (5–11 years). Children attend to information that is then encoded in memory through processes of rehearsal, organisation, and elaboration.[6] Strategies for retrieval of information from memory develop gradually. Reading depends on perception and memory and, at an early stage, awareness of speech sounds, which could be distorted by ambient noise.[7] Environmental stressors can have a great effect on the degree to which information is processed, retained, and recalled.[8]

We set up the RANCH project (road traffic and aircraft noise exposure and children's cognition and health: exposure-effect relationships and combined effects) to investigate the relation between exposure to aircraft and road traffic noise and cognitive and health outcomes. We postulated that exposure to these types of noise would be associated with impaired cognitive function and health, including annoyance in children.

Methods

Participants

Between April and October, 2002, we enrolled children aged 9–10 years from primary schools near Schiphol, Barajas, and Heathrow—airports in the Netherlands, Spain, and the UK—to a cross-sectional study. We selected schools on the basis of increasing levels of exposure to aircraft and road traffic noise with the same systematic method in every country so as to examine exposure-effect relations. We classified schools in a four-by-four grid of noise exposure in every country. We randomly selected two schools within every cell so as to

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examine the effects of increasing aircraft noise within low road traffic noise, increasing road traffic noise within low aircraft noise, and the effects of combinations of aircraft noise and road traffic noise. We matched chosen schools by the socioeconomic status of the pupils, which we measured by eligibility for free school meals, and by main language spoken at home. We selected those schools exposed to the highest amounts of aircraft noise first. In the Netherlands, we used a neighbourhood-level indicator of property value and the proportion of non-Europeans living in the area and attending the school to match schools.

We excluded from our study non-state schools in the UK and Spain, but included them in the Netherlands where degrees of achievement do not differ appreciably between school type. We also excluded schools at which noise surveys indicated either the presence of a dominant noise other than aircraft or road traffic noise, or at which insulation against noise was above a certain threshold (double or triple-glazed classroom windows) as identified with a predefined protocol with categories of likely internal-to-external noise level differences for every classroom, although some highly insulated schools were included in the Netherlands. In every noise exposure cell, in every country, we selected two schools according to a protocol. In the UK and Spain, we selected two classes of children of mixed sex from each school, and in the Netherlands one class (most Dutch schools only had one class in this age group). If there were more than two classes in the year, then we randomly selected two or one, dependent on the country. We did not exclude any children from the selected classes.

We obtained written consent from the children and their parents. In the UK, ethical approval for the study was provided by the East London and the City Local Research Ethics Committee, East Berkshire Local Research Ethics Committee, Hillingdon Local Research Ethics Committee, and Hounslow District Research Ethics Committee. In the Netherlands, ethical approval was given by the Medical Ethics Committee of The Netherlands Organisation for Applied Scientific Research, Leiden. In Spain, ethical approval was given by the Consejo Superior De Investigaciones Cientificas (CSIC) Bioethical Commission, Madrid.

Procedures

To assess exposure to noise, we used external noise measurements (dB[A]) as the independent variable (dB[A] is the unit of A-weighted sound pressure level, where A-weighted means that the sound pressure levels in various frequency bands across the audible range have been weighted in accordance with differences in hearing sensitivity at different frequencies). In the UK, we based aircraft noise assessments external to the schools on the 16-h outdoor LAeq contours provided by the Civil Aviation Authority. These contours give the average continuous equivalent sound level of aircraft noise within an area from 0700 h to 2300 h within a specified period. We initially defined road traffic noise by use of a simplified form of the UK standard calculation of road traffic noise (CRTN) prediction method, using a combination of information including proximity to motorways, major roads, minor roads, and traffic flow data.[9] We confirmed external traffic noise levels by visits and noise measurements. In the Netherlands, noise assessments were provided by modelled data on road and aircraft noise exposure linked to school locations with geographical information systems. In Spain, we visited all 96 preselected schools and made direct external measurements of road traffic noise. Aircraft noise assessment in Spain was based on predicted contours. In all three countries, we also took acute measurements of noise exposure in the classroom and outdoors at the time of testing of cognitive function, to identify any unexpected sources of noise apart from aircraft or road traffic noise that might interfere in the test situation and to assess exposure to acute aircraft and road traffic noise. The measures of acute noise exposure, using microphones, provided level differences. For aircraft noise events this measurement could be taken, in some schools, using the highest intensity points in the noise events, where interior aircraft noise levels were detectable against ambient interior noise levels.

With respect to cognitive outcomes, we measured reading comprehension with nationally standardised and normed tests—Suffolk reading scale,[10] CITO (Centraal Instituute Toets Ontwikkeling) readability index for elementary and special education,[11] and the ECL-2 (Evaluación de la Compresión Lectora, nivel 2).[12] We assessed episodic memory (recognition and recall) by a task adapted from the child memory scale.[13] This task assessed time delayed cued recall and delayed recognition of two stories presented on compact disc. Sustained attention was measured by adapting the Toulouse Pieron test for classroom use.[14] We used a modified version of the search and memory task[15,16] to measure working memory, and assessed prospective memory by asking children to write their initials in the margin when they reached two predefined points in two of the tests.

To assess health outcomes, we gave children a questionnaire that included questions on perceived health, and perceptions of noise and annoyance based on standard adult questions.[17] We also sent a questionnaire home for the parents to complete, which included questions on the perceived health of their child, and which we used to ascertain their children's mental health as measured by the parental version of the strengths and difficulties questionnaire[18]—a well validated measure of child psychological distress, sociodemographic context variables, environmental attitudes, and noise annoyance.

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We assessed sociodemographic factors as potential confounding factors and included socioeconomic position (employment status, housing tenure, crowding—an objective measure of the number of people per room at home [1·5 people per room in Spain and the UK, 1 person per room in the Netherlands]), maternal education, ethnic origin, and main language spoken at home, developing comparable measures across countries.

We did pilot studies to assess the feasibility of the cognitive tests in the Netherlands, Spain, and the UK, and, separately, the reliability, validity, and psychometric properties of the tests used against comparison tests. We translated tests and instructions from English into Dutch and Spanish, and back translated to ensure accurate conceptual translation. After piloting, we made minor alterations to the cognitive tests and environment questionnaires, mainly to improve the language and to make them more user friendly. The results of the cognitive tests were normally distributed with no floor or ceiling effects.

We did group testing in 2-h slots under close supervision to a standardised protocol (available from authors) that governed the administration of the tests across countries. In all countries, we did the tests in classrooms in the morning in the second quarter of the year. We ensured strict adherence to the protocol via cross-country quality control visits. We administered tests in a fixed order. We measured the internal and external noise levels at the schools under the supervision of local noise measurement specialists, working to a standardised noise protocol (available from authors).

Statistical analysis

We dealt with the potential confounding effects of sociodemographic factors through-the-study design (eg, by exclusion or matching) and by statistical adjustment of findings. We did analyses of the pooled data from the UK, the Netherlands, and Spain with multilevel modelling, including exposure to aircraft noise and road traffic noise as continuous variables. The advantage of multilevel modelling is its ability to

	Pooled sample	UK	Netherlands	Spain
Pupil level data				
Response rate				
Child	2844 (89%)	1174 (87%)	762 (92%)	908 (88%)
Parent	2276 (80%)	960 (82%)	658 (86%)	658 (72%)
Median age (range)	10 y 6 m (8 y 10 m–12 y 10 m)	10 y 3 m (8 y 10 m–11 y 11 m)	10 y 5 m (8 y 10 m–12 y 10 m)	10 y 11 m (9 y 5 m–12 y 4 m)
Sex				
Boys	1064/2261 (47%)	433/960 (45%)	321/643 (50%)	310/658 (47%)
Girls	1197/2261 (53%)	527/960 (55%)	322/643 (50%)	348/658 (53%)
Employed				
No	337/2256 (15%)	217/952 (23%)	48/651 (7%)	72/653 (11%)
Yes	1919/2256 (85%)	735/952 (77%)	603/651 (93%)	581/653 (89%)
Crowding				
No	1745/2218 (79%)	717/928 (77%)	444/645 (69%)	584/645 (91%)
Yes	473/2218 (21%)	211/928 (23%)	201/645 (31%)	61/645 (9%)
Home owner				
No	619/2232 (28%)	398/944 (42%)	123/652 (19%)	98/636 (15%)
Yes	1613/2232 (72%)	546/944 (58%)	529/652 (81%)	538/636 (85%)
Mean mother's education (SD)*	0·50 (0·28)	0·50 (0·28)	0·50 (0·28)	0·50 (0·28)
Long standing illness				
No	1724/2280 (76%)	703/953 (74%)	481/657 (73%)	540/670 (81%)
Yes	556/2280 (24%)	250/953 (26%)	176/657 (27%)	130/670 (19%)
Main language spoken at school				
No	269/2253 (12%)	211/960 (22%)	42/637 (7%)	16/656 (2%)
Yes	1984/2253 (88%)	749/960 (78%)	595/637 (93%)	640/656 (98%)
Mean parental support scale (SD)†	10·1 (2·0)	10·1 (1·9)	8·8 (1·9)	11·1 (1·5)
School level data				
Number of schools	89	29	33	27
Median noise exposure, dB(A) (range)				
Aircraft	52 (30–77)	52 (34–68)	54 (41–68)	43 (30–77)
Road traffic	51 (32–71)	48 (37–67)	53 (32–66)	53 (43–71)
Classroom insulation				
Single glazing	50 (56·2%)	17 (58·6%)	15 (45·5%)	18 (66·7%)
Double glazing	35 (39·3%)	12 (41·4%)	14 (42·2%)	9 (33·3%)
Triple glazing	4 (4·5%)	0	4 (12·1%)	0

Data are number (%) unless otherwise indicated. y=years. m=months. *Ranked index of standard qualification in every country. †Ordinal scale, range 3–12. Missing values: age 5%, sex <1%, employment 5%, crowding 7%, home ownership 6%, mother's education 7%, long standing illness 4%, main language 5%, parental support 6%, classroom insulation 0%.

Table 1: Sociodemographic characteristics of participants

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	Reading comprehension (n=2010)				Recognition (n=1998)			
	Model 1		Model 2		Model 1		Model 2	
	β (SE)	p	β (SE)	p	β (SE)	p	β (SE)	p
Fixed coefficients								
Intercept	0·248 (0·625)		−1·36 (0·625)		26·68 (1·51)		22·96 (1·55)	
Aircraft noise	−0·009 (0·003)	0·0089	−0·008 (0·003)	0·0097	−0·021 (0·008)	0·0082	−0·018 (0·007)	0·0141
Road noise			0·002 (0·004)	0·5413			0·005 (0·009)	0·6237
Spain	Ref		Ref		Ref		Ref	
UK	0·051 (0·089)	0·5657	0·272 (0·082)	0·0010	−0·066 (0·210)	0·7529	0·427 (0·206)	0·0383
Netherlands	0·067 (0·087)	0·4403	0·320 (0·085)	0·0002	0·213 (0·206)	0·3026	0·560 (0·211)	0·0080
Age	0·043 (0·154)	0·7800	0·162 (0·147)	0·2708	−0·085 (0·368)	0·8206	0·037 (0·361)	0·9191
Sex (female)	−0·015 (0·044)	0·7319	−0·056 (0·042)	0·1804	−0·076 (0·106)	0·4772	−0·134 (0·104)	0·1967
Employed			0·080 (0·065)	0·2159			0·350 (0·159)	0·0281
Crowded			−0·073 (0·055)	0·1797			−0·123 (0·134)	0·3584
Home owner			0·206 (0·053)	<0·0001			0·579 (0·132)	<0·0001
Mother's education			−0·713 (0·078)	<0·0001			−0·691 (0·191)	0·0003
Long standing illness			−0·148 (0·049)	0·0028			−0·045 (0·121)	0·7089
Speak main language at home			0·183 (0·076)	0·0163			0·962 (0·190)	<0·0001
Parental support			0·085 (0·012)	<0·0001			0·131 (0·029)	<0·0001
Classroom glazing			0·002 (0·028)	0·9522			0·064 (0·070)	0·3650
Random parameters (↓)								
Level 2: school	0·041 (0·013)		0·023 (0·010)		0·221 (0·071)		0·163 (0·060)	
Level 1: pupil	0·952 (0·031)		0·865 (0·028)		5·51 (0·178)		5·20 (0·168)	

Table 2: **Multilevel models for aircraft noise and reading comprehension and recognition**

take into account effects at the level of the school and the pupil simultaneously. We initially adjusted all pooled analyses for age, sex, country, and noise (model 1), and subsequently for socioeconomic status and mother's education. The final model also adjusted for children's longstanding illness, main language spoken at home, parental support for schoolwork, and the type of glazing in the windows of the child's classroom (model 2). Separately we tested whether the results of the final model changed after adjustment for acute noise exposure during testing. We also examined, interactions between noise level, sociodemographic factors, and the outcomes. We tested for significance by comparing the goodness of fit of different models with a χ^2 test of deviance.

We investigated the possibility of a curvilinear exposure-effect relation between noise (either aircraft or road traffic) and every cognitive and health outcome with fractional polynomial models.[19] We chose the best fitting model from a set of two degree fractional polynomials (of the form $\beta_1 aircraft\ noise^{p1} + \beta_2\ aircraft\ noise^{p2}$ where p_1 and p_2 belong to the set –2, –1, –0·5, 0, 0·5, 1, 2, 3), then compared the goodness of fit (deviance) of this model with that of a straight line model to test for departure from a straight line relation.

Role of the funding source

The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

2844 children from 89 schools participated (table 1). In the UK, Spain, and the Netherlands, one of 30, none of 27, and 33 of 77 schools, respectively, declined to participate. From the pool of primary schools identified near airports in the UK and Spain, we excluded 26 and 19 non-state schools, respectively. Child response rates were universally high (table 1). Home ownership, parental employment status, and the proportion of children whose main language was not the native language differed across countries and have been adjusted for in analyses.

The range of exposure to noise around the schools varied across countries, reflecting the distribution of noise; nevertheless, there was considerable overlap (table 1). In analysis we have pooled the data from the three airport noise field studies and analysed the exposure-effect relationships across the total sample,

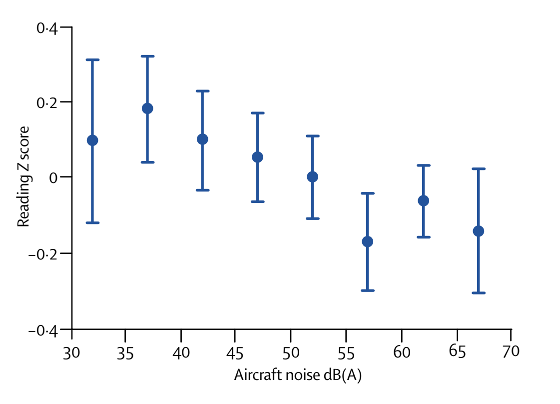

Figure 1: **Adjusted mean reading *Z* score (95% CI) for 5 dB bands of aircraft noise (adjusted for age, sex, and country)**

	β (SE)	95% CI	p
Cued recall conceptual (n=1975)			
Model 1	−0·006 (0·005)	−0·015 to 0·003	
Model 2	−0·004 (0·004)	−0·012 to 0·003	0·2684
Cued recall information (n=1974)			
Model 1	−0·030 (0·018)	−0·065 to 0·006	
Model 2	−0·022 (0·016)	−0·053 to 0·008	0·1531
Prospective memory* (n=1958)			
Model 1	−0·015 (0·009)	−0·033 to 0·003	
Model 2	−0·015 (0·009)	−0·033 to 0·003	0·1250
Working memory (n=1938)			
Model 1	−0·024 (0·022)	−0·067 to 0·019	
Model 2	−0·021 (0·021)	−0·064 to 0·022	0·3412
Sustained attention (n=1938)			
Model 1	−0·051 (0·115)	−0·277 to 0·175	
Model 2	−0·037 (0·115)	−0·263 to 0·189	0·7471
Mental health (n=2014)			
Model 1	0·015 (0·014)	−0·012 to 0·042	
Model 2	0·013 (0·013)	−0·012 to 0·038	0·3098
Self-reported health (n=1970)			
Model 1	−0·001 (0·002)	−0·005 to 0·003	
Model 2	−0·002 (0·002)	−0·006 to 0·002	0·4345
Noise annoyance (n=1969)			
Model 1	0·037 (0·004)	0·029 to 0·045	
Model 2†	0·037 (0·004)	0·029 to 0·045	0·0001

*Binomial multilevel modelling done; β therefore indicates success or failure on task. †Adjusted for country, age, sex, socioeconomic status, mother's education, length of enrolment at school, classroom glazing, ethnic origin.

Table 3: **Cognitive and health outcomes and aircraft noise exposure**

using continuous data for aircraft noise and road traffic noise prediction.

With respect to cognitive effects, in analyses of the pooled data from the UK, the Netherlands, and Spain, exposure to chronic aircraft noise was associated with a significant impairment in reading comprehension that was maintained after full adjustment (table 2). The effect sizes at different exposure levels for aircraft noise for reading across countries were consistent (test for heterogeneity p=0·9 and in the same direction of association). A 5 dB difference in aircraft noise was equivalent to a 2-month reading delay in the UK and a 1-month reading delay in the Netherlands. There are no national data available for Spain. In the Netherlands and Spain, a 20 dB increase in aircraft noise was associated with a decrement of one-eighth of an SD on the reading test; in the UK the decrement was one-fifth of an SD. The size of the effect did not differ by socioeconomic status. Figure 1 shows reading comprehension by 5 dB bands of aircraft noise adjusted for age, sex, and country. There was no significant departure from linearity (p=0·99 for comparison of straight line fit with the best fitting fractional polynomial curve).

We measured episodic memory in terms of recognition and cued recall. Cued recall included assessment of information recall and conceptual recall. Exposure to aircraft noise was linearly associated with a significant impairment in recognition, but not information recall or conceptual recall (table 2 and table 3). For recognition memory, the heterogeneity test was not significant (p=0·104), indicating that the effects did not significantly differ in magnitude across countries. Aircraft noise was also not associated with impairment in working memory, prospective memory, or sustained attention. Road traffic noise was associated with a significant increase in scores for the episodic memory scales of information recall and conceptual recall that were maintained after full adjustment (table 4). The effect sizes for information recall and conceptual recall were not significantly different

	Conceptual recall (n=1975)				Information recall (n=1974)			
	Model 1		Model 2		Model 1		Model 2	
	β (SE)	p	β (SE)	p	β (SE)	p	β (SE)	p
Fixed coefficients								
Intercept	4·07 (0·850)		2·41 (0·834)		17·63 (3·28)		11·68 (3·24)	
Aircraft noise			−0·004 (0·004)	0·2653			−0·022 (0·016)	0·1513
Road noise	0·013 (0·006)	0·0201	0·013 (0·005)	0·0066	0·040 (0·022)	0·0713	0·038 (0·019)	0·0489
Spain	Ref		Ref		Ref		Ref	
UK	0·790 (0·117)	<0·0001	1·10 (0·108)	<0·0001	1·21 (0·462)	0·0082	2·43 (0·438)	<0·0001
Netherlands	0·521 (0·112)	<0·0001	0·806 (0·110)	<0·0001	−1·08 (0·447)	0·0160	−0·025 (0·445)	0·9545
Age	−0·052 (0·204)	0·7998	0·074 (0·197)	0·7079	−0·455 (0·780)	0·5611	0·033 (0·759)	0·9653
Sex (female)	−0·113 (0·059)	0·0554	−0·150 (0·057)	0·0088	−0·236 (0·224)	0·2910	−0·363 (0·218)	0·0956
Employed			0·009 (0·088)	0·9219			0·260 (0·335)	0·4365
Crowded			−0·115 (0·074)	0·1187			−0·420 (0·281)	0·1347
Home owner			0·294 (0·072)	<0·0001			1·24 (0·276)	<0·0001
Mother's education			−0·607 (0·106)	<0·0001			−2·28 (0·403)	<0·0001
Long standing illness			−0·015 (0·067)	0·8207			0·154 (0·253)	0·5426
Speak main language at home			0·535 (0·103)	<0·0001			1·74 (0·399)	<0·0001
Parental support			0·081 (0·016)	<0·0001			0·288 (0·061)	<0·0001
Classroom glazing			0·018 (0·036)	0·6226			0·092 (0·149)	0·5349
Random parameters (↓)								
Level 2: school	0·075 (0·025)		0·032 (0·018)		1·31 (0·406)		0·729 (0·291)	
Level 1: pupil	1·66 (0·054)		1·57 (0·051)		23·98 (0·783)		22·61 (0·738)	

Table 4: **Multilevel models for road traffic noise and cued recall**

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	β (SE)	95% CI	p
Reading comprehension (n=2010)			
Model 1	0·003 (0·004)	−0·005 to 0·012	
Model 2	0·002 (0·004)	−0·005 to 0·009	0·5417
Recognition (n=1998)			
Model 1	0·006 (0·010)	−0·014 to 0·026	
Model 2	0·005 (0·009)	−0·013 to 0·023	0·6240
Prospective memory* (n=1958)			
Model 1	0·007 (0·012)	−0·017 to 0·031	
Model 2	0·007 (0·012)	−0·017 to 0·031	0·1360
Working memory (n=1938)			
Model 1	0·033 (0·027)	−0·020 to 0·087	
Model 2	0·030 (0·027)	−0·023 to 0·083	0·2742
Sustained attention (n=1938)			
Model 1	−0·020 (0·143)	−0·300 to 0·261	
Model 2	−0·046 (0·144)	−0·328 to 0·237	0·7499
Mental health (n=2014)			
Model 1	−0·012 (0·017)	−0·045 to 0·021	
Model 2	−0·018 (0·016)	−0·049 to 0·013	0·2747
Self-reported health (n=1970)			
Model 1	0·005 (0·003)	−0·001 to 0·011	
Model 2	0·005 (0·003)	−0·0004 to 0·010	0·0725
Noise annoyance (n=1969)			
Model 1	0·017 (0·004)	0·009 to 0·025	
Model 2†	0·016 (0·004)	0·008 to 0·024	0·0047

*Binomial multilevel modelling done; β therefore indicates success or failure on task. †Adjusted for country, age, sex, socioeconomic status, mother's education, length of enrolment at school, classroom glazing, ethnic origin.

Table 5: **Cognitive and health outcomes and exposure to road traffic noise**

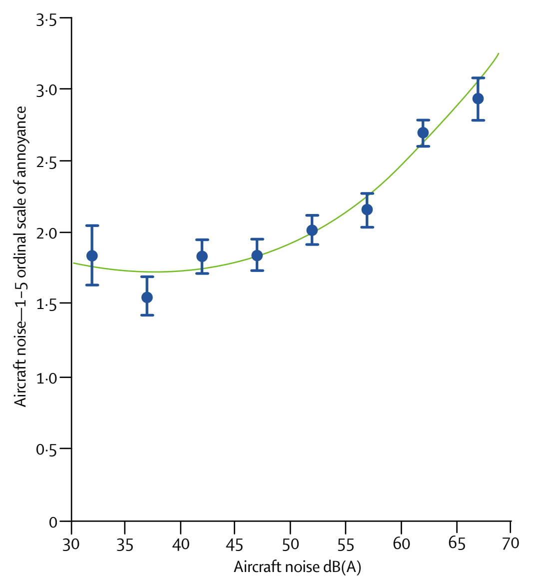

Figure 2: **Adjusted mean annoyance (95% CI) for 5 dB bands of aircraft noise (adjusted for age, sex, and country) and fitted curve***

*Fractional polynomial curve fitted to continuous aircraft noise of form $-0{\cdot}188X^2+0{\cdot}107X^2*\log(x)$ (where x=aircraft noise/10).

between countries (p=0·9 for information recall, p=0·7 for conceptual recall) and were consistent in the direction of the association with exposure to road traffic noise. There was no significant departure from linearity for information recall or conceptual recall (p=0·67 and p=0·99 for comparison of straight line fit with the best fitting fractional polynomial curve, respectively). These effects were stronger for children from crowded homes than for those whose homes were not crowded (interaction p=0·01 for both information and conceptual recall). We noted no effects of road traffic noise on reading comprehension, recognition, working memory, prospective memory, and sustained attention (table 5).

With respect to health effects, increasing exposure to both aircraft noise and road traffic noise was associated with increasing annoyance responses in children. This finding was maintained after full adjustment (table 2 and table 5). Figure 2 shows annoyance from aircraft noise by 5 dB bands adjusted for age, sex, and country. The best fitting fractional polynomial curve was non-linear and showed a steeper dose-response gradient at higher levels of aircraft noise (p=0·018, test for departure from straight line fit).

There was a linear association between road traffic noise and annoyance adjusted for age, sex, and country (p=0·11 for comparison of straight line fit with best fitting fractional polynomial curve). We noted no effects of either aircraft noise or road traffic noise on self-reported health or mental health.

Discussion

Our findings indicate a linear exposure-effect association between exposure to aircraft noise and impaired reading comprehension and recognition memory in children, and between exposure to road traffic noise and increased functioning of episodic memory, in terms of information and conceptual recall. Our results also show non-linear and linear exposure-response associations between aircraft and road traffic noise, respectively, and annoyance. Neither aircraft noise nor road traffic noise affected sustained attention, self-reported health, or mental health.

By comparison with previous studies,[20–23] our results are robust because we used data from three countries with different sociodemographic profiles, our questionnaire response rates were high, we made careful and detailed noise assessments and measured the effect of confounding factors, we adjusted for acute noise exposure, and we used standardised outcome measures. Results for aircraft noise and reading comprehension across the three countries were largely similar—ie, we noted cross-cultural replication of findings. The advantage of multilevel modelling is that it can also adjust for variance in cognitive function between schools and between countries. The limitations of our study are: that it was cross-sectional rather than longitudinal; we studied a small age range; we focused largely on exposure to noise in schools, though noise at home might also affect health outcomes; and we used different noise assessment techniques in the three countries. However, using the pooled sample, we were able to combine exposure sites with different associations between noise exposure and socioeconomic position and thus adjust, to some extent, and more so than in previous studies,[20,22,23] for socioeconomic status as a potential confounding factor. Contrary to previous work done in the UK,[20] socioeconomic status did not explain the association between noise and cognitive function in children.

An effect of aircraft noise on reading is consistent with previous findings.[21–25] Exposure to aircraft noise has been related to impairments of children's cognition in terms of reading comprehension, long-term memory, and motivation.[21–26] Tasks that involve central processing and language comprehension, such as reading, attention, problem solving, and memory seem most affected by exposure to noise. With a few exceptions,[20,27] most studies have compared groups exposed to high levels and low levels of noise, and have not examined exposure-effect relations. Moreover, most studies in children have focused on aircraft noise rather than road traffic noise. These exposure-effect associations, in combination with results from earlier studies,[21–25] suggest a causal effect of exposure to aircraft noise on children's reading comprehension. This effect is significant though small in magnitude, but does show a linear exposure-effect relation. In practical terms, aircraft noise might have only a small effect on the development of reading, but the effect of long-term exposure remains unknown.

Aircraft noise, because of its intensity, the location of the source, and its variability and unpredictability, is likely to have a greater effect on children's reading than road traffic noise, which might be of a more constant intensity.[28,29] In adults, sound that shows appreciable variation over time (changing state) impairs cognitive function whereas sound that does not vary (steady state) has little effect.[29,30] The noise of aircraft flyovers has an unpredictable rise time that might attract attention and distract children from learning tasks.

This notion does not explain why exposure to road traffic noise was related to improved episodic memory scores. Road traffic noise is unlikely to increase arousal sufficiently to improve performance on the memory tasks we used, which are difficult and might be impaired by increased arousal. Another explanation is confounding, but the only significant interaction between road traffic noise, sociodemographic status, and episodic memory was for crowding, in which the effects were stronger for those from crowded households. This unexplained finding needs further study. The absence of an association between road traffic noise and reading is inconsistent with previous studies, but the highest noise levels we recorded were 71 dB LAeq, which is lower than in previous work.[31]

Noise exposure is associated with annoyance and impairment of quality of life in children. This association is stronger for aircraft than for road traffic noise, as in adults. We noted no association between aircraft or road traffic noise and self-reported health or mental health, though other studies have shown effects of aircraft noise on blood pressure.[26,32]

Further research is needed to understand the psychological mechanisms of these cognitive effects. Children might adapt to noise interference during activities by filtering out the unwanted noise stimuli. This tuning out strategy might overgeneralise to situations where noise is not present, such that children tune out stimuli indiscriminately.[21,33] This tuning out response is supported by the findings that children exposed to noise have deficits in attention, auditory discrimination,[33] and speech perception.[25] However, our findings indicate that sustained attention is not impaired by aircraft noise, and others[15,24] have shown that noise impairs both attention and recall[15,24] without attention mediating the effect on cued recall. Teacher frustration and interruptions in communication between teachers and children could also be a mechanism for cognitive effects.[33] Similarly, learned helplessness has been proposed as a mechanism to account for deficits in motivation in children exposed to noise.[34]

The effects of exposure to noise at home, as well as at school, the interaction with classroom acoustics, the potential protective effect of classroom insulation against noise, and what children and teachers can do to overcome these effects deserve further inquiry. Our results are relevant to the design and placement of schools in relation to airports, to the formulation of policy on noise and child health, and to a wider consideration of the effect of environmental stressors on children's cognitive development. Greater specification of exposure-effect relations is an important step in confirming a causal role for exposure to environmental noise in impairments of children's cognition.

Contributors

S A Stansfeld, M M Haines, J Head, and B Berglund formulated the study design and interpreted the results. S A Stansfeld wrote the original draft of the manuscript. C Clark did the analyses, interpreted the results, and commented on the manuscript. J Head advised on analyses. B F Berry designed the noise measurements and interpreted noise effects. S Hygge helped on the choice of instruments and interpretation of the cognitive effects. I Lopez-Barrio, P Fischer, and I van Kamp led on data collection in Spain and the Netherlands, and commented on drafts and interpreted results. E Öhrström commented on the instruments, on drafts, and interpreted results.

RANCH study team

Eldar Aarsten, Tamuno Alfred, Rebecca Asker, Östen Axelsson, Sarah Brentnall, Rachel Cameron, Hugh Davies, Anita Gidlöf Gunnarsson, Emina Hadzibajramovic, Maria Holmes, Rocio Martin, Mark Matheson, Mats E Nilsson, Britth Sandin, Rebecca Stellato, Helena Svensson, and Elise van Kempen.

Conflict of interest statement

We declare that we have no conflict of interest.

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Original Contribution

Does Traffic-related Air Pollution Explain Associations of Aircraft and Road Traffic Noise Exposure on Children's Health and Cognition? A Secondary Analysis of the United Kingdom Sample From the RANCH Project

Charlotte Clark*, Rosanna Crombie, Jenny Head, Irene van Kamp, Elise van Kempen, and Stephen A. Stansfeld

* Correspondence to Dr. Charlotte Clark, Centre for Psychiatry, Barts and The London School of Medicine, Queen Mary University of London, Charterhouse Square, London, United Kingdom, EC1M 6BQ (e-mail: c.clark@qmul.ac.uk).

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The authors examined whether air pollution at school (nitrogen dioxide) is associated with poorer child cognition and health and whether adjustment for air pollution explains or moderates previously observed associations between aircraft and road traffic noise at school and children's cognition in the 2001–2003 Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health (RANCH) project. This secondary analysis of a subsample of the United Kingdom RANCH sample examined 719 children who were 9–10 years of age from 22 schools around London's Heathrow airport for whom air pollution data were available. Data were analyzed using multilevel modeling. Air pollution exposure levels at school were moderate, were not associated with a range of cognitive and health outcomes, and did not account for or moderate associations between noise exposure and cognition. Aircraft noise exposure at school was significantly associated with poorer recognition memory and conceptual recall memory after adjustment for nitrogen dioxide levels. Aircraft noise exposure was also associated with poorer reading comprehension and information recall memory after adjustment for nitrogen dioxide levels. Road traffic noise was not associated with cognition or health before or after adjustment for air pollution. Moderate levels of air pollution do not appear to confound associations of noise on cognition and health, but further studies of higher air pollution levels are needed.

air pollution; child psychology; cognition; environmental pollution; epidemiology; noise; public health; transportation

Abbreviation: RANCH, Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health.

To date, over 20 studies have shown a negative association between environmental noise, such as aircraft or road traffic noise, and children's reading abilities and memories (1–6). Cognitive tasks affected by environmental noise tend to be those involving language and central processing skills, such as reading and memory. Several pathways for associations between chronic noise exposure and children's cognition have been suggested, including teacher and pupil frustration (7), learned helplessness (8), impaired attention (7, 9), increased arousal (10), indiscriminate filtering out of noise (11), and noise annoyance (12).

Road traffic and aircraft noise have also been shown to influence cardiovascular health in adults, and there is some evidence that environmental noise may also influence children's blood pressure levels (13, 14). Studies have also found associations between environmental noise exposure and children's psychological health (5, 15, 16). However, there has been little examination of the influence of air pollution on the associations observed between environmental noise exposure and children's health and cognition. Children attending schools exposed to high levels of environmental noise may also experience traffic-related air pollution. Although evidence for associations of air pollution with children's respiratory health is robust (17, 18), evidence for associations with children's cognition is equivocal. A study in Boston found that higher levels of black carbon, a marker for traffic particles, were associated with decreased cognitive function in 202 children aged

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8–11 years, with associations being found across a range of verbal and nonverbal intelligence and memory assessments (19). However, noise exposure was not measured in that study. A study of Chinese children aged 8–10 years found some significant associations between traffic-related air pollution and neurobehavioral function (20). Conversely, a recent study of 210 Spanish children who were 5 years of age found few significant associations between nitrogen dioxide levels and a range of cognitive and motor abilities (21). Prenatal exposure to air pollution may also be associated with impaired infant mental development (22). Proposed mechanisms for the impact of chronic air pollution on cognition are inflammation or oxidative stress caused by air particles, which influence the central nervous system and lead to neurotoxicity in the brain, potentially influencing brain connectivity (23, 24). Ultrafine particulates may also directly influence the brain by being absorbed in the lungs or via the olfactory nerves (23).

Few studies have examined the impact of coexisting environmental noise and air pollution exposure on children's cognition and health (25). Studies examining the association between the 2 pollutants in general population samples indicated that there were correlations of approximately 0.5–0.6 between nitrogen dioxide and traffic-related noise levels, although local factors, such as traffic and building density, urbanicity, and road layout, influenced the association (26, 27). These studies concluded that there was enough variability between the 2 pollutants to warrant studying the influence of both pollutants using separate measures (26, 27). Little is known about how the 2 pollutants may interact to influence health and cognition (25).

The present article is a secondary analysis of the United Kingdom sample from the Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health (RANCH) project, a cross-sectional epidemiologic study of the associations between aircraft and road traffic noise exposure at school and the health and cognition of 9–10-year-old children in the Netherlands, Spain, and the United Kingdom (2). That study, which to our knowledge is the largest to date, found exposure-effect associations between aircraft noise exposure at school and reading comprehension (3) and recognition memory (2) in the cross-national data. No associations were observed between road traffic noise exposure at school and cognition, with the exception of conceptual recall and information recall, which surprisingly were higher in areas with high road traffic noise in the cross-national data (2). Neither aircraft noise nor road traffic noise affected working memory (2), and there were no significant associations between aircraft noise at school and psychological distress or self-reported health (2). Aircraft noise at school was not associated with systolic and diastolic blood pressure levels in the cross-national data (13); associations were observed for the Dutch sample but not the United Kingdom sample.

The present study had 4 aims. The first was to examine the correlations of aircraft noise exposure and road traffic noise exposure at school with air pollution measured at school for the United Kingdom RANCH sample. The second was to examine whether air pollution at school (nitrogen dioxide) was associated with poorer child cognition and health outcomes in the United Kingdom RANCH sample. We postulated that air pollution would not be associated with impaired cognitive function and health. The third and fourth aims were to examine whether adjustment for air pollution at school would explain or moderate the previously observed associations of aircraft and road traffic noise exposure at school with children's health and cognition. We postulated that air pollution would not explain or moderate these associations.

MATERIALS AND METHODS

Sampling and design

Children who were 9–10 years of age were selected to participate in this field study based on their noise exposure in schools around London Heathrow airport (2, 3). We conducted a secondary analysis of a subsample of these children for whom air pollution data were available (hereafter referred to as the air pollution subsample). Ethical approval was provided by the East London and the City Local Research Ethics Committee, East Berkshire Local Research Ethics Committee, Hillingdon Local Research Ethics Committee, and the Hounslow District Research Ethics Committee in the United Kingdom; by the Medical Ethics Committee of the Netherlands Organization for Applied Scientific Research, Leiden, the Netherlands; and by the Consejo Superior De Investigaciones Cientificas Bioethical Commission, Madrid, Spain.

Noise exposure assessment

Aircraft noise estimates for the schools were based on 16-hour outdoor L_{Aeq} contours (L_{Aeq} is the "equivalent" average sound level A-weighted to approximate the typical sensitivity of the human ear) provided and validated by the United Kingdom Civil Aviation Authority, which gave the average continuous equivalent sound levels of aircraft noise in an area from 7 AM to 11 PM in July through September of 2000. Estimates of outdoor road traffic noise at the school were based on a combination of proximity to motorways, A roads, and B roads and traffic flow data (28) and were confirmed using noise measurements taken at the facade of the school building (2). In all analyses, aircraft and road traffic noise were entered as continuous variables in dB(A); dB(A) is a measure of sound level in decibels A-weighted to approximate the typical sensitivity of the human ear. See references 2 and 3 for further information about the noise exposure assessment.

Air pollution assessment

Concentrations of nitrogen dioxide (μg/m^3) representing traffic-related air pollution for each school were derived using a combined emission-dispersion and regression modeling approach using the King's College London Emissions Toolkit, which has been validated against known measurements (29). The Emissions Toolkit provides detailed road traffic emissions for over 6,000 major and minor roads in London using hourly link-by-link traffic flow and speed data to calculate annual average emissions for pollutants from different types of vehicles. Emission estimates were for 2001 at a 20 × 20-m grid-point resolution.

The emission estimates were then inputted to the King's College London Air Pollution Toolkit (30) to model and predict the annual mean ambient concentrations of nitrogen dioxide (in μg/m^3). Model inputs included meteorological data from Heathrow airport and detailed data on traffic flow, speeds, and vehicle types from the London Atmospheric Emissions Inventory (31). Air pollution values were linked to schools using the schools' postal codes. Procedures were carried out with the use of ArcGIS system (Environmental Systems Research Institute, Inc., Redlands, California). Air pollution could only be modeled for schools within the greater London area, so it was not possible to derive air pollution data for 7 of the 29 schools in the original RANCH United Kingdom cohort.

Outcome and confounding factors assessment

Cognition. Reading comprehension was measured using the Suffolk Reading Scale 2 (32). Episodic memory was measured using a task adapted from the Child Memory Scale (33) that assessed time-delayed conceptual recall, information recall, and recognition of 2 stories presented on compact disc. A modified version of "The Search and Memory Task" (34) was used to assess working memory. See Clark et al. (3) for further details.

Health. Parents completed a self-report questionnaire that included questions on sociodemographic factors, as well as questions on the perceived health of their children (very good/good versus fair/poor/very poor) and psychological distress measured using the parental version of the Strengths and Difficulties Questionnaire (35). We used a continuous Strengths and Difficulties Questionnaire score in our analyses. Blood pressure was assessed in half of the United Kingdom sample following a standard protocol (13) using automatic blood pressure meters (OMRON 711, OMNILABO International BV, Breda, the Netherlands). We used the mean of 3 blood pressure measurements in our analyses.

Confounding factors. Data on a number of potential confounders were available (2), including socioeconomic position (employment status, housing tenure, home crowding (>1.5 people per room at home)), maternal educational level, ethnicity, and main language spoken at home (Table 1). Blood pressure analyses were adjusted for premature birth (before gestational week 36), self-reported parental high blood pressure, birth weight (<2,500 g vs. ≥2,500 g), cuff size of blood pressure monitor, temperature during testing (°C), and body mass index (weight (kg)/height (m)^2) (13).

Procedure

Group testing was carried out in the classroom in the spring of 2002 and the cognitive tests and child questionnaire were administered as part of a 2-hour testing session conducted in the morning. Written consent was obtained from parents and children. Each child took home a questionnaire for his or her parent.

Analysis

Data were analyzed using the STATA xtmixed command for multilevel modeling (StataCorp LP, College Station, Texas), which enabled variables at the school level (e.g., air pollution) and the individual level (e.g. home ownership) to be fitted in the same model. Beta values, 95% confidence intervals, and *P* values for each variable were obtained. Spearman's rho bivariate correlations were calculated to assess the strength of association between nitrogen dioxide and the noise exposure at school measures, as nitrogen dioxide was not normally distributed.

As air pollution data were available for 22 of the original 29 schools sampled in the United Kingdom RANCH cohort, descriptive statistics were run to compare characteristics of the air pollution subsample data with the original RANCH United Kingdom sample. We fitted multilevel regression models to examine the associations between aircraft and road traffic noise exposure and child cognition and health and adjusted those models for sociodemographic factors to see if the original findings (2, 3, 13) could be replicated in the United Kingdom sample and the United Kingdom air pollution subsample.

Multilevel linear and logistic regression models were used to examine the associations between air pollution and the child cognition and health outcomes. Model 1 included nitrogen dioxide levels and was adjusted for age, gender, mother's educational level, parental employment status, crowding in the home, home ownership, long-standing illness, main language spoken at home, parental support for school work, and classroom window glazing. Model 2 was additionally adjusted for aircraft and road traffic noise exposure at school. We then examined multiplicative interactions between noise exposure and air pollution. For the blood pressure analyses, model 1 was additionally adjusted for body mass index, blood pressure cuff size, room temperature, birth weight, parental high blood pressure, and prematurity. To maximize power in the analyses, complete case analyses were conducted, resulting in a different number of participants for each outcome.

RESULTS

Correlations between noise exposure and air pollution at school

The correlation between nitrogen dioxide levels with aircraft noise exposure was moderate ($r = 0.41$, $P < 0.01$). Similarly, the correlation between road traffic noise exposure at school and nitrogen dioxide was also modest ($r = 0.46$, $P < 0.01$).

Comparison of the sample with and without air pollution data at school

Data on air pollution at school were available for 75% ($n = 719$) of the original United Kingdom sample ($n = 960$). Descriptive analyses revealed few differences between the samples with and without air pollution data (Table 1). Aircraft noise exposure and road traffic noise exposure in

Table 1. Comparison of the Exposure, Cognitive, and Health Outcome Scores and the Sociodemographic Background Variables, United Kingdom RANCH Project, 2001–2003

Characteristic	Subsample With Air Pollution Data ($n = 719$)			Sample Without Air Pollution Data ($n = 241$)			Difference Between the Samples With and Without Air Pollution Data[a]		
	Range	Mean (SD)	%	Range	Mean (SD)	%	t	χ^2	P Value
Exposure data									
Aircraft noise exposure at school, dBA	34–68	54 (10.6)		46–59	52 (3.83)		3.60		<0.01
Road traffic noise exposure at school, dBA	37–67	50 (7.7)		47–63	52 (5.04)		−4.78		<0.01
Nitrogen dioxide at school, μg/m^3	29.41–79.88	42.73 (10.60)		N/A					N/A
Cognitive outcomes									
Reading comprehension	−1.49–2.51	0.20 (1.13)		−1.49–2.51	0.23 (1.11)		−0.36		0.72
Recognition memory	15–30	25.10 (2.63)		14–30	24.78 (2.75)		1.54		0.12
Information recall	0–30.5	19.02 (5.31)		0–29	18.06 (5.86)		2.30		0.02
Conceptual recall	0–7.5	5.25 (1.37)		0–7.5	5.04 (1.53)		1.93		0.06
Working memory	−11–32	15.02 (7.37)		−13–32	14.50 (7.85)		0.84		0.40
Health outcomes									
Overall Strengths and Difficulties Questionnaire score	0–34	10.16 (6.02)		0–29	9.79 (5.63)		0.81		0.42
Very good/good self-rated health			82.7			80.8		4.43	0.51
Fair/poor/very poor self-rated health			17.3			19.2			
Systolic blood pressure[b]	85–141	108.4 (10.1)		91–135	110.5 (8.0)		−1.89		0.06
Diastolic blood pressure[b]	49–106	67.1 (8.1)		46–82	66.9 (7.5)		0.16		0.87
Sociodemographic factors									
Age	8 years, 10 months–11 years, 11 months	10 years, 3 months		8 years, 10 months–11 years, 11 months	10 years, 3 months		−0.78		0.43
Male			45.6			43.6		0.30	0.58
Female			54.4			56.4			
Parent(s) not employed			22.7			22.9		0.004	0.95
Parent(s) employed			77.3			77.1			
Home overcrowded			21.7			25.7		1.53	0.22

Table continues

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Table 1. Continued

Characteristic	Subsample With Air Pollution Data ($n = 719$)			Sample Without Air Pollution Data ($n = 241$)			Difference Between the Samples With and Without Air Pollution Data[a]		
	Range	Mean (SD)	%	Range	Mean (SD)	%	t	χ^2	P Value
Home not owned/mortgaged			42.5			41.0		0.16	0.67
Child has long-standing illness			26.6			25.7		0.07	0.79
Child speaks other language at home			20.3			27.0		4.67	0.03
Classroom has single window glazing			57.3			74.7		73.23	<0.01
Mother's educational level[b]	0.004–0.853	0.48 (0.28)		0.004–0.853	0.56 (0.28)		−4.28		<0.01
Parental support scale	4–12	10.2 (2.0)		5–12	10.2 (1.9)		−0.40		0.69
Small blood pressure cuff size[c]			5.8			1.3		2.55	0.11
Low birth weight (<2,500 g)[c]			9.4			8.0		0.14	0.71
Premature birth (before gestational week 36)[c]			12.0			14.7		0.40	0.53
Parent(s) with high blood pressure[b]			20.3			25.3		0.89	0.35
Body mass index[c,d]	9–23	13.3 (2.32)		10–18	13.0 (1.71)		1.31		0.19
Temperature during blood pressure measurement, °C[c]	20–27	22.9 (1.63)		21–26	23.8 (1.35)		−4.47		<0.01

Abbreviations: dB(A), sound level in decibels A-weighted to approximate the typical sensitivity of the human ear; N/A, not applicable; RANCH, Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health; SD, standard deviation.

[a] χ^2 tests were used for categorical variables and t tests were used for continuous variables to detect differences between the samples with and without air pollution data.

[b] Measured using a relative inequality index based on a ranked index of standard qualifications in each country resulting in a standardized score ranging from 0.01 to 1.00.

[c] These factors were only included as confounders/covariates in the blood pressure regression models and the numbers were reduced. There were 276 for whom we had air pollution data and 75 for whom we did not.

[d] Weight (kg)/height (m)^2.

the air pollution subsample were slightly higher: Schools with lower noise exposure levels were also schools for which emission data were not available. There were no differences in cognitive or health outcomes or in sociodemographic factors between the samples except for the fact that the air pollution subsample had slightly lower information recall test scores, were more likely to speak English at home, and had mothers with lower educational levels.

Table 2 shows a comparison of the multilevel regression models for aircraft and road traffic noise associations with cognition and health in the original United Kingdom RANCH sample ($n = 960$) and the air pollution subsample ($n = 719$). We observed associations of similar magnitudes between aircraft and road traffic noise and cognition and health. In the air pollution subsample, aircraft noise exposure at school was significantly associated with children's recognition memory and conceptual recall. Associations with reading comprehension and information recall were borderline significant, and there were no associations with health (Table 2). No associations between road traffic noise and children's cognition or health were observed (Table 2).

The association that we found between aircraft noise exposure and recognition memory replicates that from analyses of the cross-national data (2). The borderline association for reading comprehension replicates and is of a magnitude similar to that from previous analyses of the United Kingdom RANCH data (3). We did not replicate the cross-national findings of an association between road traffic noise and conceptual or information recall (2) in either sample. Neither the cross-national nor the United Kingdom sample data set showed a significant association between aircraft noise and conceptual recall; however, the air pollution subsample did show such an association. There were no associations between aircraft noise or road traffic noise at school and psychological distress, self-rated health, or blood pressure (Table 2) in either sample, replicating the findings of previous analyses (2, 13).

Associations between air pollution, aircraft noise, and road traffic noise at school and children's cognition

After adjusting for sociodemographic factors, we found that nitrogen dioxide levels at school were not significantly associated with children's reading comprehension, recognition memory, information recall, conceptual recall, or working memory, either before or after adjustment for aircraft and road traffic noise exposure at school (Table 3). Overall, adjustment for air pollution at school had little influence on the associations previously observed between aircraft noise exposure at school and children's cognition (Table 3). Aircraft noise exposure at school remained significantly associated with poorer recognition memory, reading comprehension, information recall, and conceptual recall. There were no significant associations between road traffic noise exposure and cognition either before or after adjustment for air pollution at school.

Associations between air pollution, aircraft noise, and road traffic noise at school and children's health

There were no significant associations of nitrogen dioxide at school with children's psychological distress, systolic blood pressure, diastolic blood pressure, or self-rated health either before or after adjustment for aircraft noise and road traffic noise at school (Table 4).

Does air pollution moderate associations of aircraft noise and road traffic noise at school with children's health and cognition?

Air pollution did not moderate the associations between noise exposure and children's cognition or health. One exception was that road traffic noise exposure was associated with poorer recognition memory for children with lower nitrogen dioxide exposure ($\beta = -0.07$, $P < 0.05$, $n = 314$) compared with children higher nitrogen dioxide exposure ($\beta = 0.03$, $P = 0.13$, $n = 327$).

DISCUSSION

In the present article, we explored the associations between air pollution at school and children's cognition and health in a sample of 9–10-year-old children attending schools near London Heathrow airport. There were 4 main findings. First, there were moderate correlations of both aircraft and road traffic noise exposure at school with air pollution measured at the school. Second, there was no evidence of a relation between air pollution (nitrogen dioxide) and a range of children's cognitive and health outcomes. Third, associations between aircraft noise exposure and children's cognition could not be fully explained by air pollution. No associations between road traffic noise exposure and children's cognition were observed, either before or after adjustment for air pollution. Finally, there was little evidence that air pollution moderated the association of noise exposure on children's cognition. These results raise concerns regarding the influence of chronic aircraft noise on children's cognitive abilities.

To our knowledge, this is one of the first studies to examine the impact of both environmental noise exposure and air pollution on children's cognition and health. Air pollution was not significantly associated with a range of cognitive outcomes, either before or after adjustment for environmental noise exposure. These findings contrast with some previous studies, which found associations between air pollution and a range of cognitive abilities, including verbal and nonverbal intelligence, vocabulary, attention, and memory after adjustment for socioeconomic factors (19–21). There are several explanations for the difference in our findings compared with previous studies. Despite adjusting for socioeconomic factors, residual unmeasured confounding remains possible in all the studies. There may be differences in air pollution exposure and cognitive

Table 2. Multilevel Model Parameter Estimates for the Impact of Aircraft and Road Traffic Noise at School on Children's Cognitive Performance and Health Outcomes, United Kingdom RANCH Project, 2001–2003

Variable	Aircraft and Road Traffic Noise at School Adjusted for Sociodemographic Factors[a]							
	Original Sample (*n* = 960)				Air Pollution Subsample (*n* = 719)			
	No. of Participants	β[b]	95% CI	*P* Value	No. of Participants	β[b]	95% CI	*P* Value
Cognitive outcomes								
Reading comprehension	864				651			
Road traffic noise		−0.001	−0.014, 0.011	0.80		−0.002	−0.017, 0.013	0.77
Aircraft noise		−0.010	−0.020, 0.0005	0.06		−0.011	−0.022, 0.00021	0.05
Recognition memory	844				641			
Road traffic noise		−0.012	−0.046, 0.021	0.47		−0.012	−0.048, 0.023	0.50
Aircraft noise		−0.035*	−0.061, −0.009	0.01		−0.042*	−0.069, −0.016	<0.01
Information recall	837				638			
Road traffic noise		0.039	−0.030, 0.108	0.27		0.040	−0.014, 0.094	0.14
Aircraft noise		−0.025	−0.080, 0.028	0.35		−0.040	−0.082, 0.001	0.06
Conceptual recall	834				636			
Road traffic noise		−0.007	−0.008, 0.022	0.37		0.007	−0.007, 0.021	0.31
Aircraft noise		−0.011	−0.023, 0.001	<0.01		−0.015*	−0.025, −0.004	<0.01
Working memory	785				580			
Road traffic noise		0.038	−0.063, 0.142	0.45		0.036	−0.096, 0.167	0.60
Aircraft noise		−0.004	−0.063, 0.142	0.92		0.00077	−0.096, 0.097	0.99
Health outcomes								
Psychological distress	842				634			
Road traffic noise		−0.025	−0.084, 0.032	0.38		−0.030	−0.093, 0.033	0.35
Aircraft noise		−0.017	−0.064, 0.029	0.46		−0.023	−0.073, 0.026	0.36
Self-rated health	868				655			
Road traffic noise		0.0006	−0.024, 0.025	0.96		0.003	−0.024, 0.030	0.82
Aircraft noise		0.002	−0.018, 0.022	0.83		0.007	−0.015, 0.028	0.54
Systolic blood pressure	351				276			
Road traffic noise		−0.09	−0.25, 0.08	0.22		-0.092	−0.303, 0.118	0.39
Aircraft noise		0.02	−0.12, 0.15	0.77		0.024	−0.131, 0.179	0.76
Diastolic blood pressure	351				276			
Road traffic noise		0.02	−0.11, 0.15	0.76		0.042	−0.125, 0.211	0.61
Aircraft noise		0.01	−0.09, 0.12	0.83		0.019	−0.104, 0.144	0.75

Abbreviations: CI, confidence interval; RANCH, Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health.

* $P \leq 0.05$.

[a] All models were adjusted for age, gender, employment status, crowding, home ownership, mother's educational level, long-standing illness, main language spoken at home, parental support for schoolwork, and classroom window glazing type.

[b] Per 1-dB increase in road traffic noise or aircraft noise.

assessment between studies. Associations may be found at higher exposure levels: In our sample, the range of exposure to air pollution was low to moderate. Associations may also differ by city. Studies have assessed air pollution in the school environment (20) or the home environment (19, 21), which could also influence the findings. There may be error associated with school exposure, as children spend more time at home, which could account for our null findings. Further cross-national large studies examining exposure-effect relations between air pollution exposure and a range of cognitive abilities would further inform the field.

Overall, our findings confirm those of studies that have demonstrated associations between environmental noise and children's cognition (1, 4, 5) after taking air pollution

Table 3. Multilevel Model Parameter Estimates for Nitrogen Dioxide Levels at School on Children's Cognitive Performance, With Further Adjustment for Aircraft and Road Traffic Noise Exposure at School, in the United Kingdom Air Pollution Subsample of the RANCH Project, 2001–2003 ($n = 719$)

Variable	No. of Participants	Air Pollution at School Adjusted for Sociodemographic Factors[a]			Air Pollution, Aircraft Noise, and Road Traffic Noise at School Adjusted for Sociodemographic Factors[a]		
		β[b]	95% CI	*P* Value	β[b]	95% CI	*P* Value
Reading comprehension	651						
Nitrogen dioxide		0.00041	−0.013, 0.014	0.95	0.004	−0.009, 0.018	0.53
Road traffic noise					−0.004	−0.019, 0.012	0.65
Aircraft noise					−0.012*	−0.023, −0.000063	0.05
Recognition memory	641						
nitrogen dioxide		−0.005	−0.041, 0.031	0.78	0.012	−0.021, 0.044	0.48
Road traffic noise					−0.016	−0.054, 0.022	0.40
Aircraft noise					−0.045*	−0.073, −0.017	<0.01
Information recall	638						
Nitrogen dioxide		0.012	−0.036, 0.061	0.62	0.015	−0.033, 0.062	0.54
Road traffic noise					0.036	−0.020, 0.092	0.21
Aircraft noise					−0.043*	−0.086, −0.000036	0.05
Conceptual recall	636						
Nitrogen dioxide		−0.002	−0.015, 0.011	0.79	0.00023	−0.012, 0.013	0.97
Road traffic noise					0.007	−0.008, 0.022	0.34
Aircraft noise					−0.015*	−0.026, −0.003	0.01
Working memory	580						
Nitrogen dioxide		0.036	−0.174, 0.246	0.74	0.003	−0.295, 0.301	0.98
Road traffic noise					0.034	−0.141, 0.209	0.70
Aircraft noise					0.00086	−0.109, 0.111	0.99

Abbreviations: CI, confidence interval; RANCH, Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health.

* $P \leq 0.05$.

[a] All models were adjusted for age, gender, employment status, crowding, home ownership, mother's educational level, long-standing illness, main language spoken at home, parental support for schoolwork, and classroom window glazing type.

[b] Per 1-dB increase in road traffic noise or aircraft noise or a 1-point increase in nitrogen dioxide (μg/m^3).

into account. Aircraft noise exposure at school remained significantly associated with poorer recognition memory, reading comprehension, information recall, and conceptual recall after adjustment for nitrogen dioxide levels. Taken as a whole, these findings suggest studies that have found associations between environmental noise and children's health and cognition seem unlikely to have been seriously confounded by air pollution, although this conclusion may differ for samples with greater air pollution exposure.

However, conclusions in terms of whether air pollution confounds associations between road traffic noise exposure and children's cognition are less clear, as we failed to replicate the original cross-national RANCH finding of associations between road traffic noise exposure and improved conceptual and information recall (2) in either the original United Kingdom RANCH sample or the air pollution subsample and subsequently found no associations after adjustment for air pollution. Comparison of the original United Kingdom RANCH sample with the air pollution subsample suggests that the subsample had slightly higher noise exposures and lower maternal educational levels, were more likely to speak English at home, and had slightly higher scores on the information recall test. Overall, these differences seem unlikely to explain the lack of replication of the original RANCH road traffic noise findings for conceptual and information recall, findings that were themselves unexpected (2) and have yet to be replicated in another sample.

The finding of a significant association between aircraft noise exposure and conceptual and information recall was unexpected, as analyses of the larger cross-national (2) and United Kingdom sample did not show a significant association. It seems counterintuitive that a significant association would be found in a slightly smaller subsample, but the coefficients observed were only slightly larger in magnitude than those in the cross-national and United Kingdom samples. Given the lack of association in the better-powered cross-national data for these cognitive outcomes, these findings should be interpreted with caution.

To our knowledge, no studies have examined associations of air pollution with child health other than with respiratory health (17, 18). We found no associations between air pollution at school and a range of children's health outcomes, including psychological distress, self-rated health, and systolic and diastolic blood pressures.

Table 4. Multilevel Model Parameter Estimates for Aircraft and Road Traffic Noise at School and Nitrogen Dioxide Levels at School on Children's Health in the United Kingdom Air Pollution Subsample of the RANCH Project, 2001–2003 ($n = 719$)

Variable	No. of Participants	Air Pollution at School Adjusted for Sociodemographic Factors[a]			Air Pollution, Aircraft Noise, and Road Traffic Noise at School Adjusted for Sociodemographic Factors[a]		
		β[b]	95% CI	*P* Value	β[b]	95% CI	*P* Value
Psychological distress	634						
Nitrogen dioxide		0.012	−0.042, 0.067	0.67	0.025	−0.033, 0.083	0.40
Road traffic noise					−0.037	−0.104, 0.029	0.27
Aircraft noise					−0.028	−0.079, 0.023	0.28
Self-rated health	655						
Nitrogen dioxide		0.013	−0.006, 0.033	0.18	0.013	−0.008, 0.033	0.22
Road traffic noise					−0.00020	−0.027, 0.027	0.99
Aircraft noise					0.004	−0.018, 0.026	0.70
Systolic blood pressure	276						
Nitrogen dioxide		0.058	−0.092, 0.210	0.45	0.070	−0.120, 0.259	0.47
Road traffic noise					−0.102	−0.31, 0.11	0.35
Aircraft noise					0.017	−0.139, 0.174	0.83
Diastolic blood pressure	276						
Nitrogen dioxide		0.033	−0.084, 0.151	0.58	0.088	−0.059, 0.236	0.24
Road traffic noise					0.030	−0.136, 0.195	0.73
Aircraft noise					0.012	−0.110, 0.134	0.85

Abbreviations: CI, confidence interval; RANCH, Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health.

[a] All models adjusted for age, gender, employment status, crowding, home ownership, mother's educational level, long-standing illness, main language spoken at home, parental support for schoolwork, and classroom window glazing type except the blood pressure models, which were additionally adjusted for body mass index, cuff-size, room temperature, birth weight, parental high blood pressure, and prematurity.

[b] Per 1-dB increase in road traffic noise or aircraft noise or a 1-point increase in nitrogen dioxide (μg/m^3).

Thus, although there is a consensus that air pollution is associated with hypertension and cardiovascular death in adults (36, 37), our findings suggest that no associations with blood pressure are observable for children. This probably reflects the length of exposure required for the cardiovascular effects of air pollution to develop but could also reflect a lack of power to detect associations in our smaller blood pressure subsample or the moderate levels of pollution examined.

Few studies have examined whether air pollution moderates associations between environmental noise exposure and children's cognition and health. Van Kempen et al. (25) found that children with high air pollution exposure experienced shorter reaction times with high road traffic noise exposure. We found no evidence that air pollution moderated associations, with the exception that road traffic noise exposure was associated with poorer recognition memory for children with lower nitrogen dioxide exposure at school compared with children with higher nitrogen dioxide exposure at school. It is unclear by what mechanism lower levels of air pollution might impact the association between road traffic noise and recognition memory. This could be a chance finding given the number of interactions examined, and it needs to be replicated in a study with a wider range of air pollution exposures.

There are several limitations to the study that may influence the generalizability of the findings regarding air pollution. The sample lacks schools with high levels of air pollution. Children were not selected for the study based on air pollution exposure at school, which may have biased the distribution of air pollution levels in our sample. Data from participants attending 7 of 29 schools were excluded from the analyses because no air pollution data were available. We were restricted to examining the associations for air pollution at school and lacked information about air pollution exposure at home, which may be important (25). We could not model particulate matter less than 2.5 μm in diameter or black carbon, which could influence cognitive outcomes (19, 23, 24). Exposure misclassification associated with modeling air pollution exposure is a possibility, and the accuracy of estimation may differ for noise and air pollution.

The present study is the largest to date that examined the impact of exposure to both environmental noise and air pollution at school on children's health and cognition. Other strengths include the assessment of a wide-range of cognitive and health outcomes, a sample drawn from a wide range of noise exposure levels, adjustment for a wide-range of individual confounding socioeconomic factors, and the use of multilevel modeling to take school- and individual-level variation into account.

The results of this project have implications for national and local authorities involved in public health, transport planning, and land-use planning. In terms of policy implications, the RANCH project findings indicate that a chronic environmental stressor—aircraft noise exposure at school—could impair cognitive development in children, specifically reading comprehension and memory. Schools exposed to high levels of aircraft noise are not healthy educational environments.

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Original Contribution

Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading Comprehension

The RANCH Project

Charlotte Clark[1], Rocio Martin[2], Elise van Kempen[3], Tamuno Alfred[1], Jenny Head[1], Hugh W. Davies[4], Mary M. Haines[1], Isabel Lopez Barrio[2], Mark Matheson[1], and Stephen A. Stansfeld[1]

[1] Centre for Psychiatry, Wolfson Institute of Preventive Medicine, Barts and The London, Queen Mary's School of Medicine and Dentistry, University of London, London, United Kingdom.
[2] Consejo Superior de Investigaciones Cientificas (CSIC), Madrid, Spain.
[3] National Institute for Public Health and Environment (RIVM), Bilthoven, the Netherlands.
[4] School of Occupational and Environmental Hygiene, University of British Columbia, Vancouver, Canada.

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Transport noise is an increasingly prominent feature of the urban environment, making noise pollution an important environmental public health issue. This paper reports on the 2001–2003 RANCH project, the first cross-national epidemiologic study known to examine exposure-effect relations between aircraft and road traffic noise exposure and reading comprehension. Participants were 2,010 children aged 9–10 years from 89 schools around Amsterdam Schiphol, Madrid Barajas, and London Heathrow airports. Data from the Netherlands, Spain, and the United Kingdom were pooled and analyzed using multilevel modeling. Aircraft noise exposure at school was linearly associated with impaired reading comprehension; the association was maintained after adjustment for socioeconomic variables ($b = -0.008$, $p = 0.012$), aircraft noise annoyance, and other cognitive abilities (episodic memory, working memory, and sustained attention). Aircraft noise exposure at home was highly correlated with aircraft noise exposure at school and demonstrated a similar linear association with impaired reading comprehension. Road traffic noise exposure at school was not associated with reading comprehension in either the absence or the presence of aircraft noise ($b = 0.003$, $p = 0.509$; $b = 0.002$, $p = 0.540$, respectively). Findings were consistent across the three countries, which varied with respect to a range of socioeconomic and environmental variables, thus offering robust evidence of a direct exposure-effect relation between aircraft noise and reading comprehension.

child psychology; cognition; environment and public health; environmental exposure; noise; reading

Abbreviation: dB(A), a measure of sound level in decibels A-weighted to approximate the typical sensitivity of the human ear.

Exposure to transport noise is an increasing and prominent feature of the urban environment. The ubiquitous demand for air and road travel means that more people are being exposed to transport noise, making noise pollution an increasingly important environmental issue for public health. The effect of chronic aircraft noise exposure and road traffic noise exposure on reading comprehension in primary school children is established (1–6), but, to our knowledge, no exposure-effect relations for aircraft noise or road traffic noise and reading comprehension at the individual level have been established. This paper reports findings of the RANCH project (Road traffic and Aircraft Noise Exposure and Children's Cognition and Health), the largest known epidemiologic study undertaken of noise

Reprint requests to Dr. Charlotte Clark, Centre for Psychiatry, Wolfson Institute of Preventive Medicine, Barts and The London, Queen Mary's School of Medicine and Dentistry, University of London, Mile End Road, London, E1 4NS United Kingdom (e-mail: c.clark@qmul.ac.uk).

exposure and children's cognition and health (7), which examined exposure-effect relations between noise exposure at school and reading comprehension in the Netherlands, Spain, and the United Kingdom.

Most previous studies compared the performance of children exposed to high noise levels with children exposed to low noise levels. While demonstrating an effect of chronic noise exposure on reading, these studies provide limited information in terms of the levels at which the effects of noise on children's reading comprehension begin. Previous studies that examined exposure-effect relations between aircraft noise exposure and reading assessed reading retrospectively from school records (8, 9) and may have confounded chronic noise exposure with acute noise exposure during testing. The RANCH project examined children from schools subjected to a wide range of noise exposures, making it possible to establish exposure-effect curves for aircraft and road traffic noise to examine the lowest observable effect level of noise on reading comprehension.

To our knowledge, this study is the first to be able to make intercountry comparisons of the effect size of aircraft and road traffic noise on reading comprehension. Using the same methodology in each country enabled a large sample size to be achieved by pooling the data from each country and comparing the effect size across countries.

Areas with high levels of environmental noise are often socially deprived, and children from areas of high social deprivation perform poorly on reading comprehension tasks, leading to potential confounding (10). Some studies have demonstrated an effect of environmental noise after adjusting for the influence of socioeconomic status (1), and other studies have not (4–6, 8, 10, 11). However, longitudinal studies (12, 13) have found that a reduction in noise exposure eliminated previously observed noise-related reading deficits, suggesting that socioeconomic status does not confound the relation. This study collected comparable data on socioeconomic status in the Netherlands, Spain, and the United Kingdom to examine whether socioeconomic status confounds the relation between chronic noise exposure and reading comprehension.

The relation between noise exposure and reading comprehension may be mediated by other cognitive abilities important in the development of children's reading ability, such as attention, episodic memory, and working memory. While environmental stressors can have a strong impact on the degree to which information is processed, retained, and recalled (14), a previous study found that attention did not mediate the relation between aircraft noise and reading comprehension (1, 11). The current study collected data on attention, episodic memory, and working memory, using the same nonverbal tests in each country, to examine whether these were intervening factors in the relation between noise exposure and reading comprehension.

The aim of this study was to assess exposure-effect relations of chronic aircraft and road traffic noise with reading comprehension, using data from nationally standardized reading comprehension tasks completed by children aged 9–10 years attending schools exposed to a range of aircraft noise and road traffic noise. It was hypothesized that there would be a linear exposure-effect relation between aircraft and road traffic noise at school and reading comprehension: children exposed to high levels of noise would have poorer reading comprehension than children exposed to low levels of noise, after adjustment for socioeconomic factors. The same relation was hypothesized for aircraft noise exposure at home.

MATERIALS AND METHODS

Sampling and design

Children were selected to take part in this cross-sectional epidemiologic field study on the basis of levels of noise exposure in schools around major airports in three European countries (Schiphol in Amsterdam, the Netherlands; Barajas in Madrid, Spain; and Heathrow in London, United Kingdom). In each country, primary schools around the airport were identified. In Spain and the United Kingdom, all nonstate schools were excluded, which was not possible in the Netherlands. Within each country, schools were matched according to socioeconomic status. In the Netherlands, a neighborhood-level indicator of property value and the percentage of non-Europeans were used to match schools. In Spain and the United Kingdom, schools were matched according to the percentage of children receiving free school meals and speaking the main language at home. Main language spoken at home reflects the number of children who are bilingual—who are taught in English or Spanish and who speak another language at home, for example, Gujerati in the United Kingdom. Children who were recent immigrants and who did not speak the main language of the country proficiently were excluded from the analysis according to a consistent protocol across all countries.

The schools were visited and a noise survey undertaken. Schools were classified in terms of noise exposure on a 4-by-4 grid ranging ordinally from low to high for aircraft noise and low to high for road traffic noise. In each country, two schools were then selected in each of the noise exposure grid cells, and, within schools, mixed-ability classes of boys and girls aged 9–10 years were selected to take part. No children were excluded from the selected classes.

Noise exposure assessment

In all three countries, aircraft noise estimates were based on 16-hour outdoor LAeq contours (LAeq is the "equivalent" average sound level measured by using the A-weighting most sensitive to speech intelligibility frequencies of the human ear), which gave the average continuous equivalent sound level of aircraft noise in an area from 7 a.m. to 11 p.m. for a specified period. The aircraft noise contour data were available nationally and were not derived specifically for this study. In Spain and the United Kingdom, the contours available were from July to September for the years 1999 and 2000, respectively; in the Netherlands, the contours were from October 1999 to November 2000. These contours were used to estimate aircraft noise exposure at school and home for each participant. In the Netherlands, estimates of outdoor road traffic noise were provided by modeled data (15). In the United Kingdom and Spain, estimates of road traffic noise at school were based on a combination of modeling the proximity to motorways, major roads, and minor roads; traffic flow data; and noise measurements taken at the façade of the school building. In all countries, acute noise measurements were taken both inside and outside the classroom during testing. In all analyses, chronic aircraft and road traffic noise were entered as continuous variables in dB(A); dB(A) is a measure of sound level in decibels A-weighted to approximate the typical sensitivity of the human ear.

Outcome and confounding factors assessment

Reading comprehension measures. Reading comprehension was measured by using established, nationally standardized tests. In the United Kingdom, the 86-item Suffolk Reading Scale, level 2 was used, which is suitable for children aged 8 years to 11 years, 11 months (16). In the Netherlands, the 42-item CITO Readability Index for Elementary and Special Education was used (17). This test is designed for children aged 8–12 years. In Spain, the 27-item ECL-2 (Evaluación Comprensión Lectora) was used (18). This test is suitable for children aged 8–13 years. z scores were computed, which enabled comparisons to be made between each country's test.

Potential confounding factors. Comparable measures of potential confounding factors were achieved across countries by using a questionnaire completed by the child during testing and a parent-completed questionnaire. The questionnaires assessed socioeconomic status, parental and child health, and noise-related annoyance. Owing to the large number of potential confounders, variables were retained in the multivariate analysis if analysis of covariance showed a significant relation between the confounder and aircraft noise exposure and/or road traffic noise exposure ($p < 0.05$) (table 1). The confounders retained in the analysis were age, collected from both school records and parents; employment status: whether the parent worked full or part-time; crowding: the number of people per room in the house, defined as more than 1.5 per room in the United Kingdom and Spain and equal to or more than one per room in the Netherlands (the different cutoff points reflect the different official definitions of this concept in each country); home ownership: whether the home was rented or owned/mortgaged; long-standing illness, based on parental reports of the child having attention deficit hyperactivity disorder, asthma/bronchitis, eczema, epilepsy, depression, diabetes, or dyslexia; main language spoken at home, which indicated whether the child spoke the predominant language for the country at home: Dutch, Spanish, or English; classroom glazing, a measure of the glazing (single, double, or triple) of the windows in the child's classroom; mother's educational attainment, measured by using a relative inequality index based on a ranked index of standard qualifications in each country (19); and parental support for schoolwork, assessed by a self-report scale completed by the child.

Mediating cognitive factors. In all three countries, the same established nonverbal tests of cognition were examined (7). Standardized tests were selected, after pilot studies were conducted in each country, that could be group administered, were valid for the population being assessed in terms of age and learning range, and were suitable for children who did not speak the main language at home. Episodic memory (recognition, information recall, and conceptual recall) was measured by using a task from the Child Memory Scale (20) adapted for group administration. Sustained attention was assessed by using the Toulouse Pieron Test adapted for classroom use (21). Working memory was assessed by using a modified version of the Search and Memory Task (22, 23).

Procedure

Group testing was carried out in the classroom, and the cognitive tests were administered as part of a 2-hour testing session conducted in the morning. Written consent was obtained from both parents and the children. Ethical approval was obtained in each country.

Analysis

Data from all countries were pooled and analyzed by using MLwiN multilevel modeling software (24), which took into account the hierarchical nature of the data, with pupils being clustered in schools. Statistical significance was tested by comparing the goodness of fit of different models using a chi-square test of deviance.

Analyses of aircraft noise exposure at school and road traffic noise exposure at school were conducted separately to examine single-exposure effects. For each noise exposure type, two models were run: model 1 (unadjusted) contained only noise exposure (either aircraft or road traffic noise at school); model 2 included both noise exposures and was adjusted for age, gender, country, mother's educational attainment, parental employment status, crowding in the home, parental home ownership, long-standing illness, main language spoken at home, parental support for schoolwork, and classroom glazing type. Further analyses were then conducted, additionally adjusting model 2 for acute noise exposure during testing, dyslexia, hearing impairment, noise annoyance, episodic memory (recognition, conceptual recall, and information recall), working memory, and sustained attention. Hearing impairment was defined as suffering recurrent (earache, ear infection, glue ear, temporary hearing loss) or serious hearing problems (adenoids removed, grommets fitted, long-term hearing loss, hearing aid). Models 1 and 2 were additionally run by substituting aircraft noise exposure at home for aircraft noise exposure at school. To examine combined-exposure effects for aircraft noise, model 2 was additionally adjusted for aircraft noise exposure at school and home, using a measure whereby home aircraft noise exposure for each pupil was centered at his or her school aircraft noise exposure (school noise subtracted from home noise) to assess the effect of the difference between a pupil's home aircraft noise exposure and his or her exposure at school.

The possibility of a curvilinear exposure-effect relation between noise (either aircraft or road traffic) and reading comprehension was investigated by using fractional polynomial models (25). The best-fitting model from a set of two-degree fractional polynomials (of the form $b_1$aircraft noise^{p1} + $b_2$noise^{p2}, where p_1 and p_2 belong to the set

TABLE 1. School- and pupil-level characteristics* of the RANCH sample, overall and by country, the RANCH project, 2001–2003†

Characteristic	Pooled sample	United Kingdom	The Netherlands	Spain
		School-level data		
No. of schools	89	29	33	27
No. of classes	129	47	34	48
No. of pupils invited	3,207	1,355	824	1,028
No. of pupils participating	2,844	1,174	762	908
No. of pupils and parents participating	2,276	960	658	658
Aircraft noise exposure at school (dB(A)‡)				
Mean (SD‡)	52 (9.7)	52 (9.4)	54 (7.0)	43 (10.7)
Range	30–77	34–68	41–68	30–77
Road traffic noise exposure at school (dB(A))				
Mean (SD)	51 (7.57)	48 (7.25)	53 (8.87)	53 (5.98)
Range	32–71	37–67	32–66	43–71
Classroom glazing (%)				
Single glazing	56.2	58.6	45.5	66.7
Double glazing	39.3	41.4	42.2	33.3
Triple glazing	4.5	0.0	12.1	0.0
		Pupil-level data		
No. of pupils	2,844	1,174	762	908
Response rate (%)				
Child	89	87	92	88
Parent	80	82	86	72
Aircraft noise exposure at home (dB(A))				
Mean (SD)	50 (8.9)	53 (8.9)	49 (7.06)	46 (9.1)
Range	31–76	33–76	34–65	31–73
Age				
Mean	10 years, 6 months	10 years, 3 months	10 years, 5 months	10 years, 11 months
Range	8 years, 10 months–12 years, 10 months	8 years, 10 months–11 years, 11 months	8 years, 10 months–12 years, 10 months	9 years, 5 months–12 years, 4 months
Gender (%)				
Male	47.1	45.1	49.9	47.1
Female	52.9	54.9	50.1	52.9
Parents' employment status (%)				
Not employed	14.9	22.7	7.4	11.1
Employed	85.1	77.3	92.6	88.9
Crowding at home (%)				
Not crowded	78.6	77.3	68.8	90.5
Crowded	21.4	22.7	31.2	9.5
Parents' home ownership (%)				
Not owned	27.7	42.1	18.9	15.4
Owned	72.3	57.9	81.1	84.6
Long-standing illness (%)				
No	75.9	73.6	73.2	81.8
Yes	24.1	26.4	26.8	18.2
Main language spoken at home (%)				
No	11.9	22.0	6.6	2.4
Yes	88.1	78.0	93.4	97.6
Mother's education§ (mean (SD))	0.50 (0.28)	0.50 (0.28)	0.50 (0.28)	0.50 (0.28)
Parental support scale				
Mean (SD)	10.1 (2.0)	10.1 (1.9)	8.8 (1.9)	11.1 (1.5)
Cronbach's a	0.650	0.591	0.582	0.570

* Refer to the Materials and Methods section of the text for a description of the characteristics.

† Some missing values were excluded: age, 5%; gender, <1%; crowding, 7%; home ownership, 6%; long-standing illness, 4%; main language spoken at home, 5%; classroom glazing, 0%; mother's education, 7%; and parental support, 6%.

‡ dB(A), a measure of sound level in decibels A-weighted to approximate the typical sensitivity of the human ear; SD, standard deviation.

§ Measured by using a relative inequality index based on a ranked index of standard qualifications in each country (19); a high score equals lower educational attainment.

TABLE 2. Mean, standard deviation, and range for the reading comprehension, episodic memory, working memory, sustained attention, and annoyance tasks for the RANCH sample, overall and by country, the RANCH project, 2001–2003

Outcome	Pooled sample (n = 2,844)	United Kingdom (n = 1,174)	The Netherlands (n = 762)	Spain (n = 908)
Reading comprehension				
z score				
Mean (SD*)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Range	−2.36 to 3.07	−2.09 to 2.55	−2.05 to 2.31	−2.36 to 3.07
Original score				
Mean (SD)		51.62 (11.76)	23.12 (7.49)	11.62 (4.32)
Range		6 to 79	7 to 41	1 to 25
Recognition memory				
Mean (SD)	25.08 (2.46)	24.94 (2.64)	25.35 (2.03)	25.04 (2.51)
Range	13 to 30	14 to 30	18 to 30	13 to 30
Information recall				
Mean (SD)	17.68 (5.24)	18.60 (5.42)	16.71 (4.54)	17.33 (5.35)
Range	0 to 30.5	0 to 30.5	1 to 28	0 to 30.5
Conceptual recall				
Mean (SD)	4.86 (1.40)	5.18 (1.41)	4.98 (1.27)	4.37 (1.36)
Range	0 to 9	0 to 9	0.5 to 8	0 to 7
Working memory				
Mean (SD)	16.16 (7.28)	14.82 (7.39)	16.73 (7.06)	17.32 (7.06)
Range	−13 to 35	−13 to 32	−10 to 33	−13 to 35
Sustained attention				
Mean (SD)	101.72 (42.94)	94.96 (44.52)	102.68 (41.80)	109.57 (40.33)
Range	–97 to 222	–97 to 220	–95 to 205	–92 to 222
Aircraft noise annoyance at school†				
Mean (SD)	2.01 (1.02)	2.17 (1.08)	1.96 (0.93)	1.82 (0.98)
Range	1 to 5	1 to 5	1 to 5	1 to 5

* SD, standard deviation.

† Measured on a 5-point Likert scale; a higher score equals a higher annoyance response.

−2, −1, −0.5, 0, 0.5, 1, 2, 3) was chosen; then, the goodness of fit (deviance) of this model was compared with the goodness of fit of a straight-line model to test for departure from a straight-line relation.

RESULTS

Descriptive results

Table 1 illustrates the characteristics of the overall RANCH sample. Participants were 2,844 children aged 9–10 years (Netherlands = 762, Spain = 908, United Kingdom = 1,174) from 89 schools (Netherlands = 33, Spain = 27, United Kingdom = 29). The average age was 10 years, 6 months; 53 percent were female. The overall child response rate was 89 percent and for the parent questionnaire was 80 percent. Participation rates did not vary significantly across noise exposure categories. Completed parent questionnaires were available for 2,276 (80 percent) of the children who participated. There were sociodemographic differences between the countries in terms of parental employment status, home ownership, crowding in the home, and main language spoken at home. These findings reflect sociodemographic differences between the countries and were adjusted for in the analyses. Aircraft noise exposure ranged from 30 to 77 dB(A); mean aircraft noise exposure was lower in Spain than in the United Kingdom or the Netherlands (table 1). Road traffic noise exposure ranged from 32 to 71 dB(A) and was similar across the three countries.

Subjects for whom no values for the potential confounders outlined in table 1 were missing were included in the analysis. The subsample consisted of 88 percent of the overall sample (total $N = 2,010$; Netherlands = 583, Spain = 572, United Kingdom = 855) and did not differ significantly from the overall sample in terms of sociodemographic characteristics or in terms of reading and cognitive test scores (table 2).

Effects of aircraft noise at school on reading comprehension

Increasing aircraft noise exposure at school was significantly related to poorer reading comprehension ($v^2 = 6.62$,

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TABLE 3. Multilevel model parameter estimates for aircraft noise and road traffic noise and reading comprehension for the pooled data, the RANCH project, 2001–2003

	Model (N = 2,010)								
	Aircraft noise at school, unadjusted			Road traffic noise at school, unadjusted			Aircraft noise at school and road traffic noise at school, adjusted*		
	b	SE†	p value	b	SE	p value	b	SE	p value
Fixed coefficients									
Intercept	0.404	0.167		−0.168	0.223		−1.364	0.625	0.02
Aircraft noise at school	−0.007	0.003	0.013				−0.008	0.003	0.012
Road traffic noise at school				0.003	0.004	0.454	0.002	0.004	0.54
Spain							1.00		
United Kingdom							0.272	0.082	0.001
The Netherlands							0.320	0.084	<0.001
Age							0.162	0.147	0.271
Female gender							−0.056	0.042	0.18
Parents employed							0.080	0.064	0.21
Crowding at home							−0.073	0.054	0.18
Parents' home ownership							0.205	0.053	<0.001
Mother's education							−0.713	0.077	<0.001
Long-standing illness							−0.147	0.004	0.003
Main language spoken at home							0.183	0.076	0.016
Parental support							0.084	0.011	<0.001
Classroom glazing							0.001	0.027	0.95
Random parameters									
Level 2: school	0.042	0.013		0.049	0.014		0.023	0.010	
Level 1: pupil	0.951	0.030		0.950	0.030		0.865	0.279	

* The adjusted models were evaluated against a model with the noise source excluded. Aircraft noise adjusted $v^2 = 6.62$, df = 1, $p = 0.012$; road traffic noise adjusted $v^2 = 0.37$, df = 1, $p = 0.54$.

† SE, standard error.

df = 1, $p = 0.012$; table 3). In the adjusted model, as noise increased by 5 dB(A), performance on the reading test (measured by z scores) decreased by −0.040 marks for the overall sample. Children scored lower on the reading test if they had a mother with low educational attainment or if they had a long-standing illness; they scored higher if their parents were homeowners, if the children spoke the main language of the country, and if they perceived a high level of parental support for schoolwork. The effect of aircraft noise exposure on reading comprehension remained when the model was further adjusted for dyslexia, hearing impairment, and acute noise during testing, as well as for working memory, sustained attention, and episodic memory (conceptual recall and information recall) (table 4); the significance of the effect was borderline after adjustment for recognition memory ($p = 0.062$) and aircraft noise annoyance ($p = 0.05$).

In all three countries, the same inverse relation between aircraft noise exposure at school and reading comprehension was found (table 5, test of heterogeneity $p = 0.9$). In the Netherlands and Spain, a 20-dB(A) increase in aircraft noise was associated with a decrement of one eighth of a standard deviation on the reading test; in the United Kingdom, the decrement was one fifth of a standard deviation. The size of the effect did not differ for high and low socioeconomic position. In terms of reading age, when the national data relating to the reading comprehension tests were used (16, 17), one eighth of a standard deviation was equivalent to an 8-month difference in reading age in the United Kingdom and a 4-month difference in reading age in the Netherlands. No comparative national data were available for the Spanish ECL-2 test (18).

Figure 1 shows reading comprehension adjusted for age, gender, and country by 5-dB(A) bands of aircraft noise. There was no significant departure from linearity when we compared straight-line fit with best-fitting fractional polynomial curve ($p = 0.99$).

Effects of aircraft noise exposure at home on reading comprehension

Aircraft noise exposure at home was highly correlated with aircraft noise exposure at school (Netherlands: $r = 0.93$, Spain: $r = 0.85$, United Kingdom: $r = 0.91$) (figure 2). Increasing aircraft noise exposure at home was significantly and linearly related to poorer reading comprehension ($v^2 = 5.88$, df =1, $p = 0.015$). There was no additional effect of

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TABLE 4. Multilevel model parameter estimates for aircraft noise at school on reading comprehension, additionally adjusted for memory outcomes and aircraft noise annoyance, the RANCH project, 2001–2003

	No.	Aircraft noise at school, adjusted		
		b	SE*	*p* value
Adjusted†	2,010	−0.008	0.003	0.012
Adjusted† + working memory	1,920	−0.006	0.002	0.015
Adjusted† + recognition memory	1,978	−0.005	0.002	0.062
Adjusted† + conceptual recall	1,953	−0.006	0.002	0.018
Adjusted† + information recall	1,952	−0.006	0.002	0.028
Adjusted† + sustained attention	1,918	−0.008	0.002	0.003
Adjusted† + aircraft noise annoyance	1,926	−0.006	0.003	0.05

* SE, standard error.

† Adjusted for age, gender, country, mother's education, employment status, crowding at home, home ownership, long-standing illness, main language spoken at home, parental support, classroom glazing, and road traffic noise exposure.

home aircraft noise exposure after adjustment for aircraft noise exposure at school ($v^2 = 0.24$, df = 1, $p = 0.625$) (table 6).

Effects of road traffic noise at school on reading comprehension

Chronic road traffic noise exposure at school had no significant effect on reading comprehension either before ($v^2 = 0.44$, df = 1, $p = 0.51$; model not shown) or after ($v^2 = 0.37$, df = 1, $p = 0.54$; table 3) adjustment for aircraft noise exposure at school. In addition, there was no significant departure from linearity for reading comprehension adjusted for age, gender, and country ($p = 0.90$ for comparison of straight-line fit with best-fitting fractional polynomial curve).

DISCUSSION

The aim of this study was to compare performance on a standardized reading comprehension task for children aged 9–10 years attending schools exposed to varying levels of aircraft noise and road traffic noise around major airports in three European countries. There were three main findings. Firstly, a linear exposure-effect relation was found between aircraft noise exposure at school and impaired reading comprehension, with a similar effect being observed in all three countries. Secondly, the effect of aircraft noise on reading comprehension could not be accounted for by sociodemographic variables, acute noise during testing, aircraft noise annoyance, episodic memory, working memory, or sustained attention. Thirdly, there was no evidence of a relation between road traffic noise at school and reading comprehension. These results raise concerns regarding the effect of chronic aircraft noise exposure on children's reading ability.

This is the first study known to establish that the exposure-effect relation between aircraft noise and reading comprehension is linear. In all three countries, a negative relation was found between aircraft noise exposure at school and reading comprehension. These results are consistent with previous studies (1, 3) but less consistent with the West London Schools and the Munich studies, which reported an effect for only the most difficult items on a standardized reading test (10, 12). The current study utilized an exposure-effect measure of aircraft noise exposure, examining a wider range of noise exposures, while the previous

TABLE 5. Effect size of aircraft noise and road traffic noise on reading comprehension for the pooled data and for each country, the RANCH project, 2001–2003

	b	SE*	95% CI*	*p* value from v^2†
Aircraft noise at school				
Pooled estimate‡	−0.008	0.003	−0.014, −0.002	0.012
United Kingdom§	−0.009	0.005	−0.019, 0.001	
The Netherlands§	−0.006	0.007	−0.020, 0.008	
Spain§	−0.006	0.005	−0.016, 0.004	
Road traffic noise at school				
Pooled estimate‡	0.002	0.004	−0.005, 0.009	0.54
United Kingdom§	−0.003	0.006	−0.014, 0.009	
The Netherlands§	0.004	0.005	−0.007, 0.014	
Spain§	0.008	0.008	−0.009, 0.024	

* SE, standard error; CI, confidence interval.

† Test of heterogeneity: aircraft noise $p = 0.9$, road traffic noise $p = 0.10$.

‡ Adjusted for age, gender, country, mother's education, employment status, crowding, home ownership, long-standing illness, main language spoken at home, parental support, classroom glazing, and road traffic noise exposure.

§ Adjusted for all factors except country given in the previous footnote.

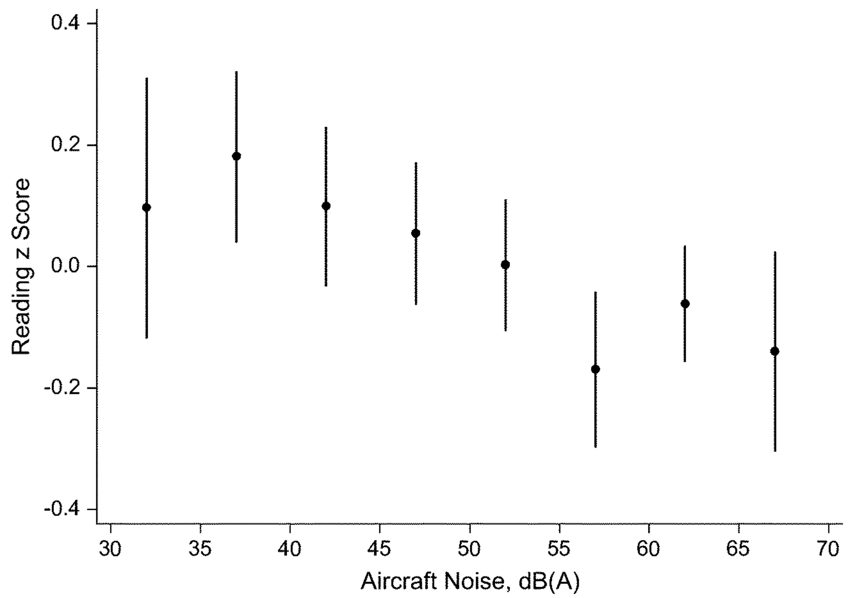

FIGURE 1. Adjusted mean reading *z* scores and 95% confidence intervals for 5-dB(A) bands of aircraft noise at school (adjusted for age, gender, and country), the RANCH project, 2001–2003. dB(A), a measure of sound level in decibels A-weighted to approximate the typical sensitivity of the human ear.

studies categorized children into low and high aircraft noise exposure, thus limiting the power of the studies.

The magnitude of the effect of aircraft noise on reading comprehension did not differ among countries. In the Netherlands and Spain, a 20-dB(A) increase in aircraft noise was associated with a decrement of one eighth of a standard deviation on the reading test; in the United Kingdom, the decrement was one fifth of a standard deviation. Although the magnitude of the effect of aircraft noise on reading is small, the consequences of long-term exposure on reading comprehension remain unknown. It is possible that children could be exposed to aircraft noise for many of their childhood years; in the United Kingdom and Spain, high environmental noise exposure is often found in socially deprived

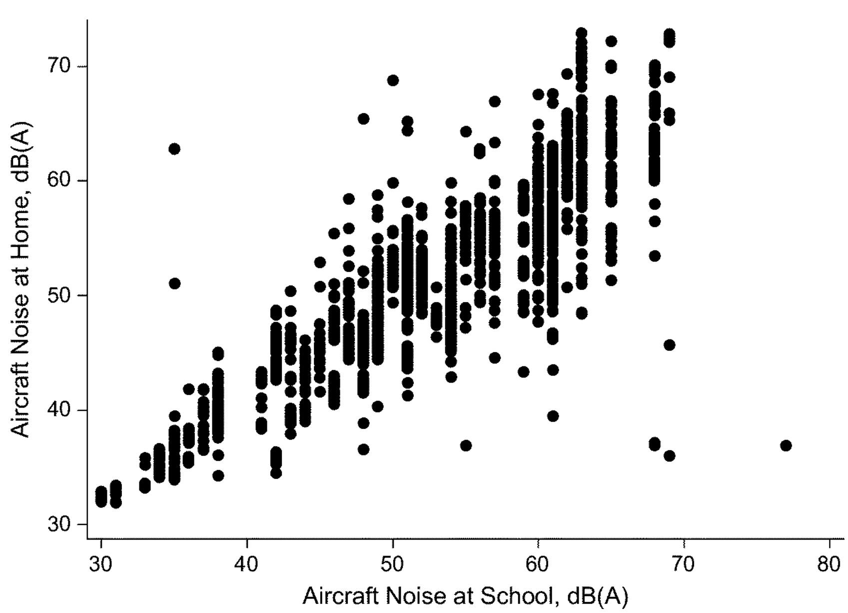

FIGURE 2. Association between aircraft noise exposure at school and aircraft noise exposure at home for the pooled data from the RANCH project, 2001–2003. dB(A), a measure of sound level in decibels A-weighted to approximate the typical sensitivity of the human ear.

TABLE 6. Multilevel model parameter estimates for aircraft noise at home and school and road traffic noise at school on reading comprehension for the pooled data*

	Model					
	Aircraft noise at home and road traffic noise at school, adjusted†			Aircraft noise at home and school, and road traffic noise at school, adjusted†		
	b	SE‡	*p* value	b	SE	*p* value
Aircraft noise at home	−0.008	0.003	0.015	−0.003	0.006	0.6
Aircraft noise at school				−0.009	0.003	0.008
Road traffic noise at school	0.002	0.004	0.50	0.002	0.004	0.5

* The adjusted models were evaluated against a model with the noise source excluded. Aircraft noise at home adjusted $v^2 = 5.88$, df = 1, $p = 0.015$; aircraft noise at home and school adjusted $v^2 = 0.24$, df = 1, $p = 0.625$.

† Both models were additionally adjusted for country, age, gender, mother's education, employment status, crowding, home ownership, long-standing illness, main language spoken at home, parental support, and classroom glazing.

‡ SE, standard error.

areas, where social mobility is low. While the Munich study (12) demonstrated that the effects of aircraft noise exposure on reading comprehension are reversible if the noise ceases, studies have yet to examine the long-term developmental consequences of exposure that persists throughout a child's education. Demand for air travel continues to increase, and further knowledge about cumulative exposure would inform intervention strategies and policy decisions.

In some previous studies, the association between noise exposure and reading has been confounded by socioeconomic status (10). Our study examined a comprehensive set of individual-level socioeconomic status variables in all three countries and found that the relation between aircraft noise exposure and reading comprehension could not be accounted for by socioeconomic status or other individual-level factors, such as long-standing illness and parental support for schoolwork. The United Kingdom sample, despite being of lower socioeconomic status, responded to noise exposure similarly to the more affluent Dutch and Spanish samples, suggesting that socioeconomic factors do not explain the effect of aircraft noise on reading.

The relation between aircraft noise exposure and reading comprehension was not mediated by sustained attention, working memory, or episodic memory: the significance of the effect was borderline after adjustment for the recognition measure of episodic memory but remained after adjustment for conceptual recall and information recall. There was limited support for a finding that the relation was not mediated by noise annoyance (1). These results, together with previous findings (1, 12), suggest that noise may either directly affect reading comprehension or be accounted for by other mechanisms. It is postulated that noise restricts attention to central cues during complex language-related tasks (4, 26, 27). The current research has not examined the psycholinguistic mechanisms that may underlie the effect, and further research on psycholinguistic mechanisms will inform the design of educational and environmental interventions for children in schools exposed to high levels of aircraft noise.

Aircraft noise exposure at school and home independently demonstrated a comparable association with reading comprehension. There was substantial colinearity between school and home aircraft noise exposure, which has been demonstrated previously (10), making it difficult to assess whether exposure at school or home differentially affected reading comprehension. After centering home aircraft noise exposure on school aircraft noise exposure (subtracting school exposure from home exposure), we demonstrated that there was no additional effect of home aircraft noise exposure after adjustment for aircraft noise exposure at school. It was not possible to fully establish the relative contribution of home and school exposure over a full 24-hour period to cognitive deficits in children in this study, and this is an important challenge for future research.

We found no significant effect of road traffic noise exposure on reading comprehension, which refuted our hypothesis and is inconsistent with previous studies (4, 5). However, the levels of road traffic noise in this study were not as high as those in some previous studies. In the Cohen et al. study (4), noise levels were typically above 80 dB(A) based on the mode of 5-minute measures at home. In this study, the annual equivalent levels ranged from 32 to 71 dB(A) at school. It is also possible that exposure to road traffic noise at home may influence reading either in its own right or by interacting with exposure at school. Unfortunately, national data on road traffic noise exposure at home were not available. No definite conclusion about the effect of road traffic noise exposure can be drawn until the results of the current study are replicated and the effect of home road traffic noise exposure is investigated.

Why should there be an effect for aircraft but not road traffic noise? Aircraft noise is more intense and less predictable than road traffic noise. The transient nature of aircraft flyovers, which have high short-term noise levels, may disrupt children's concentration and distract them from learning tasks, while the constant nature of road traffic noise may allow children to habituate and not be distracted. Banbury et al. (28) suggest that sound that varies appreciably over time will impair cognitive performance, whereas sound that does not is associated with little or no impairment. Aircraft noise exposure may also cause higher arousal levels than road traffic noise, and high arousal will interfere with performance tasks such as reading comprehension (29). A further explanation for the lack of an effect for road traffic noise exposure is that differences between countries in estimating road traffic noise exposure may have resulted in a differential quality in exposure assessment. Traffic flow may have been underestimated; exposure misclassification may also have occurred because classrooms were at varying distances from the façade of the school building.

Our study has limitations: reading measures not being exactly equivalent across countries, reliance on external measures of noise exposure, and lack of data about noise exposure over the 24 hours. However, this study represents an improvement on previous studies because of its size, in terms of both number of participants and schools. To our knowledge, it is the largest study of noise exposure and cognition in children and is the only study able to compare the reading effect size in different countries across a wide range of noise exposures. Application of multilevel modeling enabled the effect of both school-level and individual-level variables to be examined. A further strength of the study is the comprehensive number of individual-level socioeconomic variables that were examined.

In conclusion, our results suggest that aircraft noise exposure is linearly associated with impaired reading comprehension. No association was found between road traffic noise exposure and reading comprehension, either in the absence or the presence of aircraft noise. However, we could not rule out an effect at higher levels of road traffic noise. The consistent findings across the three countries, with substantial differences regarding a range of socioeconomic and environmental variables, offer robust evidence of an exposure-effect relation between aircraft noise and reading comprehension.

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EXHIBIT 25

Night time aircraft noise exposure and children's cognitive performance

Stephen Stansfeld, Staffan Hygge[1], Charlotte Clark, Tamuno Alfred[2]

Centre for Psychiatry, Wolfson Institute of Preventive Medicine, Barts and the London School of Medicine, Old Anatomy Building, Charterhouse Square, London EC1M 6BQ, UK, [1]Laboratory of Applied Psychology, Centre for Built Environment, University of Gävle, SE-801 76, Gävle, Sweden, [2]Department of Social Medicine, University of Bristol, Canynge Hall, Whatley Road, Bristol BS8 2PS, UK

Abstract

Chronic aircraft noise exposure in children is associated with impairment of reading and long-term memory. Most studies have not differentiated between day or nighttime noise exposure. It has been hypothesized that sleep disturbance might mediate the association of aircraft noise exposure and cognitive impairment in children. This study involves secondary analysis of data from the Munich Study and the UK Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health (RANCH) Study sample to test this. In the Munich study, 330 children were assessed on cognitive measures in three measurement waves a year apart, before and after the switchover of airports. Self-reports of sleep quality were analyzed across airports, aircraft noise exposure and measurement wave to test whether changes in nighttime noise exposure had any effect on reported sleep quality, and whether this showed the same pattern as for changes in cognitive performance. For the UK sample of the RANCH study, night noise contour information was linked to the children's home and related to sleep disturbance and cognitive performance. In the Munich study, analysis of sleep quality questions showed no consistent interactions between airport, noise, and measurement wave, suggesting that poor sleep quality does not mediate the association between noise exposure and cognition. Daytime and nighttime aircraft noise exposure was highly correlated in the RANCH study. Although night noise exposure was significantly associated with impaired reading and recognition memory, once home night noise exposure was centered on daytime school noise exposure, night noise had no additional effect to daytime noise exposure. These analyses took advantage of secondary data available from two studies of aircraft noise and cognition. They were not initially designed to examine sleep disturbance and cognition, and thus, there are methodological limitations which make it less than ideal in giving definitive answers to these questions. In conclusion, results from both studies suggest that night aircraft noise exposure does not appear to add any cognitive performance decrement to the cognitive decrement induced by daytime aircraft noise alone. We suggest that the school should be the main focus of attention for protection of children against the effects of aircraft noise on school performance.

Keywords: Noise, sleep, cognition, child health, memory

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Introduction

Children may be a high-risk group vulnerable to the cognitive effects of chronic noise exposure. Recent well-controlled studies have found reliable effects of exposure to aircraft noise on children's reading comprehension and long-term memory as well as annoyance.[1,2] However, both the Munich and Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health (RANCH) studies employed fairly crude averaged estimates of noise exposure, reported as daytime or 24 hour L_{Aeq} levels. To examine whether daytime exposure is better or worse than nighttime exposure, it would have been desirable to have indicators of actual as well as individual noise exposure instead of projected noise contours for large geographical areas. It would also be desirable to have separate time periods for the noise exposure, e.g., a division into daytime, evening and nighttime exposure levels, in the same way that the European Noise Directive subdivides noise exposure into L_{day}, L_{night}, L_{dn} (day and night) and L_{den} (day, evening, and night). Having that available, it would be easier to plot dose-effect curves for the different parts of the day and night and to find out whether, for example, the slopes of the dose-effect curves differ between day, evening, and night.

Some years ago, the World Health Organization (WHO) set up a task force to develop guidelines for nighttime noise exposure. One of the sub-tasks was to find out more about how nighttime noise exposure affects children's cognition.

In a literature search, no study was found that explicitly investigated the causal link of nighttime noise exposure to impaired cognition.

However, some indirect evidence in the form of the effects of reduced sleep quality on cognitive performance is reported by Jan Born and co-workers at University of Lübeck.[3-7] This research group suggests that declarative memory benefits mainly from sleep periods dominated by slow-wave sleep (SWS), while there is no consistent benefit for declarative memory from periods rich in rapid eye movement sleep (REM). This points to the importance of SWS for declarative memory, which is a plausible underlying cause-effect model, although we, in the present study, will have no direct means to test it.

Bearing this in mind, the WHO Köln office in 2005 took the initiative to sponsor supplementary analyses of the RANCH and Munich studies of aircraft noise and children, to see whether any discernible effect of night noise exposure could be detected for the cognitive measures that showed reliable changes with differing aircraft noise exposure in the initial reports.[1,2]

In the Munich study of aircraft noise and children, the same 330 children were studied in three measurement waves a year apart, before and after the switchover of airports in May 1992.[1,8,9] The children were assessed on psycho-physiological, perceptual, cognitive, motivational and quality-of-life measures. At both airports, noise-exposed, or to-be noise exposed, children were socio-demographically matched with groups with low levels of aircraft noise.

For three of the cognitive tasks,[1] there was improved performance after the closure of the old airport and impaired performance after the opening of the new airport. Mean errors on a difficult word task decreased when the old airport closed and increased when the new airport opened. Basically, the same pattern was also shown for a long-term recall task and a reading task. That is, the chronically aircraft noise exposed children at the old airport showed lower performance than their controls before the old airport closed down, but there was no difference after the closure. At the new airport, there was worse performance in the noise group than in the control group after the closure of the airport, but not before.

In the Munich study, noise exposure levels were recorded as 24 hour L_{Aeq} [inserted into Figure 1]. These noise measures were mainly intended as a check of the experimental manipulations, that is, securing that the closure and opening of the airports resulted in the expected noise levels changes, and the control groups did not change in noise exposure. However, these noise measures did not separate daytime from nighttime noise levels.

To find out whether daytime and nighttime noise exposure contributed differently to the noise effects on cognitive performance, an attempt was first made to get approximate retrospective separate estimates of nighttime and daytime noise exposure levels in the geographic areas that were included in the original Munich study of aircraft noise and children. However, this turned out to be impossible. As an alternative, self-reports of sleep quality were retrieved from the original database and analyzed across airports, aircraft noise exposure and measurement wave. The basic analytical idea was that if increased or decreased nighttime noise exposure had any effect on reported sleep quality, this would show up in the aircraft noise exposed areas at the two airports, but not in the control areas. If a consequential change in self-reported sleep quality also showed the same pattern as for changes in cognitive performance, it could then be analyzed and statistically tested as a mediator of noise effects on cognitive performance.

The RANCH project examined exposure–effect relationships between chronic aircraft noise exposure, chronic road traffic

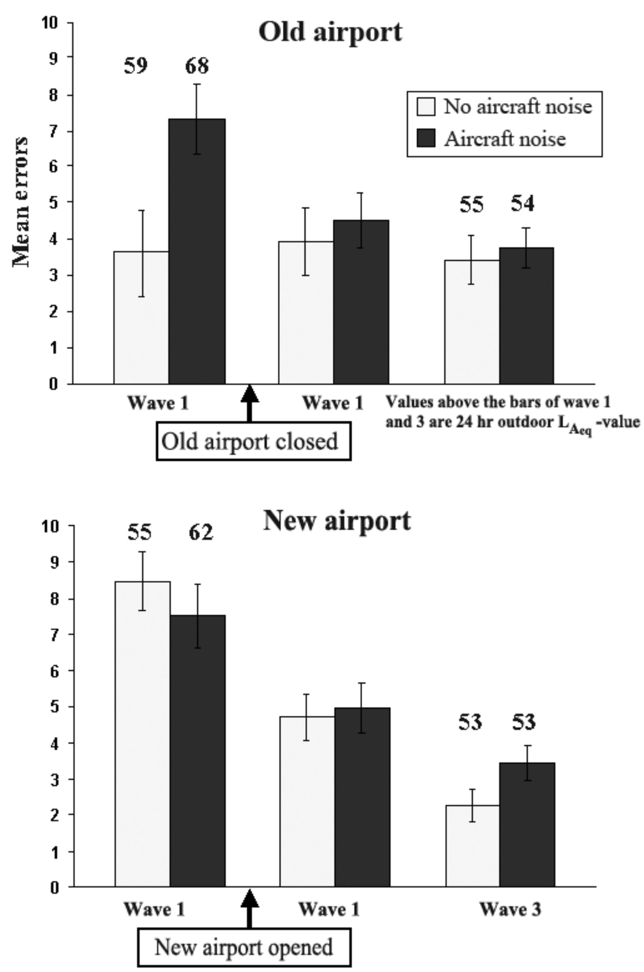

Figure 1: Mean errors on a difficult word list as a function of airport, noise group, and measurement wave. Error bars are SE of the means. Also, 24 hour outdoor L_{Aeq} values are given for waves 1 and 3 (adapted from Hygge, Evans and Bullinger)[1]

noise exposure and combinations of aircraft noise and road traffic noise exposure, and cognitive and health outcomes. It is the largest cross-sectional study of noise and children's health examining 9–10 year old children living around three major airports, Schiphol (Amsterdam, the Netherlands), Barajas (Madrid, Spain), and London Heathrow (United Kingdom).

The basic findings of the RANCH study with respect to aircraft noise were impairment of reading comprehension and recognition memory.

For the London sample of the RANCH study, it was possible to retrieve night noise contour information from the Civil Aviation Authority and link the levels to the children's home postal codes. These were secondary data analyses which took advantage of the existing data but necessarily had limitations: an ideal study might include physiological recording of sleep disturbance, measurement of personal exposure to nighttime noise and more detailed assessment of sleep quality.

Method

The Munich study

In the Munich study, 326 children took part in three measurement waves one year apart, starting around 6 months before the switchover of airports in May 1992. Two experimental groups comprised children who were (old airport) or would be (new airport) exposed to aircraft noise. Two control groups, one for the old and one for the new airport, were selected from areas that had little aircraft noise exposure, and matched with their respective experimental groups on socio-demographic characteristics. The number of children in the four groups was: Old-No aircraft noise 43, Old-Aircraft noise 65, New-No aircraft noise 107, New-Aircraft noise 111. Most children were 9–11 years old at the outset of the study (M = 10.4, SD = 0.85). Criteria for taking part in the study were a minimum of 2 years of residence and German fluency.

At each wave, the children were tested individually in silence for 1.5 hours on 2 consecutive days in a specially designed, temperature-controlled, and sound-attenuated mobile laboratory. The children worked individually on an array of different tasks. In this article, only the reading and memory tasks are reported.[1,8,9] Both in the trailer and at home, the children filled out questionnaires about life quality and also about sleep quality. On the first day, the children were accompanied by a parent, as a rule the mother, who filled out a questionnaire about, among other things, sleep quality.

Reading and memory

A standardized German reading test was employed.[10] Children read paragraphs and word lists of increasing difficulty. Some of the words in the list were pseudowords, but phonologically appropriate in German. On the first day, the children read a text in intermittent 80 L_{Aeq} broad-band noise and were tested for long-term memory (recall) in silence on the second day. Noise exposure during encoding was introduced to make the task more difficult.

Self-reports of sleep quality

For the children, four questions about sleep and sleep quality were included in the questionnaires: (1) During the last week I slept well (never–always, 0–4), (2) During the last week I was tired and out of energy (never–always, 0–4), (3) How often do you sleep poorly? (never–always, 1–5), and (4) Do you sleep well? (yes–no, 1–2).

In the questionnaires for the parents there were five questions related to sleep quality: (1) I usually get enough sleep, (2) I have a problem with falling asleep, (3) I have an uneasy sleep, (4) I wake up several times at night, and (5) I wake up too early in the morning. The replies were made by choosing one of four boxes labeled never, sometimes, often, and always (scored as 1–4).

The RANCH study

In the London sample of the RANCH study, 857children took part. They all lived around the London Heathrow Airport and were aged 9–10 years. Children were selected by external aircraft and road traffic noise exposure at school predicted from noise contour map modeling and on-site measurements. Schools were selected from a grid of increasing aircraft and road traffic noise exposure. Selected schools were matched for socioeconomic position within countries. In the UK, two classes were selected from each cell in the grid. No children were excluded from any of the selected classes.[2]

Cognitive tests

Standardized pen and paper cognitive tests were developed to measure episodic memory, working memory, prospective memory, and sustained attention. For reading comprehension nationally, standardized tests of reading were employed in each country.[11] A children's questionnaire assessed perceptions of noise and annoyance, self-rated health and opportunities for psychological restoration. Parents completed a questionnaire about confounding factors such as socioeconomic position, parental education, and ethnicity. The parental questionnaire also included the Strength and Difficulties Questionnaire to measure children's mental health.[12] The cognitive tests and questionnaires were group administered in a fixed order in the classroom. Written consent was obtained from the children and their parents. Indoor and outdoor noise measurements were made at the schools during testing.

Measurement of night noise

Night noise contour information around Heathrow Airport was obtained from the Civil Aviation Authority. Noise levels were linked to children's homes through postcodes. This enabled a nighttime measure of aircraft noise, between 11 p.m. and 7 a.m., for each child involved in the study.

Results

The Munich study

Children

As a baseline for comparisons, the effects of 24 hour aircraft noise on one of the children's cognitive tasks in the Munich study is shown in Figure 1.

An analysis of variance of the four questionnaire replies from the children, with Airport (A) and Noise condition (E) as independent between subject factors, and measurement wave (W) as a within subject factor, yielded no significant interaction A*E*W (all P values >0.41), with the exception of a significant interaction [$F(2, 548) = 3.50$, $P = 0.039$] for the item "Do you sleep well?" (yes–no, 1–2), [Figure 2]. This interaction across the airports did not come out as a significant E*W interaction when each airport was analyzed separately, indicating that although trends for the two airports moved in different directions, they were not strong enough to stand out as statistically significant at both the airports. Judging from Figure 2, it seems that sleep deteriorated most at the old airport in the No aircraft noise control group between waves 1 and 2, and did not improve in the Aircraft noise exposure group after the airport closed down. At the new airport, sleep deteriorated in the groups that became exposed to aircraft noise from wave 2 and onward, but it also worsened in the control group, but not as much.

Compared to the clear-cut pattern of results for the cognitive measures in the Munich study, as the example shown in Figure 1, it is evident also from a visual inspection that changes in self-reported sleep do not mediate the noise effect on cognition. This is corroborated by an analysis of covariance, identical to the analysis of variance behind Figure 1, with the replies to the question "Do you sleep well?" were added as a covariate. This analysis did not lower the significance level of the A*E*W interaction; it increased the level (from $P = 0.007$ to $P = 0.003$) although there was a significant effect of the covariance on the dependent measures ($P = 0.022$). Thus, these results are not consistent with the hypothesis that aircraft night noise impairs cognition by mediation of self-reported sleep quality.

Parents

An analysis of variance of the five questionnaire replies from the parents, with Airport (A) and Noise condition (E) as independent between subject factors, and measurement wave (W) as between subject factor, yielded no significant interactions A*E or A*E*W (all Ps > 0.21).

The typical response pattern across for the two airports and the three measurement waves for 258 parents are shown in Figure 3 in response to the question "I wake up several times at night".

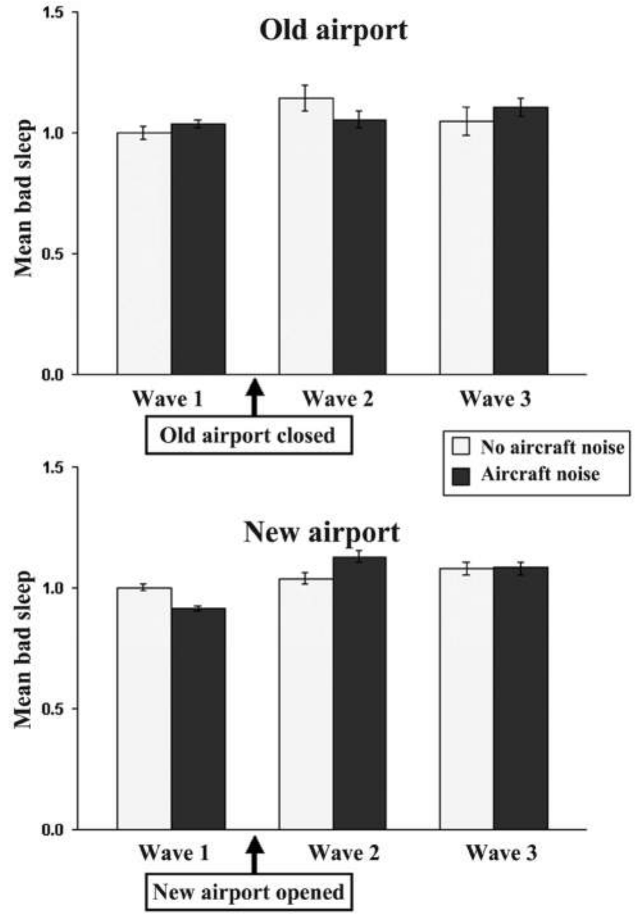

Figure 2: Means of children's self-reported good and bad sleep and awakenings during night as a function of airport, noise group, and measurement wave. A higher value indicates lower sleep quality. Error bars are SE of the means

Thus, for the Munich study, the results are not consistent with the hypothesis that aircraft night noise impairs cognition by mediation of self-reported sleep quality.

The RANCH study

Table 1 describes the distribution of nighttime and daytime aircraft noise for the sample around Heathrow Airport. Mean daytime aircraft noise was 53 dBA, whereas mean nighttime aircraft noise was 43 dBA. There was a fairly wide range of exposure for both daytime and nighttime aircraft noise exposure. The socio-demographic details of the sample are presented elsewhere.[2]

Table 2 shows the frequencies of pupils exposed to high or low levels of aircraft noise during the day and during the night. Most of the sample was exposed to less than 50 dBA during the night and less than 57 dBA during the day. However, a sizeable proportion was exposed to greater than

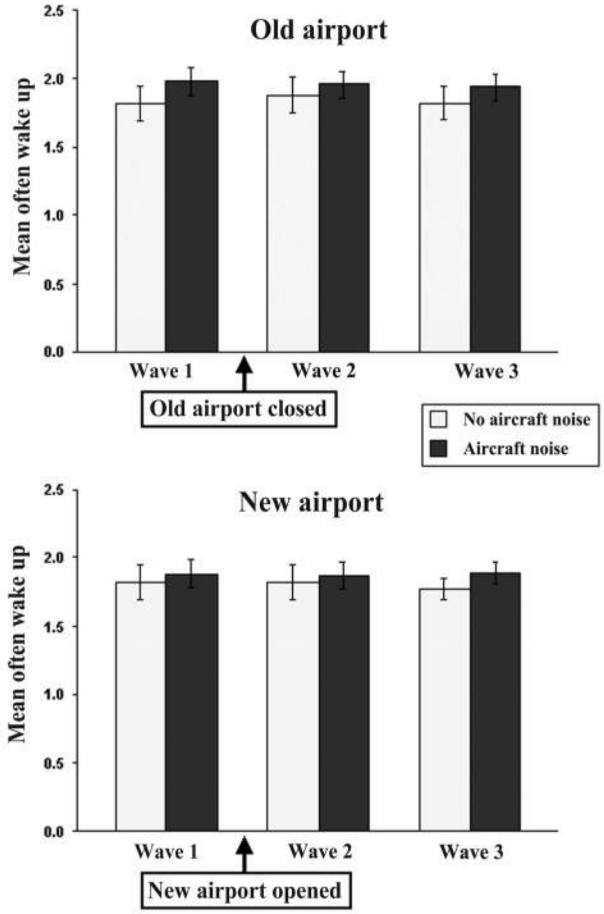

Figure 3: Means of parents' self-reported awakenings during night as a function of airport, noise group, and measurement wave. A higher value represents more frequent awakenings. Error bars are SE of the means

57 dBA during the day and greater than 50 dBA at night. Relatively fewer subjects had a higher daytime aircraft noise level and a low night aircraft noise level. Very few subjects indeed had a higher aircraft noise level exposure level at night than during the day.

Figure 4 depicts the relationship between daytime aircraft noise exposure and nighttime aircraft noise exposure for the UK sample. What this shows is that although there is a fairly strong relationship between night aircraft noise and day aircraft noise exposure, there is also quite a large amount of scatter in terms of varying night aircraft noise levels within the higher levels of daytime aircraft noise.

Tables 3 and 4 analyze the association between nighttime noise exposure and various measures of cognitive performance incorporating daytime exposure as well as nighttime exposure. Multilevel modeling was used to take into account the hierarchical nature of the dataset, with pupils being clustered within schools. Multilevel modeling makes most statistically efficient use of hierarchical data of pupils

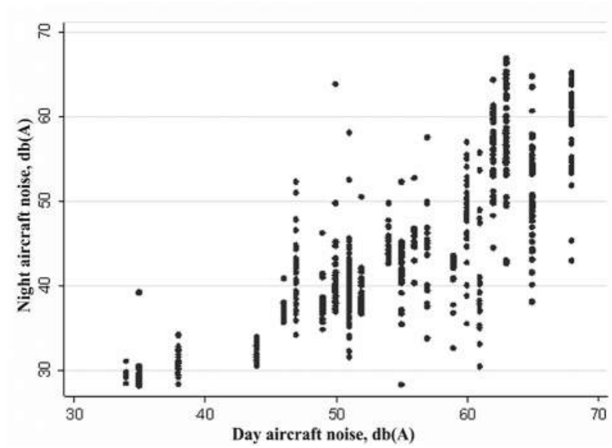

Figure 4: Relationship between daytime aircraft noise exposure at school and nighttime aircraft noise exposure

Table 1: Descriptive statistics of night and day aircraft noise in dB(A) for overall sample (N = 857)

	Mean	SD	Min	Max
Day aircraft noise	53.0	9.4	34	68
Night aircraft noise	42.9	9.7	28	67

Table 2: Number of pupils in night and day aircraft noise categories

		Day aircraft noise		Total
		Less than 57 dB(A)	57 dB(A) or more	
Night aircraft noise	Less than 50 dB(A)	516	125	641
	50 dB(A) or more	8	193	201
	Total	524	318	842

(level 1) clustered within schools (level 2), allowing both levels to be examined in the same model.[13] The multilevel method produces correct standard errors and significance tests as the analysis takes account of the clustered nature of the data. Three models are described in the tables:

Model 1: nighttime aircraft noise unadjusted for the daytime aircraft noise at school;
Model 2: adds daytime noise at school;
Model 3: is formally equivalent to model 2 but centers the nighttime aircraft noise for each pupil at their school daytime aircraft noise exposure, so its coefficient is the effect of the difference between a pupil's nighttime noise exposure and their daytime exposure at school. Therefore, increases in "night aircraft noise centered on school daytime aircraft noise" relates to the difference attributable to night noise-related effects on top of that contributed by daytime noise.

Nighttime exposure to aircraft noise was significantly associated with impairment of reading comprehension, adjusting for road traffic noise, difficulty getting to sleep, number of times awake, age, sex, parental employment

Table 3: Multilevel models for night and day aircraft noise exposure at school on reading comprehension (*N* = 842)

	Model 1		Model 2		Model 3	
	B (SE)	*P*	B (SE)	*P*	B (SE)	*P*
Fixed coefficients						
Intercept	1.56 (1.10)		1.68 (1.11)		1.68 (1.11)	
Night aircraft noise	–0.009 (0.004)	0.03	–0.004 (0.007)	0.5	—	—
Night aircraft noise centered on school daytime aircraft noise	—	—	—	—	–0.004 (0.007)	0.5
School daytime aircraft noise	—	—	–0.005 (0.007)	0.4	–0.010 (0.004)	0.02
Road traffic noise	–0.002 (0.005)	0.8	–0.002 (0.005)	0.7	–0.002 (0.005)	0.7
Difficulty getting to sleep everyday vs. not everyday	–0.311 (0.090)	0.001	–0.308 (0.090)	0.001	–0.308 (0.090)	0.001
Times awake	–0.055 (0.028)	0.04	–0.056 (0.028)	0.04	–0.056 (0.028)	0.04
Age	–0.445 (0.279)	0.1	–0.442 (0.278)	0.1	–0.442 (0.278)	0.1
Female vs. male	–0.136 (0.062)	0.03	–0.136 (0.062)	0.03	–0.136 (0.062)	0.030
Employed vs. not employed	0.050 (0.086)	0.6	0.049 (0.086)	0.6	0.049 (0.086)	0.6
Crowded vs. not crowded	–0.113 (0.080)	0.2	–0.112 (0.080)	0.2	–0.112 (0.080)	0.2
Homeowner vs. not homeowner	0.273 (0.072)	<0.001	0.275 (0.072)	<0.001	0.275 (0.072)	<0.001
Mother's education	–0.687 (0.116)	<0.001	–0.678 (0.117)	<0.001	–0.678 (0.117)	<0.001
Long-standing illness vs. none	–0.225 (0.071)	0.002	–0.225 (0.071)	0.002	–0.225 (0.071)	0.002
Speak main language vs. speak other	0.177 (0.086)	0.04	0.176 (0.086)	0.04	0.176 (0.086)	0.04
Parental support	0.096 (0.016)	<0.001	0.095 (0.016)	<0.001	0.095 (0.016)	<0.001
Classroom glazing	–0.054 (0.041)	0.2	–0.056 (0.041)	0.2	–0.056 (0.041)	0.2
Random parameters						
Level 2: School	0.014 (0.011)		0.014 (0.011)		0.013 (0.011)	
Level 1: Pupil	0.783 (0.039)		0.782 (0.039)		0.782 (0.039)	

Table 4: Multilevel models for night and day aircraft noise at school on recognition memory (*N* = 830)

	Model 1		Model 2		Model 3	
	B (SE)	*P*	B (SE)	*P*	B (SE)	*P*
Fixed coefficients						
Intercept	25.1 (3.14)		25.6 (3.16)		25.6 (3.16)	
Night aircraft noise	–0.031 (0.012)	0.01	–0.014 (0.020)	0.5	—	—
Night aircraft noise centered on school daytime aircraft noise	—	—	—	—	–0.014 (0.020)	0.5
School daytime aircraft noise	—	—	–0.023 (0.021)	0.3	–0.037 (0.013)	0.004
Road traffic noise	–0.012 (0.017)	0.5	–0.014 (0.016)	0.4	–0.014 (0.016)	0.4
Difficulty getting to sleep everyday vs. not everyday	–0.295 (0.255)	0.2	–0.284 (0.255)	0.3	–0.284 (0.255)	0.3
Times awake	–0.080 (0.077)	0.3	–0.081 (0.077)	0.3	–0.081 (0.077)	0.3
Age	0.066 (0.786)	0.9	0.093 (0.785)	0.9	0.093 (0.785)	0.9
Female vs. male	–0.145 (0.176)	0.4	–0.144 (0.175)	0.4	–0.144 (0.175)	0.4
Employed vs. not employed	0.164 (0.240)	0.5	0.159 (0.240)	0.5	0.159 (0.240)	0.5
Crowded vs. not crowded	–0.306 (0.223)	0.2	–0.300 (0.223)	0.2	–0.300 (0.223)	0.2
Homeowner vs. not homeowner	0.814 (0.203)	<0.001	0.823 (0.203)	<0.001	0.823 (0.203)	<0.001
Mother's education	–1.08 (0.329)	0.001	–1.05 (0.329)	0.001	–1.05 (0.329)	0.001
Long-standing illness vs. none	–0.074 (0.200)	0.7	–0.079 (0.200)	0.7	–0.079 (0.200)	0.7
Speak main language vs. speak other	0.798 (0.247)	0.001	0.788 (0.246)	0.001	0.788 (0.246)	0.001
Parental support	0.147 (0.046)	0.001	0.145 (0.046)	0.002	0.145 (0.046)	0.002
Classroom glazing	–0.087 (0.129)	0.5	–0.097 (0.126)	0.4	–0.097 (0.126)	0.4
Random parameters						
Level 2: School	0.193 (0.106)		0.171 (0.100)		0.171 (0.100)	
Level 1: Pupil	6.10 (0.304)		6.10 (0.305)		6.10 (0.305)	

status, crowding, homeownership, mother's education, long-standing illness, main language spoken at home, parental support for school work, and classroom glazing [Model 1, Table 3]. Difficulty getting to sleep, number of times awake in the night, female sex, low mother's education, not being a homeowner, having a long-standing illness and low parental support were also significantly related to impairment of reading comprehension in this model. After adjustment for daytime aircraft noise exposure, both the effects of nighttime aircraft noise and daytime aircraft noise became nonsignificant [Model 2, Table 3]. This is not altogether surprising as daytime aircraft noise exposure is highly correlated with nighttime aircraft noise exposure and this could be considered over adjustment. In Model 3 [Table 3] in which pupil values of home night noise exposure are centered on school noise exposure, it is demonstrated that night noise exposure does not have an additional effect to that of daytime noise exposure on reading comprehension.

Nighttime exposure to aircraft noise was also significantly associated with impairment of recognition memory, adjusting for road traffic noise, difficulty getting to sleep, times awake, age, sex, parental employment status, crowding, homeownership, mother's education, long-standing illness, main language spoken at home, parental support for school work and classroom glazing [Model 1, Table 4]. After adjustment for daytime aircraft noise exposure, both the effects of nighttime aircraft noise and daytime aircraft noise became nonsignificant [Model 2, Table 4]. Again, this is not altogether surprising as daytime aircraft noise exposure is highly correlated with nighttime aircraft noise exposure and this could be considered over adjustment. In Model 3 [Table 4] in which pupil values of home night noise exposure are centered on school noise exposure, it is demonstrated that night noise exposure does not have an additional effect to that of daytime noise exposure on recognition memory.

Neither daytime nor nighttime aircraft noise exposure was associated with impairments of recall memory, information recall, attention, working memory, self-rated health, and overall mental health measured by the Strengths and Difficulties Questionnaire.[12] Nighttime noise was also not associated with the subscales of the Strengths and Difficulties Questionnaire: emotional symptoms, conduct disorder, hyperactivity, peer problems, and prosocial behavior.

Discussion

The most consistent effects of aircraft noise found in children are cognitive impairments, though these effects are not uniform across all cognitive tasks.[14,15] Tasks which involve central processing and language comprehension, such as reading, attention, problem solving and memory, appear to be most affected by exposure to noise.[1,9,14,15] In the Munich study, a difficult word test, long-term recall of a text, and a reading test were impaired by aircraft noise (24 hour values). The supplementary analyses reported here do not support the idea that aircraft night noise, with ensuing loss in sleep quality, further adds to this deterioration.

In the RANCH study, we found the effects of chronic daytime aircraft noise exposure on reading comprehension and recognition memory, but not on recall memory or attention.[2] The findings from these further analyses of RANCH data from the UK show that nighttime aircraft noise exposure shows no additional impact on reading or recognition memory beyond the effects of daytime noise exposure. It also shows no effects of nighttime noise exposure on self-rated health or overall mental health.

The assumption behind the studies in which schools are selected as the primary focus of noise exposure is that noise exposure during the school day has the most important effects on cognitive performance. However, primary age children attending noise-exposed schools usually live in noise-exposed homes.[16] In addition, the Munich study selected children on home, not school, noise exposure.[1] It seemed possible, therefore, that aircraft noise exposure outside school hours, perhaps especially in the early morning or late at night, might also have an impact on children's learning and school performance. This was plausible for several reasons. First, effects on performance have been demonstrated in adults, which persist after the noise exposure is over; secondly, noise exposure levels in the playground or on the journey to school may be louder than those experienced in school; and thirdly, learning, especially language development, may occur as much at home as at school; fourthly, aircraft noise exposure at night, largely in the shoulder hours, might disturb sleep and cause aftereffects on children's school performance, the next day. This further set of analyses suggests that nighttime noise exposure does not affect children's school performance during the day over and above the effects of daytime noise exposure. However, it does not address whether aircraft noise exposure at home outside the night hours (11 p.m.–7 a.m.) influences school performance.

Our analyses of the effects on children's cognition of aircraft night noise have two important limitations. First, we did not have an orthogonal and independent variation of nighttime and daytime aircraft noise exposure in the way a good experiment should have to test independent effects of nighttime and daytime noise. The nighttime and daytime noise exposure in the RANCH study were so highly correlated that there was insufficient variability to test whether daytime and nighttime noise exposure had independent effects. This restricts our ability to draw a definite conclusion on the effects of night aircraft noise exposure other than that such an exposure does not appear to *add* any cognitive performance decrement to the cognitive decrement that was induced by daytime aircraft noise alone.

The second limitation is more pronounced for the Munich study than for the RANCH study, as the former has no direct measurement of night exposure levels, but is relying solely on self-report sleep quality as an indicator of night noise exposure. However, as the RANCH study could not report any effects of sleep quality measures on the direct effect from aircraft night noise to the cognitive measures in Model 3 in Tables 3 and 4, it seems to follow that there is no such effect and it is not mediated by sleep quality. In this respect, Munich and the RANCH studies corroborate each other. One further potential limitation is that because cognitive effects were tested under quiet conditions in the Munich study, any noise effects could be interpreted as being due to change in state effects.

Taken together, our analyses suggest that the school should be the main focus of attention for protection of children against the effects of aircraft noise on school performance. This conclusion may partly be evident because the study was designed to examine school level effects. Definite evidence for the mechanisms of cognitive impairments induced by night noise is still awaited, although narrowing of the attentional focus, impairments of auditory discrimination and speech perception, and communication difficulties in the classroom and learned helplessness seem to be plausible candidates. Studies specifically designed to address the effects of nighttime noise exposure are needed to provide definitive information on this topic.

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Address for correspondence:
Prof. Stephen Stansfeld,
Centre for Psychiatry,
Wolfson Institute of Preventive Medicine,
Barts and the London School of Medicine,
Old Anatomy Building, Charterhouse Square,
London EC1M 6BQ, United Kingdom.
E-mail: s.a.stansfeld@qmul.ac.uk

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Residential noise exposure and health: Evidence from aviation noise and birth outcomes☆

Laura M. Argys [a], Susan L. Averett [b], Muzhe Yang [c,*]

[a] Department of Economics, University of Colorado Denver, USA
[b] Department of Economics, Lafayette College, USA
[c] Department of Economics, Lehigh University. 621 Taylor Street, Bethlehem, PA 18015, USA

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ABSTRACT

Utilizing information on exact home addresses on birth records, we exploit arguably exogenous variation in noise exposure triggered by a new Federal Aviation Administration policy called NextGen, which unintentionally increased noise levels in communities experiencing concentrated flight patterns. We examine the fetal health impact of exposure to noise levels in excess of the EPA and the WHO recommended threshold of 55 dB. We find that the likelihood of having low birth weight (LBW) babies increases by 1.6 percentage points among mothers who live close to the airport, in the direction of the runway, exposed to noise levels over the 55 dB threshold, and during the period when NextGen was more actively implemented at the airport. Our finding has important policy implications for the trade-off between flight pattern optimization and human health in light of the long-term impact of LBW on later life outcomes.

1. Introduction

Noise pollution, defined as "unwanted or excessive sound that can have deleterious effects on human health and environmental quality"[1] has been a subject of regulation under the Noise Control Act of 1972 in the United States.[2] However, despite being a significant public concern, noise pollution has not received adequate attention from policy-makers.[3] A study by Hammer et al. (2014) estimates that, even in 2013, there were 104 million individuals at the risk of noise-induced hearing loss, and tens of millions *more* could suffer from noise-related health effects.

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* Corresponding author.
E-mail addresses: Laura.Argys@ucdenver.edu (L.M. Argys), averetts@lafayette.edu (S.L. Averett), muzheyang@lehigh.edu (M. Yang).

[1] Source: https://www.britannica.com/science/noise-pollution (accessed on May 16, 2019).

[2] For more details, see https://www.epa.gov/laws-regulations/summary-noise-control-act (accessed on May 16, 2019).

[3] The U.S. Environmental Protection Agency (EPA), under the Noise Control Act of 1972, in principle has the authority to regulate noise emissions, but the EPA in reality has lost that authority since 1981, due to funding cuts (Hammer et al., 2014).

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Adverse health effects of noise operate mainly through the activation of the central stress response system—the hypothalamic pituitary adrenal (HPA) axis. Noise-induced activation of the HPA axis can lead to disrupted sleep, increased stress hormones, and elevated blood pressure and heart rate (Hoffmann, 2018). One important feature of this response of the HPA axis is that it does not require cognitive perception of the noise (Hoffmann, 2018), leading noise exposure to be referred to as a silent killer. Pregnant women are particularly vulnerable to noise because the increased HPA axis function during pregnancy can have negative effects on fetal health (Nieuwenhuijsen et al., 2017).

In 1997, the American Academy of Pediatrics Committee on Environmental Health (1997) issued a set of six recommendations. First among them was a call to pediatricians to "encourage research to determine health effects of noise exposure on pregnant women and their fetuses and infants" (p. 726). This call, more than two decades ago, resulted in only a sparse literature on noise and infant health in general and, to our knowledge, only one relatively recent study on exposure to aircraft noise and infant health. According to a 2017 World Health Organization (WHO) review of the 14 studies in the noise and infant health literature (Nieuwenhuijsen et al., 2017), only five were recent studies (post 2000) that examined the impact of traffic and total noise on infant health (Arroyo et al., 2016; Dadvand et al., 2014; Gehring et al., 2014; Hjortebjerg et al., 2016; Hystad et al., 2014), and only one (Matsui et al., 2003) specifically examined the impact of aircraft noise on infant health, despite the fact that aircraft noise, likely due to its loud intermittent nature, is more harmful than road traffic noise (Hoffmann, 2018). Our study aims to add to that literature and provides evidence of a potential causal effect of noise exposure on infant health.

In the economics field, there is an extensive literature focusing on the causal effect of early-life exposure to pollution, with the majority being focused on air pollution, for which Currie et al. (2014) provide a comprehensive summary.[4] However, that literature so far has not examined the causal effect of noise pollution, and our study aims to fill that gap. Similar to the air pollution studies in the economics field (summarized in Currie et al., 2014), which focus on a causal effect of air pollution but with a limitation of not being able to decompose that effect along each causal pathway (e.g., oxidative stress vs. inflammation), our study also focuses on a causal effect of noise pollution but being unable to quantify each causal pathway (e.g., disrupted sleep vs. elevated stress).

In this study we focus on infant health at birth, and specifically low birth weight (LBW), defined as birth weight under 2500 g. Although in epidemiological studies an association between high-level noise exposure and LBW (but not other reproductive outcomes) has been found (Ristovska et al., 2014), causal estimates of the effect of noise exposure on LBW are still lacking. Such estimates are essential not only for informing policy-making, but also for understanding the long-term impact of those policies, given the robust association found in the literature between birth weight and adulthood outcomes related to health, education and earnings (Currie and Rossin-Slater, 2015).

Identification of a causal effect of noise exposure on health requires exogenous variation in noise exposure. While random assignment of noise exposure could produce that exogenous variation, in reality such random assignment of people is rarely possible. However, a nationwide initiative undertaken by the U.S. Federal Aviation Administration (FAA)—the Next Generation Air Transportation System (known as NextGen)—aimed at improving air travel *unintentionally* produced significant, and arguably exogenous, variation in noise exposure, which we exploit to estimate a causal effect of noise exposure on health. One important feature of NextGen is the use of precision satellite monitoring (replacing radar-based surveillance), which produces satellite-designed optimum routes that reduce flight time and save fuel. In reality, however, usage of these optimum routes by more and more aircraft, combined with landing at *lower* altitudes (resulting from precision satellite monitoring), has exposed residents living in an area under the new routes to "a constant barrage of airplanes flying over their homes" (CBS News, 2015). These residents were caught off-guard, because the implementation of NextGen by the FAA was exempted by the U.S. Congress from normal environmental impact reviews and public hearings (CBS News, 2015).

Using unique birth data that contain information on mothers' exact home addresses, we are able to identify those living close to the airport and also in the direction of the runway, where there is a NextGen-induced, sharp increase in noise exposure. Given that our birth data are from New Jersey, our study focuses on births to mothers living near Newark Liberty International Airport (EWR), one of the busiest airports in the country. We examine the impact of exposure to noise levels in excess of 55 dB,[5] the threshold used for the protection of public health by the EPA (EPA, 1974) and the WHO (Berglund et al., 1999), on birth outcomes. Using birth data from 2004 to 2016, we find an increase of 1.6 percentage points in the likelihood of having LBW babies among mothers who live close to the airport, in the direction of the runway, exposed to noise levels over the 55 dB threshold, and during the period when NextGen was more actively implemented at the airport. We also find that the effect of residential noise exposure on LBW appears to be more salient among male babies than among female babies, which is consistent with the "fragile male" hypothesis (Eriksson et al., 2010).

[4] In Currie et al. (2014) the authors provide detailed reviews, regarding study contexts, methods, data and sample size, as well as main findings of recent economic literature on the effects of early-life exposure to air pollution.

[5] Here, the noise level is measured, in decibel (dB) units, by the 24-h equivalent continuous sound level (commonly written as Leq), which is the logarithmic average of sound energy over a 24-h period (a.k.a., day-night average sound level, commonly written as DNL or Ldn). As a result, Leq itself does not represent any individual or "peak" event, but rather the sound energy averaged over a 24-h period. We give a more detailed discussion on the measurement of noise in the data section. Here, we provide some examples for different noise levels: 70 dB—"passenger car at 65 mph at 25 ft (77 dB); freeway at 50 ft from pavement edge 10 a.m. (76 dB); living room music (76 dB); radio or TV-audio, vacuum cleaner (70 dB)"; 60 dB—"conversation in restaurant, office, background music, air conditioning unit at 100 feet"; 50 dB—"quiet suburb, conversation at home, large electrical transformers at 100 feet" (source: http://www.industrialnoisecontrol.com/comparative-noise-examples.htm, accessed on July 31, 2019).

The rest of the paper proceeds as follows. Section 2 reviews the literature. Section 3 describes the data. Section 4 describes our identification strategy, followed by Section 5 where we present the regression models. We discuss the findings in Section 6 and conclude the paper in Section 7.

2. Literature review

Possible links between excessive noise exposure and adverse health outcomes have drawn the attention of researchers across a number of disciplines for decades. These studies vary by the source of noise (e.g., occupational, traffic, and aviation) and the type of health outcomes (e.g., general adult health, cognition, disease incidence, birth outcomes and infant health), but all are motivated by understanding the possible negative externalities of noise-generating activities.

2.1. Aircraft noise and birth outcomes

Because we cannot do justice to the full literature and with our focus on the fetal health impact of aircraft noise (affected by the implementation of NextGen), our review of the literature focuses on recent studies that examine the impact of aircraft noise on birth outcomes, based mainly on the following three meta-analyses. One challenge in this literature is pointed out by Stansfeld (2015), who in his review of studies relating noise and air pollution to adult health outcomes discusses the difficulty inherent in separating out the effects of noises from the effects of air pollution given their substantial covariance. We give a detailed discussion on how our study deals with air pollution, a confounding factor, in the identification strategy section.

Morrell et al. (1997), in an early meta-analysis, reviewed studies of aircraft noise and birth outcomes including premature birth, LBW and birth defects, and they report mixed results. Although one of the studies finds a significant impact on birth weight, they conclude that overall there is no strong evidence that aircraft noise significantly affects these birth outcomes. Notably none of those studies controlled for air pollution. Ristovska et al. (2014) also provide a systematic review of studies (conducted between 1973 and 2014) that include road, aircraft and occupational noise.[6] They conclude that there is likely an effect of aircraft noise on infant health but more studies are needed. Nieuwenhuijsen et al. (2017) provide the most recent meta-analysis on the association between environmental noise and adverse birth outcomes. After an examination of 12 papers that met their criteria for inclusion, the authors determined that there was weak evidence regarding an association between noise from aircraft and road traffic and the risk for low birth weight, small for gestational age or preterm birth. They included six studies that specifically focused on aircraft noise. Despite this meta-analysis being published in 2017, the most recent aircraft noise and infant health paper included in their review was published in 2003, using data up to 1997 (Matsui et al., 2003).

The literature reported in these meta-analyses that focuses specifically on aircraft noise finds varying effects of aircraft noise on infant health outcomes. Edmonds et al. (1979) and Rehm and Jansen (1978) report no effect, while Jones and Tauscher (1978), Knipschild et al. (1981), Schell (1981) and Matsui et al. (2003) find adverse effects on various birth outcomes. These authors look at various noise exposure cutoffs near several airports around the world. These studies acknowledge the potential sorting by factors that also affect noise exposure and birth outcomes (i.e., the tendency for those who live closer to the noise source to be of lower socioeconomic status), and they control for this to varying degrees. However, their results are at best viewed as associations given that none of them have treatment groups that experience truly exogenous exposure to noise. Only one of these studies explicitly notes the confounding possibility of air pollution (Jones and Tauscher, 1978). They argue, however, that the traffic density throughout the sample area (from Los Angeles County) may contribute enough air pollution that the treatment area is not different than the control area.

2.2. Possible mechanisms

Our goal is to examine the impact of aviation noise exposure on birth outcomes. Possible mechanisms for such an effect include noise-induced hormonal activation, sleep disruption and stress from excessive noise that might interfere with healthy gestation. Adverse health effects of noise operate mainly through the activation of the HPA axis (Hoffmann, 2018; Morrell et al., 1997; Nieuwenhuijsen et al., 2017), which is a human body's central stress response system. This noise-induced activation of the HPA axis triggers physiological responses, which in turn lead to, for example, disrupted sleep, increased heart rate, release of stress hormones, and elevated blood pressure (Hoffmann, 2018).

One important feature of this noise-induced activation of the HPA axis is that the activation does not require cognitive perception of the noise, meaning that the aforementioned adverse outcomes can happen to a person whether or not the person feels annoyed by the noise (Hoffmann, 2018). Furthermore, physiological responses to noise will not be changed by subjective habituation (Babisch and Kamp, 2009). Pregnant women are particularly vulnerable to noise because of the increased HPA axis function during pregnancy and the resulting release of stress hormones that can have negative effects on fetal health (Nieuwenhuijsen et al., 2017).

[6] Notably for birth outcomes, they include exactly the same studies above suggesting that little has been done on this topic recently.

3. Data

3.1. Birth data

We obtained birth records on all live births that occurred in New Jersey between 2004 and 2016 from the New Jersey Department of Health (NJDOH). One unique feature of our birth data is that it contains information on mothers' exact home addresses (geocoded by latitudes and longitudes). This information allows us to identify those who live close to the airport and also in the direction of the runway, by calculating the angle of each mother's home relative to the runway. The NJDOH data also provide information on birth weight (measured in grams), gestational length (measured in weeks), the sex of the baby, and the characteristics of the mother including her age, race and ethnicity, education, marital status, number of prenatal visits, and smoking status.[7] We focus on singleton births (96 percent of the birth records in our data), to avoid confounding factors in the determination of adverse birth outcomes that are related to carrying multiple fetuses.

3.2. Noise data

We obtained the first-ever national transportation-focused noise data from the U.S. Department of Transportation (DOT), which were released in 2017.[8] At the time of our study, only the 2014 data were available, and in three categories: aviation noise, road (highway) noise, and the combination of the two. In the DOT data, noise is measured at exact locations, based on which we merge the noise data into the birth data by each mother's home address.

In the DOT data, noise is measured by the 24-h equivalent continuous sound level (Leq), which is the logarithmic average of sound energy over a 24-h period (a.k.a. day-night average sound level or DNL, or written as Ldn). Leq is expressed in decibels (dB), and often involves a correction method called "A-weighting," to make the measured sound level reflect the way the human ear hears sound. The Leq that uses the A-weighting is denoted by LAeq, and accordingly measured in units called dBA or dB(A). In the DOT data the A-weighting method was used, so strictly speaking, noise is measured by LAeq in dBA units. Since in practice the A-weighting correction method is commonly used, and for simplicity, throughout our paper we refer to noise as measured by Leq in dB units. Note that Leq (or DNL) uses logarithmic values to base 10, and log of 10 is equal to 1. So, an increase of 10 dB indicates 10 times as much sound energy.[9]

Leq (or DNL) has been widely used as the best available method for measuring noise, and it has also been identified by the EPA as the main metric for analyzing airport noise exposure.[10] The calculation of Leq takes into account the time of day: it adds a 10-dB penalty (when taking the logarithmic average) to a noise source (e.g., an airplane) during nighttime. A related measure, called day-evening-night level (or Lden), is a metric used by the European Union, which adds a 5-dB penalty (when taking the logarithmic average) to a noise source during the evening, in addition to the 10 dB penalty used by Leq.[11]

4. Identification strategy

4.1. Sources of plausibly exogenous variation in noise exposure

Our study utilizes two sources of plausibly exogenous variation in noise exposure. The first one comes from the implementation of NextGen. Proposed by the FAA, NextGen is a nationwide initiative started in 2006 and aimed at improving air travel, reducing airport delays and saving fuel.[12] One key component of NextGen is the transition from radar-based surveillance to precision satellite monitoring of all aircraft. In contrast to radars, satellites are able to pinpoint the exact location of each aircraft, therefore allowing for aircraft to fly closely together while being safely spaced. This allows more aircraft to use the same route. The use of satellite-based navigation, due to NextGen, has brought about two important changes generating arguably exogenous variation in residential noise exposure.[13]

First, flight paths under NextGen have become satellite-designed optimum routes. These routes are more direct, with the purpose of reducing flight time and saving fuel. One important consequence of these optimum routes is that flight paths have become more concentrated. In reality, residents living in an area that is covered by the satellite-designed optimum routes have

[7] The exact wording of the question asked about maternal smoking in the NJDOH's birth records is this: "Did mother smoke cigarettes before or during pregnancy?" As a result, the variable on maternal smoking does not capture the smoking behaviors exclusively during pregnancy.

[8] For more details, see https://www.transportation.gov/highlights/national-transportation-noise-map (accessed on May 14, 2019).

[9] For more details about decibels, see http://www.gracey.co.uk/basics/decibels-b1.htm (accessed on May 14, 2019).

[10] For details, see https://www.macnoise.com/faq/what-dnl-terms-aircraft-noise (accessed on May 14, 2019).

[11] Source: https://www.eea.europa.eu/help/glossary/eea-glossary/lden (accessed on May 14, 2019).

[12] For more details about NextGen and its implementation, see https://www.faa.gov/nextgen/faqs/(accessed on May 16, 2019), for example: "NextGen is about halfway through a multi-year investment and implementation plan. For several years now, it has continually introduced new technologies to improve air travel. The FAA plans to continue implementing cutting-edge technologies, procedures, and policies that benefit passengers, the aviation industry, and the environment through 2025 and beyond."

[13] For details, see https://www.faa.gov/nextgen/what_is_nextgen/(accessed on May 16, 2019).

become the victims of an unexpected "air show" (CBS News, 2015).

Second, the use of precision satellite monitoring gives each aircraft an exact place in line for landing much earlier than before, which allows the aircraft to start a gradual descent as they approach the destination airport. While saving fuel, this gradual descent results in aircraft flying at a much lower altitude than before when approaching the airport, which significantly increases the noise exposure of residents who live underneath the flight path.[14]

The confluence of these two important changes results in a narrow band (i.e., a noise pollution corridor), within which residents are exposed to more frequent and much greater aviation noise after the implementation of NextGen. While individuals typically choose whether or not to live near an airport, we argue that conditional on those who already live close to an airport, the redistribution of aviation noise, due to NextGen, occurred in a way that is exogenous to the residents, who were caught off-guard. Indeed, as noted earlier, the implementation of NextGen by the FAA was exempted by the U.S. Congress from normal environmental impact reviews and public hearings, through the use of so-called "categorical exclusion."[15]

The second source of plausibly exogenous variation in noise exposure is based on a "conditional randomization" that is likely to exist in our empirical context. Specifically, we focus on those living within 5 miles of the airport. Conditional on choosing to live close to the airport, people probably do not have knowledge about the exact landing and takeoff paths of aircraft, or they may think they will be exposed to similar levels of aviation noise since landing and takeoff paths, prior to NextGen, were less concentrated. To assess the plausibility of this source of exogenous variation in noise exposure, we compare the characteristics of mothers who live close to the airport (within 5 miles) between two groups: one group lives in the direction of the runway, and the other group does not. We find the characteristics of mothers in these two groups to be similar, suggesting the absence of residential sorting based on the airport's runway layout among those who live close to the airport.[16]

Our exploration of the exogenous variation in noise exposure is also guided by the recent DOT National Transportation Noise Map. Fig. 1 shows the noise map for the region around EWR. As expected, there is a narrow band near the airport representing concentrated areas of high noise exposures. We further verify that the band indeed results from high levels of aviation noise (Fig. 2). The narrow band is likely to be imposed upon those who live close to the airport in a way that is exogenous to them, for the two aforementioned reasons: one is that it is unlikely to choose where to live based on airport runway layout, conditional on living close to the airport; and the other is that the rollout of NextGen was exempted from normal environmental impact reviews and public hearings.

4.2. *Difference in differences*

Although the noise map released by the DOT allows us to pinpoint the locations with the highest noise exposure near the airport, the noise data used for the map (at the time of our study) are for the year 2014 only. As a result, the noise exposure pattern shown in Figs. 1 and 2 may not be representative for the entire period of 2004–2016, the period of our New Jersey birth data. To overcome this data limitation, we utilize the information on the exact layout of EWR runways and mothers' home addresses, to identify those who live close to the airport and also in the direction of the runway. This is the treatment group of our study. The control group includes mothers who live close to the airport but not in the direction of the runway. We also split our sample into two periods. The period between 2004 and 2010 is referred to as the pre-period, and the 2011–2016 is the post-period. We use a difference-in-differences (DID) method to exploit these two sources of plausibly exogenous variation in noise exposure. This approach is similar to that implemented in Ahlfeldt et al. (2019) and Boes and Nüesch (2011) in their examinations of the impact of airport noise on property values. In particular, Boes and Nüesch (2011) identify the treatment (control) group that experienced an increase (decrease) in noise exposure after the re-routing of flights around the Zurich airport.

Fig. 3 shows the three runways of EWR: 4L-22R, 4R-22L and 11–29. Runways 4L-22R and 4R-22L, running northeast-southwest, are equally frequently used. In contrast, the much shorter runway 11–29 runs east-west and is only occasionally used primarily under certain weather conditions (e.g., strong winds).[17] In our study we focus on runway 4L-22R.[18]

Specifically, we calculate the direction of the location of each mother's home relative to the runway. This calculation uses the latitudes and longitudes of two points—the mother's home address and the mid-point of runway 4L-22R. Throughout our study we use *azimuth* as the measure for that direction, which is an angle (ranging from 0 to 360°) between the mid-point of runway 4L-22R (point A) and the mother's home address (point B) taking into account the curvature of the Earth. To calculate the azimuth of point B relative to point A, we project the vector $\overrightarrow{AB}$ onto a horizontal plane. On that horizontal plane, the reference

[14] For a more specific example, see "Residents near BWI angry about increased jet traffic and noise, want FAA to act" (reported by *ABC* on May 24, 2017, https://youtu.be/XCvdheoHS9c?t=24).

[15] Specifically, a 2012 Congressional FAA Re-Authorization bill fast-tracked the rollout of NextGen by exempting it from normal environmental impact reviews and public hearings (CBS News, 2015). The U.S. Congressional Quiet Skies Caucus was founded in July 2015, in response to the need for addressing the issue of aviation noise. The caucus includes a group of lawmakers who represent districts that have been suffering from aircraft noise (https://nqsc.org/downloads/CAUCUS.pdf). Sponsored by the co-chair of the caucus, an amendment to directing the FAA to prioritize the work on addressing the aviation noise problem was passed by the U.S. House of Representatives on June 24, 2019 (https://www.washingtonpost.com/transportation/2019/06/25/house-passes-amendment-prioritize-efforts-combat-airplane-helicopter-noise/?noredirect=on&utm_term.b814d6d71a39).

[16] Detailed discussion about the balancing checks is provided in Section 6.2.

[17] For more details about the EWR runway usage, see https://www.spotterguide.net/planespotting/north-america/united-states-of-america/newark-liberty-ewr-kewr/(accessed on May 16, 2019).

[18] Our empirical findings are expected to be the same if we focus on runway 4R-22L instead, given that these two runways are parallel and immediately next to each other.

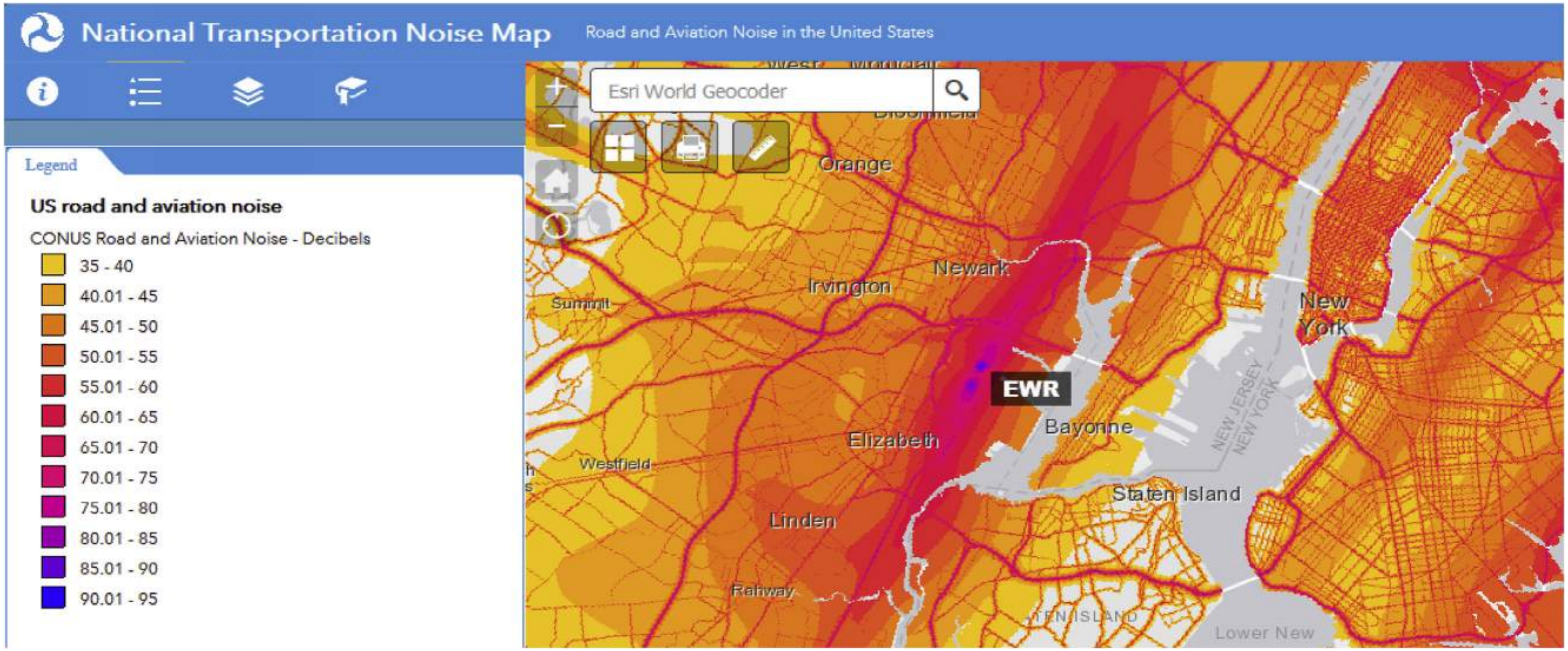

Fig. 1. Aviation and Road Noise near the Newark Liberty International Airport (EWR). Notes: This figure is extracted from the National Transportation Noise Map available at https://www.transportation.gov/highlights/national-transportation-noise-map.

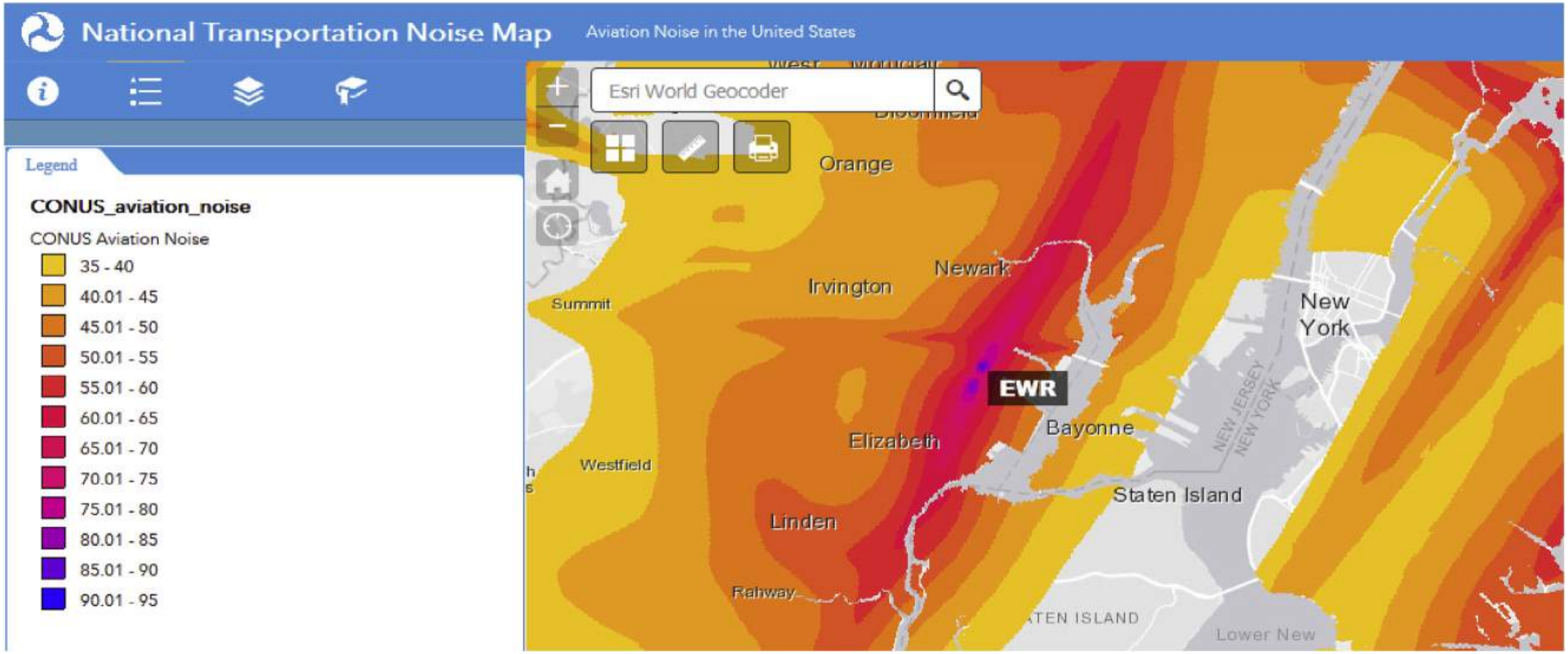

Fig. 2. Aviation Noise near the Newark Liberty International Airport (EWR). Notes: This figure is extracted from the National Transportation Noise Map available at https://www.transportation.gov/highlights/national-transportation-noise-map.

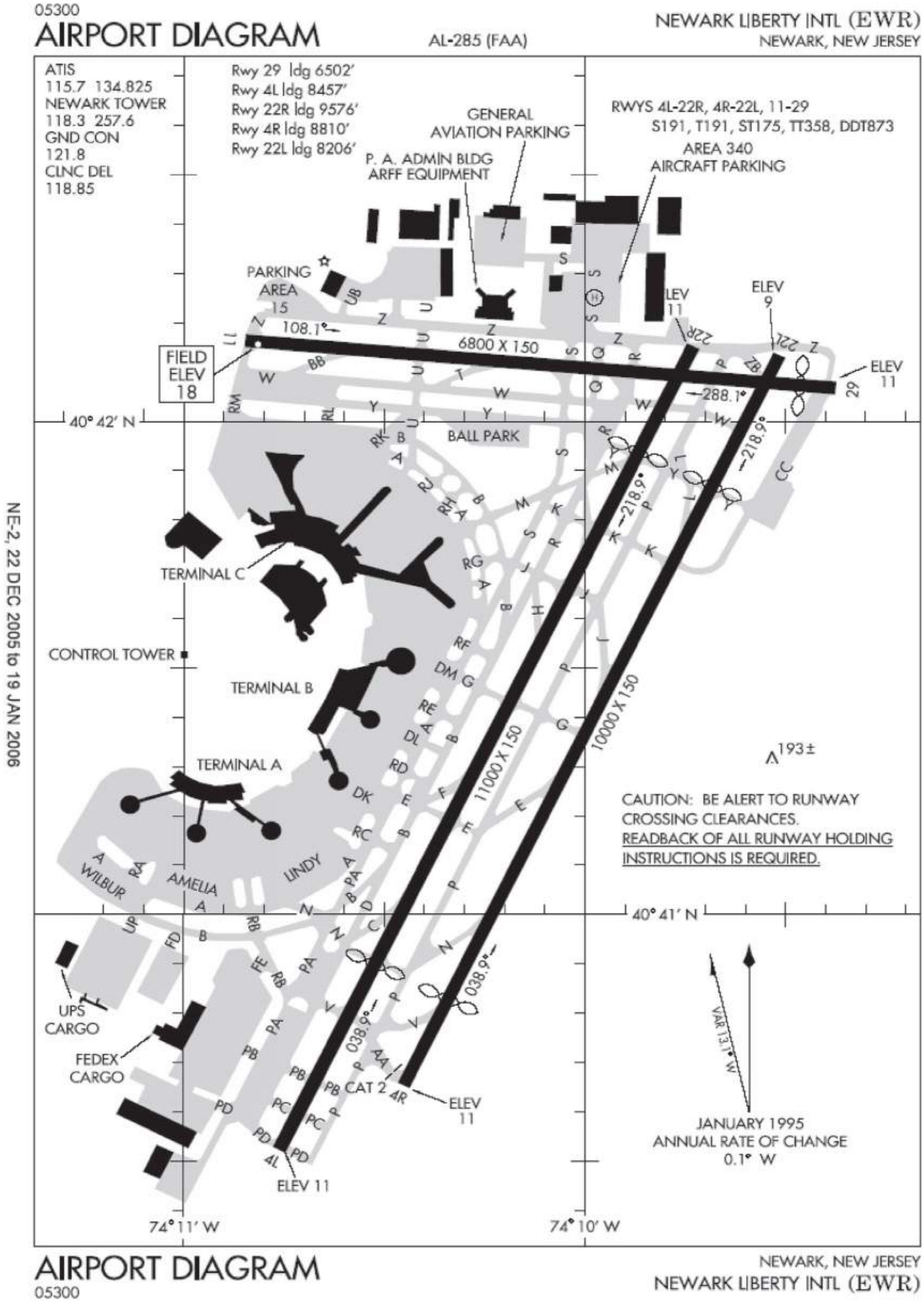

Fig. 3. Diagram of the Newark Liberty International Airport (EWR). Notes: This diagram is obtained from http://www.nycaviation.com/spotting-guides/ewr/ewr-general-information.

vector is due North, which is used for point A and has an azimuth of 0 or 360°; moving clockwise on a 360-degree circle, a point due East has an azimuth of 90°, and accordingly, 180° for due South and 270° for due West. The azimuth of point B relative to point A is given by the angle between the projected vector $\overrightarrow{AB}$ and the reference vector on that horizontal plane.

Based on the azimuth calculated, we identify mothers who live 5 degrees off, in either direction, from the runway 4L-22R,[19] and also live within 5 miles of the mid-point of runway 4L-22R.[20] The identified group is shown in Fig. 4 (Panels A and B), in a dragonfly-shaped zone, where θ (shown in Panel C) is equal to 10° (i.e., 5 degrees off from the runway 4L-22R in either direction) and r (representing the radius, shown in Panel C) is equal to 5 miles.[21]

In our study we focus on mothers living within 5 miles of the airport. Among these mothers, those living within the dragonfly-shaped zone are the treatment group, and those living outside the zone, but within the 5-mile radius, are the control group. In the tables, we refer to this treatment group as mothers "living in the direction of the runway." Although this treatment and control designation is not precisely aligned with the "noise hot spots" shown in the DOT 2014 noise map, our designation of mothers living in the direction of the runway sufficiently covers residences with higher aviation noise exposure relative to the control group. In the absence of noise data from other years, we argue that this azimuth-based treatment-control designation is an effective way of extracting exogenous variation in residential noise exposure near the airport.[22] Within this band, residents are exposed to much greater aviation noise.

In Table 1 we confirm the validity of this azimuth-based treatment zone by showing that noise levels inside this zone, although not perfectly overlapped with the noise "hot spots" shown on the DOT's noise map, are indeed significantly higher than the noise levels in the area outside the zone but within 5 miles of the mid-point of the airport runway. Column (1) reports the coefficient of living in the treatment zone on noise exposure in 2014. The difference in aviation noise level is about 17 dB. To ensure that this substantial difference in aviation noise exposure is not offset by differences in road noise, we also regress the total transportation noise on the treatment zone dummy variable. As shown in column (2), the treatment group faces total noise levels (aviation and road noise combined) that are 14 dB higher than those living in the control group. In both cases the average noise level in the treatment group is approximately equal to 63 dB, well above the 55 dB threshold used by the EPA (EPA, 1974) and the WHO (Berglund et al., 1999).

Throughout our empirical analyses, we control for the distance between a mother's home and the mid-point of runway 4L-22R. To the extent that there is residential sorting based on the distance to the airport but not based on the runway layout, we argue that, controlling for the distance between a mother's home and the airport runway, whether or not the mother lives inside the band is likely to be random.[23] The azimuth-based method of defining the treatment group in the direction of the runway allows us to approximate that band and also overcome the problem of using multiple years of birth records (to enhance statistical power) but with only one year of available noise data.

In our DID setup the pre-period (2004–2010) and the post-period (2011–2016) split the entire sample period (2004–2016) based on the timing of the implementation of the flight path component of NextGen at the EWR. The implementation of NextGen started at EWR in 2006, which is close to the beginning of our sample period.[24] The component of NextGen that is most related to precision satellite monitoring of aircraft (e.g., the use of satellite-designed optimum routes and gradual descent) is the Performance Based Navigation (PBN) component.[25] According to the timeline of NextGen implementation at EWR, the airport obtained the PBN capability around 2009–2010.[26] As a result, we use 2011–2016 as the post-period in our DID setup, and we interpret it as the period in which NextGen could have greater impact among residents living near the airport and also in the direction of the runway. Furthermore, we conduct robustness checks in which we drop the two years prior to the post-period—2009 and 2010—and in those robustness checks we find the health impact to be greater, which is consistent with the gradual rollout of

[19] To do so, we also calculated the azimuth of the runway's end-point 22R relative to the end-point 4L, using the latitudes and longitudes of these two end-points. That azimuth is equal to 25.73°, and it is compared with each mother's home azimuth relative to the mid-point of runway 4L-22R, to see if the two azimuths are different by 5°.

[20] Throughout our study we use geodetic distance (a.k.a. geodesic distance) as the distance between two locations. Geodetic distance is the length of the shortest curve between two points on the Earth. The calculation of this distance uses the latitudes and longitudes of those two points.

[21] The associated arc length shown in Panel C of Fig. 4 is equal to 0.873 miles.

[22] However, this azimuth-based treatment-control designation does not allow us to use house (i.e., mother's home address) fixed effects, because for each house there is only a single value of the azimuth (i.e., the angle ranging from 0 to 360°) relative to the mid-point of runway 4L-22R. Similarly, we are also unable to use house fixed effects when using the DOT noise data, because for each house's location there is only a single value of the noise level (measured in 2014). The lack of variation in noise levels for each house precludes the use of house fixed effects.

[23] Support for this randomization is bolstered by articles in the popular press, reporting that residents living close to airports, including those living near EWR, were caught off-guard and exposed to more frequent and significantly greater aviation noise. Furthermore, it is reported that "sound-modeling data released by the agency [the FAA] reveals that the gains and losses [from the implementation of NextGen] will not be spread evenly. Loud neighborhoods will, on average, be getting louder, while the biggest improvements will be in places that aren't that noisy to begin with" (source: https://www.cbsnews.com/news/complaints-over-noisy-new-flight-plans-11-01-2008/, accessed on August 8, 2019).

[24] For more details, see https://web.archive.org/web/20190227003132/https:/www.faa.gov/nextgen/snapshots/airport/?locationId=29 (accessed on February 19, 2020).

[25] The PBN includes RNAV (GPS) approaches, RNAV Required Navigation Performance (RNP) approaches, RNAV Standard Terminal Arrivals (STAR), RNAV Standard Instrument Departures (SID), and Q- and T-Routes (source: https://web.archive.org/web/20180120124255/https:/www.faa.gov/nextgen/where_we_are_now/nextgen_update/progress_and_plans/pbn/, accessed on February 19, 2020).

[26] For details, see https://web.archive.org/web/20190227003132/https:/www.faa.gov/nextgen/snapshots/airport/?locationId=29 (accessed on February 19, 2020).

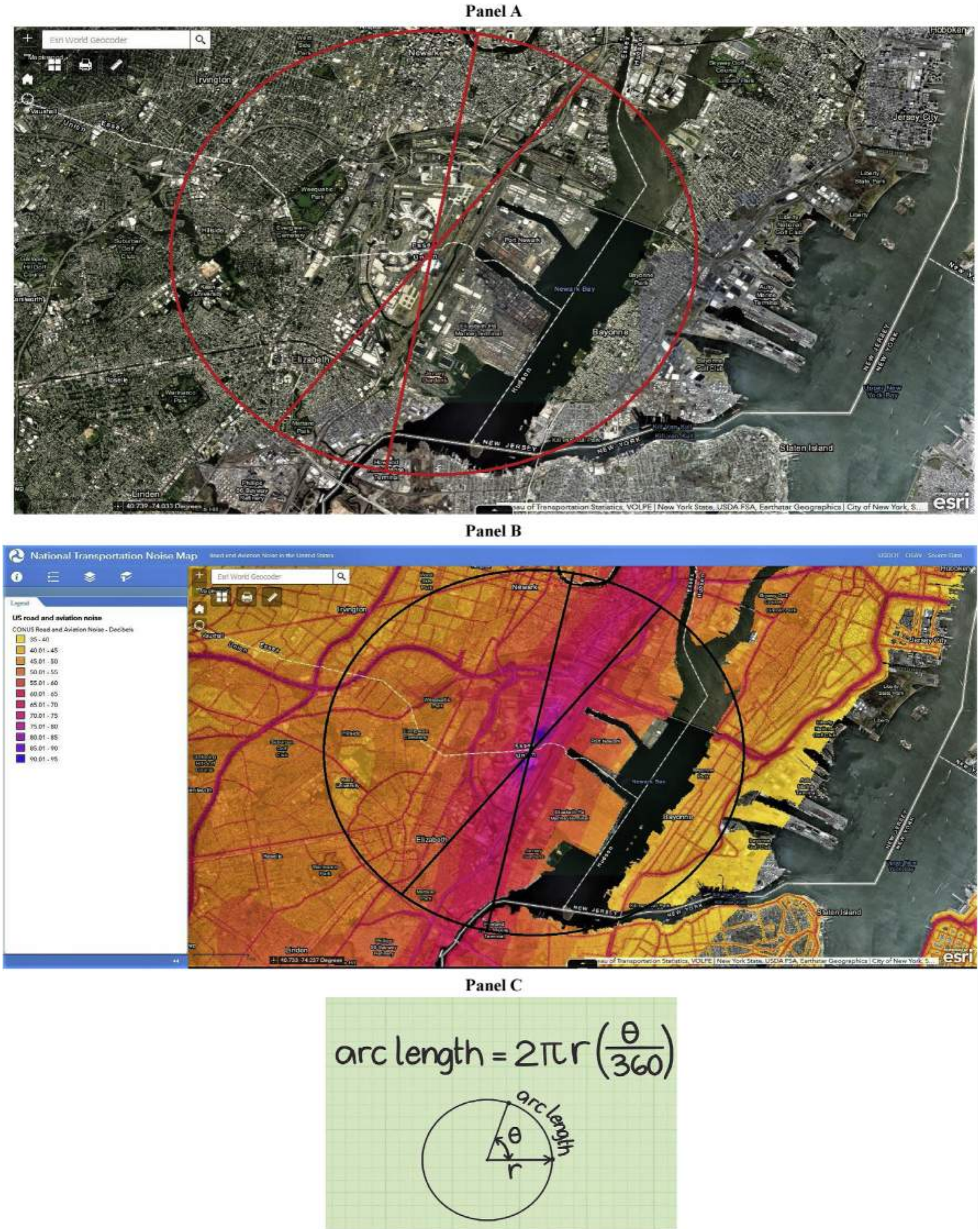

Fig. 4. Illustration of the Research Design. Notes: Panels A and B are based on the National Transportation Noise Map available at https://www.transportation.gov/highlights/national-transportation-noise-map. The center of the circle (which is also the intersection) is the Newark Liberty International Airport. Panel C is from https://www.wikihow.com/Find-Arc-Length.

Table 1
Difference in the Noise Level between Those Living near the Airport and also in the Direction of the Airport Runway and Those Living near the Airport but Not in the Direction of the Airport Runway.

Outcome variable:	Aviation noise (1)	Aviation and road noise (2)
Living in the direction of the runway (1/0)	17.03129***	14.18558***
	(1.42064)	(1.21443)
Intercept	46.27709***	49.22098***
	(1.08566)	(0.85616)
Number of observations	108,948	108,939

Notes: The estimation sample includes live and singleton births (2004–2016) of mothers who live within 5 miles of the mid-point of EWR runway 4L-22R. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. "Living in the direction of the runway (1/0)" is a dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. Each column represents a separate OLS regression of the noise variable on the "living in the direction of the runway (1/0)" variable and an intercept term. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

NextGen that continues to increase noise in this corridor.[27]

One important note regarding our DID method is that, while it helps us to control for a common trend driven by unobservables and shared by the treatment and control groups, it should not be used for estimating the impact of all aspects of NextGen. NextGen is a multi-component project, and it has been implemented in phases.[28] Our definitions of pre-period and post-period are focused only on the PBN component of NextGen.

4.3. Air pollution as a confounder

Out of concern that air pollution could be driving our results, we focus on those living close to the airport. In a small area around the airport (within a 5-mile radius in our study), we present evidence that air pollution is likely to be evenly distributed while sharp changes in noise pollution exist. By focusing on those living close to the airport, we compare those who are likely to experience similar levels of air pollution but different levels of noise pollution.

A study by Wilson and Suh (1997) shows that fine particles (e.g., those smaller than 2.5 μm, a.k.a. $PM_{2.5}$) are evenly distributed over a large area, such as a city.[29] However, air pollutant monitors are often sparsely distributed, and in fact more than 80 percent of U.S. counties do not have a single $PM_{2.5}$ monitor in place (Fowlie et al., 2019). As a result, a direct verification of the air pollutant distribution over a narrowly defined geographic area may not be possible. Nevertheless, as Fowlie et al. (2019) point out, "a growing suite of satellite observations of aerosol optical depth (AOD) makes it possible to estimate ground-level concentrations of $PM_{2.5}$ at fine spatial resolutions (<1 km)" (p. 283). In their online Appendix Figure 1, Fowlie et al. (2019) plot satellite-based estimates of annual mean concentration of $PM_{2.5}$ for the entire continental United States for the year 2005. The $PM_{2.5}$ map they produced is consistent with Wilson and Suh (1997), showing that $PM_{2.5}$ in a small geographic area tends to be evenly distributed. This is in direct contrast to the DOT's noise map, which shows that noise levels can change sharply even within a narrowly defined area.

In addition, as Schlenker and Walker (2016) point out, most of the air pollution contributed by airports stems from aircraft idling. They show that "airport runway congestion, as measured by the total time planes spent taxiing between the gate and the runway, is a significant predictor of local pollution levels" (p. 769). As a result, given the layout of the terminal gates and the runways of EWR (shown in Fig. 3), it is likely that air pollution from the airport spreads out in all directions, thus exposing the treatment and the control groups of our study, both near the runway 4L-22R, to similar levels of air pollution.

Furthermore, by controlling for the distance between a mother's home and the mid-point of runway 4L-22R in our analysis, to some degree we may also capture local air pollution levels that are affected by the airport. In our regression model (to be explained in the next section) we also add zip code-year-month-of-birth fixed effects. Assuming mothers living in the same zip code and giving birth in the same year and month are exposed to air pollution in a similar way during pregnancy, these fixed effects control for fetal health effects of prenatal exposure to air pollution.

In addition, we examine two air pollutant monitors that are from the EPA's air quality monitoring network and located within 5 miles of the mid-point of the airport runway: one monitor is located within the area of the treatment group, and the other is located within the area of the control group. We check to see whether daily readings of air pollutant concentrations from these

[27] The results of those robustness checks are reported in Panel B of Appendix Tables A1, A2 and A4.

[28] "NextGen is about halfway through a multi-year investment and implementation plan. For several years now, it has continually introduced new technologies to improve air travel. The FAA plans to continue implementing cutting-edge technologies, procedures, and policies that benefit passengers, the aviation industry, and the environment through 2025 and beyond" (source: https://www.faa.gov/nextgen/faqs/#q1, accessed on May 16, 2019).

[29] "Because fine particles travel long distances and undergo extensive atmospheric mixing, they should be distributed evenly over urban or larger areas. Measurement of fine particles at one site, therefore, should give a good measurement of the concentration of fine particles across the entire city" (Wilson and Suh, 1997, p. 1244).

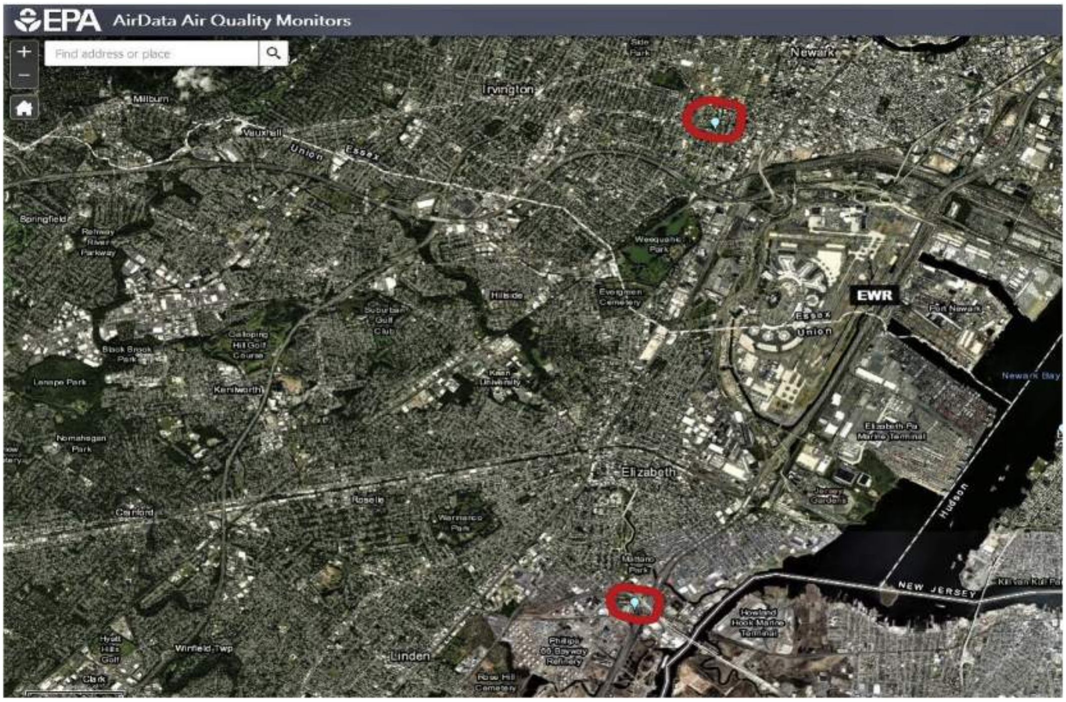

Fig. 5. Air Pollutant Monitors near the Newark Liberty International Airport (EWR). Notes: Circled (in red) are the two air pollutant monitors that have readings on carbon monoxide (CO), nitrogen dioxide (NO2) and fine particulate matter (PM2.5), with the data provided by the EPA's AQS Data Mart available at https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors. The circled monitor near the bottom of the figure is located in the "treated" area, that is, the area within 5 miles and also within 5 degrees of the mid-point of EWR runway 4L-22R. The circled monitor near the top of the figure is located in the "control" area, that is, the area within 5 miles but outside 5 degrees of the mid-point of EWR runway 4L-22R. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

two monitors are indeed similar. Similar readings from these two monitors, located in areas exposed to significantly different levels of noise pollution, will support our strategy in isolating the effect of noise pollution from the effect of air pollution. The locations of these two monitors are shown in Fig. 5. We discuss our findings in the results section.

5. Regression models

Based on the DID setup discussed above, we use the following regression models to estimate the health effect of residential noise exposure. The first regression model uses the DOT's 2014 noise data and includes births to mothers who live within 5 miles of the mid-point of the EWR's runway 4L-22R.

$$y_{i,jt} = \alpha_0 + \alpha_1 w_{1i,jt} + \alpha_2 w_{2i,jt} + \alpha_3 w_{2i,jt} \times post_t + \alpha_4 dist_{i,jt} + \mathbf{x}'_{i,jt}\alpha_5 + \delta_{jt} + \epsilon_{i,jt} \tag{1}$$

In this model, $y_{i,jt}$ denotes a birth outcome (e.g., low birth weight) of an infant born to mother i living in zip code j and giving birth in a year-month indexed by t, where the years are between 2004 and 2016. We use a comma between the subscripts i and jt to emphasize that our data are repeated cross-sections: there is no identifier for infant i's mother in the birth data, and therefore we are unable to use mother fixed effects since we cannot identify infants who were born to the same mother. In equation (1), $w_{1i,jt}$ denotes the noise level (in dB) measured in 2014 and at the home address of mother i living in zip code j and giving birth at time t. The regressor $w_{2i,jt}$ is a dummy variable (1/0) equal to one (or zero) if $w_{1i,jt}$ is greater than or equal to (or less than) 55 dB; $post_t$ is a dummy variable (1/0) equal to one for 2011–2016 and equal to zero for 2004–2010; $dist_{i,jt}$ denotes the distance (in miles) between the mother's home address and the mid-point of EWR's runway 4L-22R; $\mathbf{x}_{i,jt}$ is a vector including individual level control variables: infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for white, black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). In equation (1) an estimated α_3 represents a DID estimate.

In this regression model we also include zip code-year-month fixed effects, denoted by δ_{jt}, which are fixed effects applied to each residential zip code-birth-year-month pair. As we argued previously, the use of zip code-year-month fixed effects serves as one way of controlling for fetal health effects of prenatal exposure to air pollution. Note that zip code-year-month fixed effects account for both zip code fixed effects and year-month fixed effects. Thus, zip code-year-month fixed effects also capture any time-invariant socio-economic and demographic characteristics of the mother's residential zip code, as well as any possible seasonality (i.e., year-month) effects that exist in birth outcomes. We estimate equation (1) using ordinary least squares (OLS).

Table 2
Summary statistics.

Variables	Mean	Std. dev.	No. of obs.
Aviation and road noise (measured in dB)	49.947	6.546	1,07,401
Aviation and road noise (measured in dB) ≥ 55 (1/0)	0.205	0.404	1,07,401
Aviation noise (measured in dB)	47.153	6.177	1,07,410
Aviation noise (measured in dB) ≥ 55 (1/0)	0.116	0.321	1,07,410
Living in the direction of the runway (1/0)	0.051	0.220	1,07,495
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	3.554	0.874	1,07,495
Birth weight (measured in grams), among single births	3253.037	540.575	1,07,495
Low birth weight (1/0): birth weight < 2500 g, among singleton births	0.073	0.259	1,07,495
Gestational length (measured in weeks), among singleton births	38.592	1.839	1,07,495
Preterm (1/0): gestational length < 37 weeks, among singleton births	0.090	0.286	1,07,495
Female baby (1/0)	0.491	0.500	1,07,495
Mother's age	28.278	6.179	1,07,495
Mother is White (1/0)	0.450	0.498	1,07,495
Mother is Black (1/0)	0.456	0.498	1,07,495
Mother is Hispanic (1/0)	0.395	0.489	1,07,495
Mother having completed a four-year college or higher (1/0)	0.192	0.394	1,07,495
Mother is married (1/0)	0.401	0.490	1,07,495
Number of prenatal visits	9.095	3.541	1,07,495
Mother smoked cigarettes before or during her pregnancy (1/0)	0.061	0.240	1,07,495

Notes: Summary statistics are based on the estimation sample of Table 6 Panel C. The estimation sample includes live and singleton births of mothers who live within 5 miles of the mid-point of EWR runway 4L-22R. "Living in the direction of the runway (1/0)" is a dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014.

Standard errors are clustered at the mother's residential zip code level.[30]

The second regression model uses the azimuth-based treatment-control designation explained in the identification strategy section, and includes mothers who live within 5 miles of the mid-point of the EWR's runway 4L-22R.

$$y_{i,jt} = \beta_0 + \beta_1 d_{i,jt} + \beta_2 d_{i,jt} \times post_t + \beta_3 dist_{i,jt} + \mathbf{x}'_{i,jt}\beta_4 + \delta_{jt} + \epsilon_{i,jt} \quad (2)$$

In this model, we replace the 2014 noise measures ($w_{1i,jt}$ and $w_{2i,jt}$) with a binary indicator denoted by $d_{i,jt}$. This indicator, as explained in the identification strategy section, is equal to one (indicating the treatment group) if the home address of mother i living in zip code j and giving birth in a year-month indexed by t is within 5° and also within 5 miles of the mid-point of the EWR's runway 4L-22R; that indicator is equal to zero (indicating the control group) if the home address is outside 5°, but still within 5 miles of the mid-point of the EWR's runway 4L-22R. In equation (2) an estimated β_2 represents a DID estimate.

To make a finer comparison, we use a difference-in-differences-in-differences (DDD) model, for which we expand our estimation sample by including mothers who live between 5 and 10 miles of the mid-point of runway 4L-22R, among whom there are mothers living in the direction of the runway but actually farther away from the airport. The DDD model is specified as follows:

$$\begin{aligned} y_{i,jt} = {} & \gamma_0 + \gamma_1 w_{1i,jt} + \gamma_2 w_{2i,jt} + \gamma_3 d_{i,jt} + \gamma_4 d_{i,jt} \times w_{2i,jt} + \gamma_5 w_{2i,jt} \times post_t + \gamma_6 d_{i,jt} \times post_t + \gamma_7 d_{i,jt} \\ & \times w_{2i,jt} \times post_t + \gamma_8 dist_{i,jt} + \mathbf{x}'_{i,jt}\gamma_9 + \delta_{jt} + \epsilon_{i,jt} \end{aligned} \quad (3)$$

The definitions of variables in the above model follow equations (1) and (2).[31] In equation (3) γ_7 represents the DDD estimate. If statistically significant, γ_7 would indicate the presence of an effect on a resident who lives close to the airport, in the direction of the runway, exposed to noise levels exceeding the 55 dB threshold, and during the period when NextGen was more actively implemented at the airport. Furthermore, γ_7 would also capture, to some degree, the effect of exposure to noise that comes from aircraft takeoffs and landings, which is more health-damaging because of its loud intermittent nature (Hoffmann, 2018).[32] The use of 55-dB threshold alone (i.e., the "$w_{2i,jt}$" binary indicator) captures exposure to any type of noise that averages 55 dB, but not exclusively exposure to loud bursts from plane takeoffs and landings. Interacting that threshold with the indicator of living in the direction of the runway (i.e., "$d_{i,jt} \times w_{2i,jt}$") is one way of capturing residential exposure to intermittent loud noise

[30] In our estimation sample that includes mothers living with 5 miles of the mid-point of the EWR's runway 4L-22R and giving birth between 2004 and 2016, there are 47 clusters. The number of clusters increases to 99 in our alternative estimation sample that includes mothers living within 10 miles (detailed discussions provided in the results section) of the mid-point of runway 4L-22R and giving birth between 2004 and 2016.

[31] Another reason for expanding the estimation sample to include mothers who live between 5 and 10 miles is that estimation of equation (3) is not feasible when we only include mothers living within 5 miles of the airport runway, because of a perfect collinearity problem. In the sample only including mothers living within 5 miles of the airport runway, there is no mother living in the direction of the runway and also exposed to noise levels that are lower than 55 dB, which makes "$d_{i,jt}$" and "$d_{i,jt} \times w_{2i,jt}$" in equation (3) become perfectly correlated with each other. Including mothers living within 10 miles of the airport runway solves this perfect collinearity problem.

[32] In the absence of time-varying noise data, our study is unable to pinpoint the intensive margin of noise impact. Instead, we use this DDD model to capture the health impact of one important aspect of aviation noise, in that such noise occurs in sudden loud outbursts.

Table 3
Effects of noise exposure on low birth weight.

Outcome variable: low birth weight (birth weight < 2500 g)	
Panel A: Births ocurred between 2004 and 2010	
Aviation noise (measured in dB) ≥ 55 (1/0)	0.00392
	(0.00729)
Aviation noise (measured in dB, a continuous variable)	−0.00032
	(0.00036)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00407
	(0.00294)
Number of observations	59,141
Panel B: Births occurred between 2011 and 2016	
Aviation noise (measured in dB) ≥ 55 (1/0)	0.01470**
	(0.00681)
Aviation noise (measured in dB, a continuous variable)	−0.00078
	(0.00074)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00146
	(0.00306)
Number of observations	48,269
Panel C: Births occurred between 2004 and 2016	
Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.00698*
	(0.00376)
Aviation noise (measured in dB) ≥ 55 (1/0)	0.00555
	(0.00569)
Aviation noise (measured in dB, a continuous variable)	−0.00053
	(0.00033)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00282
	(0.00178)
Number of observations	107,410
Other control variables used in Panels A, B and C	
Individual level demographic variables	Yes
Zip code-year-month fixed effects	Yes

Notes: The estimation sample includes live and singleton births of mothers who live within 5 miles of the mid-point of EWR runway 4L-22R. The estimation in Panel C is based on the regression model described by equation (1) in the text. The estimations in Panels A and B are based on the regression model described in equation (1) in the text dropping the interaction term. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

generated specifically by aircraft, and a triple interaction (i.e., "$d_{i,jt} \times w_{2i,jt} \times post_t$") is a further way of capturing that effect by differencing out changes in unobservables that, on average, may be the same between the treatment group and the control group that are both exposed to noise levels exceeding the 55 dB threshold.

6. Results

6.1. Descriptive statistics

Table 2 reports the summary statistics, calculated based on our main estimation sample.[33] A significant proportion of mothers are exposed to noise levels exceeding the 55 dB threshold—11.6 percent in the case of aviation noise and 20.5 percent in the case of aviation and road noise, although the average noise exposure (around 47–50 dB) is below that threshold. For descriptive purpose, we use a regression model described by equation (1), which includes the 2014 noise data from the DOT, to illustrate a possible health effect of exposure to aviation noise exceeding the 55 dB threshold. Results are reported in Table 3. The DID estimate (0.00698) reported in Panel C suggests an increased risk of having LBW babies among mothers living within 5 miles of the airport who were exposed to high aviation noise (above the 55 dB threshold) during 2011–2016 while pregnant. This DID estimate is consistent with the results reported in Panels A (0.00392) and B (0.01470), in which estimations were done for the pre-period and post-period separately.[34] We interpret this DID estimate as our first indication that the adverse fetal health

[33] In the birth data we have regarding demographic characteristics, these two categories—white and Hispanic—are not mutually exclusive.

[34] In Appendix Table A1 we conduct a robustness check by dropping the middle two years of our sample period—2009 and 2010. In this robustness check we find the health impact to be greater (Panel B in contrast to Panel A), which is consistent with the gradual rollout of NextGen.

Table 4
Comparisons of maternal demographic characteristics and health behaviors.

Birth years included in the estimation sample:	2004–2010 Coefficient on "aviation noise (measured in dB) ≥ 55 (1/0)" in the regression model of each outcome variable listed in (a) through (h) (1)	2004–2016 Coefficient on "aviation noise (measured in dB) ≥ 55 (1/0) × births occurred in 2011–2016 (1/0)" in the regression model of each outcome variable listed in (a) through (h) (2)
(a) Mother's age	−0.55752 (0.80213)	0.18834 (0.17065)
(b) Mother is White (1/0)	0.01556 (0.05100)	0.01643** (0.00772)
(c) Mother is Black (1/0)	0.06102 (0.09540)	−0.01722* (0.01019)
(d) Mother is Hispanic (1/0)	0.01702 (0.04622)	0.00690 (0.00863)
(e) Mother having completed a four-year college or higher (1/0)	−0.07768 (0.06435)	0.00829 (0.01372)
(f) Mother is married (1/0)	−0.07703 (0.09902)	0.03394*** (0.00494)
(g) Number of prenatal visits	−0.24799 (0.23364)	0.05434 (0.08739)
(h) Maternal smoking (1/0)	0.02702 (0.02209)	−0.01135* (0.00618)
Number of observations	59,141	107,410
Other control variables used in the regression model of each outcome variable listed in (a) through (h)		
Aviation noise (measured in dB) ≥ 55 (1/0)	No	Yes
Aviation noise (measured in dB, a continuous variable)	Yes	Yes
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes

Notes: The estimation sample includes live and singleton births of mothers who live within 5 miles of the mid-point of EWR runway 4L-22R. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. Each column represents a separate OLS regression of each of the mother's demographic characteristics and health behaviors (listed in the table, from a to h) on an intercept, the "aviation noise (measured in dB) ≥ 55 (1/0)", the "aviation noise (measured in dB) ≥ 55 (1/0) × births occurred in 2011–2016 (1/0)" interaction term (only for column 2), and the control variables (listed at the end of the table). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

effect became more salient as the implementation of NextGen at EWR became more active.[35]

6.2. Balancing checks

There is a literature that suggests that property values are responsive to noise exposure (Ahlfeldt et al., 2019; Boes and Nüesch, 2011; von Graevenitz, 2018). Although the estimation models in Table 3 control for the distance between the mother's home and the airport runway as well as a continuous measure of noise exposure, one may still be concerned that residential sorting might occur in response to noise exposure. In Table 4 (column 1) we provide evidence showing that there are no statistically significant differences in observed maternal characteristics among those living within 5 miles of the airport during the pre-period (2004–2010) between these two groups: those exposed to aviation noise that is at least 55 dB and those exposed to aviation noise that is below 55 dB.

In addition, in column (2) we conduct a DID estimation based on equation (1) but replacing the dependent variable with each of mothers' characteristics (listed in a through h in Table 4). In this way we examine the changes over time in demographic characteristics that may reflect the presence of residential sorting. Results in column (2) indicate that any sorting that did occur is likely to come from socio-economically advantaged (and healthier) mothers. We repeat the DID estimations done in Table 4 but replacing the "aviation noise ≥55 dB" dummy variable with the "living in the direction of the runway" dummy variable and using equation (2). Results are reported in Table 5, where we confirm the same pattern found in Table 4: in the pre-period and conditional on those living close to the airport, there are no statistically significant differences in mothers' characteristics between those who are in the direction of the runway and those who are not (results reported in column 1). Furthermore, we find that it is those mothers of higher socio-economic status who are more likely to move into the treatment group (i.e., living in

[35] For more detailed information regarding EWR's implementation of individual components of NextGen, see https://web.archive.org/web/20190227003132/https:/www.faa.gov/nextgen/snapshots/airport/?locationId=29 (accessed on February 19, 2020).

Table 5
Comparisons of maternal demographic characteristics and health behaviors.

Birth years included in the estimation sample:	2004–2010 Coefficient on "living in the direction of the runway (1/0)" in the regression model of each outcome variable listed in (a) through (h) (1)	2004–2016 Coefficient on "living in the direction of the runway (1/0) × births occurred in 2011–2016 (1/0)" in the regression model of each outcome variable listed in (a) through (h) (2)
(a) Mother's age	0.04921	0.26795***
	(0.15412)	(0.06389)
(b) Mother is White (1/0)	−0.00336	0.01252***
	(0.03118)	(0.00371)
(c) Mother is Black (1/0)	−0.02000	−0.00474
	(0.03950)	(0.00612)
(d) Mother is Hispanic (1/0)	0.01901	−0.01095**
	(0.06528)	(0.00463)
(e) Mother having completed a four-year college or higher (1/0)	0.00171	0.01577**
	(0.00912)	(0.00765)
(f) Mother is married (1/0)	0.01053	0.01508
	(0.01691)	(0.01072)
(g) Number of prenatal visits	0.02960	0.00228
	(0.04269)	(0.02264)
(h) Maternal smoking (1/0)	0.00839	−0.01340***
	(0.01258)	(0.00387)
Number of observations	59,144	107,495
Other control variables used in the regression model of each outcome variable listed in (a) through (h)		
Living in the direction of the runway (1/0)	No	Yes
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes

Notes: The estimation sample includes live and singleton births of mothers who live within 5 miles of the mid-point of EWR runway 4L-22R. "Living in the direction of the runway (1/0)" is dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. Each column represents a separate OLS regression of each of the mother's demographic characteristics and health behaviors (listed in the table, from a to h) on an intercept, the "living in the direction of the runway (1/0)", the "living in the direction of the runway (1/0) × births occurred in 2011–2016 (1/0)" interaction term (only for column 2), and the control variables (listed at the end of the table). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

the direction of the runway) over time. Specifically, white, non-smoking mothers with higher levels of education are more likely to live in the treatment group in the post-period (results reported in column 2). These results suggest that residential sorting is likely to bias our results toward zero and strengthen the interpretation of a non-zero fetal health effect of exposure to high aviation noise (reported in Table 3).

However, the noise data (from the DOT) were only available for the year 2014, and as a result, there is an assumption underlying our regression model described by equation (1)—the noise exposure measured in 2014 is representative of noise exposure in other years. To relax this assumption and as discussed in the identification strategy section, we use an azimuth-based method to define treatment and control groups; the results of the associated "balancing checks" are reported in Table 5. There we find that, conditional on living close to the airport, in the pre-period mothers on average are similar between the treatment and control groups (column 1), and any residential sorting over time, if present, is likely to be mothers of higher socio-economic status moving into the treatment group (column 2), therefore biasing our finding of an adverse health effect toward zero.

6.3. DID estimation results

Next we estimate the health effects of residential noise exposure based on location relative to the runway path as specified in equation (2). These results are reported in Table 6. The DID estimates are reported in Panel C. For comparison purpose, Panels A and B report the estimates based on estimating equation (2) for the pre-period and post-period, respectively. Among all births that occurred between 2004 and 2016, the DID estimate suggests that there is an increased risk of having LBW babies, by about 0.454 percentage points[36] (column 2 of Panel C), for mothers living in the direction of the runway and in the post-period, who are likely to be exposed to higher aviation noise levels (a higher probability of exposure > 55 dB) compared with those who live equally close to the airport but are not along the runway and flight path and also compared with those living in the pre-

[36] Note that this estimate (0.454 percentage points) is smaller than the estimate (0.698 percentage points) reported in Table 3 (Panel C). Although both are of similar magnitude, they are not directly comparable. The former does not distinguish among different categories of noise (e.g., aviation noise vs. road noise), while the latter is only for aviation noise.

Table 6
Effects of living in the direction of the runway on low birth weight.

Outcome variable: low birth weight (birth weight < 2500 g) The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is:	Within 5 miles (1)	Within 5 miles (2)	Outside 20 miles (3)
Panel A: Births occurred between 2004 and 2010			
Living in the direction the runway (1/0)	0.00497***	0.00527***	−0.00433
	(0.00161)	(0.00076)	(0.00410)
Distance between mother's home and the mid-point of EWR runway	−0.00240	−0.00401	0.00023
4L-22R (measured in miles)	(0.00468)	(0.00295)	(0.00033)
Number of observations	59,144	59,144	336,340
Panel B: Births occurred between 2011 and 2016			
Living in the direction of the runway (1/0)	0.00824***	0.00915***	−0.00039
	(0.00165)	(0.00271)	(0.00449)
Distance between mother's home and the mid-point of EWR runway	0.00122	−0.00101	−0.00016
4L-22R (measured in miles)	(0.00491)	(0.00263)	(0.00042)
Number of observations	48,351	48,351	259,191
Panel C: Births ocurred between 2004 and 2016			
Living in the direction of the runway (1/0) × Births occurred in	0.00409*	0.00454*	0.00362
2011–2016 (1/0)	(0.00222)	(0.00231)	(0.00433)
Living in the direction of the runway (1/0)	0.00459***	0.00495***	−0.00423
	(0.00142)	(0.00073)	(0.00411)
Distance between mother's home and the mid-point of EWR runway	−0.00068	−0.00261*	0.00005
4L-22R (measured in miles)	(0.00406)	(0.00150)	(0.00028)
Number of observations	107,495	107,495	595,531
Other control variables used in Panels A, B and C			
Individual level demographic variables	No	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression. The estimations in Panel C are based on the regression model described by equation (2) in the text. The estimations in Panels A and B are based on the regression model described in equation (2) in the text dropping the interaction term. "Living in the direction of the runway (1/0)" is a dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

period.[37] Consistent with the results (on balancing checks) reported in Table 5 (column 1), in Table 6 we find that the estimates of the LBW effect of residential noise exposure are similar in magnitude (columns 1 vs. 2), and uniformly larger when maternal characteristics are controlled for. This is consistent with the pattern of residential sorting likely coming from mothers of higher socio-economic status (column 2 of Table 5): not controlling for mothers' characteristics (in column 1 of Table 6) is likely to cause a downward bias since mothers of higher socio-economic status are more likely to be in the treatment group in the post-period but less likely to have adverse birth outcomes.[38]

Furthermore, we examine the time-varying aspect of the treatment effect, and the results are reported in Fig. 6.[39] Consistent with the implementation timeline of NextGen discussed in Section 4.2, we find that differences in LBW between the treatment and control groups are statistically insignificant prior to 2009. These differences become statistically significant at the time when the precision satellite monitoring was being implemented at EWR (around 2009–2010), and appear to peak around 2011–2012.[40] The diminishing of the treatment effects in later years is consistent with our finding that mothers of higher socio-economic status are more likely to move into the treatment group over time.

[37] In Appendix Table A2 we conduct a robustness check by dropping the middle two years of our sample period—2009 and 2010. In this robustness check we find the health impact to be greater (Panel B in contrast to Panel A), which is consistent with the gradual rollout of NextGen.

[38] In Appendix Table A3 we report the full set of coefficient estimates (and the associated standard errors) for one set of the results reported in Table 6 (Panel C and column 2), where we show that all coefficient estimates are reasonable. For example, female babies are more likely to be LBW than male babies; mothers with higher levels of education are at a lower risk of having LBW babies; and maternal smoking is associated with an increased risk of having LBW babies.

[39] This estimation is conducted by OLS and is based on the regression model described by equation (2), replacing the interaction term "$d \times post$" with the following six interaction terms: "$d \times 1\{2004 \le s \le 2006\}$", "$d \times 1\{2007 \le s \le 2008\}$", "$d \times 1\{2009 \le s \le 2010\}$", "$d \times 1\{2011 \le s \le 2012\}$", "$d \times 1\{2013 \le s \le 2014\}$" and "$d \times 1\{2015 \le s \le 2016\}$", where s denotes birth year and $1\{condition\}$ is an indicator function, taking the value 1 (or 0) if the birth-year condition is true (or false). Our specification follows the event-study specifications used by Cook and Averett (2020) and Choi et al. (2019), in which the comparison group is comprised of the control group in each year. To ensure sufficient sample sizes, we group two birth years into one period (except the first three years of our sample period).

[40] In our DID setup, we include 2010 in the pre-period. Doing so, as Fig. 6 suggests, implies that we are providing a conservative estimate of the treatment effect.

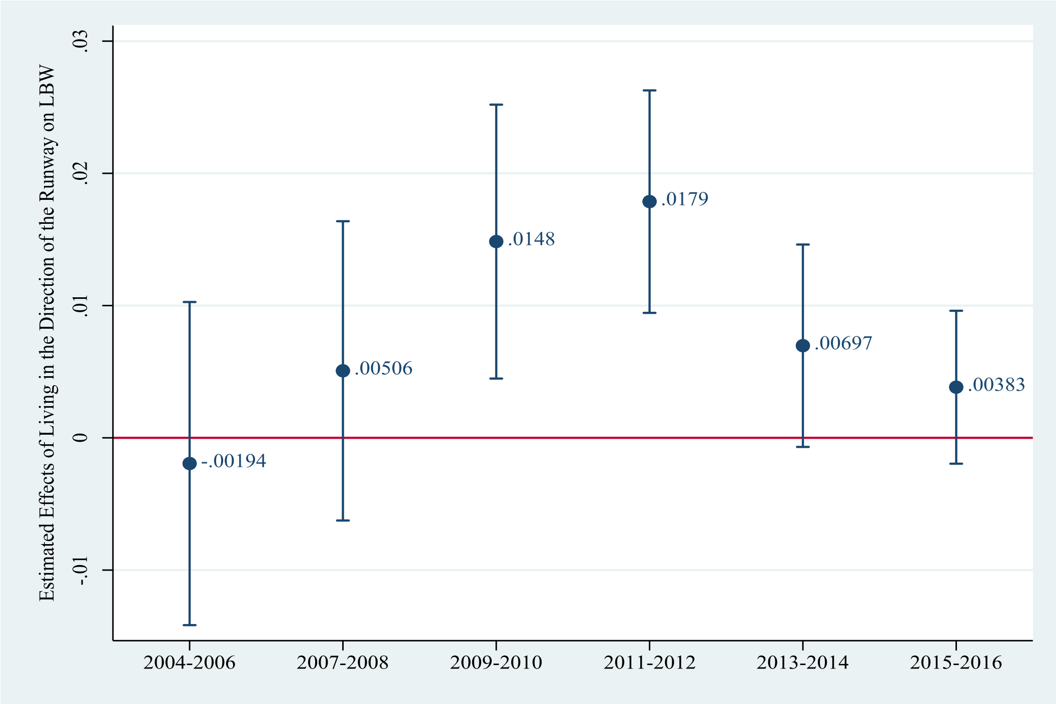

Fig. 6. Effects of Living in the Direction of the Runway on Low Birth Weight. Notes: The estimation sample includes live and singleton births that occurred between 2004 and 2016. The estimation is conducted by OLS and is based on the regression model described by equation (2) in the text, replacing the interaction term "d × post" with the following six interaction terms: "d × 1{2004 ≤ birth year ≤ 2006}", "d × 1{2007 ≤ birth year ≤ 2008}", "d × 1{2009 ≤ birth year ≤ 2010}", "d × 1{2011 ≤ birth year ≤ 2012}", "d × 1{2013 ≤ birth year ≤ 2014}" and "d × 1{2015 ≤ birth year ≤ 2016}", where 1{condition} is an indicator function, taking the value 1 (or 0) if the birth-year condition is true (or false). Reported in the "rope ladder" plots are the six point estimates and the associated 95% confidence intervals of the effects of living in the direction of the runway on low birth weight (LBW, birth weight < 2500 g). Control variables include the distance between mother's home and the mid-point of EWR runway 4L-22R; individual level demographic variables, including infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0); as well as the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors are clustered at the mother's residential zip code level. The number of observations in the estimation sample is 107,495.

Next, we conduct a test of the validity of the azimuth-based method, and the results are reported in column (3) of Table 6. Specifically, we estimate the effect of living in the direction of the runway but only for births to mothers living more than 20 miles away from the airport. In this case there should be little runway-induced variation in residential noise exposure, given the long distance between a home and the airport runway. If our azimuth-based method indeed captures runway-induced variation in residential noise exposure, then conditional on living far away from the airport, we would expect to find the coefficient on the indicator for "living in the direction of the runway (1/0)" to be statistically insignificant. Results reported in column (3) of Table 6 (Panels A and B) confirmed our expectation. Consistent with these results, the coefficient on the indicator for "living in the direction of the runway (1/0) × births occurred in 2011–2016 (1/0)" (Panel C) is also statistically insignificant.

In Table 7 we conduct two robustness checks. The first uses an estimation sample that includes only residents of three New Jersey counties—Essex, Union and Hudson—and no longer restricts the sample to be within 5 miles of the runway. Fig. 4 shows that EWR is located in both Essex and Union Counties, with its runways (4L-22R and 4R-22L, shown in Fig. 3) crossing the borderline of these two counties; Hudson County is immediately across from EWR, on the east side of Newark Bay. The estimation results based on residents of these three counties are reported in column (1) of Table 7, and the estimates are very similar to, only slightly smaller than those reported in column (2) of Table 6. This pattern is reasonable, given that in the three-county estimation sample there are some mothers living more than 5 miles away from the airport runway, who are possibly exposed to less aviation noise. If this is true, then including them in the estimation sample should make the estimate of the effect of residential noise exposure smaller.

In the second robustness check we use an estimation sample that includes only two New Jersey cities—Elizabeth and Newark, both of which are immediately next to the airport (shown in Fig. 4) and presumably heavily affected by the aviation noise. Results of this robustness check are reported in column (2) of Table 7: the estimates are extremely close to those reported in column (2) of Table 6, suggesting that the health effects detected in column (2) of Table 6 are driven mainly by aviation noise affecting those who live near the airport and in the direction of the runway.[41] We also emphasize that the robustness of the estimates reported

[41] In Appendix Table A4 we conduct a robustness check by dropping the middle two years of our sample period—2009 and 2010. In this robustness check we find the health impact to be greater (Panel B in contrast to Panel A), which is consistent with the gradual rollout of NextGen.

Table 7
Effects of living in the direction of the runway on low birth weight (robustness checks).

Outcome variable: low birth weight (birth weight < 2500 g) Estimation sample includes mothers living in:	Essex, Union and Hudson (i.e., three NJ counties) (1)	Elizabeth and Newark (i.e., two NJ cities) (2)
Panel A: Births occurred between 2004 and 2010		
Living in the direction of the runway (1/0)	0.00408***	0.00520***
	(0.00081)	(0.00094)
Distance between mother's home and the mid-point of EWR runway 4L-22R	−0.00081	−0.00326
(measured in miles)	(0.00121)	(0.00339)
Number of observations	165,902	41,267
Panel B: Births occurred between 2011 and 2016		
Living in the direction of the runway (1/0)	0.00876***	0.00960***
	(0.00274)	(0.00268)
Distance between mother's home and the mid-point of EWR runway 4L-22R	−0.00050	−0.00212
(measured in miles)	(0.00088)	(0.00130)
Number of observations	137,539	33,427
Panel C: Births ocurred between 2004 and 2016		
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	0.00470**	0.00468*
	(0.00230)	(0.00232)
Living in the direction of the runway (1/0)	0.00409***	0.00501***
	(0.00079)	(0.00075)
Distance between mother's home and the mid-point of EWR runway 4L-22R	−0.00066	−0.00260*
(measured in miles)	(0.00070)	(0.00147)
Number of observations	303,441	74,694
Other control variables used in Panels A, B and C		
Individual level demographic variables	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression. The estimations in Panel C are based on the regression model described by equation (2) in the text. The estimations in Panels A and B are based on the regression model described in equation (2) in the text dropping the interaction term. "Living in the direction of the runway (1/0)" is a dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

in column (2) of Table 6, in comparison with those reported in Table 7, is remarkable, in light of the sample size difference: in the first robustness check, the sample size used in column (1) of Table 7 is almost three times as large as the sample size in column (2) of Table 6; in the second robustness check, the sample size used in column (2) of Table 7 is about 30 percent smaller than the sample size used in column (2) of Table 6.

Next, in Table 8 we conduct a further robustness check by dropping individuals who live within 2 miles of the mid-point of runway 4L-22R.[42] We do so to evaluate the validity of the criteria for inclusion in the treatment zone (shown in Fig. 4). As previously discussed, in Table 1 we show that there is a statistically significant difference in the noise level between the treatment and control groups (by about 14–17 dB, with the average noise level in the treatment group being approximately equal to 63 dB). It is possible that individuals living next to the airport but not in the direction of runway 4L-22R (i.e., just outside the dragonfly-shaped zone) may actually experience high levels of aviation noise but are incorrectly excluded from the treatment group used by our estimation based on equation (2). In this case, we would under-estimate the effect of residential noise exposure. In Table 8 we drop those living close to the runway (specifically, within 2 miles of the mid-point of runway 4L-22R) from the estimation sample, since that is the group most likely to have an incorrect treatment-control group designation. These results, shown in Table 8, are very similar to results reported in Table 6 (column 2) and Table 7.[43]

[42] In our data the minimal distance between a mother's home and the mid-point of runway 4L-22R is 1.09 miles. Using a radius greater than that minimal distance is necessary, to ensure we obtain a substantially different sample for this robustness check.

[43] In Panel C of Table 8 the *p*-values associated with the DID estimates in columns (1) and (3) are 0.102 and 0.106, respectively, which we view as evidence suggesting the effect being marginally statistically significant. While the under-estimation aforementioned is conceivable, estimates reported in Table 8 are actually very similar to those reported in Table 6 (column 2) and Table 7. One explanation is that the observations we dropped could include: (i) those who were actually affected by aviation noise but incorrectly included in the control group (because of the use of that dragonfly-shaped zone); and (ii) those who were affected by the noise and also correctly included in the treatment group (i.e., inside the dragonfly-shaped zone). Dropping observations of case (i) should mitigate the under-estimation problem, but simultaneously dropping observations of case (ii) will exacerbate that under-estimation problem. Results in Table 8 suggest that aviation noise in the area that is 2 miles of the mid-point of runway 4L-22R could be evenly distributed. If this is indeed the case, then the use of that dragonfly-shaped zone will be ineffective in distinguishing between a treatment group and a control group. Despite this potential limitation in the use of that dragonfly-shaped zone, the robustness in the estimates shown in Table 8 (in comparison with those reported in column 2 of Tables 6 and 7) suggests that the "living in the direction of the runway (1/0)" indicator, constructed based on the dragonfly-shaped zone, is still valid in the sense of capturing excessive variation in noise that comes from the direction of, not the proximity to, the airport runway.

Table 8
Effects of living in the direction of the runway on low birth weight.

Outcome variable: low birth weight (birth weight < 2500 g) Estimation sample includes mothers:	whose homes are between 2 and 5 miles of the mid-point of EWR runway 4L-22R (1)	who live in Essex, Union and Hudson (i.e., three NJ counties) and whose homes are at least 2 miles away from the mid-point of EWR runway 4L-22R (2)	who live in Elizabeth and Newark (i.e., two NJ cities) and whose homes are at least 2 miles away from the mid-point of EWR runway 4L-22R (3)
Panel A: Births occurred between 2004 and 2010			
Living in the direction the runway (1/0)	0.00527***	0.00407***	0.00515***
	(0.00080)	(0.00082)	(0.00101)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00410	−0.00077	−0.00315
	(0.00313)	(0.00122)	(0.00365)
Number of observations	57,783	164,541	39,906
Panel B: Births occurred between 2011 and 2016			
Living in the direction of the runway (1/0)	0.00847***	0.00820***	0.00898***
	(0.00272)	(0.00281)	(0.00270)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00055	−0.00045	−0.00190
	(0.00276)	(0.00089)	(0.00138)
Number of observations	47,387	136,575	32,464
Panel C: Births ocurred between 2004 and 2016			
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	0.00399	0.00416*	0.00414
	(0.00239)	(0.00236)	(0.00240)
	[0.10194]	[0.08207]	[0.10603]
Living in the direction of the runway (1/0)	0.00490***	0.00408***	0.00495***
	(0.00075)	(0.00079)	(0.00078)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00242	−0.00061	−0.00242
	(0.00154)	(0.00071)	(0.00156)
Number of observations	105,170	301,116	72,370
Other control variables used in Panels A, B and C			
Individual level demographic variables	Yes	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression. The estimations in Panel C are based on the regression model described by equation (2) in the text. The estimations in Panels A and B are based on the regression model described in equation (2) in the text dropping the interaction term. "Living in the direction of the runway (1/0)" is a dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. Reported in [brackets] are p-values. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

6.4. DDD estimation results

Table 9 reports the DDD estimation results based on the regression model described by equation (3), aimed at capturing residential exposure to intermittent loud noise generated specifically by aircraft over the period (2011–2016) when NextGen was more actively implemented. We find that among those living within 10 miles of the airport runway, it is the combination of living within 5 degrees of the runway, during 2011–2016 and being exposed to aviation noise (measured in 2014 and measured by the 24-h equivalent continuous sound level) of at least 55 dB that appears to increase the LBW likelihood by 1.6 percentage points (column 1). As we explained in the regression models section, this effect, to some degree, represents the impact of residential exposure to intermittent loud noise coming from aircraft takeoffs and landings. This impact appears to be much smaller (about 0.5 percentage points) during 2004–2010, which is consistent with the gradual rollout of NextGen that continues to increase the noise in this corridor over time.

In contrast, among those living within 10 miles of the runway, living in the direction of the runway, during 2011–2016, but being exposed to noise levels (measured in 2014) that are lower than 55 dB is associated with a lower risk of LBW. This could be explained by the distance between a home and the runway being long enough (e.g., longer than 5 miles) to effectively reduce residential exposure to aviation noise, therefore reducing the risk of LBW.[44] We further confirm the robustness of the estimates reported in Table 9 by dropping those living within 2 miles of the runway (Table 10). This robustness check suggests that the

[44] In the sample only including mothers living within 5 miles of the airport runway, there is no mother living in the direction of the runway and also exposed to noise levels that are lower than 55 dB.

Table 9
Effects of living in the direction of the runway and exposure to high aviation noise on low birth weight, based on difference in differences in differences specification.

Outcome variable: low birth weight (birth weight < 2500 g)
The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is within 10 miles.
Birth occurred between 2004 and 2016.

	Full sample (1)	Male sample (2)	Female sample (3)
Living in the direction of the runway (1/0) × Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.01629***	0.02488***	0.01761
	(0.00491)	(0.00634)	(0.01188)
Living in the direction of the runway (1/0) × Aviation noise (measured in dB) ≥ 55 (1/0)	0.00531**	0.00296	0.00260
	(0.00261)	(0.00926)	(0.00826)
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	−0.01337***	−0.01535***	−0.02174***
	(0.00319)	(0.00571)	(0.00319)
Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.00176	0.00175	0.00550
	(0.00531)	(0.00450)	(0.00930)
Living in the direction of the runway (1/0)	−0.00085	0.00042	0.00443***
	(0.00197)	(0.00527)	(0.00168)
Aviation noise (measured in dB) ≥ 55 (1/0)	0.00480	0.00532	0.00314
	(0.00460)	(0.00602)	(0.00550)
Aviation noise (measured in dB, a continuous variable)	−0.00050*	−0.00051	−0.00056
	(0.00028)	(0.00043)	(0.00040)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00098	−0.00215	−0.00021
	(0.00089)	(0.00142)	(0.00134)
Number of observations	259,271	132,261	127,010
Other control variables			
Individual level demographic variables	Yes	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression based on equation (3) in the text. "Living in the direction of the runway (1/0)" is dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. Individual level demographic variables controlled for are infant being female (1/0) except columns (2) and (3), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

adverse health effects reported in Table 9 are not driven by those living immediately next to the runway, but are instead driven by those living relatively close to, and more importantly, in the direction of the runway, who are likely to experience high levels of aviation noise. As expected, in both Tables 9 and 10 we also find the effect of residential noise exposure on LBW appears to be more salient among male babies than among female babies. This finding is consistent with the "fragile male" hypothesis that male fetuses are more vulnerable than female fetuses to adverse environment shocks *in utero* (Eriksson et al., 2010).[45]

In Table 11 we examine the impact of residential noise exposure on another commonly studied adverse birth outcome—preterm birth, based on the same DDD model used in Tables 9 and 10. Similar to the results reported in Tables 9 and 10, we find the estimates to be robust when individuals living within 2 miles of the airport runway are excluded from the estimation sample.[46] Results in Table 11 suggest an increased risk of having a preterm birth (by about 3 percentage points, column 1) and the impact appears to be salient among male babies (column 2) but not among female babies (column 3), for those living in the direction of the runway, during 2011–2016 and exposed to aviation noise (measured in 2014) of at least 55 dB.[47]

6.5. Dealing with the air pollution confounder

Lastly, in Fig. 7 we examine the daily air pollution variation for two monitors, both located in the region covered by our estimation sample but exposed to significantly different noise levels: one monitor is located in the treatment group area, and the other is located in the control group area. We examine three specific air pollutants, which are available from the EPA's air quality monitoring network—carbon monoxide (CO), nitrogen dioxide (NO_2), and particulate matter that is smaller than 2.5 μm ($PM_{2.5}$). According to Schlenker and Walker (2016), high power operations of aircraft, such as takeoff, produce more NO_2 emissions, while low power operations, such as taxiing, produce more CO emissions. Their study finds that it is CO, not

[45] In Appendix Table A5 we repeated the estimations done in column 1 of Tables 9 and 10 but replacing the aviation noise variable with the total noise (including aviation and road noise) variable, and we obtained similar results.

[46] In Appendix Table A6 we repeated the estimations done in column 1 of Table 11 but replacing the aviation noise variable with the total noise (including aviation and road noise) variable, and we obtained similar results.

[47] Furthermore, we find that adverse outcomes also include shortened gestational length and an increased risk of fetal macrosomia (i.e., birth weight > 4000 g), which is also reflected in an increase of average birth weight. These additional estimates are available upon request.

Table 10
Effects of living in the direction of the runway and exposure to high aviation noise on low birth weight, based on difference in differences in differences specification.

Outcome variable: low birth weight (birth weight < 2500 g) The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is between 2 and 10 miles. Birth occurred between 2004 and 2016.	Full sample (1)	Male sample (2)	Female sample (3)
Living in the direction of the runway (1/0) × Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.01659*** (0.00477)	0.02453*** (0.00640)	0.01829 (0.01192)
Living in the direction of the runway (1/0) × Aviation noise (measured in dB) ≥ 55 (1/0)	0.00485* (0.00246)	0.00234 (0.00917)	0.00235 (0.00820)
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	−0.01345*** (0.00315)	−0.01541*** (0.00571)	−0.02181*** (0.00313)
Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	−0.00033 (0.00569)	0.00032 (0.00446)	0.00371 (0.01049)
Living in the direction of the runway (1/0)	−0.00064 (0.00199)	0.00084 (0.00526)	0.00451*** (0.00170)
Aviation noise (measured in dB) ≥ 55 (1/0)	0.00603 (0.00375)	0.00692 (0.00547)	0.00384 (0.00521)
Aviation noise (measured in dB, a continuous variable)	−0.00054* (0.00028)	−0.00058 (0.00042)	−0.00057 (0.00040)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00091 (0.00090)	−0.00190 (0.00143)	−0.00028 (0.00136)
Number of observations	256,946	131,087	125,859
Other control variables			
Individual level demographic variables	Yes	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression based on equation (3) in the text. "Living in the direction of the runway (1/0)" is dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. Individual level demographic variables controlled for are infant being female (1/0) except columns (2) and (3), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

NO_2, that affects the health of residents living within 10 km (i.e., 6.2 miles) of the airports in California, with one caveat: "One potential omitted variable that we unfortunately cannot measure well is particulate matter, a pollutant which may emerge from combustion emissions and has been shown in the past to increase infant mortality due to respiratory causes" (p. 800). In Panel A of Fig. 7 we plot the daily variation, measured in 2014 (the same year of the noise data) for each of the three air pollutants—CO, NO_2 and $PM_{2.5}$—by each monitor. Overall, we do not find any noticeable difference in the daily variation of each of the three air pollutants between the two monitors, except that CO levels measured at the monitor located in the treatment group were higher than those measured at the monitor located in the control group during the summer (July, August and September) of 2014. However, this pattern seems to be transitory and specifically for the summer of 2014: we do not find this pattern in Panel B of Fig. 7, where we plot the daily variation of each of the three air pollutants measured in 2015. Overall, results in Fig. 7 suggest that air pollutant concentrations, although likely to vary significantly *at* airport runways (due to plane takeoffs and landings), could be evenly distributed within a small area relatively close to the runways. The even distribution of air pollutant concentrations in a small area with sharply different noise levels allows us to disentangle the effect of noise from the effect of air pollution.

7. Conclusion

In this study we find that among all births that occurred between 2004 and 2016, there is an increase of 1.6 percentage points in the likelihood of having a LBW baby among mothers living close to the airport, in the direction of the runway, exposed to noise levels over the 55 dB threshold, and during the period when NextGen was more actively implemented at the airport. To identify this causal effect of noise exposure on health, we utilize two sources of plausibly exogenous variation in noise exposure. The first one is based on a possible randomization in the exact residential location relative to the airport runway direction, conditional on living close to the airport. The second one comes from the implementation of NextGen. For the latter, our study has important implications regarding the unintended consequence of the FAA policy on fetal health. Although the immediate impact is on fetal health, this can have far-reaching impacts on adult health. Attention to this unintended consequence is especially important in

Table 11
Effects of living in the direction of the runway and exposure to high aviation noise on preterm births, based on difference in differences in differences specification.

Estimation sample includes births that occurred between 2011 and 2016. Preterm birth (1/0): gestational length < 37 weeks, among singleton births	Full sample (1)	Male sample (2)	Female sample (3)
Panel A: The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is within 10 miles.			
Living in the direction of the runway (1/0) × Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.03044**	0.03014**	0.03474
	(0.01464)	(0.01346)	(0.02146)
Living in the direction of the runway (1/0) × Aviation and road noise (measured in dB) ≥ 55 (1/0)	−0.01864**	−0.01404	−0.01911
	(0.00865)	(0.01524)	(0.01484)
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	−0.02130***	−0.01042	−0.03662***
	(0.00770)	(0.01236)	(0.00677)
Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.01079	0.00725	0.01456
	(0.00657)	(0.00785)	(0.01087)
Living in the direction of the runway (1/0)	0.01848***	0.01301	0.02149***
	(0.00673)	(0.01201)	(0.00366)
Aviation and road noise (measured in dB) ≥ 55 (1/0)	0.00281	0.00162	0.00734
	(0.00315)	(0.00633)	(0.00878)
Aviation and road noise (measured in dB, a continuous variable)	−0.00047	−0.00060	−0.00032
	(0.00033)	(0.00052)	(0.00032)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00095	−0.00226	0.00012
	(0.00134)	(0.00191)	(0.00187)
Number of observations	259,271	132,261	127,010
Panel B: The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is between 2 and 10 miles.			
Living in the direction of the runway (1/0) × Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.03009**	0.02925**	0.03483
	(0.01470)	(0.01359)	(0.02152)
Living in the direction of the runway (1/0) × Aviation and road noise (measured in dB) ≥ 55 (1/0)	−0.01890**	−0.01413	−0.01966
	(0.00865)	(0.01514)	(0.01470)
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	−0.02135***	−0.01045	−0.03667***
	(0.00771)	(0.01237)	(0.00676)
Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.01046	0.00715	0.01444
	(0.00690)	(0.00799)	(0.01107)
Living in the direction of the runway (1/0)	0.01862***	0.01331	0.02159***
	(0.00674)	(0.01199)	(0.00366)
Aviation and road noise (measured in dB) ≥ 55 (1/0)	0.00339	0.00186	0.00857
	(0.00308)	(0.00637)	(0.00811)
Aviation and road noise (measured in dB, a continuous variable)	−0.00049	−0.00067	−0.00032
	(0.00033)	(0.00051)	(0.00032)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00088	−0.00204	0.00006
	(0.00135)	(0.00194)	(0.00190)
Number of observations	256,946	131,087	125,859
Other control variables used in Panels A and B			
Individual level demographic variables	Yes	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression based on equation (3) in the text. "Living in the direction of the runway (1/0)" is dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. Individual level demographic variables controlled for are infant being female (1/0) except columns (2) and (3), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

light of the many efficiency benefits attributed to NextGen.[48] In this sense, our results are aligned with a recent study by Zafari et al. (2018), who explicitly model the trade-off between NextGen's flight path optimization and potential adverse health impacts from noise, and they find that benefits in terms of increased fuel efficiency and reduced flight time may be offset by unintended adverse effects on health in terms of reduced quality-adjusted life years (QALYs). Our study broadens the scope of that finding by taking into account compromised fetal health.

[48] For example: "The FAA estimates that NextGen's implemented improvements have accrued $4.7 billion worth of benefits from 2010 to 2017, which consists of $2.6 billion in decreased passenger travel time, $1.8 billion in lower aircraft operating expenses, and $300 million in safety benefits" (source: https://www.faa.gov/nextgen/faqs/, accessed on May 16, 2019). Schlenker and Walker (2016), in the examination of daily pollution exposure caused by idiosyncratic air traffic congestion that results in excessive aircraft idling and taxiing time for individuals living within 10 km (i.e., 6.2 miles) of the airports, find that increased exposure in daily air pollution levels increases hospitalization for respiratory and heart-related conditions. Their results suggest that policies that improve airport efficiency for companies and passengers can have positive health externalities to nearby residents.

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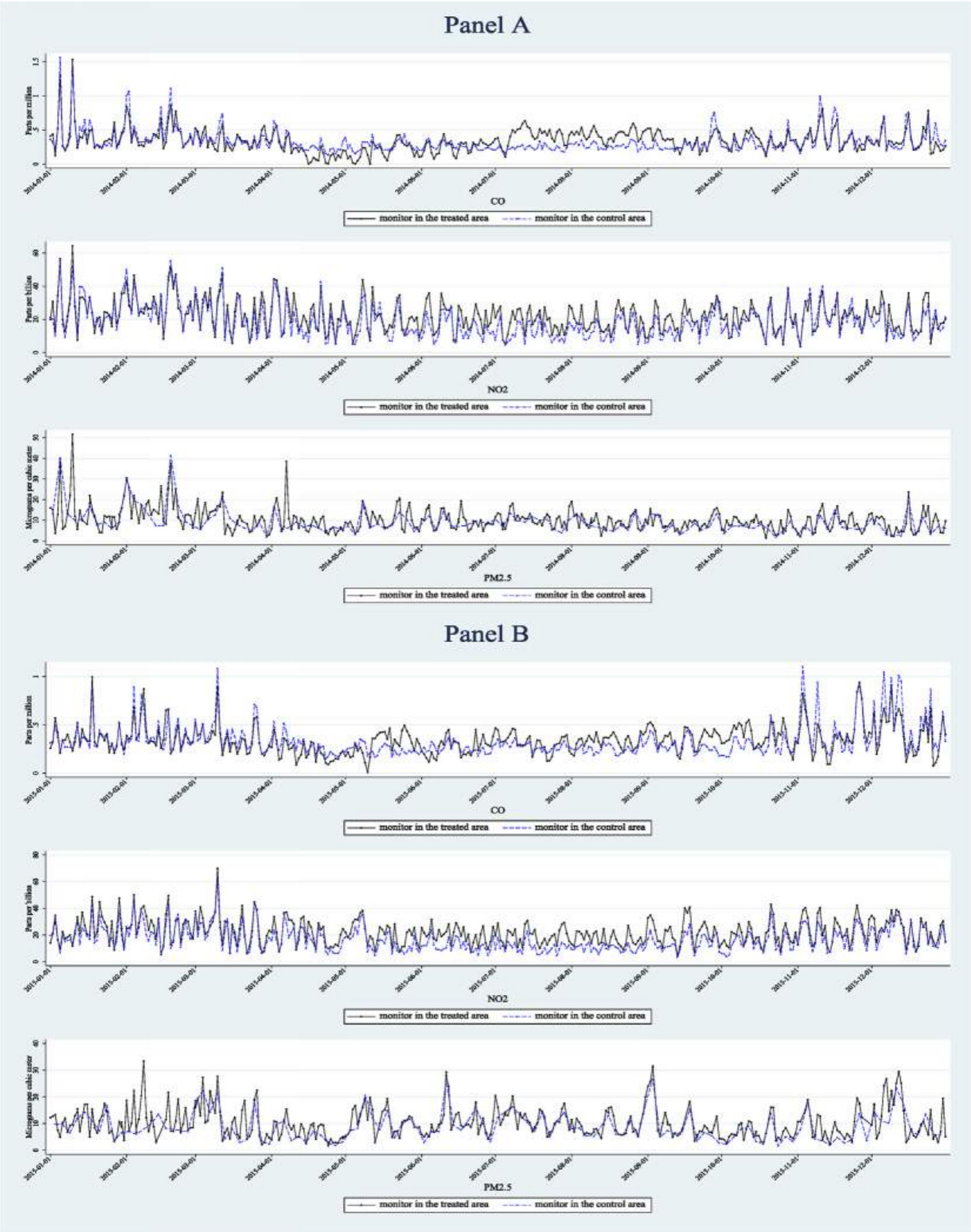

Fig. 7. Carbon Monoxide (CO), Nitrogen Dioxide (NO2) and Fine Particulate Matter (PM2.5) near the Newark Liberty International Airport (EWR). Notes: Data are from the EPA's AQS Data Mart available at https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors. Depicted are the CO readings averaged over every 1-h period each day, NO2 readings averaged over every 1-h period each day, and PM2.5 readings averaged over every 24-h period each day. Panel A shows the air pollutant monitors' daily readings throughout the entire year of 2014. Panel B shows the air pollutant monitors' daily readings throughout the entire year of 2015. The "treated" area is the one located within 5 miles and also within 5 degrees of the mid-point of EWR runway 4L-22R. The "control" area is the one located within 5 miles but outside 5 degrees of the mid-point of EWR runway 4L-22R.

Cost-effectiveness calculations using research on the health effects of airport noise were the focus of Zafari et al. (2018) in evaluating the full-time expansion of a change in flight routes that concentrated flights over densely populated areas near LaGuardia Airport (in New York City) as part of the NextGen implementation. Using the results of analyses focused on health and airport noise, Zafari et al. (2018) quantify the health impact of increased noise exposure against the transportation efficiencies in terms of operating expenses and passenger time and productivity. Using only research on health costs related to increased anxiety (Hardoy et al., 2005) and risks associated with increased cardiovascular diseases (Hansell et al., 2013), their calculations suggest that eliminating the flight consolidation under the LaGuardia flight modification would result in improved QALYs at a cost of $10,006/QALY. Interventions deemed to be cost-effective are generally evaluated against a cost of $50,000/QALY, suggesting that eliminating these flight consolidations is a low-cost, health-improving option. They note that their calculation does not include the plausibly larger effects of noise on children's health (Zafari et al., 2018). Given that their calculation did not include any impact of aviation noise on LBW and preterm births, the inclusion of the results of our study in this calculation would potentially provide a lower cost/QALY estimate and further indication of the cost-effectiveness of revamping the NextGen's flight path consolidation program, especially for high-volume airports experiencing concentrated high aviation noise.

Appendix A

Appendix Table A1
Effects of Noise Exposure on Low Birth Weight.

Outcome variable: low birth weight (birth weight < 2500 g)	
Panel A: Births occurred between 2004 and 2016	
Aviation noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.00698*
	(0.00376)
Aviation noise (measured in dB) ≥ 55 (1/0)	0.00555
	(0.00569)
Aviation noise (measured in dB, a continuous variable)	−0.00053
	(0.00033)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00282
	(0.00178)
Number of observations	107,410
Panel B: Births occurred in 2004–2008 and 2011–2016. T = 1 for births that occurred in 2011–2016; T = 0 for births that occurred in 2004–2008	
Aviation noise (measured in dB) ≥ 55 (1/0) × T (1/0)	0.00716**
	(0.00296)
Aviation noise (measured in dB) ≥ 55 (1/0)	0.00831
	(0.00676)
Aviation noise (measured in dB, a continuous variable)	−0.00087**
	(0.00035)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00391**
	(0.00158)
Number of observations	90,868
Other control variables used in Panels A and B	
Individual level demographic variables	Yes
Zip code-year-month fixed effects	Yes

Notes: The estimation sample includes live and singleton births of mothers who live within 5 miles of the mid-point of EWR runway 4L-22R. The estimation is based on the regression model described by equation (1) in the text. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

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Appendix Table A2
Effects of Living in the Direction of the Runway on Low Birth Weight.

Outcome variable: low birth weight (birth weight < 2500 g) The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is:	Within 5 miles	Within 5 miles	Outside 20 miles
	(1)	(2)	(3)
Panel A: Births ocurred between 2004 and 2016			
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	0.00409*	0.00454*	0.00362
	(0.00222)	(0.00231)	(0.00433)
Living in the direction of the runway (1/0)	0.00459***	0.00495***	−0.00423
	(0.00142)	(0.00073)	(0.00411)
Distance between mother's home and the mid-point of EWR runway 4L-22R	−0.00068	−0.00261*	0.00005
(measured in miles)	(0.00406)	(0.00150)	(0.00028)
Number of observations	107,495	107,495	595,531
Panel B: Births occurred in 2004–2008 and 2011–2016. T = 1 for births that occurred in 2011–2016; T = 0 for births that occurred in 2004–2008			
Living in the direction of the runway (1/0) × T (1/0)	0.00844**	0.00860**	0.00641
	(0.00358)	(0.00358)	(0.00479)
Living in the direction of the runway (1/0)	0.00037	0.00107	−0.00698
	(0.00301)	(0.00127)	(0.00522)
Distance between mother's home and the mid-point of EWR runway 4L-22R	−0.00123	−0.00323**	0.00007
(measured in miles)	(0.00418)	(0.00132)	(0.00031)
Number of observations	90,950	90,950	509,116
Other control variables used in Panels A and B			
Individual level demographic variables	No	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression based on equation (2) in the text. "Living in the direction of the runway (1/0)" is a dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

Appendix Table A3
Effects of Living in the Direction of the Runway on Low Birth Weight (Full Results for Table 6 Panel C and Column 2).

Outcome variable: low birth weight (birth weight < 2500 g) The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is:	Within 5 miles
Births ocurred between 2004 and 2016	
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	0.00454*
	(0.00231)
Living in the direction of the runway (1/0)	0.00495***
	(0.00073)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00261*
	(0.00150)
Female baby (1/0)	0.01165***
	(0.00189)
Mother's age	0.00146***
	(0.00025)
Mother is White (1/0)	−0.01676***
	(0.00372)
Mother is Black (1/0)	0.00503**
	(0.00222)
Mother is Hispanic (1/0)	−0.01019***
	(0.00252)
Mother having completed a four-year college or higher (1/0)	−0.00541**
	(0.00255)
Mother is married (1/0)	−0.01145***
	(0.00165)
Number of prenatal visits	−0.00941***
	(0.00047)
Mother smoked cigarettes before or during her pregnancy (1/0)	0.04789***
	(0.00309)
Zip code-year-month fixed effects	Yes
Number of observations	107,495

Notes: The estimation sample includes live and singleton births. The estimation is based on the regression model described by equation (2) in the text. "Living in the direction of the runway (1/0)" is a dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

Appendix Table A4
Effects of Living in the Direction of the Runway on Low Birth Weight (Robustness Checks).

Outcome variable: low birth weight (birth weight < 2500 g) Estimation sample includes mothers living in:	Essex, Union and Hudson (i.e., three NJ counties) (1)	Elizabeth and Newark (i.e., two NJ cities) (2)
Panel A: Births ocurred between 2004 and 2016		
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	0.00470**	0.00468*
	(0.00230)	(0.00232)
Living in the direction of the runway (1/0)	0.00409***	0.00501***
	(0.00079)	(0.00075)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00066	−0.00260*
	(0.00070)	(0.00147)
Number of observations	303,441	74,694
Panel B: Births occurred in 2004–2008 and 2011–2016. T = 1 for births that occurred in 2011–2016; T = 0 for births that occurred in 2004–2008		
Living in the direction of the runway (1/0) × T (1/0)	0.00857**	0.00876**
	(0.00355)	(0.00363)
Living in the direction of the runway (1/0)	0.00024	0.00098
	(0.00132)	(0.00127)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00069	−0.00277*
	(0.00070)	(0.00144)
Number of observations	257,323	63,189
Other control variables used in Panels A and B		
Individual level demographic variables	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression based on equation (2) in the text. "Living in the direction of the runway (1/0)" is a dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

Appendix Table A5
Effects of Living in the Direction of the Runway and Exposure to High Aviation and Road Noise on Low Birth Weight, Based on Difference in Differences in Differences Specification.

Outcome variable: low birth weight (birth weight < 2500 g) among singleton births Birth occurred between 2004 and 2016. The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is:	within 10 miles (1)	between 2 and 10 miles (2)
Living in the direction of the runway (1/0) × Aviation and road noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.01747***	0.01708***
	(0.00567)	(0.00567)
Living in the direction of the runway (1/0) × Aviation and road noise (measured in dB) ≥ 55 (1/0)	0.00436	0.00418
	(0.00271)	(0.00271)
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	−0.01384***	−0.01388***
	(0.00429)	(0.00428)
Aviation and road noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.00018	−0.00013
	(0.00360)	(0.00361)
Living in the direction of the runway (1/0)	−0.00078	−0.00068
	(0.00236)	(0.00237)
Aviation and road noise (measured in dB) ≥ 55 (1/0)	−0.00332	−0.00290
	(0.00292)	(0.00286)
Aviation and road noise (measured in dB, a continuous variable)	0.00002	0.00001
	(0.00015)	(0.00015)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00081	−0.00074
	(0.00096)	(0.00097)
Number of observations	261,232	258,907
Other control variables		
Individual level demographic variables	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression based on equation (3) in the text. "Living in the direction of the runway (1/0)" is dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. Individual level demographic variables controlled for are infant being female (1/0) except columns (2) and (3), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

Appendix Table A6
Effects of Living in the Direction of the Runway and Exposure to High Aviation and Road Noise on Preterm Births, Based on Difference in Differences in Differences Specification.

Outcome variable: preterm births (gestational length < 37 weeks) among singleton births Birth occurred between 2004 and 2016. The distance between mother's home and the mid-point of EWR runway 4L-22R in the estimation sample is:	within 10 miles (1)	between 2 and 10 miles (2)
Living in the direction of the runway (1/0) × Aviation and road noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.03459*** (0.01167)	0.03415*** (0.01167)
Living in the direction of the runway (1/0) × Aviation and road noise (measured in dB) ≥ 55 (1/0)	−0.01738*** (0.00650)	−0.01751*** (0.00651)
Living in the direction of the runway (1/0) × Births occurred in 2011–2016 (1/0)	−0.02276*** (0.00757)	−0.02281*** (0.00758)
Aviation and road noise (measured in dB) ≥ 55 (1/0) × Births occurred in 2011–2016 (1/0)	0.00503 (0.00349)	0.00498 (0.00354)
Living in the direction of the runway (1/0)	0.01713*** (0.00557)	0.01721*** (0.00558)
Aviation and road noise (measured in dB) ≥ 55 (1/0)	−0.00344 (0.00329)	−0.00322 (0.00332)
Aviation and road noise (measured in dB, a continuous variable)	−0.00012 (0.00012)	−0.00013 (0.00012)
Distance between mother's home and the mid-point of EWR runway 4L-22R (measured in miles)	−0.00091 (0.00133)	−0.00085 (0.00134)
Number of observations	261,232	258,907
Other control variables		
Individual level demographic variables	Yes	Yes
Zip code-year-month fixed effects	Yes	Yes

Notes: The estimation sample includes live and singleton births. Each column is a separate OLS regression based on equation (3) in the text. "Living in the direction of the runway (1/0)" is dummy variable, which is equal to one for mothers living within 5 degrees of the mid-point of EWR runway 4L-22R and equal to zero otherwise. The data on noise are from the U.S. Department of Transportation. The variables on noise are measured in decibels (dB) for each mother's residential address and for year 2014. Individual level demographic variables controlled for are infant being female (1/0) except columns (2) and (3), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), the number of prenatal visits, and maternal smoking (1/0). The zip code-year-month fixed effects are the fixed effects applied to each mother's residential zip code-year-month of birth pair. Standard errors (reported in parentheses) are clustered at the mother's residential zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

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Lehigh News

Muzhe Yang and his coauthors examine the unintended consequences of an air traffic modernization project on babies' birth weight.

Muzhe Yang: How Airplane Noise Affects Fetal Health

Yang examines the unintended consequences of an air traffic modernization project on babies' birth weight.

Prolonged exposure to loud noise is more than annoying—it is bad for human health. In addition to the obvious potential damage to hearing, chronic noise exposure has been linked to adverse cardiovascular effects, such as increased heart attack risks.

Now, for the first time, researchers have provided a causal estimate linking high-level noise exposure to another key health challenge: low birth weight(< 2,500 grams or approximately 5.5 pounds).

Health economists from Lehigh, Lafayette College and the University of Colorado, Denver were able to pinpoint a causal link by studying residential neighborhoods impacted by changes in airplane flight patterns in and out of Newark Liberty International Airport, one of the largest U.S. airports.

Muzhe Yang, who holds the Francis J. Ingrassia '75 and Elizabeth McCaul Endowed Professorship in Lehigh's Department of Economics, and his coauthors used unique birth records from 2004 to 2016

Lehigh's Department of Economics, and his coauthors used unique birth records from 2004 to 2016 containing information on mothers' home addresses and National Transportation noise data providing measured noise levels at exact locations. Their analysis revealed an increase of 1.24 percentage points—or 17 percent—in the risk of having a low birth weight baby among mothers living close to the airport and in the direction of the runway. This is compared with the rate of low birth weight among singleton births, which is 7.3 percent.

The effect increases to approximately 2 percentage points—or 27 percent—among births that occurred from 2011 to 2016, when the flight pattern changes were being implemented at the Newark airport.

The team presented its findings at the Eighth Conference of the American Society of Health Economists in Washington, D.C., and the 13th World Congress of the International Health Economics Association in Basel, Switzerland.

"Our findings have important policy implications regarding the trade-off between flight pattern optimization and human health," says Yang. "This is especially important given the long-term negative impact of low birth weight on a range of later-life outcomes such as lifetime earnings, educational achievement and long-term health."

Unintended Consequences

The changes in flight patterns around the Newark airport, as well as many airports in the United States, were triggered by a Federal Aviation Administration (FAA) air traffic control initiative called Next Generation Air Transportation System, or NextGen. Designed to reduce flight time and save fuel, one component of NextGen employs precision satellite monitoring instead of old-fashioned radar to guide airplanes. The satellite-designed optimum routes are made to be more direct. The satellite monitoring allows for more planes in the air, safely spaced and flying closer together, so more planes can use the same route.

Usage of these new routes by more and more aircraft and the adoption of a gradual descent approach—resulting in planes coming in to land at lower altitudes—have exposed residents living in areas under the satellite-designed routes to, as one resident impacted by changes in Arizona told CBS News, "a constant barrage of airplanes flying over their homes."

NextGen provided the researchers with a rare circumstance to study the causal effect of noise pollution on birth weight, in which noise exposure is close to being randomly assigned because residents were caught off-guard. The implementation of NextGen by the FAA was exempted by the U.S. Congress from normal environmental impact reviews and public hearings. The randomness and the sharp change in noise exposure are important to ensure that the estimated effect of noise pollution on birth weight is not confounded by other factors that are related to both noise pollution and fetal health, such as air pollution. This study focuses on mothers living close to the airport, where air pollution is likely to be evenly distributed while sharp changes in noise pollution exist.

"The National Transportation noise data provided a map that revealed sharp changes in noise exposure in areas near the airport," says Yang. "We find that NextGen indeed created a narrow band around the runways, which is a noise pollution hotspot. We argue that conditional on those who already live close to the airport, the redistribution of aviation noise, due to NextGen, occurred in a way that is outside of the residents' control."

To the extent that there is residential sorting based on the distance to the airport but not based on the runway layout, and given the unexpected changes NextGen brought to the public, the team argues that, by controlling for the distance between a mother's home and the airport runway, whether or not the mother lives inside the band, the noise distribution becomes random.

“We hope our study helps people recognize the adverse effect of noise exposure on fetal health,” says Yang, “as well as the urgency of finding solutions to the problem of excessive noise endured by communities overflown by aircraft using satellite-designed optimum routes.”
Why It Matters: The findings about noise exposure and its connection to low birth weight have policy implications regarding the trade-off between airplane flight pattern optimization and human health.

Photo by Vincensius Soetedja/Getty

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Noise annoyance predicts symptoms of depression, anxiety and sleep disturbance 5 years later. Findings from the Gutenberg Health Study

Manfred E. Beutel[1], Elmar Brähler[1], Mareike Ernst [1], Eva Klein[1], Iris Reiner[1], Jörg Wiltink[1], Matthias Michal[1,2], Philipp S. Wild[2,3,4], Andreas Schulz[3], Thomas Münzel[2,5], Omar Hahad[5], Jochem König[6], Karl J. Lackner[7], Norbert Pfeiffer[8], Ana N. Tibubos[1]

1 Department of Psychosomatic Medicine and Psychotherapy, University Medical Center of the Johannes Gutenberg-University Mainz, Mainz, Germany
2 DZHK (German Center for Cardiovascular Research), partner site Rhine-Main, Mainz, Germany
3 Preventive Cardiology and Preventive Medicine, Center for Cardiology, University Medical Center of the Johannes Gutenberg-University Mainz, Mainz, Germany
4 Center for Thrombosis and Hemostasis, University Medical Center of the Johannes Gutenberg-University Mainz, Mainz, Germany
5 Center for Cardiology - Cardiology I, University Medical Center of the Johannes Gutenberg-University Mainz, Mainz, Germany
6 Institute for Medical Biostatistics, Epidemiology and Informatics, University Medical Center Mainz, Mainz, Germany
7 Institute of Clinical Chemistry and Laboratory Medicine, University Medical Center of the Johannes Gutenberg-University Mainz, Mainz, Germany
8 Department of Ophthalmology, University Medical Center of the Johannes Gutenberg-University Mainz, Mainz, Germany

Correspondence: Manfred E. Beutel, Department of Psychosomatic Medicine and Psychotherapy, University Medical Center of the Johannes Gutenberg-University Mainz, Untere Zahlbacher Str. 8, 55131 Mainz, Germany, Tel: +49 6131 17 2841, Fax: +49 6131 17 6688, e-mail: manfred.beutel@unimedizin-mainz.de

Background: Cross-sectional studies have shown that noise annoyance is strongly associated with mental distress, however, its long-term effects on mental health is unknown. We therefore investigated whether noise annoyance predicts depression, anxiety and sleep disturbance in a large, representative sample 5 years later. **Methods:** We investigated longitudinal data of $N = 11\,905$ participants of the Gutenberg Health Study, a population-based, prospective, single-centre cohort study in mid-Germany (age at baseline 35–74 years). Noise annoyance was assessed at baseline and 5-year follow-up (sources: road traffic, aircraft, railways, industrial, neighbourhood indoor and outdoor noise; and day vs. nighttime). Depression, anxiety and sleep disturbance were assessed using the Patient Health Questionnaire-9 and Generalized Anxiety Disorder-2. Participants suffering from depression, anxiety or sleep disturbance at baseline were excluded from the respective multivariate analyses of new onset at follow-up. **Results:** General noise annoyance remained stable. Daytime noise annoyance predicted new onset of depressive, anxiety symptoms (also nighttime annoyance) and sleep disturbance (beyond respective baseline scores). Additional predictors were female sex, lower age and low socioeconomic status (SES). Regarding specific sources, daytime baseline aircraft annoyance predicted depression and anxiety. Sleep disturbance was most consistently predicted by neighbourhood annoyance (baseline and follow-up) and follow-up annoyance by aircraft (night) and road traffic (day and night). **Conclusions:** We identified current and past noise annoyances as risk factors for mental distress and sleep disturbance. Furthermore, women, younger adults and those with lower SES are particularly susceptible to noise annoyance. Our results indicate the need to provide regulatory measures in affected areas to prevent mental health problems.

Introduction

Noise has been commonly defined as unwanted sounds of different intensities. Noise annoyance is the main indicator of adverse subjective reactions to environmental noise.[1,2] Interfering with daily activities, feelings, thoughts, sleep or rest, noise annoyance is accompanied by negative emotional responses, such as irritability, distress, exhaustion and cognitive appraisals such as lack of control over the exposure to noise.[3,4] Based on a national health interview survey of $N = 19\,294$ adults, the cross-sectional German Health Update study found that men and women who reported high overall noise annoyance had more than 2-fold odds of impaired mental health than those who were not annoyed.[5] In a recent Swiss study, long-term annoyance by transportation noise (aircraft, road, railways) was associated with a decrease of physical activity.[6] In a large community sample we recently found that rates of depression and anxiety were about twice as high in participants with extreme vs. no noise annoyance by different sources of noise; aircraft noise, however, was the most prevalent source of annoyance.[3] Reported high annoyance due to aircraft noise was also found to be associated with mental and physical symptoms and an increased use of psychotropic drugs,[7] general practice and outpatient services,[8] and reduced quality of life.[9] In Europe, sleep disturbance has been regarded the leading adverse non-auditory consequence of exposure to noises.[10] In a recent Japanese study,[11] sensitivity to turbine noise and visual annoyance contributed to insomnia in addition to noise exposure. In this study, noise annoyance, but not noise exposure, was related to a high level of health complaints. In the Danish Health and Morbidity

Surveys participants who were very annoyed by noises from neighbours reported considerably poorer health and more stress.[12]

To date, studies on the association of noise annoyance and mental health are scarce and limited to cross-sectional designs. While annoyance is related to the objective measurement of noise, individual factors such as noise sensitivity or lifestyle factors such as working schedules may also affect individuals' reactivity to different sources of noise.[13] Thus, cross-sectional studies on associations between mental health and noise annoyance do not differentiate whether noise annoyance induces or amplifies mental health problems, or rather whether mental health problems increase noise sensitivity and, thereby, noise annoyance as well. Indeed, in a review van Kamp and Davies[13] concluded that mental disorders constitute a risk for heightened noise sensitivity (along with chronic somatic illness, tinnitus and shift work) and related adverse health effects. We therefore aimed to determine whether noise annoyance can also predict future mental distress and sleep disturbance. We analysed the 5-year follow-up measurement point of a large community sample from the German city of Mainz and the county of Mainz-Bingen, which has been increasingly affected by the expansion of the Frankfurt Rhine-Main airport, compounded by road and railway noise.[14] Main outcomes were depression and anxiety, the most prevalent symptoms of mental disorders in the community, and sleep disturbances as the most prevalent adverse health effect of noise. We compared levels of noise annoyance at baseline and at a 5-year follow-up. We determined whether noise annoyance from different sources at baseline predicted follow-up depression, anxiety and sleep disturbance beyond the current levels of annoyance (while also adjusting for sociodemographic characteristics and shift work).

Methods

Procedure and study sample

As described in Wild *et al.*[15] and Hohn *et al.*,[16] the Gutenberg Health Study is a population-based, prospective, observational single-centre cohort study in the Rhine-Main region, Germany. Its primary aim is to analyse and improve cardiovascular risk factors and their stratification. The study protocol and documents were approved by the ethics committee of the Medical Chamber of Rhineland-Palatinate and the local data safety commissioner. All study investigations were conducted in line with the Declaration of Helsinki and principles outlined in recommendations for Good Clinical Practice and Good Epidemiological Practice. Participants were included after informed consent. The sample was drawn randomly from the local registry in the city of Mainz and the district of Mainz-Bingen, stratified 1:1 for sex and residence and in equal strata for decades of age. Inclusion criterion was age 35–74 years. Insufficient knowledge of German language, psychological or physical impairment hindering participation in the study led to exclusion.

At baseline, 15 010 participants were examined between 2007 and 2012. Of those, 14 732 (98.1%) filled out the Patient Health Questionnaire (PHQ)-9.[17] A total of 12 422 took part in the follow-up (82.8%). Of those, $N = 11\,905$ filled out the noise annoyance items on both occasions. Case numbers were further reduced by exclusion of individuals with depressive, anxiety, respectively, sleep disturbance symptoms at baseline (leaving, e.g. 9842 participants for the analysis of new onset of depression).

Materials and assessment

The 5-h baseline-examination in the study centre consisted of an assessment of prevalent classical cardiovascular risk factors and clinical variables (somatic and psychological), a computer-assisted personal interview, laboratory examinations from venous blood samples, blood pressure and anthropometric measurements. All examinations were performed according to standard operating procedures by certified medical technical assistants.

Measures

Sociodemographic variables and psychological measures were assessed via self-report: sex, age in years, employment (yes/no), income, living with a partner (yes/no) and socioeconomic status (SES). SES was defined according to Lampert *et al.*[18] from 3 (lowest SES) to 21 (highest SES) based on education, profession and income. Participants were also asked if they performed night shift work (no/yes), defined as working hours between 11 p.m. and 5 a.m.[19]

Depressive symptoms were assessed with the PHQ-9 at baseline and follow-up. This established instrument assesses symptom burden based on the most important criteria of major depression as defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV). Internal consistency for the PHQ-9 was good, Cronbach's alpha = 0.80.[17] Respondents rated the PHQ-9 items on 4-point Likert scales 'Over the last 2 weeks, how often have you been bothered by any of the following problems?' Answer categories were 0 = not at all, 1 = several days, 2 = more than half the days, 3 = nearly every day. Caseness at follow-up was defined by a score ≥10. Löwe *et al.*[20] found a sensitivity of 81% and a specificity of 82% for depressive disorder determined by this cutoff point.

Sleep disturbance was assessed with the corresponding item of the depression module of the PHQ-9:[21] 'Trouble falling or staying asleep, or sleeping too much'. Respondents rated severity of sleep disturbances on a 4-point Likert scale: 'Over the last 2 weeks, how often have you been bothered by any of the following problems?'; not at all (=0), several days (=1), more than half the days (=2), nearly every day (=3). Clinically relevant sleep disturbance was defined if it occurred on more than half the days over the last 2 weeks.[21]

Generalized anxiety was assessed with the two-item short form of the Generalized Anxiety Disorder-7.[22] It comprises the items 'Feeling nervous, anxious or on edge' and 'Not being able to stop or control worrying'. The answer format was identical to the PHQ-9. A sum score of 3 or higher (range 0–6) among these two items indicated generalized anxiety with good sensitivity (86%) and specificity (83%).[22]

Noise annoyance was assessed in accordance with Felscher-Suhr *et al.*[23] using single questions in the following format: 'How annoyed have you been in the past years by... [source of noise]?' Six potential sources of noise annoyance (road traffic, aircraft, railways, industrial/construction, neighbourhood indoor and outdoor) were separately rated, as both 'during the day' and 'during your sleep' (i.e. inferring nighttime sleep). Ratings were done on a 5-point scale (not, slightly, moderately, strongly, and extremely) (in line with widely used standards, see e.g.[4]) Following the International Commission on Biological Effects of Noise recommendations, strongly and extremely were combined (to 'highly annoyed').[4]

Statistical analysis

Descriptive analyses were performed as absolute and relative proportions for categorical data, means and standard deviations (SDs) for continuous variables and medians with interquartile ranges if not fulfilling normal distribution. We assessed all categories of noise (aircraft, road traffic, etc.) by day and by night separately as predictors of incident depression, respective anxiety and sleep disorders (above vs. below clinical cut-off). In order to assess overall noise annoyance, we used the highest annoyance rating of all categories of noise as an indicator of overall noise annoyance, regardless of whether it affected daytime or sleep.[3] Baseline and follow-up annoyance data were compared by *t*-test and TOST equivalence test (two one-sided *t*-tests)[24] for multiple testing. In order to assess new onset of distress, we excluded all participants who were above cut-off scores in the separate analyses for depression, anxiety and sleep disturbance, respectively, took antidepressants or anxiolytics at baseline. Poisson regression models with robust variance estimates were used to estimate risk ratios (RR). In these analyses, annoyance was used continuously, per point. Prediction models included the follow-up annoyance score, sex, SES, employment and night shift work.

P-value <0.05 was considered significant. All *P*-values should be regarded as continuous parameters that reflect the level of statistical evidence, and they are therefore reported exactly. Statistical analysis was carried out using R version 3.3.1.[25]

Results

Sample characteristics

Complete noise annoyance and depression data at baseline and follow-up were available for a total of $N = 9842$ participants. Their mean age was 54.2 years (SD 10 years) and 46% were women, In accordance with our previously reported baseline data,[3] the majority of participants (80%) reported at least some degree of noise annoyance at follow-up (i.e. they were at least slightly annoyed by noise from any source); 28% rated their annoyance as strong or extreme. The proportion of distressed participants increased continuously with the degree of annoyance at follow-up; about twice as many extremely annoyed participants fulfilled criteria of depression (12.3% vs. 6.7%), respectively, generalized anxiety (9.9% vs. 5.0%) and sleep disturbance (25.5% vs. 16.2%) compared to those without noise annoyance.

Noise annoyance over the course of the study

Figure 1 shows mean noise annoyance at baseline and follow-up according to day and night for the specific sources and overall annoyance.

As figure 1 shows, annoyance during the day was higher compared to the night. There was a statistically significant, but slight decrease only of daily and nightly aircraft noise annoyance (when corrected for multiple testing by TOST equivalence test). Aircraft noise annoyance, however, was rated highest during the day and during the night. During the day, it was followed by road traffic, neighbourhood, industrial and railways noise annoyance. At night, neighbourhood noise annoyance exceeded road, and railways was higher than industrial annoyance. The overall level of annoyance remained the same over 5 years.

Poisson regression analysis of baseline noise annoyance on depression, anxiety and sleep disturbance at follow-up (controlling for noise annoyance at follow-up and sociodemographic characteristics)

Table 1 presents the results of Poisson regression analyses of noise annoyance at day and night at baseline and follow-up annoyance at day and night on depression, anxiety and sleep disturbance at follow-up. Prediction models included the respective baseline score, sex, SES, employment and night shift work.

As the table shows, overall baseline noise annoyance at day and at nighttime was a significant predictor of depressive symptoms (night), anxiety (day and night) and sleep disturbance (day), in addition to annoyance at follow-up (day and night). Additional predictors of distress and sleep disturbance were female sex, lower age and SES. In the fully adjusted model, night shift work was associated with higher depression, but not with anxiety, respectively, sleep disturbance.

Table 2 shows the summary of findings for the specific sources of noise.

As table 2 shows, baseline and follow-up annoyance by neighbourhood noise was predictive of depression, anxiety and sleep disturbance (day and night). Daytime baseline aircraft noise annoyance was associated with depressive symptoms and anxiety, and follow-up nighttime aircraft noise annoyance with sleep disturbance. Road

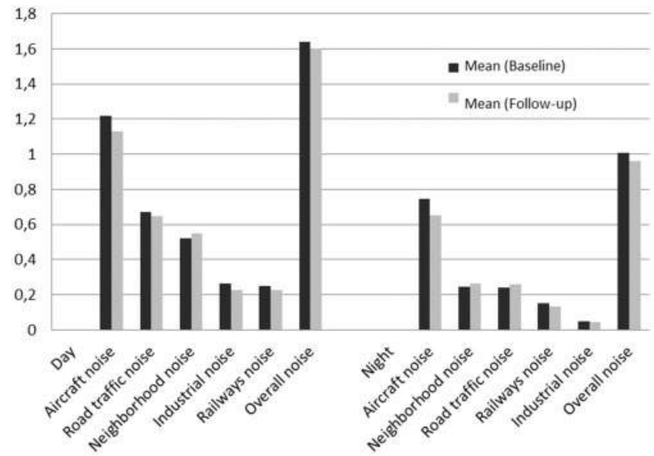

Figure 1 Mean noise annoyance by different sources at daytime and at nighttime ($N = 11\ 905$)

traffic annoyance at follow-up was consistently associated to depression, anxiety and sleep disturbance (day and night). Follow-up noise annoyance from railways (day) was predictive of depression and anxiety. Daytime baseline and follow-up annoyance with industrial noise were predictive of depressive symptoms and anxiety; the same was true for follow-up annoyance at night.

Discussion

To the best of our knowledge, this is the first longitudinal study predicting mental distress and sleep disturbances in a large community sample by annoyance from the major sources of noise (aircraft, road, railways, industrial and neighbourhood).

In the prospective study, overall noise annoyance remained stable over a period of 5 years. Annoyance at baseline was predictive of new onset depressive and anxiety symptoms beyond the follow-up scores—even over a period of 5 years. Additional predictors were female sex, lower age and SES. Night shift work was also associated with depression.

When we differentiated these overall findings according to specific sources, aircraft noise annoyance significantly decreased over time, but remained the leading source of annoyance at day and at night. During the day, road traffic annoyance was the second most annoying source of noise, followed by neighbourhood, industrial and railways noise; at night, neighbourhood exceeded road traffic and railways exceeded industrial noise annoyance.

Overall, baseline annoyance remained predictive of follow-up distress and sleep disturbances, even when follow-up annoyance was included in the regression model. Thus, long-term effects of annoyance on major mental health variables persisted. This applied to aircraft, neighbourhood and industrial noise annoyance. Noise annoyance baseline scores from specific sources (aircraft, neighbourhood, industrial) remained significant predictors of depression and anxiety, in addition to annoyance at follow-up.

Findings extend previous cross-sectional analyses[3,5] showing that the degree of annoyance was associated with impaired mental health longitudinally. Thus, our new findings imply that annoyance adds to the burden of mental distress and sleep disturbance in the long run. Based on previous findings,[10] we surmise a bidirectional relationship. That is, mental distress may increase the vulnerability to noise (via heightened sensitivity to noise). Annoyance reactions including interference with daily activities, sleep and rest, negative emotional responses and cognitive appraisals such as lack of control over the exposure to noise[4] contribute to future mental distress and sleep disturbance. While the overall size of effects of our follow-up findings was small, we could demonstrate consistent and incremental adverse effects of noise annoyance even beyond established predictors, particularly the follow-up annoyance scores, sociodemographic

Table 1 Poisson regression analyses of long-term effects of noise annoyance

	Day		Night	
	RR	95% CI (L–U)	RR	95% CI (L–U)
Prediction model of depressive symptoms	N = 9780		N = 9785	
Overall noise annoyance (BL)	1.06	0.97–1.16	1.12	1.04–1.22
Overall noise annoyance (FU)	1.13	1.03–1.23	1.10	1.02–1.19
Female sex	1.34	1.10–1.64	1.32	1.09–1.61
Higher age	0.76	0.68–0.85	0.76	0.67–0.85
Higher SES	0.96	0.94–0.98	0.96	0.93–0.98
Employment	1.11	0.83–1.48	1.10	0.83–1.47
Night shift work	1.28	1.03–1.60	1.29	1.04–1.61
Prediction model of anxiety symptoms		N = 9947		N = 9923
Overall noise annoyance (BL)	1.13	1.04–1.24	1.13	1.04–1.23
Overall noise annoyance (FU)	1.11	1.02–1.22	1.10	1.02–1.19
Female sex	1.41	1.14–1.78	1.40	1.14–1.72
Higher age	0.75	0.67–0.84	0.75	0.67–0.84
Higher SES	0.99	0.97–1.01	0.99	0.97–1.01
Employment	1.24	0.92–1.67	1.25	0.93–1.68
Night shift work	0.91	0.71–1.12	0.92	0.72–1.18
Prediction model of sleep disturbance		N = 9324		N = 9299
Overall noise annoyance (BL)	1.05	1.00–1.10	1.04	0.99–1.09
Overall noise annoyance (FU)	1.09	1.04–1.14	1.14	1.09–1.19
Female sex	1.39	1.25–1.56	1.37	1.23–1.53
Higher age	0.94	0.88–1.00	0.94	0.88–1.00
Higher SES	0.99	0.98–1.00	0.98	0.97–1.00
Employment	1.03	0.89–1.20	1.03	0.88–1.19
Night shift work	1.06	0.93–1.21	1.07	0.94–1.21

Notes: With respect to age, the effect is specified per 10 years of age. Employment: yes vs. no, Night shift work: no vs. yes.
BL, baseline; FU, follow-up; SES, socioeconomic status; CI, confidence interval.

Table 2 Prediction of depressive and anxiety symptoms and sleep disturbance at follow-up by different sources of noise annoyance for day and night

	Depression (PHQ-9)		Anxiety (GAD-2)		Sleep disturbance	
Overall	N = 9841	N = 9825	N = 10 005	N = 9986	N = 9376	N = 9357
Noise annoyance by source	Day	Night	Day	Night	Day	Night
BL	NS	1.12 (1.04–1.22)	1.13 (1.04–1.24)	1.13 (1.04–1.23)	1.05 (1.00–1.10)	NS
FU	1.13 (1.03–1.23)	1.01 (1.02–1.19)	1.11 (1.02–1.22)	1.03 (1.02–1.19)	1.09 (1.04–1.14)	1.14 (1.09–1.19)
Aircraft	N = 9835	N = 9821	N = 10 001	N = 9985	N = 9370	N = 9353
BL	1.12 (1.02–1.23)	NS	1.11 (1.01–1.22)	NS	NS	NS
FU	NS	NS	NS	NS	NS	1.09 (1.04–1.159
Road	N = 9840	N = 9821	N = 10 004	N = 9984	N = 9375	N = 9354
BL	NS	NS	NS	NS	NS	NS
FU	1.15 (1.03–1.28)	1.28 (1.13–1.46)	1.24 (1.16–1.38)	1.32 (1.17–1.50)	1.12 (1.05–1.19)	1.19 (1.10–1.28)
Neighbourhood	N = 9835	N = 9821	N = 9999	N = 9982	N = 9371	N = 9355
BL	1.15 (1.04–1.28)	1.27 (1.14–1.41)	1.20 (1.08–1.32)	1.21 (1.09–1.34)	1.13 (1.06–1.19)	1.10 (1.02–1.17)
FU	1.27 (1.15–1.40)	1.22 (1.09–1.35)	1.23 (1.11–1.35)	1.24 (1.12–1.38)	1.10 (1.04–1.17)	1.18 (1.11–1.26)
Railways	N = 9827	N = 9818	N = 9991	N = 9981	N = 9364	N = 9351
BL	NS	NS	NS	NS	NS	1.10 (0.99–1.22)
FU	1.14 (1.01–1.37)	NS	1.14 (1.03–1.26)	NS	NS	NS
Industrial	N = 9829	N = 9816	N = 9994	N = 9979	N = 9365	N = 9351
BL	1.14 (1.02–1.29)	NS	1.12 (1.06–1.35)	NS	NS	NS
FU	1.23 (1.10–1.37)	1.33 (1.08–1.63)	1.23 (1.10–1.38)	1.39 (1.16–1.67)	NS	NS

Notes: Presented are RRs of symptoms at follow-up based on Poisson regression analyses (95% confidence intervals) with the predictors noise annoyance (separately for different sources of noise/overall noise annoyance). Adjustments for sex, age, socioeconomic status, employment and night shift work.
BL, baseline; FU, follow-up; PHQ-9, Patient Health Questionnaire-9; GAD-2, Generalized Anxiety Disorder-2; NS, not significant.

risk factors and shift work. Furthermore, while we found some variation in specific associations, not only the main sources of transportation-related noise (road, aircraft, railways), but also neighbourhood-related and industrial noise adversely affected mental health and sleep quality.

Consistent with our previous findings,[3] noise annoyance remained highly prevalent affecting almost 80% (28% highly annoyed) of the population of the city of Mainz and the adjacent county of Mainz-Bingen, of which aircraft noise remained the most burdensome factor. The fact that the period of prediction has covered 5 years demonstrates that noise annoyance is not simply a temporary problem, or is not simply mastered by gradual adjustment over time. Clearly, different sources of noise annoyance accumulate in urban areas like the Rhine-Main region.[14] Mental distress and sleep disturbance pose additional risks for metabolic and cardiovascular diseases, which have been increasingly discussed as corollaries of noise exposure and related annoyance reactions.[21,26]

Our findings underscore the need to protect mental health by reducing noise and related annoyance. We therefore propose that all specific sources of noise annoyance, including neighbourhood noise annoyance, need to be scrutinized under preventive aspects. Air traffic has a very uneven regional distribution in Germany.[5] As the ongoing debate about public health hazards of aircraft noise has illustrated, German politics have been reluctant to define limits for transportation noise emissions. Even the night flight ban in the Rhine-Main region which was instated in 2011 in the context of the implementation of an additional runway has been limited to a time slot from 11 p.m. to 5 a.m. Individuals with sleep cycles not matching this exact time slot, e.g. those working night shifts, are considerable exemptions not covered from the noise-reducing flight ban at nights.[27] Despite the night flight ban, night noise annoyance has been significantly associated with sleep disturbance at follow-up. While annoyance decreased slightly, aircraft noise remained by far the leading source of annoyance at day and at night. Projecting rapid growth of the urban population increasingly exposed to noise due to the growing demand of transportation, the World Health Organization has developed environmental noise guidelines for Europe[28] which provide benchmarks for regulatory and preventive measures.

Limitations

While we consider annoyance a valid indicator of adverse mental health effects of noise, we did not assess objective noise parameters. Both, annoyance and mental health variables were assessed by self-report, only. As we do not have objective independent measures of mental disorders, we cannot preclude confounding. Mean noise annoyance remained constant, but we did not assess if individual participants had moved during the time period and if this affected noise exposure and level of annoyance. Following the scope of the paper, we analysed both, overall annoyance and annoyance due to specific sources of noise. We used internationally accepted and validated measures of depression and anxiety; however, we did not ascertain mental diagnoses. Sleep disturbance was assessed by a single, yet validated item. Further work is needed to study combinations of specific sources and moderators of noise annoyance (e.g. sex, socio-economic factors, combined multiple sources of noise annoyance) in depth.

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Key points

- In a longitudinal study of a representative population sample, noise annoyance at day and at night predicted depressive, anxiety symptoms and sleep disorders 5 years later.
- Current noise annoyance as well as noise annoyance 5 years ago contributed to distress and sleep disorders.
- Women, younger individuals and those with a lower socio-economic status were at an increased risk.
- The study highlights the need to provide affected urban areas with regulatory measures to prevent detrimental effects on the population's well-being.

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The quantification of the psychiatric revolution: a quasi-natural experiment of the suicide impact of the Basaglia Law

Caterina Ronchetti[1], Veronica Toffolutti [2,3], Martin McKee [3], David Stuckler[1,2]

1 Department of Social and Political Science, Bocconi University, Milano, Italy
2 "Carlo F. Dondena" Centre for Research on Social Dynamics and Public Policies, Bocconi University, Milano, Italy
3 Department of Public Health and Policy, London School of Hygiene and Tropical Medicine, London, UK

Correspondence: Veronica Toffolutti, "Carlo F. Dondena" Centre for Research on Social Dynamics and Public Policies, Bocconi University, Via G. Roentgen, 1, 20136 Milano, Italy, Tel: +39 02 5836 5077, Fax: +39 02 5836 2798, e-mail: veronica.toffolutti@unibocconi.it

Background: The Italian 180/1978 reform abolishing asylums is one of the most contested mental health programs ever implemented. It aimed to shift care of mental illness into the community improving outcomes and reducing expenditure. It was a model for successive deinstitutionalization initiatives across Europe and North America. However, there were longstanding concerns that, without expansion of community care, it may have deprived patients with mental illness access to support, placing them at increased risk of suicide. **Methods:** Regression discontinuity models were used to quantify the association between the number of suicides and the introduction of the Basaglia Law, disaggregated by age-group and gender, covering 20 Italian regions during the period 1975–84. Models were adjusted for potential socio-demographic confounding factors, region-specific fixed effects and pre-existing time-trends. **Results:** Italian regions implemented the Basaglia Law to varying degrees over time. We observed that, after adjusting for pre-existing time trends, the implementation was associated with a consistent increase in the number of suicides for all the age-groups [incidence rate ratio, age 15–44: 1.29, 95% confidence interval (CI) 1.18–1.41; age 45–74: 1.45, 95% CI 1.37–1.54] and for both genders (males: 1.47, 95% CI 1.41–1.53; females: 1.36, 95% CI 1.25–1.47). Hospital closure appeared to be an important mediating mechanism. **Conclusions:** The Basaglia Law was associated with a significant increase in the number of suicides, with evidence of an association with closures of facilities, leaving those with mental illness with nowhere to go, as the envisioned community care structures failed to be developed as originally planned.

Introduction

'La follia è una condizione umana. In noi la follia esiste ed è presente come lo è la ragione. Il problema è che la società, per dirsi civile, dovrebbe accettare tanto la ragione quanto la follia, invece incarica una scienza, la psichiatria, di tradurre la follia in malattia allo scopo di eliminarla. Il manicomio ha qui la sua ragion d'essere.'

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Article

Aircraft Noise and Quality of Life around Frankfurt Airport

Dirk Schreckenberg [1,]*, Markus Meis [2], Cara Kahl [3], Christin Peschel [1] and Thomas Eikmann [4]

[1] ZEUS GmbH, Sennbrink 46, 58093 Hagen, Germany; E-Mail: peschel@zeusgmbh.de (C.P.)
[2] Hörzentrum Oldenburg GmbH, Marie-Curie-Str. 2, 26129 Oldenburg, Germany; E-Mail: M.Meis@Hoerzentrum-Oldenburg.de (M.M.)
[3] Department of Psychology, University Hamburg, Von-Melle-Park 5, 20146 Hamburg, Germany; E-Mail: cara.kahl@uni-hamburg.de (C.K.)
[4] Institute of Hygiene and Environmental Medicine, Faculty of Medicine, Justus-Liebig-University Giessen, Friedrichstr. 16, D-35392 Giessen, Germany; E-Mail: thomas.eikmann@hygiene.med.uni-giessen.de (T.E.)

* Author to whom correspondence should be addressed; E-Mail: schreckenberg@zeusgmbh.de; Tel.: +49-2331-4787-194; Fax: +49-2331-4787-592.

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Abstract: In a survey of 2,312 residents living near Frankfurt Airport aircraft noise annoyance and disturbances as well as environmental (EQoL) and health-related quality of life (HQoL) were assessed and compared with data on exposure due to aircraft, road traffic, and railway noise. Results indicate higher noise annoyance than predicted from general exposure-response curves. Beside aircraft sound levels source-related attitudes were associated with reactions to aircraft noise. Furthermore, aircraft noise affected EQoL in general, although to a much smaller extent. HQoL was associated with aircraft noise annoyance, noise sensitivity and partly with aircraft noise exposure, in particular in the subgroup of multimorbid residents. The results suggest a recursive relationship between noise and health, yet this cannot be tested in cross-sectional studies. Longitudinal studies would be recommendable to get more insight in the causal paths underlying the noise-health relationship.

Keywords: aircraft noise; annoyance; disturbance; non-acoustical factors; noise sensitivity; environment; health; quality of life; stress theory; HQoL; EQoL

1. Introduction

Frankfurt Airport (Frankfurt am Main, Germany) is an important international airport in Europe with an estimated 486,000 movements (10% at night-time), 53 million passengers and 2 million tons of cargo (in 2008). For 2020 about 701,000 movements (88 Mio passengers, more than 3 million tons of cargo) are predicted. In order to manage this predicted amount of movements it is intended to construct a new 4th runway to increase the current capacity of 83 to 120 flight movements per hour. The opening of the new runway is expected in 2011.

After the announcement of the airport expansion in 1998 a regional mediation process started and a round table, the Regional Dialogue Forum Frankfurt Airport (RDF), was formed in order to continue information on and discussion about the development of the airport. Members of the RDF are representatives of action groups, local authorities, trade unions, churches, regional industry, and aviation industry. After a feasibility study about the assessment of aircraft noise effects was carried out in 2003 [1] the RDF commissioned a main field study on the effects of aircraft noise in communities in the vicinity of Frankfurt Airport. This main field study (FRA-S) was carried out from 2004 to 2006 and took place before the final approval decision about the expansion was made at the end of 2007. The study aimed at assessing the reactions to aircraft noise of residents around an international airport in a situation between the announcement and the planned implementation of the expansion of the airport. The objectives of the field study in particular were:

- to assess the impact of aircraft noise before airport expansion, *i.e.*, the construction of the new 4th runway;
- to get an update of the regional exposure-response relationship for aircraft noise annoyance and disturbances due to aircraft noise (communication, restoration, concentration/work, sleep);
- to get information about the *status quo* of environmental and health-related quality of life and any effects of aircraft noise on that *status quo*.

A report with the results of the study was finalized in 2006 [2]. This article presents the main findings of FRA-S with regard to reactions to aircraft noise (annoyance) and more comprehensive outcomes concerning the environmental and health-related quality of life.

2. Working Model of Aircraft Noise Effects

To meet the objectives as defined by the RDF the study comprises, beside the assessment of aircraft noise exposure, instruments for the ascertainment of aircraft noise annoyance and its non-acoustical co-determinants, as well as instruments for the assessment of environmental (EQoL) and health-related quality of life (HQoL).

The underlying theoretical concept used as a working model in this study is based on noise-related stress models [3,4] referring to the transactional stress concept of Lazarus and colleagues [5]. These models describe the relationship between noise exposure, coping, and annoyance [4], and further mental as well as physical health outcomes [3]. That is, long-term noise annoyance can be understood as strain (reappraisal) resulting from an assessment process including the perceived disturbance and annoyance due to the sound (primary appraisal) and the perceived control over the noise situation [6], *i.e.*, among others the perceived possibilities to cope with noise [3] (secondary appraisal). Chronic psychological strain, going along with physiological stress reactions to noise exposure [7] may increase the risk of health problems, in particular cardiovascular diseases [7] and/or disorders in mental health [8].

Whereas van Kamp [3] describes the role of appraisal of stressors (noise), activation, and coping with the noise for the prediction of health complaints, Stallen [4] points out the importance of the social aspect of noise ("you expose me") on perceived control and, thus, on annoyance and further source-related attitudes. Stallen's model provides a theoretical frame for the often found associations between non-acoustical, attitudinal factors (e.g., attitudes towards the source and towards authorities) and noise annoyance [9-11] indicating that these attitudes co-determine noise annoyance in a similar of even higher extend than the annoying sound itself [10,12]. Stallen identifies the noise policy or the way the sound production is managed as a second external stimulus of stress reactions to noise in addition to the sound itself. This social-psychological perspective of noise reactions is supported by findings about the impact of procedural (un-)fairness [13] and the regional political discourse [14] on aircraft noise annoyance.

In environmental psychological approaches the role of the perceived environmental context on human's well-being and health (person-environment fit) has been emphasized for many years and stress models as described above are supplemented by the description of the restorative as well as aversive impact of the (physical) environment [15]. Following this research perspective, aircraft noise can be understood as an environmental stressor affecting the perceived environmental quality as well as stress-induced health outcomes.

In a similar way, the multi-dimensional concept of quality of life, including aspects of emotional, functional, mental, physical, and social well-being as perceived by the individual [16], offers a wide frame to investigate the possible health-related outcomes of (aircraft) noise. In several studies the association between transportation noise, environmental (EQoL) and health-related quality of life (HQoL) was investigated [17-19]. In this study, in line with the suggestion of Lercher [20] to combine transactional and contextual stress models (including environmental context factors) and to conceptually integrate the notion of EQoL and HQoL in environmental health impact assessment, the noise-related stress concept and the deduced instruments and assessments include the following aspects:

- Aircraft noise exposure as the environmental stressor of interest.
- Psychological reactions to aircraft noise: disturbances due to aircraft noise, measures to cope with aircraft noise and—as a key psychological stress reaction—aircraft noise annoyance, defined as "a psychological concept which describes a relation between an acoustic situation and a person who is forced by noise to do things he/she does not want to do, who cognitively and emotionally evaluates this situation and feels partly helpless" [21, p. 525].
- Contextual, personal and attitudinal (social) factors potentially co-determining noise reactions

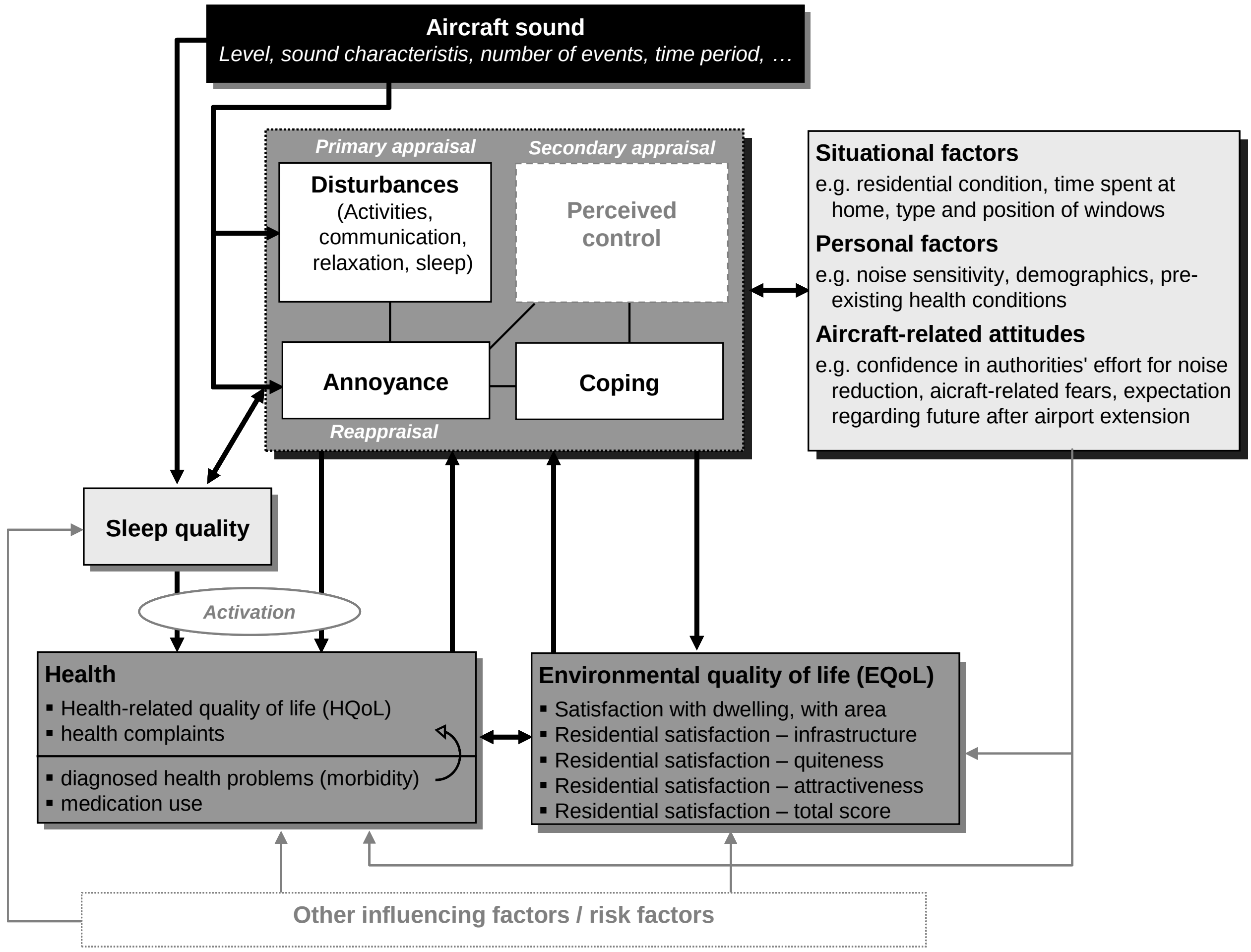
- Sleep quality potentially affected directly by aircraft noise exposure at night or indirectly by the reactions to aircraft noise at daytime.
- Health-related variables as further outcomes of aircraft noise: health complaints, HQoL.
- EQoL: Residential satisfaction in total and with regard to infrastructure, quietness, attractiveness.

Note, that, although there is evidence of impacts of noise on health (mediated by psychological noise reactions), the aircraft noise exposure-annoyance-health association can also be interpreted the other way around: that is, vulnerable people—those who are more sensitive to noise and/or those who suffer from pre-existing illness—may have reduced behavioural or cognitive resources to cope with the noise exposure and therefore react with stronger annoyance to the noise and, hence, perceive a reduced HQoL [22]. It was shown in other publications concerning the FRA-S data that the prevalence of chronic and acute health diseases ever diagnosed by a doctor as well as the frequency of medicine use were not associated with aircraft noise exposure in terms of higher prevalence of diseases and medical consumption with increasing aircraft sound levels [23,24]. However, several diagnosed diseases and the use of headache drugs, sleeping drugs, calmatives, and asthma drugs were found to be associated with noise sensitivity [24], an individual disposition that, while independent from noise exposure, increases the susceptibility of an individual to noise in general [25]. Whether noise sensitivity and the diagnosed health diseases and medical consumption, respectively, are both indicators of a general 'vulnerability' [26,27] or of a common underlying personal dimension such as neuroticism [28] or negative affectivity [29,30], or whether pre-existing illnesses modify the sensitivity to noise (and other environmental stressors) in general, and therewith causes elevated reactions to noise, is not yet clear. Nevertheless, it is plausible to assume that most of the assessed diagnosed diseases and medical consumption indicate objective health problems and therewith resident's morbidity which (pre-)exists independently from the aircraft noise exposure. It is further hypothesized that multimorbidity—here defined as the occurrence of two or more health diseases –, cause, similar to noise sensitivity, a reduced ability to cope with aircraft noise and in line with this moderates the impact of aircraft noise on HQoL.

Similar to the health variables, residential satisfaction and noise reactions such as annoyance may be reciprocally associated with each other. Several studies found associations of residential satisfaction with noise annoyance [31,32]. It is somewhat unclear whether residential satisfaction is a secondary reaction to noise (mediated by annoyance) or a modifier of noise reactions prior to noise annoyance or both.

The different variables of reactions to noise, further outcomes with regard to HQoL and EQoL as well as potential personal, attitudinal and situational factors co-determining these variables are included in a summarized conceptual model of aircraft noise effects in Figure 1. It is not the aim of this paper to verify this model in detail. In FRA-S the working model was rather used as an orientation for the development of the questionnaires and the statistical analyses.

Figure 1. Conceptual working model of aircraft noise effects.



3. Methods

3.1. Sample and Procedure

The field study on the effects of aircraft noise on residents' quality of life was carried out in 2005 in communities within a 40-kilometre distance from Frankfurt Airport. The subjects were sampled using a stratified random sampling method. That is, 66 residential areas were selected according to the aircraft noise exposure in 2003 with equivalent sound level contours for daytime $L_{Aeq,16h}$ (6 *am* to 10 *pm*) as strata (see [2] for more details). Within the selected areas a total of 3,795 randomly selected residents was asked for an interview, of which 2,312 took part in the study (response rate 61%). The interviews were carried out from April to December 2005. The month in which a subject was contacted by the interviewer was selected at random. The participants were interviewed in face-to-face interviews (on average 45 minutes long) with regard to their residential situation, health-related quality of life, annoyance and disturbances due to noise, in particular to aircraft noise (study part I). The exposure to noise from aircraft, railway and road traffic noise was calculated for the address of each participant. In addition, a subsample of 200 persons assessed on four successive days their hourly aircraft noise annoyance, main activity, location, and—in case of indoor stay—the window position (study part II). This article presents the results of study part I.

3.2. Measures

3.2.1. Noise Exposure

For the address of each participant aircraft noise exposure was modelled on the base of the flight movements of the six busiest months of the year 2005 according to the German aircraft noise calculation procedure with aircraft categories as proposed by the German Federal Environment Agency in 1999 (*AzB-99*; [33]) . Several acoustical parameters were calculated including the equivalent sound level (L_{Aeq}), maximum sound level (L_{max}), and number of events (flight movements) above specified thresholds. For the analyses described in this article, aircraft noise load was indicated by the equivalent sound level for daytime ($L_{Aeq,16h}$; 6 *am*–10 *pm*), night-time ($L_{Aeq,8h}$; 10 *pm*–6 *am*), and for 24 hours of the day using the Day-Night level L_{dn} (including a penalty of 10 dB(A) for the night-time) as well as the Day-Evening-Night Level L_{den} (including a penalty of 5 dB(A) for the evening and 10 dB(A) penalty for the night-time). In addition, address-related road traffic and railway sound levels for daytime ($L_{Aeq,16h}$) and for the night-time ($L_{Aeq,8h}$) were assessed on the base of noise maps.

3.2.2. Questionnaire

According to the conceptual model of aircraft noise effects described above, the following topics were assessed in the questionnaires:

- Residential situation and residential satisfaction
- Reactions to environmental noise, in particular aircraft noise
- Attitudes related to aircraft and Frankfurt Airport in general
- Health-related variables: health-related quality of life, health complaints, diagnosed diseases, use of medicine, sleep quality
- Personal factors: socio-demographic factors, individual noise sensitivity

The variables assessed in the questionnaire and analyzed within the context of this paper are listed in Appendix 1 of this article.

4. Results

Altogether, 2,312 residents were interviewed in the field study. In one case the address was not matched to the correct Gauss-Krueger coordinates, which were necessary to estimate address-related aircraft noise exposure. Therefore, the statistical analyses are based on data of 2,311 persons. The sample distributions of the study participants with regard to gender, age, socio-economical status, and aircraft noise exposure are shown in tables 2 and 3.

Table 2. Number of participants by gender, age, and socio-economic status.

Variable		**N**	**% valid**
Gender	Male	1,034	44.8
	Female	1,276	55.2
	Missing[#]	1	
Age	17–19 years	69	3.0
	20–29 years	240	10.5
	30–39 years	293	12.8
	40–49 years	420	18.4
	50–59 years	344	15.1
	60–69 years	440	19.3
	70–79 years	322	14.1
	80 years and more	155	6.8
	Missing	28	
Socio-economic status	Low	318	14.6
	Middle	1,145	52.5
	High	717	32.9
	Missing	131	

[#] In one case during the study (between study part I and II) a sex change occurred.

Table 3. Number of participants by indicators of aircraft noise exposure.

Sound level class (L_{Aeq}) in dB	**Day-Evening-Night L_{den} in dB**		**Day-Night L_{dn} in dB**		**Day $L_{Aeq,16h}$ in dB**		**Night $L_{Aeq,8h}$ in dB**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
<40	0	4.2	132	5.7	0	0	381	16.5
40–45	98	22.7	560	24.2	363	15.7	741	32.1
45–50	524	26.6	597	25.8	565	24.4	462	20.0
50–55	615	19.2	506	21.9	497	21.5	523	22.6
55–60	443	27.3	516	22.3	700	30.3	204	8.8
≥60	631				186	8.0	0	0.0
Total	2,311	100.0	2,311	100.0	2311	100.0	2,311	100.0
Mean	54.7		54.1		51.9		45.9	
Standard deviation	6.1		5.9		6.2		6.6	
Minimum	42.4		41.9		40.8		24.4	
Maximum	65.9		64.8		62.7		57.6	

4.1. Aircraft Noise Annoyance

Results of correlation analyses between parameters of aircraft noise exposure and the aircraft noise annoyance experienced by the interviewed residents indicate that aircraft noise annoyance is associated with sound levels (equivalent, mean maximum sound level) as well as with the number of flyovers (N55, N70). However, the strongest exposure-annoyance relationship for aircraft noise was found between the equivalent sound level and aircraft noise annoyance (Table 4).

Table 4. Product-moment correlation between aircraft noise annoyance in the last 12 months before the interview and parameters of aircraft noise exposure.

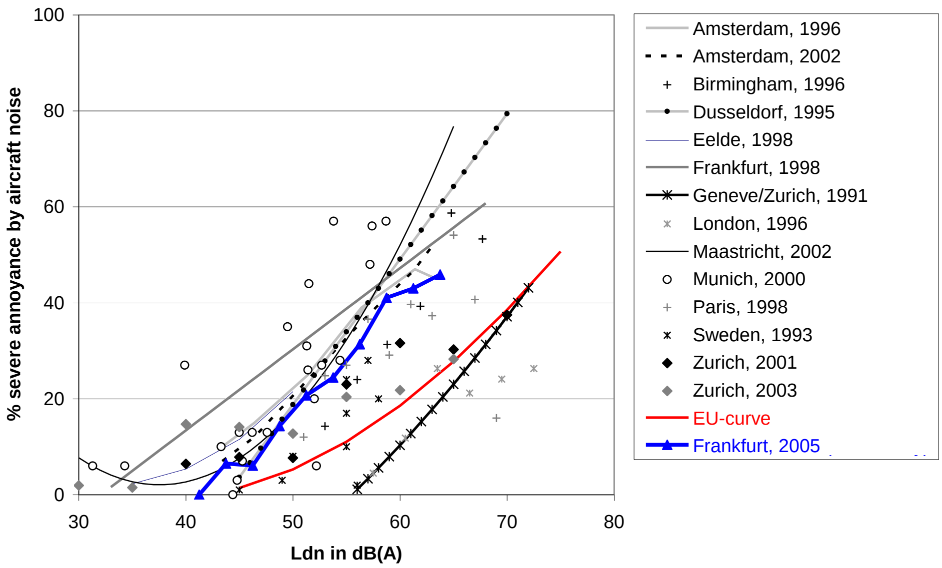
	Scale	n	Equivalent sound level (unweighted, weighted)			Mean maximum sound level		Number of events above threshold	
			$L_{Aeq,24h}$	L_{den}	L_{dn}	$L_{max55,24h}$	$L_{max70,24h}$	$N_{55,24h}$	$N_{70,24h}$
Aircraft noise annoyance	5-pt.	2,308	0.45	0.43	0.42	0.39	0.34	0.33	0.34
	11-pt.	2,272	0.43	0.42	0.41	0.36	0.29	0.34	0.34

Exposure-response relationships were analyzed for the percentage of highly annoyed people. According to Schultz [41], a person has been defined as being highly annoyed (HA) when he or she chose the upper 27–28% of categories of the annoyance scale. This is the case for annoyance judgments of category 8 or higher on the 11-point scale. Results of this study with regard to the percentage of people highly annoyed by aircraft noise (%HA) was compared with findings of other international studies. Figure 2 shows the international comparison with regard to %HA related to the Day Night Level L_{dn} [42]. As can be seen, moderate sound levels already lead to severe noise annoyance due to aircraft noise. Compared to the generalized curve for %HA due to aircraft noise revealed by the meta-analysis of Miedema and Oudshoorn [43], also published in the EU position paper on noise annoyance with regard to L_{den} ([44] see red 'EU-curve'), the blue 'Frankfurt curve' indicates higher annoyance at a given Day Night Level L_{dn}. Nevertheless, the 'Frankfurt 2005-curve' is largely in line with most of the findings of the other field studies presented in Figure 2 and with results of further recently published studies not presented in Figure 2 [46,47]. The underlying data of the 'EU-curve' date from 1965 to 1992. Some authors suggest that the recently published studies on aircraft noise annoyance not included in the meta-analyses of Miedema and colleagues indicate a trend of increasing aircraft noise annoyance at a given sound level over the last decades [42,47,48]. These authors consider the respective EU-curve on aircraft noise annoyance as outdated.

In order to identify further aircraft noise reactions and non-acoustical factors associated with aircraft noise annoyance correlation analyses have been done between aircraft noise exposure, annoyance, and further reactions to aircraft noise as well as attitudinal, situational, and personal factors. The coefficients are presented in Table 5.

Aircraft noise annoyance is relative highly correlated with all disturbance judgments, both with disturbances of daily activities indoors (day and night) and outdoors (Table 5). In accordance with this result, with increasing sound levels and aircraft noise annoyance residents more often take measures to cope with the aircraft noise and to avoid disturbances due to aircraft noise. The results in Table 5 further indicate that the source-related attitudes and expectations are associated with aircraft noise annoyance. This is in line with results of many field studies on community reactions to noise [9,11]. These attitudes are also in a less degree but still significant (except positive expectations) correlated with the aircraft sound level. The correlation with aircraft noise exposure decreases after adjusting for annoyance. This indicates that the attitudes can be understood as (secondary) reactions to aircraft noise partly mediated by annoyance. This is confirmed by the finding that each partial correlation between aircraft sound level and annoyance controlled by each attitudinal factor is marginal lower in comparison to the zero-order correlation between aircraft sound level and annoyance. The interpretation of the source-related attitudes as secondary to aircraft noise annoyance is also supported by results of structural equation modeling done by Kroesen and colleagues, who found that none of the paths from the psychological factors to aircraft noise annoyance were significant, whereas for a part of the attitudinal factors (concern about negative health effects of noise, belief that noise can be prevented) the reverse path from the annoyance to the attitudes was statistically significant [49].

Figure 2. Dose-response data for severe aircraft noise annoyance from several surveys using a cut-off point of 70–75% of response scale for definition of high annoyance (HA).



Source: van Kempen, und van Kamp ([42], p. 25, Figure 3b)—modified and supplemented; EU-curve: generalized dose-response curve for aircraft noise annoyance [43,44]. Source of the data of Zurich 2001/2003: Brink *et al.* [45]. Blue line and dots: data of the Frankfurt Noise Effect Study presented in this paper. References of all the other studies: see [42].

Among the personal factors the individual noise sensitivity is correlated with aircraft noise annoyance ($r = 0.36$) but as expected not with the aircraft sound level. In comparison to this socio-demographical factors play a minor role for aircraft noise annoyance as results of two-factorial ANOVAs with aircraft noise annoyance [11-point scale] as the dependent variable and 5-dB-L_{den}-class as well as each of the selected grouped socio-demographic variables as independent factors suggest. This is in line with previous research [9]. However, some effects of these variables on annoyance were found, although with little effect size: Age was found to be non-linear related to aircraft noise annoyance, that is annoyance due to aircraft noise was higher in the group of middle-aged adults (40–60 years) in comparison to those younger or older than this group ($F[2;2229] = 11.14$, $p < 0.001$, $\eta_p^2 = 0.01$). This non-linear effect of age on noise annoyance is also reported by Miedema and Vos [11] and van Gerven *et al.* [50].

Interviewed residents with a lower socio-economic status reported less annoyance due to aircraft noise than residents with middle and higher socio-economic status ($F[1;2252] = 14.80$, $p < 0.001$, $\eta_p^2 = 0.01$). In accordance with this house owners were found to be more annoyed by aircraft noise than tenants ($F[1;2252] = 60.77$, $p < 0.001$, $\eta_p^2 = 0.03$). Probably those residents who could afford ownership fear the loss of house values and in line with this are more annoyed by aircraft noise in comparison to those without properties. In fact, the fear of diminished house prices is correlated with aircraft noise annoyance ($r = 0.54$, $p < 0.001$) and with aircraft sound level L_{den} ($r = 0.17$, $p < 0.001$). As expected the correlation coefficients are much higher for house owners (house price–annoyance: $r = 62$, $p < 0.001$; house price–L_{den}: $r = 0.32$, $p < 0.001$) than for tenants (house price–annoyance $r = 0.37$, $p < 0.001$; house price–L_{den} $r = -0.09$, $p = 0.006$).

Table 5. Correlations and partial correlations of aircraft sound level (L_{den}) and aircraft noise annoyance with selected questionnaire variables.

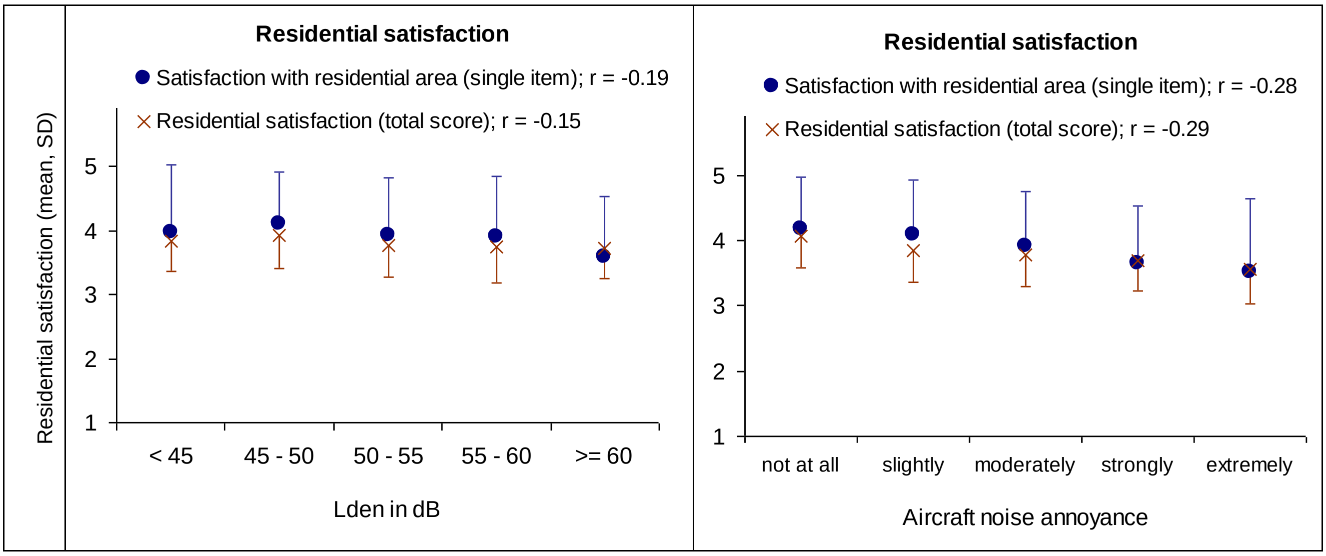
Variables	Correlation		Partial correlation		
	Noise annoyance (11 pt.)	Noise level L_{den}	Noise annoyance (11 pt.) [1]	Noise level L_{den} [2]	between annoyance (11 pt.) and L_{den} [3]
Aircraft noise annoyance					
annoyance (5-pt.)	0.87	0.43	0.84	0.14	
annoyance (11-pt.)	1.00	0.43	1.00		
Disturbances of ...					
communication indoor	0.79	0.48	0.74	0.25	0.09
relaxation/concentration indoor	0.79	0.42	0.75	0.15	0.17
communication outdoor	0.81	0.40	0.77	0.11	0.19
relaxation outdoor	0.79	0.38	0.75	0.08	0.22
nocturnal sleep	0.76	0.37	0.72	0.08	0.24
Coping					
Measures to cope with noise	0.81	0.41	0.77	0.13	0.17
Source-related attitudes					
Negative expections	0.74	0.24	0.72	−0.12	0.38
Positive expections	−0.14	0.01#	−0.16	0.08	0.43
Econom. expectations	−0.40	−0.19	−0.36	−0.02#	0.39
Aircraft-related fears	0.71	0.28	0.68	−0.03#	0.33
Confidence in authorities	−0.35	−0.20	−0.29	−0.06	0.39
Residential satisfaction					
Satisfaction with dwelling	−0.04#	−0.12	0.01#	−0.11	0.42
Satisfaction with residential area	−0.28	−0.19	−0.23	−0.08	0.40
Infrastructure	−0.11	0.01#	−0.13	0.08	0.43
Quietness, insulation	−0.47	−0.30	−0.40	−0.21	0.34
Attractiveness, neighbours	−0.17	−0.10	−0.15	−0.02#	0.42
Residential satisfaction (total score)	−0.29	−0.15	−0.26	−0.01#	0.41
Sensitivity					
Noise sensitivity	0.36	0.08	0.36	-0.09	0.43

Partial correlation adjusted for [1] L_{den}, [2] aircraft noise annoyance (11-pt. scale), [3] variable in row;
not significant ($p > 0.01$); n = 2,127–2,311.

4.2. Environmental Quality of Life

Table 5 shows that the residential satisfaction, in particular the satisfaction with the residential area outside the dwelling (single item and total residential satisfaction score including mainly area-related attributes), is correlated with annoyance and—weakly but significantly—with aircraft noise exposure. In particular satisfaction with house insulation and quietness in the residential area are both correlated with aircraft noise exposure and annoyance. In the partial correlation analyses between aircraft noise exposure and the satisfaction scores controlled by annoyance, the exposure-satisfaction association diminishes (except for satisfaction with house insulation and quietness) in comparison to the respective zero-order correlation. However, the annoyance—exposure correlation remains almost the same in the partial correlation analyses controlled by residential satisfaction. The correlation between satisfaction with quietness and aircraft noise exposure decreases somewhat after control for annoyance, but remains on a relative moderate level. This indicates that residential satisfaction, in particular the satisfaction with house insulation and quietness in the local area, can be interpreted as a secondary reaction to aircraft noise exposure partly mediated by annoyance. Note, that the aircraft noise exposure-annoyance correlation also decreases after control for the satisfaction with house insulation and quietness, suggesting that the annoyance may in turn partly be moderated by the satisfaction with house insulation and quietness. All in all, for residents living in the vicinity of Frankfurt Airport the results of the correlational analyses indicate that being stressed by aircraft noise lessen the satisfaction with the residential area and, thus, the perceived local environmental quality of life in general (see also Figure 3).

Figure 3. Means and standard deviation of residential satisfaction (single item, total score) by aircraft noise exposure (left side) and by aircraft noise annoyance (right side).



4.3 Health Related Quality Of Life (SF12/36), Sleep Quality, and Health Complaints

The following tables show descriptive statistics for the health complaints and SF12/36 scores as indicators of HQoL and for sleep quality (PSQI score) as indicator of nocturnal HQoL. The statistics are grouped by aircraft sound level for daytime and night-time (Table 6) and by aircraft noise annoyance and noise sensitivity (Table 7). Although on a descriptive level subjects of different sound level groups differ with regard to single health variables, no systematic increase with increasing noise exposure could be observed. Actually, HQoL with regard to vitality and mental health decreases with increasing aircraft sound level at daytime from <45 dB(A) up to the sound level class 50–55 dB(A), but then increases again for residents exposed to higher sound level classes at daytime. Similar, residents exposed to the lowest and highest aircraft sound level classes for daytime and night-time reported less health complaints with regard to the stomach, the limbs and in total than residents with aircraft noise exposure in between these sound level classes. The sleep quality is worst for residents exposed to 50 to 60 dB(A) at daytime and 50 to 55 dB(A) at night-time than for residents with less or higher aircraft noise exposure.

Table 6. Description of health variables grouped by aircraft sound level at daytime ($L_{Aeq,16h}$) and night-time ($L_{Aeq,8h}$).

Health variables	**Aircraft sound level**											
	at daytime—$L_{Aeq,16h}$ [dBA]						**at night-time—$L_{Aeq,8h}$ [dBA]**					
	40−45	**45−50**	**50−55**	**55−60**	**≥60**		**<40**	**40−45**	**45−50**	**50−55**	**≥55**	
SF12/36 HQoL scores: mean (SD)												
Vitality	70.8	65.9	66.6	67.5	67.8	**	68.3	66.7	67.9	67.7	67.5	
(SF36)	(18.7)	(17.8)	(18.7)	(19.1)	(17.8)		(18.5)	(18)	(18.2)	(20.1)	(17.8)	
Mental health	77.3	75.6	73.5	75.5	78.3	**	75.1	76.0	75.4	75.0	77.1	
(SF36)	(13.8)	(14)	(15.9)	(15.1)	(13.7)		(14)	(14.4)	(15.6)	(15.4)	(13.7)	
Mental health	54.1	53.4	52.4	53.6	54.5	**	53.4	53.4	53.2	53.4	54.4	
(SF12)	(6.1)	(6.9)	(7.8)	(6.9)	(6.6)		(6.3)	(7.1)	(7.2)	(7.2)	(6.7)	
Physical health	51.1	49.5	50.1	49.9	50.1		50.2	49.8	50.6	49.8	49.9	
(SF12)	(8.7)	(9.9)	(9.2)	(9.2)	(9.7)		(9.5)	(9.7)	(8.7)	(9.4)	(9.5)	
GSCL-24 health complaints: mean (SD)												
Exhaustion	46.1	47.6	48.0	47.7	46.5		47.4	47.8	46.6	47.7	46.9	
	(9.1)	(9.9)	(9.3)	(9.8)	(8.6)		(9.7)	(9.6)	(9.3)	(9.8)	(8.8)	
Stomach complaints	48.1	48.5	48.6	49.1	46.8	*	49.2	48.6	47.6	49.2	47.1	**
	(7.4)	(7.6)	(8.1)	(7.8)	(6.3)		(8.0)	(7.7)	(7.1)	(8.0)	(6.7)	
Limb complaints	45.9	47.8	47.1	47.5	44.3	**	47.3	47.3	45.8	48.0	45.4	**
	(9.3)	(9.7)	(9.9)	(9.7)	(9.3)		(10.0)	(9.6)	(9.6)	(9.9)	(9.2)	
Cardiac complaints	47.6	47.8	48.4	48.4	46.7		48.0	48.2	47.4	48.5	47.2	
	(7.4)	(7.6)	(8.0)	(8.1)	(6.9)		(7.8)	(7.7)	(7.6)	(8.2)	(7.0)	
Total score	45.5	47.0	47.0	47.2	44.3	**	46.9	47.0	45.4	47.5	45.1	**
	(9.2)	(9.5)	(9.7)	(9.8)	(9.0)		(9.7)	(9.5)	(9.5)	(9.8)	(9.1)	
Sleep quality: mean (SD)												
Sleep quality (PSQI)	3.4	3.8	4.0	4.1	3.4	**	3.7	3.9	3.7	4.2	3.6	*
	(2.8)	(3.0)	(3.1)	(3.1)	(2.8)		(2.9)	(3.1)	(3.0)	(3.1)	(2.8)	

** $p < 0.01$; * $p < 0.05$ (adjusted for number of tests)

Table 7. Description of health variables grouped by aircraft noise exposure and noise sensitivity.

Health variables	Aircraft noise annoyance						Noise sensitivity					
	not at all	slight-ly	mode-rately	very	extre-mely		not	a little	mode-rately	rather	very	
SF12/36 HQoL scores: mean (SD)												
Vitality	73.6	70.9	68.4	64.6	60.7	**	73.8	69.5	66.9	63.4	53.3	**
(SF36)	(18.4)	(18.0)	(17.4)	(17.9)	(19.0)		(18.0)	(17.0)	(17.5)	(20.4)	(22.4)	
Mental health	79.6	77.8	76	74.0	71.1	**	81.3	77.6	74.9	71.7	63.9	**
(SF36)	(13.2)	(13.8)	(14.1)	(15.0)	(16.1)		(14.6)	(13.1)	(13.8)	(16.1)	(18.2)	
Mental health	55.2	54.2	53.5	53.1	51.5	**	55.1	54.3	53.2	51.7	49.4	**
(SF12)	(5.1)	(6.0)	(6.5)	(7.2)	(8.9)		(6.2)	(5.8)	(6.8)	(8.8)	(9.0)	
Physical health	51.1	51.4	50.2	49.1	48.5	**	51.2	50.9	50.1	48.2	45.3	**
(SF12)	(9.3)	(8.1)	(8.8)	(9.7)	(10.8)		(9.2)	(8.9)	(8.8)	(9.9)	(12.5)	
GSCL-24 health complaints: mean (SD)												
Exhaustion	44.8	45.1	46.4	48.7	51.7	**	45.0	45.8	47.9	50.0	54.1	**
	(8.1)	(7.8)	(8.7)	(10.3)	(10.7)		(8.1)	(8.2)	(9.7)	(10.7)	(12.1)	
Stomach complaints	47.5	47.3	48.5	49.1	50.1	**	46.0	48.0	49.1	49.5	51.7	**
	(7.0)	(6.6)	(7.5)	(8.2)	(8.4)		(6.3)	(7.2)	(7.7)	(8.4)	(9.3)	
Limb complaints	45.7	45.2	46.3	47.9	49.9	**	44.4	45.7	47.5	49.2	52.6	**
	(8.6)	(8.2)	(9.4)	(10.4)	(10.9)		(8.9)	(8.5)	(9.8)	(10.6)	(12.3)	
Cardiac complaints	46.3	46.5	47.8	49.1	50.1	**	46.1	47.0	48.1	50.2	52.7	**
	(6.1)	(6.3)	(7.6)	(8.6)	(8.8)		(6.5)	(6.7)	(8)	(8.9)	(9.4)	
Total score	44.4	44.4	46.0	47.8	50.2	**	43.4	45.2	47.3	49.2	52.9	**
	(8.4)	(7.9)	(9.2)	(10.4)	(10.5)		(8.4)	(8.5)	(9.6)	(10.5)	(11.6)	
Sleep quality: mean (SD)												
Sleep quality (PSQI)	2.6	3.2	3.7	4.2	5.5	**	2.7	3.2	4.1	5.2	6.0	**
	(2.2)	(2.7)	(2.7)	(3.0)	(3.6)		(2.6)	(2.6)	(3.0)	(3.3)	(3.6)	

** $p < 0.01$; * $p < 0.05$ (adjusted for number of tests)

Accordingly, with increasing aircraft sound levels no increase in the risk (odds ratio) of HQoL below average, bad sleep quality and in the intensity of health complaints above average could be observed in logistic regression analyses with the health-related variables as criteria and aircraft noise exposure at daytime (for sleep quality: at night-time), annoyance, and noise sensitivity as predictors (Table 8). Similar results of the regression analyses were observed when the predictor L_{Aeq} for daytime was exchanged with L_{Aeq} for night-time. All regression analyses were adjusted for age, gender, socio-economical status, home ownership, residential satisfaction, usual window position in the sleeping room at night, and number of hours away from home. For analysing the impact of aircraft noise on physical health, e.g., cardiovascular risk effects in noisy areas it is obvious and a gold standard also to adjust regression models as described above for variables like body mass index, smoking and alcohol usage. But this study aimed at the effects of aircraft noise on annoyance, subjective health, environmental quality, and HQoL. For this purpose we decided in the study protocol in the beginning of the study not to include all these variables, due to budget limit and time limit of the duration of the interviews.

Table 8. Associations between aircraft noise exposure at daytime ($L_{Aeq,16h}$), aircraft noise annoyance, noise sensitivity, and health variables (Odds ratios [OR] per unit and ±95% confidence interval [CI]).

Health variables	Aircraft sound level $L_{Aeq,16h/8h}$ #			Aircraft noise annoyance			Noise sensitivity		
	OR	CI−	CR+	OR	CI−	CR+	OR	CI−	CR+
Health-related quality of life (SF36/12 scores < median)									
Vitality (SF36)	**0.95**	0.93	0.97	**1.25**	1.13	1.37	**1.13**	1.02	1.26
Mental health (SF36)	**0.96**	0.94	0.98	**1.13**	1.03	1.24	**1.40**	1.26	1.55
Mental health (SF12)	**0.96**	0.94	0.98	1.06	0.97	1.17	**1.22**	1.10	1.36
Physical health (SF12)	**0.97**	0.95	0.99	**1.13**	1.01	1.26	**1.19**	1.06	1.34
GSCL-24 health complaints (above 50% = average of population in Germany)									
Exhaustion	**0.98**	0.96	1.00	**1.36**	1.23	1.51	**1.40**	1.26	1.56
Stomach complaints	0.99	0.97	1.01	**1.12**	1.02	1.24	**1.18**	1.06	1.30
Limb complaints	**0.96**	0.94	0.98	**1.22**	1.10	1.34	**1.48**	1.33	1.65
Cardiac complaints	**0.96**	0.94	0.98	**1.32**	1.19	1.47	**1.35**	1.21	1.50
Total score	**0.96**	0.94	0.98	**1.41**	1.27	1.56	**1.53**	1.37	1.71
Sleep quality (bad sleep quality: PSQI score > 5))									
Bad sleep quality	**0.95**	0.93	0.97	**1.45**	1.29	1.63	**1.42**	1.25	1.61

Adjusted for railway and road traffic sound level, age, gender, socio-economical status, home ownership, residential satisfaction, usual window position in the sleeping room at night, number of hours away from home; # $L_{Aeq,8h}$ (10 *pm*–6 *am*) for sleep quality, $L_{Aeq,16h}$ (6 *am*–10 *pm*) for all other health variables; bold: OR significant on significance level $p < 0.05$.

Table 8 shows that the health-related variables are proportionally related to psychological reactions to noise, indicated by annoyance due to aircraft noise. That is, the risk of health complaints (GSCL-24 scores), bad sleep quality (PSQI), and poor SF12/36 HQoL scores are related to annoyance indicating lower health-related quality of life with increasing aircraft noise annoyance. However, for the SF12 mental health score in the model including $L_{Aeq,16h}$ as predictor this association failed the level of significance.

In addition, the risk of reduced HQoL is associated with an increase in individual sensitivity to noise with regard to all assessed HQoL variables. The results hold true for logistic regression analyses with sound level and annoyance as continuous as well as categorized predictors with the lowest class of sound level and annoyance as reference. The findings are similar for regression models including both sound level and annoyance as predictors and for separate models with either sound level or annoyance as predictor. Logistic regression models calculated separately for males and females reveal similar results.

Whether the "V"-shaped differences in HQoL across the aircraft sound level classes (see Table 6) persist in different subgroups distinguished with regard to socio-demographic, attitudinal (expectation concerning the future QoL after airport expansion), situational (usual window position), and personal (noise sensitivity, multi-morbidity) factors was tested in two types of GLM (with a significance level of $p < 0.01$). The first type of GLM includes aircraft sound level, age, gender, and socio-economical status as independent variables and selected HQoL variables (SF12/36 scores, total health complaints, sleep quality) as dependent variables. The second type includes, beside aircraft sound level, the attitudinal, situational, and personal factors as independent variables.

Due to limited space in this paper not all results of the GLM are presented here (see [2] for more details). To summarize: no interaction occurred that would indicate a significant moderating effect of the socio-demographic variables on the impact of aircraft-noise exposure on health outcomes. Significant main effects were observed with regard to sound level (see Table 6), age (older residents reported lower HQoL than younger), gender (female residents reported lower HQoL than males), and socio-economical status (residents with lower status reported lower HQoL than residents with higher status).

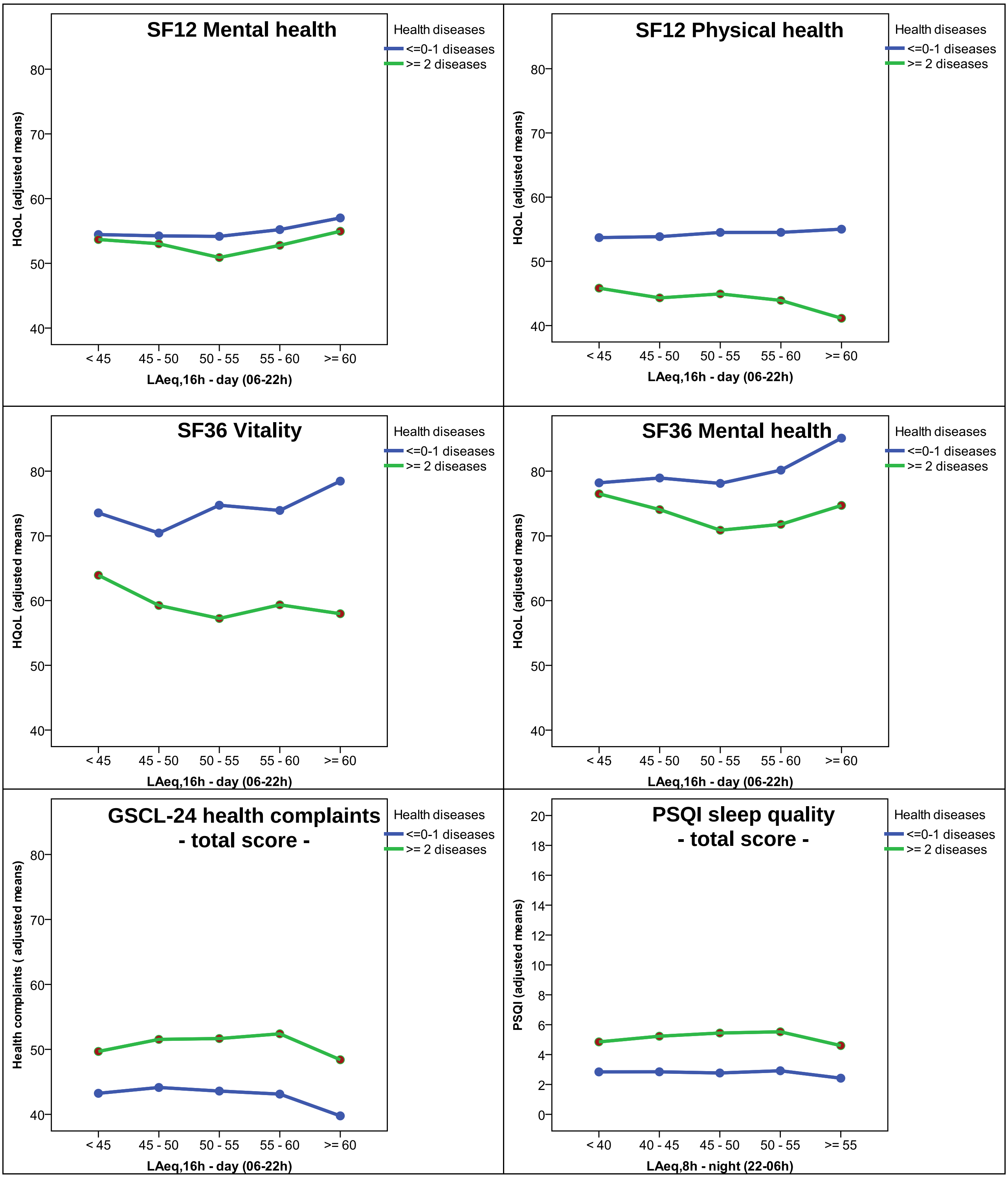
Results of the second type of GLM indicate higher HQoL for residents with up to one diagnosed health disease in comparison to those with two or more diseases, lower HQoL for those reporting negative expectations with regard to future (residential) life and for those judged themselves as being higher sensitive to noise in general compared to the lower noise-sensitive residents. With regard to potential impacts of aircraft noise on HQoL in subgroups of the residents the interactions between the described non-acoustical variables and aircraft noise exposure are of interest. Statistically significant interactions with aircraft sound levels were observed for the usual window position at daytime and for noise sensitivity. Yet, these interactions reflect marginal effects and cannot be interpreted in terms of a systematic moderating effect on the aircraft noise-HQoL relationship. This is somewhat different for the interaction morbidity x L_{Aeq} (for night-time concerning the criterion 'PSQI sleep quality' and for daytime with regard to the other HQoL criteria); see Table 9 and Figure 4. As can be seen from Figure 4, in the subgroups of residents reporting at least two health diseases (ever) diagnosed by a doctor, HQoL decreases somewhat with increasing aircraft noise exposure. This is particular true for residents exposed to lower to middle-ranged aircraft sound levels up to about 55 dB LAeq with regard to the SF12/36 scores (except SF12 mental health). In contrast to this, the HQoL of residents with less than two diseases remains constant or increases somewhat with increasing aircraft sound level. This interaction is not observed with regard to the reported health complaints and sleep quality. However, the described interaction confirms the notion of pre-existing health problems moderating the impact of (aircraft) noise exposure on health-related quality of life as described above in section 2.

Table 9. Results of multi-factorial GLM with HQoL variables as criteria.

Effect[1]	**df factor**	**SF 36 vitality**		**SF36 mental health**		**SF12 mental health**		**SF12 physical health**		**GSCL total health complaints**		**PSQI sleep quality**	
		F	p	F	p	F	p	F	p	F	p	F	p
L_{Aeq}[2]	4	2.1	0.079	2.8	0.025	4.2	0.002	0.9	0.455	3.9	0.003	1.4	0.223
Morbidity	1	298.2	0.000	83.5	0.000	29.2	0.000	635.6	0.000	314.2	0.000	273	0.000
L_{Aeq} × morbidity	4	4.6	0.001	3.8	0.004	1.8	0.125	3.9	0.004	1.4	0.217	0.5	0.713
df error		1,882		1,882		1,857		1,857		1,844		1,764	

[1] Results based on GLM with L_{Aeq} (five 5-dB-classes), morbidity (0–1 *vs.* ≥2 diseases), expectations about residential future (worse *vs.* better/no change), noise sensitivity (median split: low *vs.* high), daytime window position (closed *vs.* open/tilted); [2] PSQI sleep quality: $L_{Aeq,8h}$ for night-time; all others: $L_{Aeq,16h}$ for daytime.

Figure 4. Results of GLM: Adjusted means of HQoL (SF12/36 scores, total health complaints, PSQI sleep quality) by aircraft sound level classes ($L_{Aeq,16h/8h}$) and morbidity.



One reason for the finding that above 50–55 dB(A) there is no consistent decrease in HQoL with increasing aircraft sound level could be a kind of self-selection, *i.e.*, people with severe health problems have moved away or decided not to live in high aircraft noise-exposed areas in the vicinity of Frankfurt Airport. But this *post hoc* explanation cannot be proved with the present data, because no information about migration is available in this study. However, length of residence was assessed in the questionnaire. Nonetheless, adding this variable as a covariate in the GLMs described above does not reveal more information or lead to alternative conclusions.

In a pilot study, Cischinsky *et al.* [51] investigated the in- and out-migration in the region around Frankfurt Airport (Rhine-Main region). Although aircraft noise was not the most important reason for the migration it became more important on subsequent motivation ranks. Nevertheless, because high aircraft noise-exposed areas in the vicinity of Frankfurt Airport have also other infrastructural disadvantages, a clear conclusion about the causal link between aircraft noise and migration motivation could not be drawn in the study of Cischinsky and colleagues.

The result of an association between (severe) aircraft noise annoyance and HQoL is confirmed by results from other studies [52,53]. Results of the adjusted regression analyses suggest furthermore an association independently from the annoyance between noise sensitivity and most of the investigated health variables. This is in line with other studies that report relations between noise sensitivity, annoyance, and health complaints [27,54,55]. Yet, the causal path of the association between noise annoyance, noise sensitivity, and health effects is not clear. There are mainly three different explanatory approaches and interpretations discussed with regard to this issue: (1) Noise sensitivity is an indicator of an individual's vulnerability, which is closely related to (reported) health problems and which modifies individual noise reaction, suggesting that the noise exposure-annoyance-health relationship itself may be spurious [26]; (2) The noise sensitivity-annoyance-health relationship responsible for the dilution of a direct association between noise exposure and (reported) health incorporates a recall bias, which is absent when noise sensitivity is assessed before the occurrence or diagnosis of health disorders [56]; (3) The pre-existing health status and noise sensitivity are two interrelated 'vulnerability' factors which sap one's energy to cope with noise (and other stressors), and, thus, moderate the impact of noise exposure on noise reactions (annoyance) as well as on HQoL in general [22,27,57].

It seems that 'recall bias' is not the whole story. This interpretation of the findings neglects the relationship between noise sensitivity and physiological functions [58,59]. And, a recall bias would be more plausible in terms of reported health complaints (misleadingly?) attributed to noise but not in terms of a positive noise sensitivity-health association diluting a direct noise-health association. The third explanation seems to be the most plausible one. It fits with results of previous noise-related studies about the effect of health status on noise reactions [22,27,60]. It is also in line with general stress models recognizing pre-existing chronic health problems as stress-enhancing [61] and partly with results of this study, where it was shown that among the multimorbid residents reported HQoL decreased somewhat with increasing aircraft sound levels at least in low to middle-ranged sound level classes.

5. Conclusions

In 2005 a field study about residents' responses to aircraft noise was carried out in 66 residential areas in the vicinity of the Frankfurt International Airport. Residents (2,312) were interviewed with regard to their reactions to aircraft noise and their environmental as well as health-related quality of life. For the address of each participant sound levels for aircraft, road traffic, and railway noise were assessed. The study took place between the announcement (in 1998) and the approval decision (at the end of 2007) of the airport expansion (construction of a 4th runway).

Among several indicators of aircraft noise exposure the equivalent sound level showed the highest correlation with aircraft noise annoyance. The percentage of people (highly) annoyed by aircraft noise was found to be higher than predicted from general exposure-response curves. However, the degree of aircraft noise annoyance in communities around Frankfurt Airport is, all in all, in line with results from other recently published studies. Beside the sound level, non-acoustical factors, in particular the expectations with regard to future residential life after airport expansion and the confidence in authorities' effort for aircraft noise reduction, were associated with the reactions to noise and with HQoL. The results of this study indicate that aircraft noise exposure not only has an impact on noise-specific (stress) reactions but also—although with much lower effect size—on perceived EQoL in general.

The HQoL variables were found to be associated with aircraft noise annoyance as well as with the individual noise sensitivity. The more residents were annoyed by aircraft noise the poorer was their HQoL. This is in particular true for higher noise-sensitive residents than for lower sensitive ones. In addition, within the group of multimorbid residents an association between aircraft sound level and HQoL was observed. However, again, this effect was rather small.

All in all, it could be shown that the impact of aircraft noise on residents living in the vicinity of an airport effects noise-specific stress reactions (annoyance, disturbances) as well as QoL in general. Yet, the strengths of the impact of aircraft noise exposure on QoL decreases coming from noise-specific reactions (e.g., annoyance) to environmental-specific reactions (EQoL) and finally to health-related outcomes (HQoL). Furthermore, it became obvious that the noise-HQoL relationship is not a simple, uni-directional one. It is likely that aircraft noise affects the health of people in particular when they face limited resources to cope with the noise, e.g., due to pre-existing illness and/or elevated sensibility to noise in general. Limited coping ability, again, enhances the strain and enables the development of further stress-related health problems and limitations in HQoL. Admittedly, this assumed recursive process cannot be tested in cross-sectional studies, nor in experimental studies on acute noise reactions. Longitudinal studies would be recommendable to get more insight in the causal paths underlying the noise-health relationship.

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Appendix

Appendix 1. Variables assessed in the questionnaire.

Variable category	Variable	Number of items	Response scale	Cron-bach's α	Ref.
Annoyance	Aircraft noise annoyance in the last 12 months before the interview	2	intensity scales: verbal 5-pt., numerical 11-pt.		34
Disturbances of activities due to aircraft noise	…of communication indoor	3	5-pt. intensity scale; mean score	0.92	
	…of communication outdoor	1			
	…of relaxation/concentration indoor	2		0.93	
	…relaxation outdoor	1			
	…nocturnal sleep	3		0.92	
Coping with aircraft noise	Measures done within an aircraft noise situation (coping)	16	5-pt. frequency scale; mean score	0.94	
Air traffic related attitudes	Fears concerning air traffic	4	5-pt. intensity scale; mean score	0.86	
	Confidence in authorities' effort for aircraft noise reduction	7		0.86	
	Expectation concerning airport expansion				
	Negative expectation	6	5-pt. intensity scale; mean score	0.91	
	Positive expectation	3		0.71	
	Economic expectation	2		0.76	
Residential satisfaction	Satisfaction with dwelling	1	5-pt. intensity scale		
	Satisfaction with residential area	1	5-pt. intensity scale		
	Satisfaction with infrastructure (6 items), attractiveness of residential area (3 items), quietness (3 items)	12	5-pt. intensity scale; subscores and total score: mean scores	0.82	32

Appendix 1. *Cont.*

Variable category	Variable	Number of items	Response scale	Cron-bach's α	Ref.
Health-related quality of life (HQoL)	Vitality (SF-36)	4	SF subscales: Transformed scale with values between 0 and 100. Higher values indicate higher HQoL		35
	Mental health (SF-36)	5			35
	Mental health (SF-12)	6			35
	Physical health (SF-12)	6			35
	Health complaints (GSCL 24): exhaustion (6 items); stomach (6), limbs (6); cardiac (6), total (24)	24	Subscores transformed to scale from 0 to 100. Reference sample [36]: mean = 50, SD = 10		36
Health diseases (morbidity)	Self-reported diagnosed diseases; Multimorbidity: 0-1 diseases *vs.* 2 or more diseases	18	ever had; in the last 12 months; dichotomized		37; 38
Sleep	Sleep quality (PSQI total index)	18	sum score: 0 to 21; values > 5 = bad quality		39
Personal factors	Noise sensitivity (single item)	1	5-pt. intensity scale		
	Age				
	Gender		female / male		
	House ownership		tenant / owner		
	Socio-economical status 'Scheuch-Winkler index'	3	includes income, education, occupational status		40

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STANDARDIZED GENERAL-PURPOSE NOISE REACTION QUESTIONS FOR COMMUNITY NOISE SURVEYS: RESEARCH AND A RECOMMENDATION

COMMUNITY RESPONSE TO NOISE TEAM OF ICBEN

(The International Commission on the Biological Effects of Noise)

J. M. FIELDS

10407 Royal Road, Silver Spring, MD 20903, U.S.A. E-mail: jfields@capaccess.org

R. G. DE JONG

TNO Prevention and Health, Section Environment, P.O. Box 2215, 2301 CE Leiden, The Netherlands

T. GJESTLAND

SINTEF Telecom and Informatics, N-7465 Trondheim, Norway

I. H. FLINDELL

Institute of Sound and Vibration Research, University of Southampton, Southampton SO17 1BJ, England

R. F. S. JOB

Department of Psychology, University of Sydney, NSW 2006 Australia

S. KURRA

Istanbul Technical University, Faculty of Architecture, Division of Environment, Taksim 80191, Istanbul, Turkey

P. LERCHER

Institute of Hygiene and Social Medicine, University of Innsbruck, Austria

M. VALLET

INRETS-LTE, Case 24, 69675 Bron Cedex, France

T. YANO

Kumamoto University, Kurokami 2-39-1, Kumamoto 860, Japan

RESEARCH TEAM AT RUHR UNIVERSITY

R. GUSKI

Department of Psychology, University of Ruhr, Bochum, Germany

U. FELSCHER-SUHR

University of Ruhr, Bochum, Germany

AND

0022-460X/01/190641 + 39 $35.00/0

R. SCHUMER

FernUniversitiit Hagen, Germany

(Received 30 August 2000)

Differences in survey questions' wordings and weakness in some questions used to measure noise annoyance have interfered with accumulating knowledge about the factors that affect different communities' responses to noise. In 1993 an ICBEN team, Community Response to Noise, set the goal of creating high-quality survey questions that would yield internationally comparable measures of overall reactions to noise sources. After 7 years of discussions and research the team has developed and tested a method that attempts to meet those goals. The team recommends the use of a pair of multi-purpose questions in community noise surveys. The wording of the questions is presented for the nine languages for which a standardized empirical study protocol has been followed to select annoyance scale words. The team's protocol can be used to create comparable questions for additional languages in the future.

I. INTRODUCTION

The development of a useful, widely acceptable, and scientifically strong body of knowledge about reactions to environmental noise is dependent upon the accumulation of knowledge from many studies. Knowledge about community residents' reactions to noise has come primarily from over 300 combined socio-acoustic surveys [1] in which residents' reactions to noise are analyzed in relationship to those residents' objectively determined, acoustical noise environment. It has long been recognized that a major barrier to accumulating a useful body of knowledge from these surveys has been the difficulty in comparing the surveys' results [2-4]. This is due in part to the use of different survey questions.

Comparable questions are of special importance in these socio-acoustical surveys for two reasons: (1) A major survey product is a tabulation of answers to a noise reaction question (percent of residents with high annoyance) that is used to judge whether the reactions at the same exposure in different locations, cultures and countries are sufficiently similar to support uniform national and international noise regulations. (2) Relatively standard procedures are already used to measure the surveys' fundamental acoustical variables such as the total noise exposure, the peak noise levels, the numbers of noise events and the timing of the noise events. Previous studies using diverse noise-reaction questions seem to indicate that reactions in different communities to the same noise exposure may vary as much as would be predicted by a 30-decibel difference within a community [5, p. 238]. Given the diverse social survey questions used, however, this lack of agreement could be due to diverse social survey questions. After more than 35 years and 350 surveys, different studies continue to use their own diverse, non-comparable reaction questions. While it is not clear that any particular noise-reaction question is best, it is clear that the lack of a shared question hinders the accumulation of comparable information. Over the last 35 years the widespread recognition of this problem has generated several analyses of the problem and recommendations for standard noise reaction questions [6-8].

In 1993 the Community Response to Noise Team (Team 6) of the International Commission on the Biological Effects of Noise (ICBEN) developed a program to facilitate comparisons between socio-acoustic surveys. The result of the first part of this program, the development of reporting guidelines for socio-acoustic surveys, was published in 1997 [9]. The team's second major project, the development of scientifically sound, comparable noise-reaction questions, is the subject of this article.

In the years after the 1993 ICBEN meeting, a group of researchers including the ICBEN Team 6 members, a University of Ruhr team and other community noise acousticians reviewed previous studies, conducted workshops and performed research with the goal of developing a noise reaction measure for social surveys that has the following characteristics:

1. permits valid international comparisons of survey results within and between languages;
2. provides a high-quality, reliable measure of a general reaction to a noise experienced in a residential environment;
3. yields transparent results that will be consistently interpreted by survey respondents, policy makers, and report readers;
4. yields an interval-level measurement scale (i.e., the response scale answers are equally spaced) meeting the assumptions for regression and many other analysis techniques;
5. is likely to be widely adopted internationally;
6. is suitable for all questionnaire administration modes (face-to-face, telephone or self-administered).

Designing questions to meet these criteria requires choices on such issues as the type of question (open-ended or closed), the description of the reaction (e.g., annoyance, bother, disturb), the word referring to the acoustical environment (e.g., noise, sound), the specification of the residential conditions (e.g., overall or night/day, inside/outside, open-/closed windows, etc.), the type of answer scale (verbally labelled or only numbered), the exact words on a verbal answer scale, the number of points on that scale (e.g., 4-points, 11-points, etc.), and the general wording of the question. This article reports the steps that were taken to address these issues. The first section reviews relevant research. The next section reports on additional research that the team conducted to select annoyance scale modifiers. Finally, the two recommended noise reaction questions and the rationale supporting them are described. The 5-point verbal scale question is:

> "Thinking about the last(.. 12 months or so..), when you are here at home, how much does noise from(..noise source ...) bother, disturb, or annoy you; Extremely, Very, Moderately, Slightly or Not at all?"

The (0-10) point numeric scale question is (see section 4.1 for the full wording):

> ".... what number from zero to ten best shows how much you are bothered, disturbed, or annoyed by (.. source..) noise?

The rationale for specifying the exact wording for two questions is not to eliminate all other reaction measures. Although these questions are valuable for comparisons and for measures of general reactions, many noise reaction issues require additional noise reaction questions.

2. REVIEW OF RESEARCH ON QUESTION WORDING DIFFERENCES

Bibliographic searches reveal a large body of social science literature on the effects of questionnaire design and question wording on answers to social survey questions [10-12]. Although this general literature is valuable, it does not resolve many question wording choices for a noise survey or any specific survey because: (1) contradictory effects can be hypothesized for any particular situation so that it is not clear which effect, if any, may be dominant; (2) the underlying principles that explain some published findings are not sufficiently specific to be applied to a specific situation; (3) the published literature is likely to be biased toward reporting positive effects (i.e., instances in which questionnaire design did not affect results are less likely to be published).

TABLE 1

Effect of scale points on reporting amount of television viewing

QUESTION: How much television do you watch a day? (N = 132)

	Low watching choices scale (%)			High watching choices scale (%)		
Under 2½ hours	Up to ½ h	7%	84%	Up to 2 ½h	63%	63%
	½-1 h	18%				
	1-1 ½h	26%				
	1½-2 h	15%				
	2-2 ½h	18%				
Over 2½ hours	More than 2 ½h	16%	16%	2½–3 h	23%	37%
				3–3 ½h	8%	
				3 ½–4 h	5%	
				4-4 ½h	2%	
				More than 4 1/4 h	0	

The remainder of this section reviews and reports upon findings on five choices that must be made in the design of a noise reaction question. A sixth issue, the choice between a 4- and 5-point scale, is discussed in section 5.2.

2.1. RESEARCH ON ANSWER-SCALE LABELS

Research on the effect of variations in question wording has directed the current research effort toward an examination of alternative answer scales. Previous community noise surveys have used a range of answer scales but do not provide a firm basis for comparing alternative labels because the surveys that have differed from one another in their answer scales have also differed from one another in enough other ways that the effects of answer scale differences could not be isolated. As a result our knowledge about the importance of these issues comes from consistent findings from non-noise studies.

One of the most dramatic and most often replicated findings on the effect of answer-scale labelling is a finding from a German experiment on answers to the question "How much television do you watch a day?" [13, p. 391]. In Table 1, it is seen that on the low watching category scale where five of the six scale points are for under 2·5 h of daily television viewing, 84 per cent of the respondents reported low watching (i.e., under 2·5 h). In contrast, on the high watching category scale, where 2·5 h is only one of six points, only 63 per cent reported low watching (chi square= 7·7, $p < 0{\cdot}005$). This research shows that alternative presentation formats for logically identical questions can affect the answers about even a factual matter.

Although no equally definitive study has been conducted for noise annoyance scales, two studies suggest that similar effects may occur. In a small laboratory study of ratings of 13 nuisances, Rohrmann found that when "very" was point #4 on a 5-point scale, an average of 31 per cent reported being at least "very" annoyed (i.e., point #4, "very" or point #5, "extremely"), but when "very" was point # 5 on the scale only 14 per cent chose "very" annoyed and thus would be estimated to be at least very annoyed (analysis of data provided by Rohrmann, 1998). Another laboratory noise study found that subjects gave slightly lower annoyance responses at low noise levels to the same 5-point annoyance scale when that 5-point question was preceded by a binary annoyance question about any annoyance (Is the sound annoying?) [14]. Neither of these studies provides a firm basis for question design decisions because the first study included only 30 subjects and the second study's design is likely to have underestimated the effect of a binary question since all subjects knew that they would also answer the following 5-point scale. These noise studies do, however, reinforce the findings from other studies about the importance of using strictly comparable annoyance scales.

Researchers faced with comparing the results from different surveys with different annoyance scales have devised more or less elaborate methods for attempting to calibrate the scales based, for the most part, on intuition and logical considerations [3, 15: p. 3434]. The research reviewed in this section suggests that such calibrations are uncertain and that a firmer basis for between-survey comparisons is identically worded and scaled survey questions.

2.2. RESEARCH COMPARING NEGATIVE AND BIPOLAR SCALES

Most noise annoyance questions use a unipolar scale that extends from a negative pole to a neutral point. One study that asked about negative reactions also includes an unusual bipolar scale that extends from a negative to a positive pole. This study about both aircraft and road-traffic noise near Toronto airport [16, Appendix A] first asked a neutral screening question, "Do you ever notice ... sounds." from "aircraft" and "main road traffic noise ... " If respondents "noticed" a sound they were asked to " ... rate each of the sounds ... " on a bipolar 9-point verbal scale that included the four positive points of "Extremely, Considerably, Moderately, Slightly Agreeable", one "Neutral" point, and four negative points of "Extremely, Considerably, Moderately, Slightly Disturbing." Later respondents used a more conventional unipolar 0-10 numeric scale of "How do you rate.(the same). noise ... " where the end points were labelled "0 Not at all disturbed" and "10 Unbearably disturbed". Precise conclusions about differences between negative and positive questions are limited with this survey for several reasons: (I) respondents not "noticing" a sound were not asked the bipolar question, (2) the scales had different numbers of points, (3) the bipolar road traffic question included a negative descriptor ("road traffic *noise"),* and (4) the unipolar scale had an extreme label for the top point ("Unbearably disturbed").

Our reanalysis of these data found that strictly positive reactions ("agreeable") were given by small proportions of respondents; about 4 per cent for aircraft (at all noise levels) and from 1 to 10 per cent for road traffic (depending on noise level). The variations by noise level for road traffic may be partly due to the "notice" filter question that could have foreclosed some positive reactions at low noise levels and partly due to sampling error (the estimate of 10 per cent is surrounded by a 95 per cent confidence interval of ± 6 per cent). In Table 2, the aircraft noise responses for unipolar and bipolar questions are compared in alternating columns within three noise classes. In the table the sum of the positive and neutral categories on the bipolar scale are seen to be almost the same as the sum of the two lowest points on the 11-point numeric scale. For road traffic the percentages were the same (69 per cent) for the sample as a whole. The estimates of the percentages with high annoyance ratings ("extremely" for the bipolar scale or point # *9* or # 10 for the unipolar) are seen in Table 2 to be similar or greater for the bipolar scale than for the unipolar scale. A similar pattern was observed for the road traffic data. Although the differences in the Toronto survey questions' wording and numbers of scale points interfere with a precise comparison of bipolar and unipolar scales, they do suggest that a bipolar scale and unipolar scale will give simj)ar estimates of the proportion of the population that is annoyed by noise. The extent of similarity would be judged to be less from these data if the end points of the numeric scale had not been collapsed before making the comparisons presented above. The results for any type of analysis, however, do suggest that there are some positive reactions, but that surveys that

TABLE 2

Comparison of reactions to aircraft noise measured by one bipolar scale and one unipolar negative scale in three noise ranges (Toronto aircraft/road survey)

Definition of scale points		% choosing the annoyance response by scale type at three noise levels					
		<60 dB LAeq(24)		60-69 dB LA_{eq}(24)		"?.70 dB LAeq(24)	
Bipolar	*Unipolar*	Bipolar	*Unipolar*	Bipolar	*Unipolar*	Bipolar	*Unipolar*
Not hear or Extremely to slightly agreeable or Neutral	*0 Not hear or Not at all disturbed*	34%	*30%*	20%	*12%*	9%	*8%*
	1		*3%*		*2%*		*6%*
Slightly disturbing	*2*	23%	*9%*	18%	*7%*	25%	*2%*
	3		*7%*		*5%*		*5%*
	4		*9%*		*8%*		*12%*
Moderately disturbing	5	**15%**	*12%*	17%	*15%*	16%	*13%*
	6		*7%*		*13%*		*9%*
Considerably disturbing	*7*	13%	*11%*	15%	*14%*	24%	*9%*
	8		*6%*		*10%*		*13%*
Ex.tremely disturbing	*9*	16%	*4%*	31%	*5%*	27%	*ff%*
	/0 Unbearably disturbing		*4%*		*/0%*		*13%*
Total		**101%** (323)	*/00%* *(323)*	101% (251)	*IOI%* *(249)*	IOI% (93)	*JO/%* *(93)*

require information about posItIve reactions could measure them in separate questions asked of all respondents regardless of whether or not they may "notice" the noise.

2.3. RESEARCH ON THE PRESENCE OF A MIDDLE ALTERNATIVE

Research on the effects of middle, neutral alternatives on answers to bipolar opinion questions [10, p. 162] suggests to some investigators that a 5-point scale may distort annoyance responses towards the choice of point # 3 (the middle alternative) on a 5-point noise annoyance scale. Such a pattern would suggest that an even number of scale points might yield a better scale. This possibility has been examined by analyzing the 5-point annoyance questions from six community noise surveys that contain 53 different noise situations in which over 12 000 respondents used a total of seven questions to give 73 noise environment ratings (one survey with 20 environments included two separate 5-point scales). The analysis measured the extent to which any point on these 5-point answer scales exhibited a heaping of responses. "Heaping" is arbitrarily defined as a five percentage point higher choice for one answer than for both of the adjacent answers or, in the case of an endpoint, than for the single adjacent answer.

The first assessment method (simple heaping) determined how many of the 73 ratings of noise environments had a peaking or "heaping" of responses at each scale point. The heaping, defined by the 5 per cent rule, is seen in Table 3 to not be present in 16 per cent of the ratings and to be primarily concentrated at either endpoint for more than half of the rating environments. Nonetheless, there is more heaping at point # 3 (the middle) point than at point # 2 or point # 4 on the scale. Because such simple heaping at a scale point could be due to the noise level itself, a second assessment method is more conclusive.

The second assessment method (multi-modal heaping) tabulates the number of environments that exhibit departures from an expected response pattern. Given the most popular response category for a particular noise environment, the expected pattern is for the proportion of respondents selecting each response category to monotonicaly decrease away from that most popular response category. Multimodal heaping occurs at the midpoint when the midpoint of the scale interrupts the normal monotonic decrease from another popular scale point. For example, such bimodal heaping occurred in the 40-44 LAeq environments for study USA-220 when 68 per cent of the respondents chose point # 1, 8 per cent chose point # 2, 13 per cent point # 3, 5 per cent point # 4, and 5 per cent point # 5. When the 73 rating environments were examined from all studies, there was no multimodal heaping 85 per cent of the time. For the remaining 15 per cent (11 environments) such multi-modal heaping involved point # J in 9 environments, point # 5 in 7, point #2 in I, point #4 in J, and point #3, the middle point, in 5. In short, multi-modal heaping involved the middle point only 7 per cent of the time and did not occur at all 85 per cent of the time. If some heaping does occur, it appears to occur so infrequently as to not preclude the choice of a 5-point scale. The absence of heaping may be due to fact that the middle alternative on this unipolar scale does not represent the convenient opportunity to express an "undecided" response as does a bipolar scale for which the phenomena has been reported for non-noise topics.

2.4. RESEARCH ON THE WORDING OF NOISE QUESTION STEMS

Social science research has shown that seemingly innocuous differences in the wording of the stems of survey questions can have dramatic effects on respondents' answers [17]. One classic question wording experiment has been repeated 4 times over 36 years with a similar question wording effect each time. Each time part of the sample was asked "Do you think the United States should forbid public speeches against democracy?" About 25 per cent more respondents opposed such speeches when they were asked an alternative question that had exactly the same policy implications: "Do you think the United States should allow public speeches against democracy?" [10, p. 277]. This is one of many examples in which the wording of survey questions clearly affects respondents' answers.

Results from noise annoyance questions have shown large effects for some variations in question wording but not for other, seemingly important, differences in question wording. The only noise annoyance survey in which alternate forms of questionnaires were used with closely matched samples of respondents (respondents from adjacent households) found that many variations in question wording or location had no effect on answers [18, p. 250; 19]. The amount of speech interference reported at a specific location in the room where the interview was conducted was no less for the half of the respondents with whom the habitual present tense was used(" ... does the noise from the trains make you stop talking or pause or speak louder?") than for those with whom the word "ever" was used and even marked for emphasis by the interviewer(" ... has the noise from trains *ever* made you stop talking or pause or speak louder?") [19].

TABLE 3

Scale points with a simple heaping of responses (six studies providing seven data sets)

Study (ID Number in catalog [1])	Scale type	Number of interviews	Number of groups with heaping of answers (e.g., 5% more than adjacent categories)						Total number of groups
				Scale point at which heaping occurs					
			No heaping	Point # 1 (lowest)	Point # 2	Point # 3 (middle)	Point # 4	Point # 5 (highest)	
1967 4-Airport: USA-022	Numeric	3499	0	9	0	1	0	4	10
1969 3-Airport: USA-032	Numeric	2899	0	3	0	1	0	7	8
1970 2-Airport: USA-044	Numeric	1945	0	7	0	2	0	2	9
LAX-Night: USA-082	Verbal	1471	1	0	0	1	0	0	2
Noise change: USA-203	Verbal	953	1	0	0	1	0	2	4
Sonic boom: USA-375	Verbal	1546	6	12	1	0	2	2	20
Sonic boom: USA-375	Numeric	1568	4	9	4	2	0	1	20
Total†			12 (16%)	40 (55%)	5 (7%)	8 (11 %)	2 (3%)	18 (25%)	73

†*Note:* Percentages and numbers can exceed the totals because some groups had heaping at more than one scale point.

The conclusion drawn from the research reviewed in this section is that it is not possible to predict when question wording may have large effects or no effects at all. The safest course for comparisons is to base comparisons on identical questions that are presented in similar contexts.

2.5. RESEARCH ON THE LOCATION OF NOISE REACTION QUESTIONS WITHIN A QUESTIONNAIRE

In community noise reaction surveys of a single noise source, the primary response question is usually placed before more extensive sets of questions about the same source to avoid the possibility of biasing respondents' answers by heightening their awareness of the effects of that noise source. Three field experiments have been conducted, however, where the location of the primary response question was varied in the questionnaires but did not affect answers.

In two of the experiments the noise response question was asked twice in each questionnaire, first in the traditional location early in the questionnaire and second, after 10 to 20 min of detailed questions about the noise source, near the end of the questionnaire. Neither an experiment in a road traffic survey [20] nor an experiment in a railway survey [19] found any evidence that answers at the end of the questionnaire expressed any higher noise annoyance. In the road traffic survey, for example, the percentage of the sample expressing each of seven degrees of dissatisfaction from lowest (1 = definitely satisfactory) to highest (7 = definitely unsatisfactory) was 8, 6, 8, 16, 17, J3 and 32 per cent at the beginning of the questionnaire and 8, 6, 9, 15, 14, 15 and 33 per cent at the end of the questionnaire for the 2881 respondents who answered both questions. A similar lack of an effect was found for the railway survey even for the half of the sample that was informed just before the ending question that one of the sponsors was " ... British Rail, the people who run the railways ... " [19, p. 62]. For both the road traffic and railway survey the mean of the respondents' differences in answers between the first and second question (each question was scored from 1 to 7) was not significantly different from zero ($p > 0{\cdot}05$).

In a third survey in which approximately 743 ratings were given by 275 respondents over four rounds of interviews about home energy usage, the same 7-point numeric noise dissatisfaction scale preceded a 4-point verbal scale by two questions in one version of the questionnaire and followed that 4-point verbal scale in a second version of the questionnaire [21]. When these data were analyzed for this report no difference was found for the 7-point scale when the question appeared in different locations. For the 4-point verbal scale, somewhat greater annoyance was expressed when the 4-point scale came first (about 10 per cent more were "very"annoyed and about 7 per cent fewer were "not at all annoyed"). This result does not, therefore, support the hypothesis that annoyance scores are biased by placing a noise annoyance question in the less conventional location at the end of a questionnaire. In each of the three experiments, the lack of a location effect remained after controls for noise level were introduced into the analyses.

The existing research suggests that departures from the standard beginning-of-questionnaire location do not bias answers to noise-response questions. However, a remaining concern about question placement arises from the finding that answers to noise annoyance questions can be different for different times of day [22, p. 64] and for outside locations [23, p. 185]. Although the first two question experiments reviewed in this section occurred in questionnaires that asked about many locations and times of day, none of the three experiments placed the general noise annoyance question immediately after questions that focused on only a single time of day or only the out-of-doors environment. In the absence of such tests it seems best to avoid placing a question immediately after a series of questions that specify a single time of day or location in the home.

3. METHOD FOR DEVELOPING HIGH-QUALITY, MULTI-PURPOSE, COMPARABLE NOISE REACTION QUESTIONS

The ICBEN team's initial goal to develop comparable questions was broadened to include the additional five question-quality goals described in section 1.0. The present section describes the principles, steps and methods that were followed in developing the recommended noise reaction questions.

3.1. STEP #1: REVIEW PREVIOUS RESEARCH AND TEAM MEMBERS' EXPERIENCES TO SET THE BASIC FORM OF THE QUESTION

Socio-acoustic community surveys have been conducted on a regular basis since the late 1950s. After the first few studies, a broad consensus developed to use direct, close-ended questions as the primary measures of overall reactions to noise in residential areas. When the committee members reviewed questions from previous surveys and considered their own experiences they accepted that consensus. The reasons for accepting the various parts of this consensus are described later in section 5 ("Basis For Choosing These Questions"). The committee also noted that there were many differences in the detailed wording of the questions that might affect respondents' answers and thus concluded that for the purposes of comparisons between surveys it was important to agree upon a standard wording. The approach to developing a standard wording was different for the question stem (the question itselQ and the answer scale (the answers that respondents choose to report their reactions).

3.2. STEP #2: RELY ON REVIEWS AND EXPERT JUDGMENT TO REFINE THE WORDING OF THE QUESTION STEM IN ENGLISH

The draft of the wording for the question stem was circulated to all committee members, revised, and then subjected to thorough examination in workshops by general audiences at acoustical conferences and by small groups of community noise study experts. The early draft versions of the questions were also published in conference proceedings [24, 25]. The questions used wordings and concepts that were among those that had been found to be acceptable in previous surveys. Although it was the English version of the question that was subjected to this review, most of the participants in the review process were not native English speakers and thus considered the appropriateness of the question for their own languages.

3.3. STEP #3: TRANSLATE AND BACK-TRANSLATE TO DEVELOP AND ADAPT THE QUESTION STEM FOR LANGUAGES OTHER THAN ENGLISH

After the question stem was developed in English, the participants translated the question into their own languages. This translation process was expected to be routine except for the choice of a replacement for the phrase "bother, annoy, or disturb" that would convey the idea of a general negative reaction as it does in English. The translators did not attempt to

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exactly translate these three terms but rather to select from one to three terms that would convey the same general negative reaction in their own languages. As a check on the adequacy of the translation, the question stem was translated back into English by at least one other native speaker who had not previously worked on the project. Any differences were resolved by the native speakers.

3.4. STEP #4: CONDUCT PARALLEL STUDIES FOLLOWING A UNIFORM PROTOCOL TO SELECT VERBAL MODIFIERS FOR THE ANSWER SCALES

When the committee met to review proposed wordings, there was general agreement on the wording of the question stem but not on the selection of verbal modifiers for the answer scales or on the number of points for a verbal answer scale. The committee decided that neither dictionary translations nor expert judgment provided a sufficient basis to select verbal modifiers with good metric qualities for a single language or consistent meanings across different languages. It was decided that empirical studies were needed in each language to choose verbal modifiers that would have the same positions on an underlying scale of intensity of reaction to noise. These empirical studies from the first nine languages also provided information that helped in deciding between a 4- and 5-point verbal answer scale (see section 5.4).

4. THE RECOMMENDATION

ICBEN's Community Response to Noise Team (Team 6) recommends that each survey use two questions to measure annoyance reactions for the purpose of making comparisons between social surveys. This section presents the English version of the two questions (including their accompanying answer cards) and the instructions for administering the questions.

4.1. THE RECOMMENDED NOISE-REACTION QUESTIONS

The recommended measurement procedure consists of one verbal answer scale question *(Q. V.)* and one numeric answer scale question *(Q.N.).* In English, the questions are the following (other languages are in Appendix A):

[ASK ALL RESPONDENTS]

Q.V "Thinking about the last (..12 months or so..), when you are here at home, how much does noise from (..noise source..) bother, disturb, or annoy you; Extremely, Very, Moderately, Slightly or Not at all?"

Q.N "Next is a zero to ten opinion scale for how much (..source..) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between choose a number between zero and ten. Thinking about the last (..12 months or so..), what number from zero to ten best shows how much you are bothered, disturbed, or annoyed by (..source..) noise?"

The words appearing in parentheses are to be replaced by phrases that are most appropriate for the noise source and time period being studied. When these questions are used in an interviewer-administered questionnaire, respondents choose their answers from the answer cards in Figure 1.

Card Q.V

Extremely
Very
Moderately
Slightly
Not at all

Card Q.N

0	1	2	3	4	5	6	7	8	9	10
Not at all										Extremely

Figure I. Answer cards for recommended annoyance questions.

On the basis of the findings in section 6 it is recommended that the top two scale points on the 5-point scale ("very" and "extremely") be combined to measure the proportion of respondents who are "highly" annoyed.

Although these two questions are methodologically sound and preferred for comparisons between surveys, some surveys may require additional general noise reaction questions. The purpose of each particular survey must dictate whether these two questions are to be the primary reaction questions for the survey or would be supplementary questions included for the purposes of making comparisons between surveys.

4.2. INSTRUCTIONS FOR ADMINISTERING THE QUESTIONS WITHIN A SURVEY

To obtain comparable annoyance measures the questions must be presented to respondents in an identical way. The following guidelines are suggested to ensure the uniform administration of these questions (Justifications for the guidelines are given in section 5):

1. *Ask all respondents both questions.* Two questions are needed to obtain a reliable measure of reactions. Each and every respondent is first asked both of these questions. If it is necessary to determine whether some respondents do not hear the noise source, a question about the audibility of the noise can be asked separately.

2. *Present the full scale, exactly as worded, to all respondents.* Interviewers should not rephrase or "explain" questions. The questions should not be divided into parts by, for example, using an initial, screening, binary question about whether the respondent is "annoyed".

3. *Place the questions early in the questionnaire, unless this conflicts with other survey objectives.* Most noise/annoyance surveys put the first noise/annoyance question early in the questionnaire before it is clear that the focus of the survey is on noise generally or on noise from a particular source. If these proposed questions can be the primary noise/annoyance questions for a survey, then it is recommended that they be placed early in the questionnaire. If other noise annoyance questions are more important for the survey's purposes, then the recommended questions can be placed later.

4. *If pretests indicate that the questions are perceived as repetitious, include appropriate instructions.* If the questions are not placed early in the questionnaire, potential interviewer or respondent discomfort with apparently repetitious questions can be solved with

introductions to the questions similar to the following:

> *(Introduction A)* "Now we return to the noise from (.source.) and take everything into account we have discussed. Thinking about the last ... [insert recommended questions] *(Introduction B)* "People in other countries have answered this next question to tell us how they feel about noise. Now you can use it for the noise here. Thinking about the last ... [insert recommended questions]" *(Introduction* C) "Even though all of the questions are slightly different, I know a few of them can seem similar for people in your situation. If any seem repetitious for you, just give a quick answer and we will move to other questions."

5. *Prepare written instructions for interviewers.* For telephone or personal interviews the interviewers should be provided with written instructions that: (1) instruct interviewers to ask questions exactly as written, (2) train interviewers to respond to "I don't understand" with methods that do not require paraphrasing the question, (3) urge respondents to choose between the offered answers, (4) encourage all residents to answer these questions (new residents can be instructed to answer about only their recent period of residence), and, if repetition is expected to be a problem, (5) provide interviewers with instructions for respondents who find the questions to be repetitious.

5. BASIS FOR CHOOSING THESE QUESTIONS

Considerable thought and research went into the selection of the two questions recommended in the previous section. This section gives the rationale for the general type of question approach, the types of answer scales, the exact wording for these question stems, and the selection of the response modifier words for the answer scales.

5.1. THE TYPE OF QUESTION

The recommended questions are short, direct (closed) rating questions that ask about only neutral or negative reactions and are intended for all respondents. Before recommending these questions careful consideration was given to the sometimes-voiced assumption that such direct questions could give biased estimates of the numbers of people who are "truly" annoyed by noise.

5.1.1. *Direct rating question with closed scale*

These direct rating questions name the noise source, ask for respondents' feelings about the noise source, and present respondents with choices between a limited number of answers. After some initial research with indirect questions [26] such direct rating questions have been almost universally accepted as the primary measure of the relationship between noise and residents' reactions. Answers to such direct questions are more explicit and readily interpreted than indirect questions or comparison questions, the two other types of questions that are sometimes used for special purposes in noise surveys.

Indirect questions attempt to ascertain the underlying impact of noise with either open questions in which the noise source is not identified, complaint questions in which respondents report complaint actions rather than feelings, or behavioral questions in which respondents report behavioral adaptations rather than feelings. Although useful for specific purposes, none has supplanted the direct questions as the primary indicator of noise impact because these questions can only be used to indirectly infer how people feel about noise impact. In addition, such indirect questions are less highly related to noise exposure [27, p. 187] Indirect, open questions that allow respondents to volunteer their own answers are expensive to analyze and result in answers that cannot be directly compared.

The other type of question, a comparison question, provides an anchor for a rating by asking respondents to compare their feeling about the specified noise to their feeling about some other object. The overwhelming problem with comparison questions is the absence of a common, shared anchor that could provide a uniform point of comparison across surveys or even across neighborhoods in the same survey. The most obvious anchors, other neighborhood nuisances, vary so greatly from site to site that they cannot be used for comparing noise responses at different sites. Magnitude estimation techniques could, in theory, use other shared reference points to resolve this problem, but previous research has found that such techniques are not sufficiently refined for a question to be recommended for wide usage in noise-reaction surveys (Fields, 1996).

5.1.2. *Unipolar scale (Negative neutral)*

The recommended questions ask about the negative problem, "noise", and use unipolar scales that extend from a negative pole ("extremely annoyed") to a neutral position ("not at all annoyed") but not to a positive pole ("extremely enjoyable"). The practice of asking about such negative reactions is almost universal in community noise surveys. The decision to ask about the negative problem was made with the knowledge from previous surveys and the analysis in section 2.3 that reactions to transportation noise are overwhelmingly either negative or neutral and that scales with both positive and negative scale points yield almost the same response distributions as those with only negative scale points. In addition a question about the negative concept of "noise" is expected to be more quickly and easily understood than a question that asked for a positive rating of "sounds". Of course, positive reactions can still be studied by asking additional questions about positive reactions.

5.1.3. *One-part question for every respondent*

The same two questions are asked of every respondent regardless of length of residence, audibility of noise source, or degree of annoyance. This uniform administration procedure simplifies the questionnaire design, increases the comparability of measures in different surveys, increases the accuracy of the data and still provides the flexibility to analyze the responses of only subgroups of respondents. New residents can, for example, be asked the question, but be removed from some analyses. The alternative procedure of designing an additional internationally accepted uniform screening question that would eliminate new residents would almost certainly create additional differences between surveys as the different investigators decided how to define such terms as "new"(one month or one year) or a "change in residence" (e.g., Would a move within a neighborhood be a change?).

The questions are not screened or broken into separate parts primarily because such screening procedures distort the measurement of reactions by interfering with obtaining clear, unambiguous measures of annoyance. The difficulty is that research suggests that both audibility and "any annoyance" screening questions contain measures of degree of annoyance and are affected by the screening question's use of only two scale points (binary response of "yes" or "no"). An English road-traffic survey, for example, shows that a screening question about "hearing" or "not hearing" a noise source is not interpreted according to a dictionary definition of audibility. In that probability sample of the population of England, automobiles could be heard at all homes (all the respondents lived on a road), but J1 per cent reported that they could not hear "cars, lorries or other road traffic" [28, p. 35]. In accord with the types of "conversational norms" that are found in interviews [29, p. 43], it is likely that when these respondents were asked a patently unreasonable question, they reinterpreted the question to not be about audibility but rather to be about low levels of annoyance (e.g., "Do not REALLY hear the noise"). A similar reinterpretation could be expected in answers to any binary screening question about being "annoyed" or "not annoyed". Research on answers scales cited in section 2.1 leads to the expectation that some respondents who would answer "slight" annoyance on a 5-point scale would give a response of "no annoyance" on a binary, 2-point scale. A screening question introduces additional ambiguity in interpreting the responses to a 5-point annoyance scale since the four points on that scale presented after the answer "yes" to a binary "any annoyance" question might be perceived as forming a 4-point scale. Since annoyance is a finely graded response rather than a simple, unambiguous, binary condition, it is to be expected that the number of scale points will affect answers. A more accurate measure of the audibility of noise sources can be obtained from a question that follows the primary annoyance question and, as a result, makes it clear that not annoyed respondents can still report hearing a noise.

5.1.4. *General, non-specific reaction question*

The recommended questions seek to obtain general, persistent reactions that allow respondents to integrate their experiences over different times and locations in their home. The questions are designed to obtain overall assessments from respondents who differ from one another in their sensitivities to noise in different locations and time-of-day conditions. These questions do not specify one particular combination of conditions because an overall response measure necessarily involves an integrated response over a range of different types of experiences and sensitivities. The questions do not explicitly list the range of conditions over which the experiences should be integrated for five reasons: (1) a complete list would involve too many conditions (room of home, location on property, season of year, day of week, hour of day, window-opening conditions, activity during exposure, number of noise events, peak levels of noise events, etc.); (2) a long list may lead respondents toward objective assessments of sound exposure levels and away from subjective feelings about exposures; (3) a long, complex question may confuse some respondents who will resolve the complex task by just answering for one condition, perhaps the first or last condition mentioned, while ignoring their most important, but seemingly insufficiently sophisticated, general subjective response; (4) a long list of conditions is more difficult to adapt to different cultures, languages and types of buildings; (5) a long question is less likely to be included in many surveys.

5.2. THE TYPE OF ANSWER SCALE

The initial goal for this project was to choose a single answer scale. After several international workshops, however, both the 5-point verbal scale and the 0-10 numeric scale were chosen.

5.2.1. *A verbal and a numeric scale*

Each of the scales has a different strength. The verbal scale is needed for the clearest, most transparent communication between respondents and policy makers or other readers of social survey reports. The simple task of choosing a word is most likely to be easily performed by respondents of any degree of sophistication in any culture. The resulting selected word is, when presented in a report, simply passed on to readers as the respondent's choice. The protocol for choosing the words (described in section 5.4) attempts to ensure that the commonly understood meaning of the word is consistent with its position on the scale.

The numeric scale is felt to provide greater assurance that the scale points are equally spaced and thus meet the assumptions for linear regression and similar powerful analysis techniques that can represent the continuous range of responses to noise. The numeric scale also reduces the possibility of distortion by idiosyncratic interpretations of the verbal labels for scale points.

5.2.2. *Two scales*

Having more than one scale for a cross-survey comparison and, in fact, all analysis purposes is consistent with the most basic principles of increasing the reliability of psychometric measurements [30-32]. In addition a second scale provides some assurance against translation difficulties and provides the previously listed strengths of both verbal and numeric scales.

5.2.3. *A 5-point verbal scale*

Verbal scales of six points or more were rejected because such long scales were judged to be too cumbersome for telephone interviews (at least for a unipolar scale). Scales of three points were rejected as not providing a sufficient range of alternatives. On a 3-point scale there would only be two degrees of annoyance for those who were other than "not at all annoyed". In the absence of empirical data, the standard psychometric criteria of reliability and validity could not be used in selecting between 4- and 5-point scales. Although both scale lengths have been used in previous noise surveys, the effects of length cannot be evaluated with noise-annoyance data because scale length is confounded with other differences between surveys and with wording differences in the question stems. As a result five other criteria were considered, upon which 5-point scales were slightly better on two criteria and equivalent on the remaining three.

5.2.3.1. *Consideration A-resolution of scale.* Logic and some research [33] suggest that five points provide additional resolution by allowing respondents to give a more finely graded, exact response than a 4-point scale.

5.2.3.2. *Consideration B-mitigation of end-of-scale scoring effects.* Respondents who tend to avoid ends of scales are given an additional usable rating point on a 5-point scale. In addition the 5-point scale slightly reduces the differences between those respondents who assume that the top word ("extremely") represents the endpoint (an intensity of 100 per cent on an underlying 0-100 per cent scale) and those who assume the top word is the mid-point of an interval (an intensity of 90 per cent for the top fifth of the 5-point scale compared to 87·5 per cent for a 4-point scale). The recommendation that the top two points on a 5-point scale be combined to measure "highly annoyed" further mitigates these end-of-scale scoring distortions for the 5-point scale.

5.2.3.3. *Consideration C-rating of best 4- and 5-point scales in modifier study.* The standard annoyance modifier study, to be described in section 5.4, applies three criteria to choose the best verbal modifiers for one 4-point and one 5-point scale for each of nine languages. The three criteria are: (I) extent to which the available words are equally spaced on the annoyance continuum; (2) extent to which respondents agree on the location of the words on the annoyance continuum; (3) percentage of subjects who prefer the usage of the words for a scale. These same three criteria were used to compare the presumed quality of the best 4-point and best 5-point scale that could be identified for each language. These comparisons did not show a preponderance of evidence for either the 4- or 5-point scale. In eight of the nine languages, some criteria supported one scale and some the other (only in French did all three criteria support a single scale, the 5-point scale).

5.2.3.4. *Consideration D-previous scale usage.* No previous, widely used verbal scales could be accepted on the basis of the present research. The words in the most widely used 4-point verbal scale ("not at all, a little, moderately, or very") [34, 35] were not the words chosen using the 4-point scale criteria applied for this study ("not at all, somewhat, significantly, extremely"). The intensity scores for the previous scale's words of 1-13-44-76 were systematically lower than the equidistance criterion of 0-33-67-100. Similarly, no previous widely used, 5-point verbal scale provided a basis for choosing between scales. Three studies have used the same five words in a similar annoyance scale [36-38]. The results from several additional studies using the same words are not comparable, however, because they used a two-part annoyance question in which respondents were first screened with a 2-point scale ("annoyed or not") and then, if they indicated annoyance, were asked for an annoyance response for the remaining four points [39,4Q pp. 1056-1057].

5.2.3.5. *Consideration £-skewed scale distributions.* Four-point scales are sometimes seen as preferable to 5-point scales that might have middle alternatives that could encourage a heaping of responses on that middle answer. The noise-scale research reviewed in section 2.2 indicates, however, that this is not an important issue for noise reaction questions.

Eleven-point (0-10) *numeric scale.* A 0-10-point scale is likely to be easily understood by peoples of all countries and cultures who are familiar with currency in a base-IO monetary system and other familiar counting situations. The mid-point of a 0-10 scale is readily and correctly assumed to be "5" unlike the mid-point of a 10-point scale (1-10) that is 5·5 not 5·0.

Scale card visual aids. Visual displays of answers shown with the recommended question in section 4.1 are used in self-administered interviews and are recommended as an aid for personal interviews even though they could not be used in most telephone interviews. The 0-10 scale is presented as a simple, equally divided line rather than as a more complex graphic such as a thermometer because of concerns that an artistically rendered thermometer with a large bulb or other graphic device might not appear to have equal intervals. The line is arrayed horizontally to reduce the space needed in a self-administered questionnaire. For the 5-point verbal scale, the words are visually presented vertically with the most intense response word at the top. The words are vertically arranged because the varying length of the words would mean that a horizontal placement could not be equally spaced. The words are not identified with numbers because numbers might distort respondents' judgments away from the words' intrinsic intensity scores and thus also away from the intensity scores that are assumed to apply by the report readers who base their interpretation on only the words. For example, the choice ofO or 1 for the lowest scale point might alter the meaning of "not at all annoyed" of this unipolar scale if "O" was interpreted as absolutely no annoyance while "1" was interpreted as I/5th of the total annoyance scale in some cultures.

5.3. THE WORDING OF THE QUESTION STEM

Given the rationale in the previous section, the actual wording of each question in each language was carefully crafted. Back translations were performed by at least one individual for each question for each language before the final wordings were accepted.

To illustrate the details involved in the final decisions on wording, the English, 5-point verbal scale is divided into phrases in the next paragraph in bold italics with explanations in square brackets following each phrase or choice of words.

"Thinking about the last (..12 months or so..), when [# 1: The indefinite "thinking" and "12 months or so" encourages a general response to the noise, rather than an exclusive, comparison of the last 12 months with any other period.] ***you*** [# 2: The respondent's own reaction, not that of family members, is requested.] ***are*** [# 3: The habitual, present tense of the verb, "are", encourages the habitual, general response as explained in # 1.] ***here at home,*** [#4: This phrase is intended to measure the general evaluation for the respondent's dwelling environment while excluding the broader neighborhood shopping and recreation areas (as might be suggested by "around here") and not strictly limiting answers to inside the building (as would be implied by "in your house").] ***how much*** [# 5: This phrase prepares the respondent for choosing an answer of degree of response.] ***does*** [Habitual present tense-see # 3.] ***noise*** [# 6: The single word "noise" rather than the phrase "the noise" is used to avoid the implication that such noise must be present. "Noise" is used rather than a neutral word for the reasons given in section 5.1.J ***from (.. noise source...)*** [# 7: The name of the noise source is specified not left unclear.] ***bother, disturb, or annoy*** [# 8: These three words were judged to be necessary to convey the general impression of a negative reaction in English.] ***you:*** [Own reaction reinforced-See # 2.] ***Extremely, Ve,y, Moderately, Slightly*** [# 9: These four words were selected by the protocols contained in the empirical study described in the next section.] ***or Not at all?"*** [# 10: This phrase was found to have the lowest annoyance intensity rating in several studies [14, 41].]

The wording for the 0-10 numeric scale was equally carefully considered. The numeric scale question was constructed with about twice as many words because the concept of a numeric, 0-10 scale is more difficult to explain, especially when a visual device cannot be used in a telephone interview. When a visual answer card can be used, careful attention is needed to its construction. For the numeric scale, for example, the scale points are equally separated and the labels for the endpoints are centered on their scale points and are in a sufficiently small font that they do not overlap other scale points.

5.4. RESEARCH TO SELECT THE RESPONSE MODIFIER WORDS FOR THE ANSWER SCALES

This section describes the standardized research project that choose the labels for the answers to the 5-point verbal scale and for the endpoints of the 0-10 numeric scale for each language. The project draws heavily on techniques originally designed for scaling of modifiers generally [42] and then developed for use with noise surveys in 1966 in Germany [43] and later in the United States [41]. This section describes the four steps followed in all languages with examples drawn primarily from the English language study.

5.4.1. *Forming a pool of test words*

The group of participating researchers from each country created a final list of 21 candidate response modifiers for evaluation in their language. In English a longer list was initially developed by brainstorming about possible modifiers and listing modifiers that had been used in noise annoyance surveys or that had been examined in previous response modifier experiments on noise [14, 41] or on any subject matter [44, 45]. To meet minimal standards for clarity of meaning in a questionnaire for oral administration to the general population these long lists of modifying phrases were screened using the following six criteria: (1) the phrase is sufficiently short to be understood when read in a list of five modifiers (e.g., exclude: "very definitely extreme"); (2) the phrase is used in common speech (e.g., exclude "unfathomly"); (3) the phrase does not mix positive and negative modifiers (i.e., exclude phrases such as "not too strongly" or "not very much" because they might easily be misunderstood); (4) the phrase is a modifier, not an unmodified restatement of the basic response (e.g., exclude "annoyed" or "disturbed" without a modifier); (5) the modifier describes a feeling and not an extreme behavioral reaction or level of adaptation (e.g., Both "unbearable" and "unacceptable" contain the logical contradiction that the resident is living with the noise); (6) the modifier does not use the superlative form of an adverb (e.g., both "the absolute worst" and "the most awful" are not likely to be literally true and thus may measure respondents' tendencies toward hyperbole rather than their feelings). These criteria excluded many items that had been used in previous adverbial modifier studies. The investigators also conferred with colleagues on the content of the list.

5.4.2. *Collecting data*

Empirical data were collected on the 21 words in each language by having subjects in each language follow the same protocol to evaluate the language's words. The protocol was initially written in German and English by native speakers of both languages at the Department of Psychology, Ruhr University in Bochum, Germany. The protocol was then sent to each of the language teams and translated into the remaining seven languages. The protocol addressed subject recruitment procedures, subject briefing instructions, oral instructions to be read to the subjects and the wording of the instructions for the questionnaire.

Subjects included a mixture of university students and employees of technical firms. The average age was about 35 years, but varied from 19 to 44 for different study sites. After providing some background information the subjects completed the questionnaire by performing the following four tasks to evaluate the 21 words:

Task #1: Intensity grouping. Subjects placed each word in one of nine groups ranked from no annoyance to "… the most annoyance you can imagine" (This introduced respondents to the words, but the results were not used in the analysis.).

Task #2: Intensity scoring. Subjects indicated the intensity associated with each word by placing the word on its own 10-cm line that extended from "No/lowest degree of annoyance" to "Highest degree of annoyance."

Task # 3: 5-point preference question. Subjects selected one preferred word for each of the scale points by first choosing a word "that you would be most likely to use" for the "greatest amount of bother or annoyance you might feel" and then expressing a preference for the three words that should complete the remaining three points on a 5-point scale. (The lowest point was predetermined.)

Task #4: 4-point preference question. Subjects selected one word for each of the 4-point scale points by expressing a preference for the two words that should complete the remaining two points on a 4-point scale. For both the 4- and 5-point preference questions subjects were instructed to choose words that "people would normally use when talking". Subjects were instructed to select words that were "equally spaced" between "not at all annoyed" and the previously chosen high annoyance word.

The questionnaires were completed by 1754 subjects at over 25 sites in 12 countries in nine languages (Dutch/Flemish = 93, English = 231, French = 45, German = 61, Hungarian = 47, Japanese = 1102, Norwegian = 56, Spanish = 59, Turkish = 60). The data from the experiments were then analyzed at two central locations as well as at most of the participating laboratories. At least 12 reports have been written about the results for specific languages [46-57].

5.4.3. *Analyzing data*

A separate but identical analysis was conducted for each language. The result of this analysis was a series of eight ratings for each word that could in turn be used to apply the ICBEN protocol for selecting one word for each scale point. The eight ratings are divided between three for the 5-point scale analysis, three for the 4-point scale analysis and two that would be used for both analyses. The eight ratings are presented for the English language 5-point scales in Table 4 and Figures 2 and 3. Results for the remaining languages are given in Appendix A. The eight ratings are the following:

Intensity score average: the average of the positions in which subjects marked the word on the 10-cm scale when the marks are scored in millimeters (0-100). The average is computed after the distance is expressed in millimeters from Oto 100. The intensity score is given in the first row (x) of Table 4 for each of the 21 English words. Intensity scores for each English study site are given in Figure 2. The 95 per cent confidence interval for each site's score is marked by the line extending from each site's symbol in Figure 2.

Intensity score standard deviation: the root mean square of the intensity scores. A large number indicates a lack of agreement on a word's position. The standard deviation (o-) is given in the second row of Table 4.

Scale point candidacy: 5-point scale: the single scale point (# 1, # 2, # 3, # 4, or # 5) for which the word is a candidate. This is the scale point for which the word was most often chosen as the preferred word on a 5-point scale. Each word's candidacy is shown by its grouping in Table 4 and Figures 2 and 3.

Scale point candidacy: 4-point scale: same as preceding definition but 4-point scale. These 4-point scale results are given in the lower portion of Table 4.

Net preference score: 5-point scale: percent of subjects preferring the word for that word's "candidate" position decreased by the percent preferring the word for other position(s). The net preference score may be negative if a word is chosen for more than two positions. The net preference score for the complete sample appears in the "Net.Pref.%" row in the middle of Table 4 and, for each site, in Figure 3 together with the 95 percent confidence interval for that score.

Net preference score: 4-point scale: same as preceding definition but the 4-point scale is in the last row of Table 4.

Difference from scale point intensity criterion: 5-point scale: the difference between the word's intensity score and the intensity criterion for that word's candidate scale point. The intensity criteria for the 5-point scale are 0, 25, 50,75, 100 for points # 1 - # 5 respectively. Differences are given in the "A = IC-Inten" (Intensity Criterion-Intensity score) row of data in Table 4.

Difference from scale point intensity criterion: 4-point scale: same as preceding definition but 4-point scale with the 4-point criteria ofO, 33·3, 66·7 and 100 with results being given in the next-to-the-last row of Table 4.

5.4.4. *Selecting words*

The scale point candidacy ranking described above resulted in the pools of candidate words for each scale point that are indicated in Table 4 and Figures 2 and 3. The analysis then proceeded by choosing among the words in each pool. The best candidate was selected from the pool based on three scores: "Net preference score", "Difference from scale point intensity criterion", and "Intensity score standard deviation". In the simplest case, the same word was best on all three scores. For example, the selection of "extremely" from among the three candidates for the fifth point of the 5-point scale is seen to be such a case in Table 4 where "extremely" is closest to the intensity score ("A = IC-Inten" = - 5),

TABLE 4

Reaction modifier study results for 230 English-language subjects at 5 sites (England, Australia (2 sites) and U.S.A. (2 sites))

Modifier word candidates (Words chosen for the 5-point verbal scale are underlined)	Means for best scale
1..1!2LI Insigl Barel IHardl I A IS1i9hl Parti ISomewl Fairl IRathel Imporl Consi ISubstlSignil IHighl IStronl Sever ITremel lbest	
l--2L._lnificly Y llittll!;..!.:,:__lally lhat Y latelylr ltantllderablantialficanl_ Y lgly lely lnctousl!!Jtl:i	!scale
l lantlyl I le I__ I I I__ I Y lly Illy ltly I__ I I lly I__	I

IIntenl x | .771 7.571 8.12110.28113.19115.13129.62IJ5.11110.48143.12111.89165.09112.24164.SO167.22175.62178.69179.11190.74192.25194.B5I

lsity I o | •.961 8.6•1 8.05112.•JI e.061 9.35112.97115.25114.9• 110.93111.20114.32116.99115.31!1•.21112.05110.151 9.•• I n.101 9.<21 8.681

I5-point scale — Grouping of modifier candidates for 5-Point scale — !Best 5-pt; four words

!Scale Pt.#	IPt.#11	Point #2 of 5	Point #3 of 5	Point #4 of 5	IPoint #5 of 5	Ifour +words
IIntensicy	I O 00 I	Intensity Criteria (IC) = 25.00	I.C. = 50.00	Incensity Criteria (IC) = 75.00	IC = 100.00	lll=lO. 2I

Ii:l•IC-Inten. | 1l -171 -171 -151 -121 -101 5I 111 -101 -1 I -21 151 -131 -111 -81 1 I 4l 5I -9 I -s I -slr.=s.•ol

INet Pref. %1100.01 0.871 6.061 7.79122.94136.361 o.a11-o.4J111.69134.20112.120.431 5.631 4.J11 7.79120.35121.21110.J9122.08113.85159.741x=38

Is-point scale — Grouping of modifier candidates for 4-Point scale — !Best 4-pt: three words

Scale Pt.#	IPt.#11	Point ff2 of 4	Point #3 of 4	IPoint #4 of 4	Ithree +words
!Intensity	I OOOI	Intensity Criteria (IC) = :n.33	Intensity Criteria (IC) = 66.67	IC = 100.00	10=12.11

Ill=IC-Inten. I 1l -261 -251 -211 -201 -181 -4 I 2l 7l 10 I -19 I -21 -4 I -2 I 1l 9 I 121 13 I -9 I -81 -5IZi=2. 101

!Net Pref. %1100.01 1.731 2.161 2.601 9.52116.021 9.09115 58112.551 9.521 .871 1.30120.1511O.J9115.15111.699.521 4.33122.08112.12160.611x=10

*For a 4-point scale the protocol selects: Point #-1,.not at all, Point #2"'somewhat, Point ff3=significantly, Point #4=@Y.tremely.

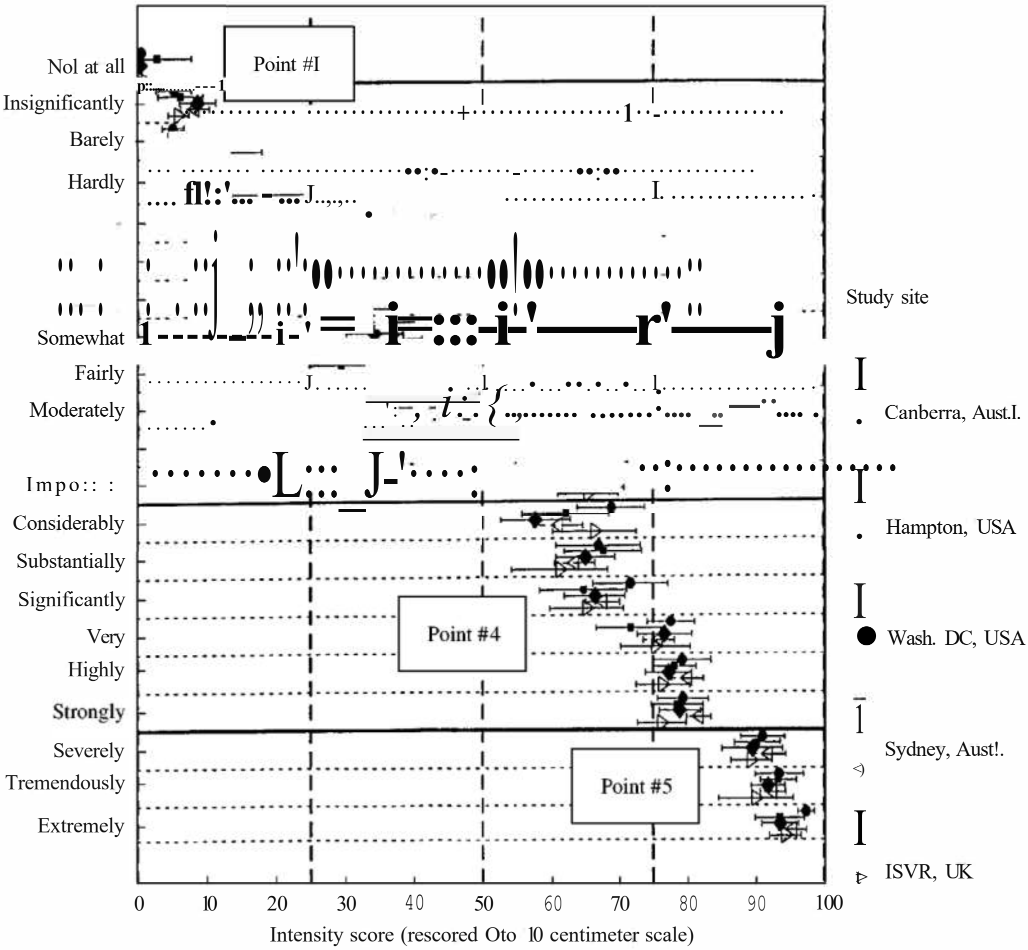

Figure 2. Intensity scores for 21 English words grouped by 5-point scale group (vertical lines are 5-point scale criteria of 0, 25, 50, 75, 100).

has the highest net-preference score at 59·74 per cent, and has the lowest, standard deviation (8·68).

When the different criteria favored different words, however, a more complex scheme was used to select the best word after eliminating weaker candidates from that scale point's eligible pool. The best word was the word remaining after words were eliminated one by one as each failed a criterion at one of the following 13 successive steps: (Step # 1) Net preference score;,.:: 5 per cent; (2) Unsigned difference from scale point intensity criterion < 15 (e.g., A = IC-Inten. < 15); (3) Net Preference score within 20 points of most popular remaining candidate word for the scale point (e.g., A% Pref < 20); (4) Standard deviation within 15 points of smallest remaining modifier's standard deviation (e.g., ,'\(j = < 15); (5) A = IC-Inten. < 10; (6) A% Pref < 15; (7) L\(j = < 10; (8) A = IC-Inten. < 5; (9) A% Pref < 10; (10) ,'\(j = < 5; (11) Select the remaining word closest to intensity criterion; or if tied, (12) Select highest remaining preference score; or if tied, (13) Select lowest remaining standard deviation score. The application of these more complex criteria can be illustrated with the selection of "Slightly" for point #2 of the 5-point scale. Of the seven candidate words three are eliminated at step # 1 because they all have net preference scores of less

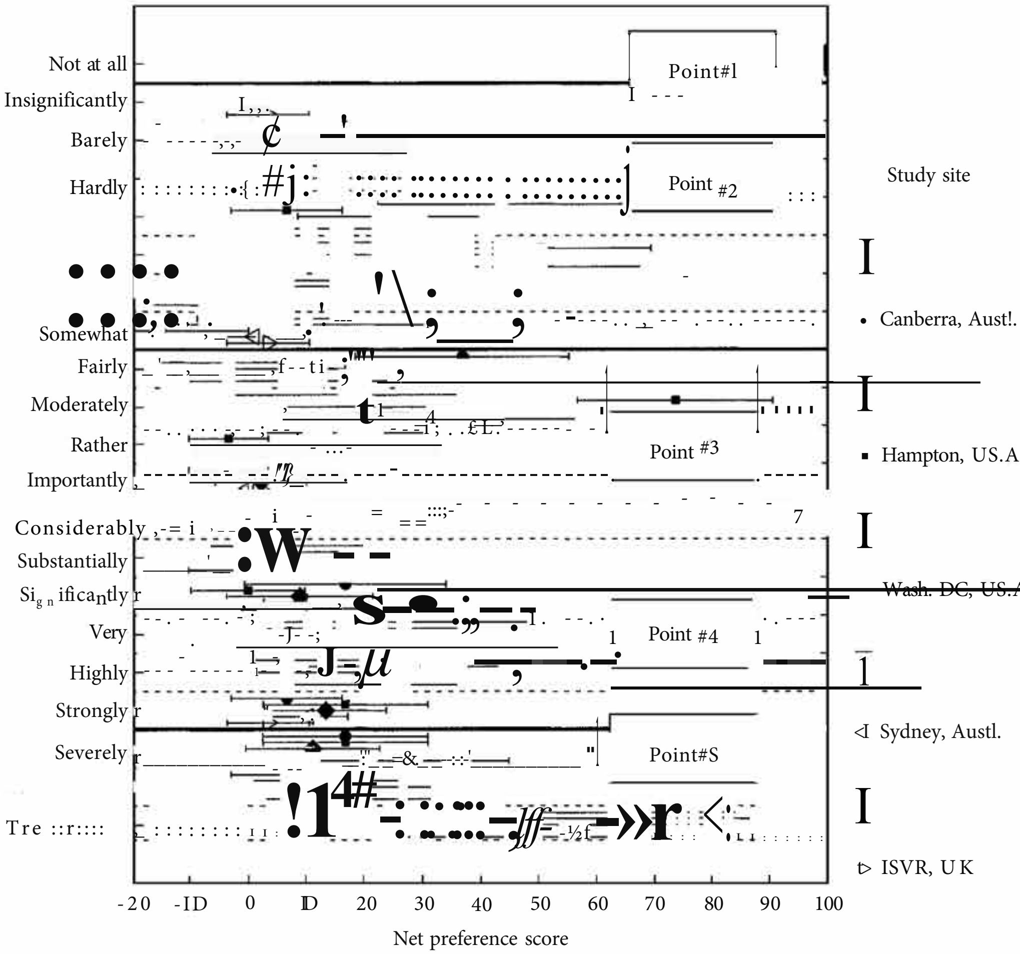

Figure 3. Subjects' preferences for 21 English words for a 5-point scale.

than 5 (Insignificantly, Partially and Somewhat). Next "Barely" is eliminated at Step # 2 because its intensity score of 8· 12 is more than 15 points (A = 17) from the criterion of 25·00. Next "Hardly" is eliminated at Step # 3 because its net preference score of 7·79 is more than 20 points below that for "Slightly" (score of 36-36), the most popular remaining word (A% Pref= 28·57). Step # 4 does not eliminate either of the remaining words but "A little" is eliminated at Step # 5 because its intensity score of 13· 19 is more than 10 points (A = 12) from the criterion of 25·00. This leaves one word, "Slightly", that is therefore selected as the word for point # 2 on the 5-point scale.

The rules for the selection procedure also permitted words to be eliminated if the investigators for a language decided, based on empirical data or their professional judgment, that a word either (1) was either extremely awkward linguistically, or (2) had a regulatory or other meaning that could cause the word to be misinterpreted, or (3) would receive different intensity scores from members of different age groups, cultural groups or other groups. In addition, the investigators examined the selected words and considered whether the juxtaposition of the independently selected modifiers might collectively change the meanings of the modifiers so that the subjects' original judgments would no longer be valid. These more subjective criteria were invoked in only two instances noted in footnotes to the German and Hungarian tables in Appendix A

6. DEFINITION OF HIGH ANNOYANCE

The intensity score results from the annoyance modifier study (defined in section 5.4.3) support a recommendation that the top two points ("very" and "extremely") of the 5-point verbal scale be combined to define the widely used noise impact indicator of "percentage highly annoyed". The intensity scores for 10 words within 20 units of the "highly" intensity score (79 units) are the following: "considerably (62), "substantially" (64), "importantly" (65), "significantly" (67), "very" (76), "highly" (79), "strongly" (80), "severely" (91), "tremendously" (92), and "extremely" (95). "Very" is the closest of the five chosen scale words to "highly". Both words are also close to 75, the intensity criterion for the fourth point on the intensity dimension. These findings are the primary reason for recommending that "very" be used to define "high" annoyance on this 5-point verbal scale. Using two points ("very" and "extremely"), rather than one point to define "high" annoyance also has the advantage of reducing the effects of any tendencies to avoid or select the endpoints of scales. This is also the division point that was used in the 1978 article in which the "percentage highly annoyed" was proposed as a community response measure [3, p. 399]. This is less severe than the 72 per cent cutting point that was proposed for numeric scales in that article since these top two points could be considered to exceed only 60 per cent of the 5-point scale. However, it should be noted that the 60 per cent division encompasses such words as "considerably" (62 per cent), "substantially" (64 per cent), and "importantly" (65 per cent); all of which indicate that the recommended high annoyance division identifies levels of annoyance that are not regarded as being trivial or moderate. No recommendation is offered here for a definition of "high" annoyance using the more abstract numeric scale, as the respondents' answers do not provide a clear basis for a division. Empirical research comparing these verbal and numeric questions could provide a firm basis in the future.

7. CONCLUSIONS AND DISCUSSION

The two questions proposed in this paper provide the most carefully studied basis for comparing results from different surveys and languages. The study team therefore recommends that these two questions be included in future studies of reactions to community noise. In the course of developing the questions, however, the team has become aware of unresolved issues and changes in methods that could be explored if another group considers revisions in the future.

While the modifier-choice study methodology has been carefully designed, was widely discussed before being adopted and is recommended as the basis for establishing comparable scales, some aspects of the methods generated undesired results. Restricting respondents to the choice of only one modifier per scale point on the preference questions yielded poor measures of the extent to which several modifiers were equally acceptable. The results from the intensity grouping question (Task # 1 in section 5.4.2) could not be used because of response errors that might have been eliminated by a revised protocol. Greater care might have been taken to ensure that the words, especially those for upper scale points, were ones that public opinion polling experts widely use in the particular language. The upper scale point is of special importance because subjects tended to choose the most extreme word for the upper scale point.

Some issues surrounding the choice of intensity criterion for annoyance words have not been fully resolved. It is not clear whether criteria for scale categories should be specified by their endpoints (0, 25, 50, 75, 100 for a 5-point scale) or some central tendency measure (e.g., mid-points of 10, 30, 50, 70, 90 for a 5-point scale). Although the lowest point has a conceptually unambiguous meaning, the interpretation of the upper point is subject to the extremity of the concept used. The central tendency criterion probably overestimates reactions at the lowest noise levels where answers in the lowest category may represent absolutely no annoyance. On the other hand, the endpoint criterion probably overestimates reactions at other noise levels where respondents to the highest point would not all place themselves at 100 per cent on an underlying intensity scale.

A method for combining the results from the two scales has not yet been suggested because it raises additional issues concerning the intensity score criteria (as discussed in the previous paragraph) and the ways in which respondents choose different scale points. Empirical research using results from these questions should soon provide a firm combination rule. Attempts to combine the results from these different scales on the basis of previous research are weakened by the likelihood that the central tendencies for annoyance levels within the same broad response category will change with noise level, the boundaries between scale points for different scales are not the same, the respondents may consider both the meaning of a word and position of a word (e.g., Table 1), the people in different cultures may differ in their relative sensitivity to a word's meaning and its scale position [58], factors other than intensity of annoyance influence the choice of answers (e.g., the uneven distributions in Table 2), and, for non-identical questions, the wordings of the question stem may affect the responses to the questions. The most sophisticated mid-point scoring approach to such comparisons that is currently available requires assumptions about these features and some investigator judgment [15, p. 3434]. The unresolved complexities in these comparisons are a major reason that this article has advocated the use of both of these standard, comparable questions for survey comparisons.

It is not known whether some of the details of the wording and presentation of the questions create small differences in responses. For example, answers might be affected by such features as: the order of presentation of answers (low ("not at all") to high ("extremely") or high to low), use of "noise" or "sound", visual graphics for scales, or the wording for the location ("here at home" or "around home"). By standardizing the method our approach has enhanced comparisons between surveys. Additional careful, multi-cultural international research on these particular issues could provide a firmer basis for evaluating the present decisions. In the absence of such research, the proposed questions provide the firmest available basis for making comparisons between answers in different surveys.

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APPENDIX A: ANNOYANCE QUESTIONS FOR NINE LANGUAGES: RECOMMENDED WORDING AND RESULTS OF MODIFIER EVALUATION STUDIES

This appendix contains two types of information for each of the nine languages that have conducted the standard noise modifier study. First, the agreed-upon wording for the two proposed noise reaction questions is given. Second, the results from the annoyance modifier study are presented in an identical format for each language. The format and definitions of terms that appear in the tables were explained in section 5.4.4 where the English results in Table 4 were discussed. The words that are chosen by the ICBEN study procedure for the 5-point verbal scale are underlined in the heading of the table. Footnotes indicate that investigator judgment was exercised in the choices of one word in the German scale and one word in the Hungarian scale.

ENGLISH RESULTS

RECOMMENDED QUESTIONS:

Q.V. Thinking about the last (.. 12 months or so..), when you are here at home, how much does noise from (..noise source..) bother, disturb, or annoy you; Extremely, Very, Moderately, Slightly or Not at all?

Q.N. Next is a zero to ten opinion scale for how much (..source..) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between choose a number between zero and ten. Thinking about the last (.. 12 months or so..), what number from zero to ten best shows how much you are bothered, disturbed, or annoyed by (..source..) noise?

NOTE: The table of English results is not reproduced here as the results were reported in Table 4 in section 5.4.4.

DUTCH (FLEMISH)

Q.V. Wanneer u denkt aan de afgelopen (... 12 maanden of zo ...), in welke mate stoort of hindert het geluid van (... geluidbron ....) u als u bier, bij u thuis bent; extreem, erg, tamelijk, een beetje of helemaal niet?

Q.N. Hier is een schaal van nu! tot tien waarop u kunt aangeven in welke mate geluid u stoort of hindert als u bier thuis bent. Als u helemaal niet gehinderd wordt kiest u de nul, als u extreem gehinderd wordt kiest u de tien. Als u daar ergens tussenin zit, kiest u een getal tussen nu! en tien. Als u denkt aan de afgelopen (... 12 maanden of zo ...), welk getal van nu! tot tien geeft bet beste aan in welke mate u gestoord of gehinderd wordt door geluid van (... geluidbron ....) als u bier thuis bent? (See Table Al).

FRENCH

QV: Si vous pensez aux (... douze derniers mois ...), quand vous etes ici, chez vous, le bruit de (... source ...) vous gene-t-il: extremement, beaucoup, moyennement, legerement, pas du tout?

QN: Voici une echelle d'opinion graduee de zero à dix. Vous devez noter sur cette echelle la fac;on dont le bruit de (.... source ...) vous gene lorsque vous etes ici, chez vous: notez zero si le bruit ne vous gene pas du tout et notez dix si le bruit vous gene extremement. Si vous etes entre ces deux situations, choisissez une note intermediaire entre zero et dix. Maintenant, si vous pensez aux (... douze derniers mois ...), quand vous etes ici, chez vous, quelle note comprise entre zero et dix exprime le mieux à la fac;on dont le bruit de (... source ...) vous gene? (See Table A2).

TABLE A1

*Reaction modifier study results for 93 Dutch*Flemish-language subjects at three sites (Netherlands (2 sites) and Belgium)*

Modifier word candidates (Words chosen for the 5-point verbal scale are *underlined)*	Means for best scale
lhelem lniet lil.L.l lniet l | lnauwe llijkslg | lweini | liets | llicht lelijkl | l lenigz beet lins l_e_l | lmatigl | camel lD.L | lbehool aanzi rlijklenlij lk | lveel | lI 1_ _ ll | sterkj zeer 1 | lernst llg | lenorm | lontze lttendl | luiterl mate | ext re 1-2 - | lbest scale	
IIntenl x | .•11 1.42 l 9.44112 .42 l1s.6sl 16. 39 l16 .so 12s. 93 l34 .36139.18 l62.10168. 00 l69 .o3 l74.21177. 00100 .2s100. sol 85. n 101 .43 l89 .00 l97. 79 l	
lsity l a | .711 2.611 7.691 6.52110.341 9.991 9.44l13.SOl13.92ll4.7ll1698ll5.73l11.96ll0.811lO 561 8.74110.181 9.861 9.32110.301 2.711	

I5-point scale — Grouping of modifier candidates for 5-point scale	Best 5-pt: four words
IScale Pt.# | 1st | Point #2 of s | Point tD of s | Point #4 of 5 | Pt #5 of 5	
IIntensity | O 00 | Intensity Criteria (IC) = 25. 00 | I.C. = 50.00 | I.C. = 75.00 | IC = 100.00	lo= 9.,l
ILi=IC-Inten. | 01 -241 -161 -131 -9 | 91 -8 | 1 l -161 -111 12 | 1s | 19 | -11 3 | s l Sl -141 -131 - l l l	-2111=3.331
INet Pref. \l9B.92l-1.00115.05111.201 6.45111.83125.811 3.23ll0.7Sl30.111 5.381 1.oa1 3.23lll.83l16.13l 9.6Bll5.05l 4.301 4.301	.0011,.121x=J6

14 -point scale — Grouping of modifier candidates for 4-point scale•	IBest 4-pt: three words
Scale Pt.# I 1st | Point #2 of 4 | Point #J of 4 | Point #4 of 4	
IIntensity I 0. 00 I Intensity Criteria (IC) .. 33. 33 I Intensity Criteria (IC) -.. 66 .67 | IC ... 100.00	p,-10.01
11\:::i:IC-Inten. | 01 -321 -241 -211 -181 -171 -171 -1 | 1| 6l -51 11 2l 01 lll 14 | 1• | _,. l -13 | -11 l	-2111,1. ss 1
!Net Pref. \l9B.921-LOBl 1.08117.201 4.301 9.68l19.3Sll6.13l16.13l 7.53117.201 9.68117.201 4.30lll.83ll2.90l 5.381 9.6812.1511.08l74.19l	x=33

i.For a 4-point scale the protocol selects: Point#1=helemaal niet, Point#2=matig, Point ff3=aanzienlijk, Point #4=extreem.

O 0 M. T ll r CS tr, A.

TABLE A2

Reaction mod(fier study results for 45 French-language subjects at one site

```
|                  Modifier word candidates {Words chosen for the 5-point verbal scale are underlined}          IMeans |
|                                                                                                               for   |
|     1...f2!L.I pas lpresql un lguerel un llegerl a lmodE!rlmoyenlassezlplutOlbeauclvraimltres lfortelhautelconsilE!normlterril lbest |
|     1->ll!....I     lue  lpetitl    | peu Iement Ipeine Iement Inemen I   It   121!11...._lent |   Iment Iment Id€rab Iement Ibleme lI   scale |
|     |tout_|        I pas I peu I    |    l_ _   l     |   l_t_l    |    |_    |   |   |   |   lement I   Int   l_t_l              |

IInt en I x | .22 I 1. 09 I 9 .42112 .67 I13. 33 I16 .10 I10 .11111.02142 . u I50.29 I52 .4o I53 .51 I14 .4ol 75. 96 I19 .51 I04. 11 Ia4 .36 I n .31 I94. 09 I98 .02 I99. 2• I |
lsity I o   | .521 1. 1 9 1 e.121 9.13110.33111.19112.•2110. 7 4 113 .93 1 4.60IH.oa116.4ol 9.02111.3,111.331 9.53112.601 9.751 6.6sl 3.221 1.651 |

I5-point scale                      Grouping of modifier candidates for 5-point scale                           IBest |
|                                                                                                      +5-pt: |
!Scale Pt.# I 1st I        Point I12 of 5          |   Point U3 of 5     |      Point #4 of 5        |    Pt #5 of 5    Ifour |
|                                                                                                     +words |
IIntensity I O. 00 I Intensity Criteria (IC) = 25. 00 |  I.C. = 50. 00  | Intensity Criteria (IC) = 75. 00 I IC = 100.00 |  O= 7 .1 I
|
1£>-IC-Inten. I  01 -241 -161 -121 -121  -9 |  -1 | -38 |  -0 |  0|  2 I -211  -1 |  ||  5 I  91  9|  -B1  -6 I  -2 I  -| 1Z1=2 .13 I

INet Pref. %1100.0I .00I 2.22117. 7 8 1 8.B9126.67137. 7 B I 2.221 2.22173.33111.111 2.22120.00122.22122.22124.441 .001 2.221 4.44120.00113.33lx=s1 |

14-point scale                      Grouping of modifier candidates for 4-point: scale•                         IBest |
|                                                                                                      +4-pt: |
| Scale Pt.# | 1st |              Point #2 of 4                     |       Point #3 cf 4         |   Point #4 of 4    Ithree |
|                                                                                                     +words |
!Intensity I 0.00I    Intensity Criteria (IC) = 33. 33            |  In-censi cy Criteria (IC) = 66. 67 I   IC = 100.00   I'= 8.51

I =IC- In ten. I  01 -321 -241 -211 -201 -171 -151 -221  9 I  11 I  191 -131  a|  9|  13 I  11 I  10 |  -a |  -6 |  -2 I  -11Z1=S.861

INet Pref. %1100.01 .001 2.221 4.441 2.22131.11111.101-2.22117.781 6.671 .00111.11124.44122.22111.11113.331 2.221 2.221 6.67120.001n.111x=38 |
```

*For a 4-point scale the protocol selects: Point#:l=pas du tout, Point#2=moderement, Point ff3=beaucoup, Point #4::extremement _

GERMAN

Q.V. Wenn Sie einmal an die letzten (... 12 Monate ...) hier bei Ihnen denken, wie stark haben Sie sich <lurch Larm von (... Quelle ...) insgesamt gestort oder belastigt gefi.ihlt: AuBerst, stark, mittelmaBig, etwas, oder uberhaupt nicht?

Q.N. lch habe hier eine Messlatte von Null bis Zehn, auf der Sie angeben konnen, wie sehr Sie der Larm von (... Quelle ...) insgesamt gestort oder belastigt hat. Wenn Sie sich auBerst gestort oder belastigt fuhlten, wahlen Sie die Zehn, wenn Sie sich uberhaupt nicht gestort oder belastigt fuhlten, geben Sie bitte die Null an, und wenn Sie irgendwo dazwischen liegen, wahlen Sie eine Zahl zwischen Null und Zehn. Wenn Sie nun an die letzten (... 12 Monate ...) bier bei Ihnen denken, welche Zahl zwischen Null und Zehn gibt am besten an, wie stark Sie sich <lurch den Larm von (... Quelle ...) insgesamt gestort oder belastigt fuhlten? (See Table A3).

HUNGARIAN

Q.V. Tekintve az ut6bbi (... idoszakot, 1 evet ...) mennyire zavarja Ont a (..zajforras ...) zaja, amikor otthon tart6zkodik: rettenetesen, nagyon, kozepesen, kisse vagy egyaltalan nem.?

Q.N. Kepzeljen elegy O-t61 10-ig te1jedo skalat arr61, hogy erzese szerint mennyire zavarja Ont a (... zajforras ...) zaja, amikor otthon tart6zkodik. Ha egyaltalan nem zavarja, valassza a 0-t, ha retttenetesen zavarja, valassza a 10-et, ha pedig a ketto kozotti mertekben zavaija, valasszon egy megfelelo szamot Oes 10 kozott. Tekintve az ut6bbi (... idoszakot, 1 evet ...) milyen 0-10 kozotti szammal jellemezne azt, hogy a (... zajforras ...) zaja mennyire zava,ja Ont? (See Table A4).

JAPANESE

Q.V. Kako (... 12 ka getsu kurai ...) wo furikaette, anata wa jitaku de (... soon gen wo ireru ...) karano soon de dono teido nayamasareru, aruiwa, jamasareru, urusai to kanjiru deshoka: hijoni, daibu, tasho, sorehodonai, mattakunai?

Q.N. Tsugi wa, anata ga jitaku de (... soon gen wo ireru ...) karano soon de dono teido nayamasareru, aruiwa, jamasareru, urusai to kanjiru ka wo shimesu tame no Okara IO made no suji de arawashita shakudo desu. Moshi, anata ga mattaku urusaku nai to kanjiru nara Owo erande kudasai. Hijoni urusai to kanjiru nara 10 wo erande kudasai. Moshi, sono teido ga korera no aida no dokoka ni areba, 0 kara 10 made no suji no uchi tekito na mono wo erande kudasai. Kako (... 12 ka getsu kurai ...) wo furikaette, anata ga (... soon gen wo ireru ...) karano soon de nayamasaretari, aruiwa, jamasaretari, urusai to kanjiru teido wo mottomo yoku arawasu no wa 0 kara 10 made no dono suji deshoka?

(NOTE: The Japanese question is transliterated into an English alphabet using the Hepburn system. This is only one of several possible systems, each of which yields slightly different spellings and diacritical marks. The question can be downloaded in Japanese script from the site at this address: http://acoust.arch.kumamoto-u.ac.jp/standarcL questions.html) (See Table AS).

TABLE A3

Reaction mod(fier study results for 61 German language subjects at 2 sites

Modifier word candidates (Words chosen for the 5-point verbal scale are und•rl.ined) | Means for for best lacale

IUberhl nicht Ikaum I ein Iwenigl etwas Iteilwl einig lmitte Iziemlich lbetra. lbeson Istark Isehr Ierheb Ienorm Iungeml auBerl AuBer IvOlli Itotal Ibest

li!!!ELI | Iwenigl 1_ _ leioe lermaBl lich lchtlilders I_ _ I |lich | Iein Iorden l. Ig• 1· lacale

|nicht | | | | 1_ _ 1 len 19..__I lch | | | | ltlichl _ _ 1 | |

IInr:enl X | .481 I.JOI 9.33113.10113.92118.61135.28136.JO147.B4160.0S170.20172.BO176.20176.70177.J3184.51179.54[87.74190.74194.30195.441

lsicy I o | .591 1.391 5.26113.101 9.731 9.99113.34114.571 6.90116.13113.56112.15113.19113.12112.24111.97115.49110.961 9.931 7.341 6.041

I5-point. scale | Grouping of modifier candidates for 5-point scale | Best 5-pt: four words

!Scale Pt.# I 1st I | Point. #2 of 5 | IPoint fD of 5 | Point #4 of 5 | Point #5 of 5 | Ifour words

IIncensic.y I O.OOI Intenait.y Criteria {IC) • 25.00 | I I.C- • 50.00 | Intensity Criteria (IC) • 15.00 | JC • 100.00 | I1- 9.5 I

1!1=TC-ln-cen.1 | Ol -241 -161 -121 -111 -•I 101 _,. I -21 10 | -5 I -2 I 1| 2 | 21 101 -201 -121 -91 -61 -5111•3.58I

INet Pref. %1100.0I .001 a.2011a.03113.11136.011 1.6•1 3.2a1s,.101 3.2s1u.111 6.5611e.031u.11114.75I 1.641 1.6•1 .00122.95121.311,o.981>'•37 |

14 -point scale | Grouping of modifier candidates for 4-point scale,... | IBes'C 4-pt: three words

| Scale Pt.# | 1st | Point #2 of 4 | Point #3 of 4 | Point #4 of 4 | three words |

IIntensity I Q.00 I | Intensity Criteria (IC) = 33.33 | Intensity Criteria (IC} = 66.67 | IC = 100.00 | 1<'=11.71

1.0.=IC-Inten, | 01 -321 -241 -201 -191 -151 2 | 3 I 15 | -/ | •| 61 101 101 111 -151 -201 -121 -91 -61 -5111-3.341

INet Pref. 11100.DI .00I 1.641 3.281 9.B4119.67121.31126.23I .00114.75118.031 8.20118.031 9.841 8.201 1.641 .00I 4.92124.59121.31139.34IX=26 |

,. German-speaking reseai:chers selected the third most. highly rated word "aeusserst" for point #5 on the scale. "Total , the most highly scored word, was rejected due to expected regional and age-rela-ced differences in its interpretation. "VOllig", the second highest scored word, was rejected because the phrase "v61lig gestoert" is commonly used for people who are mentally ill.

"'For a 4-ooint scale the 'OrOtocol selects: Point# 1e Uberha.upt nicht, Point# 2•teilweise, Point 1f.3=betrachtlich, Poin't ff4=tot.aL

TABLE A4

Reaction mod(fier study results for 47 Hungarian-language subjects at two sites

```
| Modifier word candidates (Words chosen for the 5-point verbal scale are underlined) IMeans |
| +for |
| legy.31 l nem lalig lpicit lkicsi lnemil lkisse lkeves leszre lmerse lkOzep ljelen lmegle ler6se lki.HOn lnagyo lm6dfe lt\Jlsa lmerte lvi?gte lrette lbest |
| ltaUnl | | lt leg l_ _ l•• lvehec lkelte lesen_ lc6sen lhet,s h lOsen" l lett lgosan lktele llenUl lnetet lscale |
| l_nem_l | | | | 1_ _ 1 l6en In 1 _ 1 len | | 1 _ 1 | InUl | 11 |
IIntenl X | .7<1 1.111 7.3<110.38ll2.57ll2.77l13.'7ll5.94l2.819132.21145.11l62.85l67.17l72.28l74.2ll7632179.89188.30190.21196.62196.981 |
laity l o | 1.nl 1.661 5.751 7.221 a.361 a.•61 8.751 7.93116.42111.731 a.00121.o,11a.as11s.09115.75115.50112.9al 0.6,111.sol 5_1,1 4.831 |
I5-point scale Grouping of modifier candidates for 5-point scale IBest |
| +5-pt: |
lScale Pt.# l 1st l Point #2 of 5 | Point #3 of 5 | Point #4 of 5 | Pt #5 of s lfour |
| +words |
IIntensity I Q.00 I Intensity Criteria (IC) - 25.00 I I.C. - 50.00 | Intensity Criteria (IC) - 75.00 I I C = 100.00 lo= 9.,l
|
It.-IC-Inten.l || -241 -181 -151 -121 -121 -121 -91 -221 -1a l -5 l -12 l -al -3 l -1 | 1l 5l 131 -101 -31 -3 lZl=s.06 l
INet Pref. \llOO.Ol .0014.261213125.531 4.26129.791 2.131 .001 6.38140.43112.771 2.13po.6<1 8.51114.891 8.511 6.381 8.5ll!7.02l61.70lx=35 |
I4-point. scale Grouping of modifier candidates for 4-point scale"• IBest |
| --+4-pt: |
| Scale l?t.#l 1st l Point #2 of 4 | Point #3 of 4 lPoi't #4 of 4 lthree |
| +words |
lIntensity l Q.00 l Intensity Criteria (ICJ - 33.33 | Intensity Criteria (IC) - 66.67 | IC - 100.00 lo-n.al
III=IC-Inten.l 1 -321 -261 -231 -211 -211 -201 -171 -5 l -1 l 12 l -•l 1l 6l Bl 10 l 131 221 -101 -3 | -,1r.=1.ss1
INet Pref. \llOO.Ol .ool 4.261 .OOll0.64ll0.64ll7.021 6.38112.77 127.661 4.26ll2.77 l21.2Bll4.89l 6.38117.021 2.131 6.381 8.5lll7.02l61.70lx=37 |
```

. Hungarian-speaking researchers selected the second most highly rated word "nagyon" for point #5 on the scale. "Kill0n6sen", the most highly scored word, was rejected because it could have the meaning of "peculiarly" in this context.

"'For a 4-point scale the protocol selects: Point#l=egycllta.lan nem, Point.#2:mE!raekelt.en, Point #3:meglehet6aen, Point #4=rettenetesen.

TABLE A5

Reaction modifier study results for 1102 Japanese-language subjects at eight sites

	Matta kunai	Hoton donai	Amari nai	Taish itenai	Soreh odona	Wazuk ani	Sukos hi	Ikura ka	Yaya	TashO	Hikak uteki	War in i	Dai bu	Totem o	S6t6	Taihe n	Kanar i	Sugok u	Hidok u	HijOn i	K1wam ete	Means for best (scale
Intensity x	1.03	6.85	18.58	19.56	21.03	25.98	3<.75	39.19	43.50	<<.54	55.87	57.«	75.26	83.89	18• 9<	86.32	83.90	89.61	9o.96	93.8<	91.90	
Intensity σ	2.60	7.74	12.62	13.09	13.02	18.28	18.41	18.21	17.90	17.70	15.02	15.32	12.79	12.13	11.00	10.27	11.45	9.27	8.50	8.31	12.78	
5-point scale	Grouping of modifier candidates for 5-point scale																					Best
Scale Pt. #	1st	Point #2 of 5					Point #3 of 5						Point #4 of 5					Pt #5 of 5				+5-pt: four words
Intensity	0.00	Intensity Criteria (IC) =25.00					I.C. = 50.00						Intensity Criteria (IC) =75.00					IC = 100.00				Δ:13.11
Δ=IC-Inten.	1	-18	-6	-5	-4	1	-15	-11	-1	-5	6	7	0	9	10	11	9	-10	9	-6	-8	Δ=3.99
Net Pref.	%100.0	5.17	23.05	12.43	17.51	6.62	3.45	2.54	6.90	12.25	12.16	8.35	15.34	12.52	6.17	4.63	19.96	7.62	5.90	33.94	29.58	x=.20
4-point scale	Grouping of modifier candidates for 4-point scale**																					Best
Scale Pt. #	1st	Point #2 of 4										Point #3 of 4						Point #4 of 4				+4-pt: three words
Intensity	0.00	Intensity Criteria (IC) = 33.33										Intensity Criteria (IC) = 66.67						IC = 100.00				Δ=13.3
Δ=IC-Inten.	1	-26	-15	-14	-12	-1	1	6	10	11	-11	-9	9	17	10	20	17	-10	-9	-6	-8	Δ=5.41
Net Pref.	%100.0	1.36	11.34	7.17	9.53	8.44	23.0S	6.53	7.0B	2.63	B.89	5.72	21.78	8.62	1.09	3.99	10.71	10.62	7.35	33.30	J0.94	x=26

•Note: The phrase ".. nai" indicates that the word is normally presented in sentences that also contain the word "nai".

**For a 4-point scale the protocol selects: Point #1=Mattaku .. nai, Point #2=Sukoshi, Point #3=Daibu, Point #4=hijOni.

NORWEGIAN

Q.V. Tenk etter pa st¢ysituasjonen de siste (... 12 manedene ...). Hvor plaget er du av st¢y fra (... st¢ykilde ...) nar du er hjemme? Er du voldsomt plaget, mye plaget, ganske plaget, litt plaget, ikke plaget.?

Q.N. Angi pa en skala fra null ti! ti hvor plaget du er av st¢y fra (... st¢ykilde ...) nar du er hjemme. Hvis du ikke er plaget, velger du null. Hvis du er voldsomt plaget, velger du ti. Hvis du vurderer st¢yplagen mellom disse grensene, velger du et tall mellom null og ti. Tenk etter pa st¢ysituasjonen de siste (... 12 manedene ...). Hvilket tall mellom null og ti angir hvor plaget du er av st¢y fra (... st¢ykilde ...) nar du er hjemme? (See Table A6).

SPANISH

Q.V. Tomando en consideraci6n los ultimos (... 12 meses ...), indique Vd. en que cuantia le molesta o perturba el ruido producido por (... indicar la fuente de ruido ...) cuando se encuentra en su casa: extremadamente, muy, medianamente, ligeramente, absolutamente nada.

Q.N. A continuaci6n se da una escala de opinion de cero a diez para que Vd. pueda expresar en que cuantia le molesta o perturba el ruido producido por (... indicar la fuente de ruido ...) cuando se encuentra en su casa. Por ejemplo, si Vd. esta "absolutamente nada" molesto por el ruido deberia escoger el cero, y si Vd. esta "extremadamente" molesto deberia escoger el diez. Tomando en consideraci6n los t'.1ltimos (... 12 meses ...), indique que nt'.1mero desde el cero al diez expresa mejor la cuantia en que Vd. esta molesto o perturbado por el ruido producido por (... indicar la fuente de ruido ...) (See Table A7).

TURKISH

Q.V. Yakla 1k son (... 12 ayl ...) di.i iindiigiiniizde, (... giiri.ilti.i kaynagmdan ...) gelen gi.iri.iltii, burada evinizdeyken sizi ne kadar rahats1z etmektedir? Feci ekilde, 90k, orta derecede, hafif9e, hi<; degil?

Q.N. imdi, burada evinizdeyken (.kaynak.) gi.iriiltiisi.iniin sizi ne kadar rahats1z ettigini "s1f1r" ile "on" aras111da sayilarla gosteren bir gori.i (veya kanaat) ol<;egi verilmektedir. Eger hi<; rahats1z degilseniz "s1f1r"1 se<;iniz, eger feci ekilde rahats1z iseniz "on"u sec;iniz, bunlann aras111da iseniz "s1fir" ile "on" aras111da bir sayl sec;iniz. Yakla 1k son (. 12 ayl..) di.i iinerek (.kaynak.) giiriiltiisiinden olan rahats1zhg1111z1 "s1f1r"dan "on"a kadar hangi sayl en iyi gosterir? (See Table A8).

TABLE A6

Reaction mod(fier study results for 56 Norwegian-language subjects

```
|                      Modifier word candidates (Words chosen for the 5-point verbal scale are underlined)                 |Means |
|          +--------------------------------------------------------------------------------------------+-----+-----+for  |
|          |ikke_ |ubet |litt_| noe |minim |moder |delv i|endel |noksa |forho |midde |gansk |temme |betyd |L...!!!U:'.L |meget |veldi |sva,rt |sterk |alvor |volds |best |
|          |_ _  lydelil_ _ _|     |•lt   |•t    |s     |      |      |ldsvills |   |e _llig     |elig |_ _ | |  19  |     |t     |pig   |QIDL_| scale |
|          |_ _  lg |  |  |  |  |  |  |  |s |  |  |  |  1_ _  1 |  |  |  |  |  1_ _  1 |
+----------+------------------------------------------------------------------------------------------------------------+
|Inten| X  | .57 | 6.15 |15.6612s.61 | s.48134.s2 |35.86 |40.98 |•• .681•1.02147 .59 |so .52|66.,1 112.11 112.45 119.18|83.80 |86.63 |87.6• |93.59196.sol |
|aity | o  | 1.391 4.411 1.a8111.ao1 4.15|13.39|11.75|14.67|1•.49|14.1a16.34114.95112.03116.291 9.241 9.49111.751 9.041 7.481 1.2,1 s.111 |
+----------+------------------------------------------------------------------------------------------------------------+
|5-point scale                         Grouping of modifier candidates for 5-point scale                               |Best |
|          +----------------------------------------------------------------------------------------------+-----------+5-pt: |
|Scale Pt.# | 1st | Point #2 of 5 |            Point #3 of 5            |          Point #4 of 5          |Pt #5 of 5 |four |
|          +------------------------------------------------------------------------------------------------------+words |
|Intensity | O 00 | (IC) = 25.00 |       Intensity Criteria = 50.00       | Intensity Criteria {IC) = 75.00      ire = 100.0010   9.51 |
|          +------------------------------------------------------------------------------------------------------------+
|Ill-IC-Int.en.| 1| -18| -9| 11 <51 -151 -141 -9| -5| -3| -2| 1| -9| -3| -3| 4 9| 12| 131 -6| -•1=3.981 |
+------------------------------------------------------------------------------------------------------------------------+
|Net ?ref. tllOO.OI 3.57144.64128.571 1.791 1.791 1.79114.291 5.361 l.79l19.64ll0.711 1.79ll2.SOl26.79l 1.791 1.791 .OOl 3.57l32.14l35.7llx=29 |
+------------------------------------------------------------------------------------------------------------------------+
|4-point scale                         Grouping of modifier candidates for 4-point scale'                              |Best |
|          +-------------------------------------------------------------------------------------------------------+4-pt: |
| Scale Pt.#| 1st |              Point #2 of 4              |            Point #3 of 4            |     Pt #4 of 4     |three |
|          +-------------------------------------------------------------------------------------------------------+words |
|Intensity | O 00 |   Intenoity Criteria (IC) = 33.33        | Inten.oity Criteria (IC) = 66.67     |   IC = 100.00      IO=II.31 |
+------------------------------------------------------------------------------------------------------------------------+
|8•IC-Inten.| 11 -271 -181 -8| -28| 1| 3| 8| 11| -20| -1•| -16| 01 s| 6| 131 -161 -131 -121 -6| -• 1n-s.051 |
+------------------------------------------------------------------------------------------------------------------------+
|Net ?ref. %1100.0I l.79123.21132.141 .OOl 7.14123.211-19.61 1.791 1.791 1.791 7.111 7.11119.64132.141 5.361 1.791 7.141 8.93l33.93l35.7llx=26 |
+------------------------------------------------------------------------------------------------------------------------+
```

*For a 4-point scale the protocol selects: Point#l=ikke, Pointff2=delvis, Point /:t3=betydelig, Point #4=voldsomt.

TABLEA7

Reaction modifier study results for 59 Spanish-language subjects at two sites

	Modifier word candidates (Words chosen for the 5-point vecbal scale are ***underlined)*** — Means for
	labsollinsiglcasi lapenal muy lescasl un lligerlalgo I un laprec lmoderlmedialbastalconsil�laltamlfuertlsumarnlenorml�lbea
	luta.. Inificlnada Is lpoco lamenc lpoco lament l Itanto Iciabl lamame l � I nte lcterabl_ _ lente Iement Iente Iement Imadam Iscale
	Inada_ lant* I le I _ e _ I le• Inte 1=---1 Ile• I_ _ _I le le l!a!ill....l
IIntenl x	.ool 3.611 0.121 8.63 I 9.75l l0.98 I16 .61121.93123. 56120. 83141. 71144 .oo 147. 34 I58.63164. 20173. 391 so.oo 102 .59183.51 I89. 79 I97. n I
Isity I o	.001 5.4BI 4.831 7.881 1.111 6.9ol 7.83l14.03l12.49ll4.7□120.89110.101 4.67114.31119.39110.481 s.121 9.92112.321 1.,01 2.931
I5-point scale	Grouping of modifier candidates for 5-point scale — IBest 5-pt:
IScale Pt.#	I 1st I — Point #2 of 5 — IPoint #3 of 5 — Point #4 of 5 — lPt #5 of 5 — lfour words
IIntensity	I o. oo I — Intensity Criteria (IC) = 25. 00 — I.C. = 50. 00 — I Intensity Ct-iteria (IC) = 75. 00 — 11c = 100.0010= 8.01
Iti.=IC-Inten.	o I -211 -171 -161 -151 -141 -8 -3 I -1 • -8 -6 I -,1 -161 -111 -2 I 5 B , I -101 -2111=2.401
INet Pref.	%1100. ol 3. 391 3.39 I10.17 I 3. 391 8.47 I15 .2s 120 .34 llo .17 I .oo I 1.69 I15 .25130. s1116. 95113.56116.95115.251 6. 78 I .ool 13.56 I83 .os lx=38
I4-point scale	Grouping of modifier candidates for 4-point scale** — IBest. 4-pt:
Scale Pt.#	I 1st — Point #2 of 4 — Point #3 of 4 — I Pt 4 of 4 — Ithree words
lIntensity	l o. oo l — Intensity criteria (IC) = 33. 33 — Intensity criteria (IC) = 66 .67 — Ire = 100.0010= 9.91
I�=IC-Inten.	01 -3ol -251 -251 -2•1 -221 -111 -111 -101 -S 81 -231 -191 -8 -2 I 7 I U 161 11 I -10 I -2111=6. 10 I
INet Pref.	11100.01 .001 5.081-3.391 .001 1.69l16.9Sl28.8ll22.031 8.471 5.081 5.08l11.B6l30.5lll5.2Sll6.95I 3.391 1.691 1.691l0.17l84.75IJ<=46

Words that end with "" have been abbreviated from the complete word that ends with "...mente".

** For a 4-point scale the protocol selects: Point#l:::absolutamente nada, Pointff2::calgo, Point #3=bastante, Point #4=extremadamente.

TABLE A8

Reaction mod/fier study results for 60 Turkish-language subjects at one site

	Modifier word candidates (Words chosen far the 5-point verbal scale are underlined)	!Means for best scale
	l.....b.i.s:_ldegillonemsl cok l lbirazl bir lbirazl az Isoy le 12.ilLI epeyc Ibayag Iolduk lI cok Ifevka Iciddi Iyuk.se lasiri [.kf.LI	
	ldegill lizolcl az 1f!L.._lcik lrniktal I cok lboylelderecle l i lea l_ _ lfazlallade lbicirnl kdere lderecl sekil	
	l_ _ l lude , ____ , lr l lede__l l 1_ _ 1 l lde !cede lede l 9 L - l	
lIntenf x	l 2.62[4.s8111.12111.67!1s.6sl19_ss124.98!2s.78l26 1a131 .57l46.3Sl68.27l69.2a!GS.8Sf74.60l80.40l8S.60l82 97183 .s2[91.93[94.3of	
lsity l 0	8.841 a.51[13.161 e.67f11.11111.09f15.55l13.5of16.19[16.041 9.89[13.24115.45116.52!14.65!11.62[13.94[16.53[12.271 5.7ol 7.121	

I5-point scale	Grouping of modifier candidates for 5-point scale	!Best 5-pt: four words
lScale Pt.#	l 1st l Point #2 of 5 | Point #3 of 5 I Point #4 of 5 | Pt #5 of 5	four
lIntensity	l O 00 l Intensity Criteria (IC) = 25.00 | I.C. = 50.00 I Intensity Criteria (IC) = 75.00 | IC = 100.00	l0=10.8l
1 =IC- In ten.	3 -201 -14[-13[-9 l -s l ol 1l 1l 7l -• l 18[19 l -9 l ol Sl 11 l el 9l -8 l	-6111=2.13[
!Net Pref.	%[100.0l 1.671 8.33[6.67111.67121.671 6.67115.00l 1.671 .00148.331 .ool-1.671 5.00[18.33[1.671 8.331-1.67[8.33l30.00[51.67	lx=33

I4-point scale	Grouping of modifier candidates for 4-point scale*	[Best 4-pt: three words
Scale Pt.#	l 1st l Point #2 of 4 | Point #3 of 4 | Point #4 of 4	lthree
!Intensity	l 0.00[Intensity Criteria (IC) = 33.33 | Intensity Criteria (IC) = 66.67 | IC = 100.00	lo,12 21
lll•lC-Inten.	3 -291 -221 -221 -181 -141 -0 l -0 l -7 l -21 -20 l 2 3 -11 a l 1• l 19 -171 -161 -0 l	-6111=5.86[
!Net Pref.	i1100.01 3.33[s.001 6.67110.00l 5.00111.67111.67[3.33[13.331 1.67111.671 8.33[16.67[15.00l 1.671 s.oof 6.671 .00130.oofs3.33l	?.=26

"'For a 4-point scale the protocol selects: Point#l=hi<;: degil , Point#2=s0yle b6yle, Point #3=epeyce, Point #4=feci sekilde.

TECHNICAL SPECIFICATION

ISO/TS 15666

First edition
2003-02-01

Reviewed and confirmed in 2017

Acoustics — Assessment of noise annoyance by means of social and socio-acoustic surveys

Acoustique — Évaluation de la gêne causée par le bruit au moyen d'enquêtes sociales et d'enquêtes socio-acoustiques

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 15666 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

Introduction

This Technical Specification is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

Many countries have already developed regulations concerning the acceptability of environmental noise exposure, while others are likely to do so in the future. Such regulations often take into account relationships between noise exposure and noise-induced annoyance.

Measurement of environmental noise has been standardized. For example, ISO 1996 contains detailed specifications about basic quantities and procedures, about acquisition of (noise) data, and about the application of these data to set noise limits. ISO 3891 specifies measurements of aircraft noise heard on the ground. No International Standard yet recommends practices for measuring the prevalence of noise-induced annoyance, however.

The intent of this Technical Specification is to provide specifications for the assessment of noise annoyance by social and socio-acoustic surveys. When these specifications are met, the statistically relevant possibilities of comparing and pooling survey results will be increased, thus offering more and better quality information for use by environmental policy makers.

Acoustics — Assessment of noise annoyance by means of social and socio-acoustic surveys

1 Scope

This Technical Specification provides specifications for socio-acoustic surveys and social surveys which include questions on noise effects (briefly referred to hereafter as "social surveys"). Its scope includes questions to be asked, response scales, key aspects of conducting the survey, and reporting the results. This Technical Specification does not prescribe methods for the analysis of data obtained from these questions.

It is recognized that specific requirements and protocols of some social and socio-acoustic studies may not permit the use of some or all of the present specifications. This Technical Specification in no way lessens the merit, value or validity of such research studies.

The scope of this Technical Specification is restricted to surveys conducted to obtain information about noise annoyance "at home". Surveys conducted to obtain information about noise annoyance in other situations, such as recreational areas, work environments and inside vehicles, are not included.

This Technical Specification concerns only the questions on noise annoyance used in a social survey and the most important additional specifications needed to accomplish a high level of comparability with other studies. Other elements which are required to provide high-quality social surveys, but which are not specific for social surveys on noise (such as sampling methods), can be found in textbooks (e.g. see references [1] and [2]).

Compliance with the recommendations of this Technical Specification does not guarantee the collection of accurate, precise or reliable information about the prevalence of noise-induced annoyance and its relationship to noise exposure. Other aspects of study design, as well as uncertainties of estimation and measurement of noise exposure, can influence the interpretability of survey findings to a great extent.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1996-1, *Acoustics — Description and measurement of environmental noise — Part 1: Basic quantities and procedures*

ISO 1996-2, *Acoustics — Description and measurement of environmental noise — Part 2: Acquisition of data pertinent to land use*

ISO 1996-3, *Acoustics — Description and measurement of environmental noise — Part 3: Application to noise limits*

ISO 3891, *Acoustics — Procedure for describing aircraft noise heard on the ground*

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

3.1
noise-induced annoyance
one person's individual adverse reaction to noise

NOTE 1 The reaction may be referred to in various ways including, for example, dissatisfaction, bother, annoyance and disturbance due to noise (see reference [3]).

NOTE 2 Community noise annoyance is the prevalence rate of this individual reaction in a community, as measured by the responses to questions specified in Clause 5, and expressed in appropriate statistical terms.

3.2
socio-acoustic survey
social survey in which noise-induced annoyance is assessed and values of measured or calculated noise metrics are attributed to the subjects' residential environment

NOTE Many general social surveys of environmental factors including noise are not considered to be "socio-acoustic" surveys because they do not have associated noise data.

4 Specifications for wording and scaling of questions on annoyance

Two questions have been formulated: one question with a verbal rating scale; one with a numerical rating scale.

a) Question with verbal rating scale

Thinking about the last (12 months or so), when you are here at home, how much does noise from (noise source) bother, disturb or annoy you?

— *Not at all?*

— *Slightly?*

— *Moderately?*

— *Very?*

— *Extremely?*

b) Question with numerical rating scale, with introduction

Introduction:

This uses a 0-to-10 opinion scale for how much (source) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose 0; if you are extremely annoyed choose 10; if you are somewhere in between, choose a number between 0 and 10.

Question:

Thinking about the last (12 months or so), what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by (source) noise?

The rationale for the specification and wording is presented in Annex A. The most accurate translations into several other languages are presented in Annex B.

5 Additional specifications for conducting social and socio-acoustic surveys when asking about noise annoyance

General specifications for conducting social surveys of any kind are found in numerous articles, papers and textbooks (e.g references [1] and [2]). This clause does not give a comprehensive overview of these general specifications. The focus in this clause is on additional specifications with respect to the design of the questionnaire when asking about noise annoyance. More information is given in Annex A.

a) Each respondent shall be asked both questions specified in Clause 4. Respondents shall not be eliminated on the basis of some previous question about whether they "hear" the noise, nor on the basis of length of residence. If it is necessary to determine whether some respondents do not hear the noise source, a question about the audibility of the noise may be asked separately later in the interview.

b) Respondents shall not first be asked if they are annoyed or not and then, if they are annoyed, about their degree of annoyance.

c) The questions shall be placed early in the questionnaire, unless this conflicts with other survey objectives, and before other, more detailed, questions about noise have been asked. If other questions on noise annoyance are more important for the survey's purposes, the specified questions may be asked later.

d) When asking a question about annoyance, do not imply that the noise should be present in the respondent's situation at home. Ask, for instance, about "noise from aircraft" instead of "noise from the aircraft".

e) If pre-tests indicate that the questions are perceived as repetitious, include appropriate instructions. An example is presented in Annex A.

f) If show cards are used, the answer categories of the five-point verbal scale shall be presented without numbers, as follows:

CARD QV
NOT AT ALL
SLIGHTLY
MODERATELY
VERY
EXTREMELY

The show card for the numerical scale shall be as follows:

CARD QN										
NOT AT ALL									EXTREMELY	
0	1	2	3	4	5	6	7	8	9	10

The chosen answer shall be marked clearly within one box.

g) Prepare written instructions for interviewers. For telephone or personal interviews, the interviewers shall be provided with written instructions that

— instruct interviewers to ask questions exactly as written,

— train interviewers to respond to “I don't understand” with methods that do not require paraphrasing the question,

— urge respondents to choose between the offered answers,

— encourage all residents to answer these questions (new residents can be instructed to answer about only their recent period of residence), and

— if repetition is expected to be a problem, provide interviewers with instructions for respondents who find the questions to be repetitious.

6 Specifications for assessing the degree of annoyance

Results of the questions shall be given as the frequency or cumulative distributions of the individual annoyance scores, if available for each category of noise exposure. Other (summarizing) statistics such as the mean or median annoyance score, or percentages of respondents who are annoyed to a certain degree, may be given.

No specification is given for defining the percentage of respondents who should be regarded to have at least a certain degree of annoyance, such as for example “highly” annoyed. This depends on the cut-off scores used in individual countries or preferred by individual researchers. On the basis of the specified frequency distributions, any cut-off score may be chosen.

7 Specifications for reporting core information from social and socio-acoustic surveys

In Table 1, minimum specifications are presented for reporting core information from social and socio-acoustic surveys in scientific reports. This information is essential to judge whether comparisons with other surveys can be made. More detailed information can be found in reference [4].

Table 1 — Minimum specifications for reporting core information from social and socio-acoustical surveys in scientific reports

Topic area	Item	Topic	Required information
Overall design	1	Survey date	Year and months of social survey
	2	Site location	Country and city of study sites
	3	Site selection	Any important, unusual characteristic of the study period or sites Map or description of study site locations relative to the noise source
	4	Site size	Rationale for site selection Site selection and exclusion criteria
	5	Study purpose	Number of study sites Number of respondents by site State original study goals
Social survey sample	6	Sample selection	Respondent sample selection method (probability, judgmental, etc.) Respondent exclusion criteria (age, gender, length of residence, etc.)
	7	Sample size and quality	Response rate Reasons for non-response
Social survey data collection	8	Survey methods	Method (face-to-face, telephone, etc.)
	9	Questionnaire wording	Exact wording by primary questionnaire items (including answer alternatives)
	10	Precision of sample estimate	Number of responses for main analyses
Acoustical conditions	11	Noise source	Type of primary noise source (aircraft, road traffic, etc.) Types of noise source operations that are included or excluded Protocols to define the noise source (e.g. minimum level, operations, days of week)
	12	Noise metrics	Give the complete description of any noise metric reported, according to ISO 1996-1, ISO 1996-2, ISO 1996-3 or ISO 3891 (if applicable): — Provide $L_{\text{Aeq,24h}}$, L_{dn} and L_{den} (or L_{Aeq} by time-period) for all locations or — provide conversion rule(s) to estimate $L_{\text{Aeq,24h}}$, L_{dn} and L_{den} under the specific study conditions from the study's preferred metric — Discuss the adequacy of the conversion rule(s) — Provide impulse and/or tone corrections
	13	Time period	Hours of day represented by noise metric Period (months, years) represented by noise metric
	14	Estimation/ measurement procedure	Estimation approach (modelling, measurement during sampled periods, etc.)
	15	Reference position	Nominal position relative to noise source and reflecting surfaces Present exposure (or give conversion rule) for noisiest façade, specifying whether reflections from the façade are taken into account or not
	16	Precision of noise estimate	Best information available on precision of noise exposure estimates
Basic dose/ response analysis	17	Dose/response relationships	Tabulation of frequency of annoyance ratings for each category of noise exposure

Annex A
(informative)

Rationale for wording and scaling of questions on annoyance

A.1 Introduction

In this annex the rationale for the specifications for wording and scaling of the specified questions about annoyance is presented. A more comprehensive and detailed clarification can be found in reference [7].

A.2 Types of question

Direct rating questions

- name the noise source,
- ask for respondents' attitude towards the noise, and
- present respondents with choices between a limited number of answers.

Such direct rating questions have been almost universally accepted as the primary measure of the relationship between noise and residents' reactions. Answers to such direct questions are more explicit and more readily interpreted than indirect questions or comparison questions (the two other types of questions that are sometimes used for special purposes in noise surveys).

Indirect questions attempt to ascertain the underlying impact of noise on people with

- open questions in which the noise source is not identified,
- questions in which respondents report complaint actions rather than an attitude, or
- questions in which respondents report behavioural reactions rather than an attitude.

Although useful for specific purposes, these have not supplanted the direct questions as the primary indicator of noise impact because they can only be used to infer indirectly how people feel about noise impact. In addition, such indirect questions are less highly related to noise exposure (see reference [7]). Indirect, open questions that allow respondents to volunteer their own answers are expensive to analyse and result in answers that cannot be directly compared.

The other type of question, a comparison question, provides an anchor for a rating by asking respondents to compare their attitude towards the specified noise to their attitude towards some other object. The overwhelming problem with comparison questions is the absence of a common, shared anchor that could provide a uniform point of comparison across surveys or even across neighbourhoods in the same survey. The most obvious anchors, other neighbourhood nuisances, vary so greatly from site to site that they cannot be used for comparing noise responses at different sites. Magnitude estimation techniques could, in theory, use other shared reference points to resolve this problem, but previous research has found that such techniques are not sufficiently refined for a question to be recommended for wide usage in noise-reaction surveys (see reference [8]).

A.3 Noise, not sound

In many languages it is linguistically odd to use the word “sound” in relation to unwanted sound. In connection with unwanted sound usually the word “noise” is used.

A.4 Unipolar scales (neutral-negative)

From many previous surveys, it has been found that reactions to transportation noise are overwhelmingly either negative or neutral. Therefore the questions should use unipolar scales that extend from a negative pole (extremely annoyed) to a neutral position (not at all annoyed), but not to a positive pole (extremely enjoyable).

A.5 Two questions

This Technical Specification recommends the use of two questions on annoyance and two annoyance scales in each questionnaire. Using more than one scale is consistent with the most basic principles of increasing the reliability of psychometric measurements.

A.6 A verbal and a numerical scale

Each of the scales has a different strength. The verbal scale is needed for the clearest, most transparent communication. The simple task of choosing a word is most likely to be easily performed by respondents of any degree of sophistication in any culture. The resulting selected word is, when presented in a report, simply passed on to readers as the respondent’s choice. The protocol used to choose the answer scale words attempts to ensure that the commonly understood meaning of the word is consistent with its position on the scale.

The numerical scale is needed to provide a check on the consistency of the respondent’s answer on an important issue. Furthermore, the numerical scale is useful as a second question that may not be as subject to the choice of words as a verbal scale is, which is an advantage in a multiracial society and in international work.

A.7 General, non-specific reaction questions

The recommended questions seek to obtain general, consistent reactions that allow respondents to integrate their experiences over different times and locations in and around their home (e.g. on a balcony, in a garden). They do not specify one particular combination of conditions because an overall response measure necessarily involves an integrated response over a range of different types of experiences. The questions do not explicitly list the range of conditions over which the experiences should be integrated for the following five reasons.

a) A complete list would involve too many conditions (e.g. room in a home, location on property, season of year, day of week, hour of day, window-opening conditions, activity during exposure, number of noise events, and peak levels of noise events).

b) A long list may lead respondents toward objective assessments of noise exposure levels and away from subjective feelings about exposures.

c) A long, complex question may confuse some respondents who will resolve the complex task by just answering for one condition, perhaps the first or last condition mentioned, while ignoring their most important, but seemingly insufficiently sophisticated, feelings about their general subjective response.

d) A long list of conditions is more difficult to adapt to different cultures and languages.

e) A long question is less likely to be included in many surveys.

A.8 Wording of the questions

The details involved in the final decisions on wording of the English, five-point verbal scale are as follows.

a) *Thinking about the last (12 months or so), when...*

The indefinite "thinking" and "12 months or so" encourages a general response to the noise, rather than an exclusive comparison of the last 12 months with any other period.

b) *..you*..

The respondent's own reaction, not that of family members, is requested. In the instructions for interviewers, it should be made clear from the beginning of the interview that the respondent's own reaction is required. Therefore in the question itself the word "you" should be sufficient; "you personally" might complicate the understanding of the question by the respondent, especially in other cultures.

c) *..are*..

The habitual, present tense of the verb "are" encourages the habitual, general response as explained in a). Therefore the present tense should be used instead of the (grammatically more correct) past tense.

d) *..here at home*..

This phrase is intended to measure the general evaluation for the respondent's dwelling environment while excluding the broader neighbourhood shopping and recreation areas (as might be suggested by "around here") but not strictly restricting answers to inside the building (as would be implied by "in your house"). In the instructions for interviewers, the following preamble to the question should be included: "at home means inside your home or outdoors at home, for example in the garden or on the balcony".

e) *..how much.*.

This phrase prepares the respondent for choosing an answer of degree of response.

f) *..does.*.

Present tense; see c).

g) *..noise.*.

The single word "noise" rather than the phrase "the noise" is used to avoid the implication that the present noise should be considered. "Noise" is used rather than a neutral word for the reasons given earlier.

h) *..from (noise source)*..

The name of the noise source is specified, not left unclear.

i) *..bother, disturb or annoy.*.

These three words were judged to be necessary to convey the general impression of a negative reaction in English. In other languages, the general impression of a negative reaction could require less (or more) words.

j) *..you.*.

Own reaction reinforced; see b).

k) *..not at all*..

This phrase was found to have the lowest annoyance intensity rating in several studies (see reference [8]).

l) *slightly, moderately, very, extremely*

These four words were selected by the protocols contained in the empirical study described in reference [5]

A.9 Choice of response descriptors in other languages than English

The translation of each question in each language should be performed by translation and back-translation. For languages other than English, the labels for the categories on the 5-point verbal scale and the endpoints for the 0-to-10 numerical scale should be chosen on the basis of empirical studies conducted using a standard technique in each language and not be simply translated from English. The studies should be conducted following the protocol presented in reference [5]. These types of study were actually carried out in the following nine languages: Dutch, English, French, German, Hungarian, Japanese, Norwegian, Spanish and Turkish. The questions and answer categories in these languages are presented in Annex B.

NOTE If an ISO Member Body doubts the correctness of the translations presented in Annex B, it should initiate a replicate study to improve the translations as they stand now. Just changing the wording based on personal preference instead of based on empirical studies does not seem a fruitful approach.

A.10 11-point numerical scale

The 0-to-10 scale was selected because it is assumed that a 0-to-10 scale would be more readily understood and manipulated than a shorter 7-point, 9-point or 10-point scale. Most people are familiar with base-10 numeric systems through currency and other familiar counted materials. Logically, 0 will always stand for “not at all”, and 10 for “extremely”. The scale should not be reversed.

As with all questions in a questionnaire, there needs to be a provision for coding missing data responses such as “don't know”, “refusal” or “skipped in error”. It is recommended that the survey organizations include a code for such answers.

CAUTION — These possible answers should not, however, be shown or read to respondents. They would not, therefore, appear in a mail questionnaire. One of the primary findings from question-wording experiments is that the number of don't knows is very much increased if the respondent sees or is offered this option.

Interviewers should use such a code only after having encouraged the respondent to choose one of the offered responses with a phrase, such as *“Which of the answers comes closest to your view?”*

A.11 5-point scale for verbal questions

For the purpose of comparisons between surveys, the same number of points are needed on all verbal answer scales. The discussion about the use of dichotomous answer scales clearly indicates that the number of scale points do have an effect on answers that cannot be accounted for by the labels that are used. In considering the evidence, it was decided that a 5-point scale is preferable. The available evidence suggests that a 5-point scale is either preferable or no different than the 4-point scale. See also reference [5].

Also, the 5-point verbal scale must be completed with “don’t know” as an answer alternative. See also A.10.

A.12 Appropriate time period

The phrase “12 months or so” appears in parentheses in the questions because the length of the time period may need to be different for different surveys. The period that is asked about in the questionnaire should be a period for which the noise exposure can be estimated sufficiently accurately. In general, a period of approximately one year is recommended to encourage respondents to give their general reactions to the acoustical environment. However, if there have been recent changes in the noise environment, or if the focus of the study is on a particular time, or if is it not possible to make sufficiently accurate estimates for a long time period, then some shorter period may need to be specified.

A.13 Abstraction level of noise source

If one of the purposes of a survey is to make comparisons (e.g. to compare noise annoyance in different areas, or noise annoyance over the years, or noise annoyance caused by different sources), the noise sources should be described on the same abstraction level.

NOTE Different abstraction levels are for instance “road traffic” and “lorries”.

A.14 Written instructions for interviewers

A.14.1 General instructions for opinion questions

All opinion questions should be read exactly as written. They should not be paraphrased or explained by the interviewers. A great deal of care went into choosing each word in each question and each respondent should hear exactly these same words and not some additional words that an interviewer may add. It was found that in almost all cases when a respondent says he or she does not understand a question, the problem can be solved by repeating the question. This gives the respondent a second chance to listen and provides a period for the respondent to think more about the answer. In the rare case where the respondent still asks what the question means, the interviewer should respond: “*Whatever it means to you*”.

Occasionally a respondent may decline to choose one of the answer categories, or may reply with a long qualified statement that does not fit within one of the pre-coded categories. In either case, the interviewer should just repeat the question and, if necessary, add the phrase “*And so, which of these answers comes closest to your own*?” If the respondent still finds it impossible to answer or choose, then a "Not Answered" response should be filled in.

A.14.2 Instructions specific to a matrix question

NOTE The question QX, presented later, is just an example.

Question QX uses the same answer scale for all nine noise sources mentioned. Be sure to read the full question, including the answers, about the first noise source, road traffic, and then, after road traffic is rated, about aircraft. For most respondents it will not be necessary to read the entire question again. Instead the phrase “*And how about noise from (trains)*?” can be repeated each time and will be sufficient. If there is a digression or any discussion between items, be sure to reread the complete question and all five alternatives again. If the respondent hesitates or appears to be confused at any point, read all five alternatives again.

Circle the respondent’s answer. Only circle NA (Not Answered) if the respondent replies “*do not know*”, or refuses, or the question is skipped in error.

QX *Thinking about the last 12 months or so, when you are here at home, how much does noise from (road traffic) bother, disturb, or annoy you: not at all, slightly, moderately, very or extremely?*

	NOT AT ALL	**SLIGHTLY**	**MODERATELY**	**VERY**	**EXTREMELY**	**NA**
Road traffic	NOT	SLIGHT	MOD	VERY	EXT	NA
Aircraft	NOT	SLIGHT	MOD	VERY	EXT	NA
Trains	NOT	SLIGHT	MOD	VERY	EXT	NA
Factories or machinery	NOT	SLIGHT	MOD	VERY	EXT	NA
Construction work	NOT	SLIGHT	MOD	VERY	EXT	NA
Animals outside	NOT	SLIGHT	MOD	VERY	EXT	NA
Children outside	NOT	SLIGHT	MOD	VERY	EXT	NA
Other people outside	NOT	SLIGHT	MOD	VERY	EXT	NA
Any other noises (specify)	NOT	SLIGHT	MOD	VERY	EXT	NA

A.14.3 If pretests indicate that the questions are perceived as repetitious

If the questions are not placed early in the questionnaire, potential interviewer or respondent discomfort with apparently repetitious questions can be solved with introductions to the questions similar to the following.

a) *Now we return to the noise from (source) and take everything we have discussed into account. Thinking about the last*... {insert recommended questions}.

b) *People in other surveys have answered this next question to tell us how they feel about noise. Now you can use it for the noise here. Thinking about the last*... {insert recommended questions}.

c) *Even though all of the questions are slightly different, I know a few of them can seem similar for people in special circumstances like yourself. If any seem repetitious for you, just give me a quick answer and I will move right along to other questions.*

Annex B
(informative)

Wording in nine languages of questions on annoyance

B.1 Introduction

The use of a verbal and a numerical scale is necessary with the questions as formulated in Clause 4. The questions, and especially the verbal scale, will be used in as many languages as possible. It is not enough to merely translate the questions and labels of the verbal scale from English into any other language, because a literal translation can lead to slightly other meanings (connotations) of words.

The International Commission on Biological Effects of Noise has recognized this problem and initiated an international study designed to accomplish translations that would have the same meaning in each country. The results are presented in this annex. More details of the study can be found in reference [5]. A difference between the ICBEN study and this Technical Specification is that here the order of the answer categories of the verbal scale has been reversed.

NOTE Questions in languages other than the three official ISO languages (English, French and Russian) are published under the responsibility of the member bodies of the countries concerned.

B.2 English

QV *Thinking about the last (12 months or so), when you are here at home, how much does noise from (noise source) bother, disturb or annoy you: not at all, slightly, moderately, very, or extremely?*

QN Next is a 0-to-10 opinion scale for how much (source) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose 0; if you are extremely annoyed choose 10; if you are somewhere in between choose a number between 0 and 10.

Thinking about the last (12 months or so), what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by (source) noise?

B.3 Dutch (including Flemish)

QV *Als u denkt aan de afgelopen (12 maanden of zo), in welke mate ergert, stoort of hindert geluid van (geluidbron) u als u hier thuis bent?: helemaal niet, een beetje, tamelijk, erg of extreem?*

QN Hier is een schaal van nul tot tien waarop u kunt aangeven in welke mate geluid u hindert, stoort of ergert als u hier thuis bent. Als u helemaal niet gehinderd wordt kiest u de nul, als u extreem gehinderd wordt kiest u de tien. Als u daar ergens tussenin zit, kiest u een getal tussen nul en tien.

Als u denkt aan de afgelopen (12 maanden of zo), welk getal van nul tot tien geeft het beste aan in welke mate u geërgerd, gestoord of gehinderd wordt door geluid van (geluidbron) als u hier thuis bent?

B.4 French

QV *Si vous pensez aux douze derniers mois, quand vous êtes ici, chez vous, le bruit de (citez la source) vous gêne-t-il: pas du tout, légèrement, moyennement, beaucoup ou extrèmement?*

QN Voici une échelle d'opinion graduée de zéro à dix. Vous devez noter sur cette échelle la façon dont le bruit de (citez la source) vous gêne lorsque vous êtes ici, chez vous: notez zéro si le bruit ne vous gêne pas du tout et notez dix si le bruit vous gêne extrèmement. Si vous êtes entre ces deux situations, choisissez une note intermédiaire entre zéro et dix.

Maintenant, si vous pensez aux douze derniers mois, quand vous êtes ici, chez vous, quelle note comprise entre zéro et dix exprime le mieux la façon dont le bruit de (citez la source) vous gêne?

B.5 German

QV *Wenn Sie einmal an die letzten (12 Monate) hier bei Ihnen denken, wie stark haben Sie sich durch Lärm von (Quelle) insgesamt gestört oder belästigt gefühlt?: überhaupt nicht, etwas, mittelmäßig, stark, oder äußerst?*

QN Jetzt kommt eine Messlatte von Null bis Zehn, auf der Sie angeben können, wie sehr Sie der Lärm von (Quelle) insgesamt gestört oder belästigt hat. Wenn Sie sich äußerst gestört oder belästigt fühlten, wählen Sie die Zehn, wenn Sie sich überhaupt nicht gestört oder belästigt fühlten, geben Sie bitte die Null an, und wenn Sie irgendwo dazwischen liegen, wählen Sie bitte eine Zahl zwischen Null und Zehn.

Wenn Sie nun an die letzten 12 Monate hier bei Ihnen denken, welche Zahl zwischen Null und Zehn gibt am besten an, wie stark Sie sich durch den Lärm von (Quelle) insgesamt gestört oder belästigt fühlten?

B.6 Hungarian

QV *Tekintve az utóbbi (időszakot, 1 évet) mennyire zavarja Önt a (zajforrás) zaja, amikor otthon tartózkodik: egyáltalán nem, kissé, közepesen, nagyon, vagy rettenetesen?*

QN Képzeljen el egy 0-tól 10-ig terjedő skálát arról, hogy mennyire zavarja Önt a (zajforrás) zaja, amikor otthon tartózkodik. Ha egyáltalán nem zavarja, válassza a 0-t, ha rettenetesen zavarja, válassza a 10-et, ha pedig a kettő közötti mértékben zavarja, válasszon egy megfelelő számot 0 és 10 között.

Tekintve az utóbbi (időszakot, 1 évet) milyen 0-10 közötti számmal jellemezné a (zajforrás) zavaró hatását?

B.7 Japanese

Signs not available.

B.8 Norwegian

QV *Tenk etter på de siste (12 månedene) når du er hjemme. Hvor mye er du plaget av støy fra (støykilde)? Er du ikke plaget i det hele tatt, litt plaget, middels plaget, mye plaget eller voldsomt plaget?*

QN Angi på en skala fra null til ti hvor plaget du er av støy fra (støykilde) når du er hjemme. Hvis du ikke er plaget i det hele tatt, velger du null. Hvis du er voldsomt plaget, velger du ti. Hvis du vurderer støyplagen mellom disse grensene, velger du et tall mellom null og ti.

Tenk etter på de siste (12 månedene). Hvilket tall mellom null og ti angir hvor plaget du er av støy fra (støykilde) når du er hjemme?

B.9 Spanish

QV *Tomando en consideración los ultimos (12 meses), indique Vd. en qué cuantía le molesta o perturba el ruido producido por (indicar la fuente de ruido), cuando se encuentra en su casa: absolutamente nada, ligeramente, medianamente, mucho o extremadamente*

QN A continuación se da una escala de opinión de cero a diez para que Vd. pueda expresar en qué cuantía le molesta o perturba el ruido producido por (indicar la fuente de ruido) cuando se encuentra en su casa. Por ejemplo, si Vd. está nada molesto por el ruido debería escoger el cero, y si Vd. está extremadamente molesto debería escoger el diez.

Tomando en consideración los últimos (12 meses), indique qué numero, cero al diez, expresa mejor la cuantía en que Vd. está molesto o perturbado por el ruido producido por (indicar la fuente de ruido)

B.10 Turkish

(TÜM DENEKLERE SORULACAKTIR)

QV *Yaklaşık son on iki ayı düşündüğünüzde, (gürültü kaynağından) gelen gürültü, burada evinizdeyken sizi ne kadar rahatsız etmektedir? değil, hafifçe, orta derecede, çok, hiç feci şekilde?*

QN Şimdi, evinizdeyken (....) gürültüsünün sizi ne kadar rahatsız ettiğini “sıfır” ile “on” arasında sayılarla gösteren bir ölçek verilmektedir. Eğer hiç rahatsız değil seniz “sıfır”ı seçiniz, eğer feci şekilde rahatsız iseniz “on” u seçiniz, bunların arasında iseniz “sıfır” ile “on” arasında bir sayı seçiniz.

Yaklaşık son 12 ayı düşünerek (......) gürültüsünden olan rahatsızlığınızı “sıfır”dan “on”a kadar hangi sayı en iyi gösterir?

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INTERNATIONAL STANDARD

ISO 1996-1

Third edition
2016-03-01

Acoustics — Description, measurement and assessment of environmental noise —

Part 1: Basic quantities and assessment procedures

Acoustique — Description, mesurage et évaluation du bruit de l'environnement —

Partie 1: Grandeurs fondamentales et méthodes d'évaluation

Reference number
ISO 1996-1:2016(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The committee responsible for this document is ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This third edition cancels and replaces the second edition (ISO 1996-1:2003), which has been technically revised. In particular, the following subclauses and annexes have been added or revised: 3.6, 6.3.1, 6.5, 8.1, 8.2.1 i), Annex A, Annex D, Annex E, Annex F, Annex G, and Annex H.

ISO 1996 consists of the following parts, under the general title *Acoustics — Description, measurement and assessment of environmental noise*:

— *Part 1: Basic quantities and assessment procedures*

— *Part 2: Determination of sound pressure levels*

Introduction

To be of practical use, any method of description, measurement, and assessment of environmental noise is intended to be related in some way to what is known about human response to noise. Many adverse consequences of environmental noise increase with increasing noise, but the precise dose-response relationships involved continue to be the subject of scientific debate. In addition, it is important that all methods used be practicable within the social, economic, and political climate in which they are used. For these reasons, there is a very large range of different methods in use around the world for different types of noise, and this creates considerable difficulties for international comparison and understanding.

The broad aim of the ISO 1996 series is to contribute to the international harmonization of methods of description, measurement, and assessment of environmental noise from all sources.

The methods and procedures described in this part of ISO 1996 are intended to be applicable to noise from various sources, individually or in combination, which contribute to the total exposure at a site. At the stage of technology at the time of publication of this part of ISO 1996, the evaluation of long-term noise annoyance seems to be best met by adopting the adjusted A-weighted equivalent continuous sound pressure level, which is termed a "rating level".

The aim of the ISO 1996 series is to provide authorities with material for the description and assessment of noise in community environments. Based on the principles described in this part of ISO 1996, national standards, regulations, and corresponding acceptable limits for noise can be developed.

Acoustics — Description, measurement and assessment of environmental noise —

Part 1:
Basic quantities and assessment procedures

1 Scope

This part of ISO 1996 defines the basic quantities to be used for the description of noise in community environments and describes basic assessment procedures. It also specifies methods to assess environmental noise and gives guidance on predicting the potential annoyance response of a community to long-term exposure from various types of environmental noises. The sound sources can be separate or in various combinations. Application of the method to predict annoyance response is limited to areas where people reside and to related long-term land uses.

Community response to noise can vary differently among sound sources that are observed to have the same acoustic levels. This part of ISO 1996 describes adjustments for sounds that have different characteristics. The term "rating level" is used to describe physical sound predictions or measurements to which one or more adjustments have been added. On the basis of these rating levels, the long-term community response can be estimated.

The sounds are assessed either singly or in combination, allowing for consideration, when deemed necessary by responsible authorities, of the special characteristics of their impulsiveness, tonality, and low-frequency content, and for the different characteristics of road-traffic noise, other forms of transportation noise (such as aircraft noise), and industrial noise.

This part of ISO 1996 does not specify limits for environmental noise.

NOTE 1 In acoustics, several different physical measures describing sound can have their level expressed in decibels (e.g. sound pressure, maximum sound pressure, and equivalent continuous sound pressure). The levels corresponding to these physical measures normally will differ for the same sound. This often leads to confusion. Therefore, it is necessary to specify the underlying physical quantity (e.g. sound pressure level, maximum sound pressure level, and equivalent continuous sound pressure level).

NOTE 2 In this part of ISO 1996, quantities are expressed as levels in decibels. However, some countries validly express the underlying physical quantity, such as maximum sound pressure, in pascal or sound exposure in pascal-squared seconds.

NOTE 3 ISO 1996-2 deals with the determination of sound pressure levels.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 Expression of levels

NOTE For levels defined in 3.1.1 to 3.1.6, it is essential that frequency weighting or frequency bandwidth, as applicable, be specified, and time weighting, if applicable, be specified.

3.1.1
time-weighted and frequency-weighted sound pressure level
ten times the logarithm to the base 10 of the ratio of the time-mean-square of the sound pressure to the square of a reference value, being obtained with a standard frequency weighting and standard time weighting

Note 1 to entry: Sound pressure is expressed in pascal (Pa).

Note 2 to entry: The reference value is 20 μPa.

Note 3 to entry: Time-weighted and frequency-weighted sound pressure level is expressed in decibels (dB).

Note 4 to entry: The standard frequency weightings are A-weighting and C-weighting as specified in IEC 61672-1, and the standard time weightings are F-weighting and S-weighting as specified in IEC 61672-1.

3.1.2
maximum time-weighted and frequency-weighted sound pressure level
greatest time-weighted and frequency-weighted sound pressure level within a stated time interval

Note 1 to entry: Maximum time-weighted and frequency-weighted sound pressure level is expressed in decibels (dB).

3.1.3
***N* percentage exceedance level**
time-weighted and frequency-weighted sound pressure level that is exceeded for N % of the time interval considered

Note 1 to entry: N percentage exceedance level is expressed in decibels (dB).

EXAMPLE $L_{\text{AF95,1h}}$ is the A-frequency-weighted, F-time-weighted sound pressure level exceeded for 95 % of 1 h.

3.1.4
peak sound pressure level
ten times the logarithm to the base 10 of the ratio of the square of the peak sound pressure to the square of the reference value

Note 1 to entry: The reference value is 20 μPa.

Note 2 to entry: Peak sound pressure level is expressed in decibels (dB).

Note 3 to entry: Peak sound pressure should be determined with a detector as defined in IEC 61672-1. IEC 61672-1 only specifies the accuracy of a detector using C-weighting.

Note 4 to entry: The peak sound pressure is the maximum absolute value of the instantaneous sound pressure during a stated time interval.

3.1.5
sound exposure level
L_E
ten times the logarithm to the base 10 of the ratio of the sound exposure, E, being the integral of the square of the sound pressure, p, over a stated time interval or event of duration, T (starting at t_1 and ending at t_2), to a reference value, E_0

$$L_E = 10 \lg \frac{E}{E_0} \text{ dB}$$

where

$$E = \int_{t_1}^{t_2} p^2(t)\,dt\ ;$$

$$E_0 = 400\ \mu Pa^2\ s$$

Note 1 to entry: Sound exposure is expressed in pascal-squared seconds. Sound exposure level is expressed in decibels (dB).

Note 2 to entry: Because of practical limitations of the measuring instruments, p^2 is always understood to denote the square of a frequency-weighted and frequency band-limited sound pressure. If a specific frequency weighting as specified in IEC 61672-1 is applied, this should be indicated by appropriate subscripts; e.g. $E_{A,1\ h}$ denotes the A-weighted sound exposure over 1 h.

Note 3 to entry: The duration, T, of the integration is included implicitly in the time integral and need not to be reported explicitly. For measurements of sound exposure over a specified time interval, the duration of integration should be reported and the notation should be $L_{E,T}$.

Note 4 to entry: For sound exposure levels of an event, the nature of the event should be stated.

Note 5 to entry: When applied to a single event, the sound exposure level is called "single-event sound exposure level".

3.1.6
equivalent continuous sound pressure level

$L_{eq,T}$

ten times the logarithm to the base 10 of the ratio of the time-average of the square of the sound pressure, p, during a stated time interval of duration, T (starting at t_1 and ending t_2), to the square of the reference sound pressure, p_0

Note 1 to entry: The A-weighted equivalent continuous sound pressure level is

$$L_{Aeq,T} = 10\lg \frac{\frac{1}{T}\int_{t_1}^{t_2} p_A^2(t)\mathrm{d}t}{p_0^2}\ \mathrm{dB}$$

where

$p_A(t)$ is the A-weighted instantaneous sound pressure at running time t;

p_0 is equal to 20 µPa.

Note 2 to entry: The equivalent continuous sound pressure level is also termed "time-averaged sound pressure level". It is expressed in decibels (dB).

3.2 Time intervals

3.2.1
reference time interval

time interval to which the rating of the sound is referred

Note 1 to entry: The reference time interval may be specified in national or international standards or by local authorities to cover typical human activities and variations in the operation of sound sources. Reference time intervals can be, for example, part of a day, the full day, or a full week. Some countries define even longer reference time intervals.

Note 2 to entry: Different levels or sets of levels may be specified for different reference time intervals.

3.2.2
long-term time interval
specified time interval over which the sound of a series of reference time intervals is averaged or assessed

Note 1 to entry: The long-term time interval is determined for the purpose of describing environmental noise as it is generally designated by responsible authorities.

Note 2 to entry: For long-term assessments and land-use planning, long-term time intervals that represent some significant fraction of a year should be used (e.g. 3 months, 6 months, and 1 year).

3.3 Ratings

3.3.1
adjustment
quantity, positive or negative, constant or variable, that is added to a predicted or measured acoustical level to account for some sound character, the time of day, or the source type

3.3.2
rating level
predicted or measured acoustic level to which an adjustment has been added

Note 1 to entry: Measurements such as day/night sound pressure level or day/evening/night sound pressure level are examples of rating levels because they are calculated from sound measured or predicted over different reference time periods, and adjustments are added to the reference time interval equivalent continuous sound pressure levels based on the time of day.

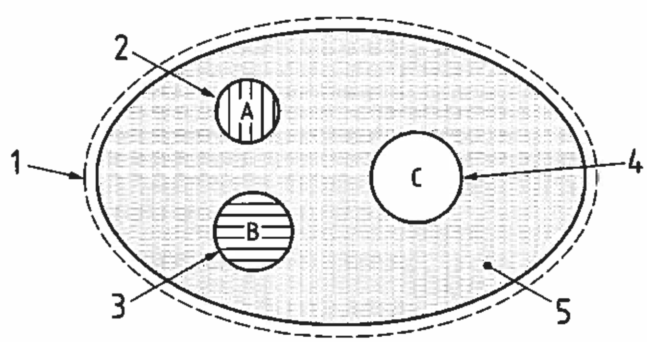
Note 2 to entry: A rating level may be created by adding adjustments to a measured or predicted level(s) to account for some character of the sound such as tonality or impulsiveness.

Note 3 to entry: A rating level may be created by adding adjustments to a measured or predicted level(s) to account for differences between source types. For example, using road traffic as the base sound source, adjustments may be applied to the levels for aircraft or railway sources.

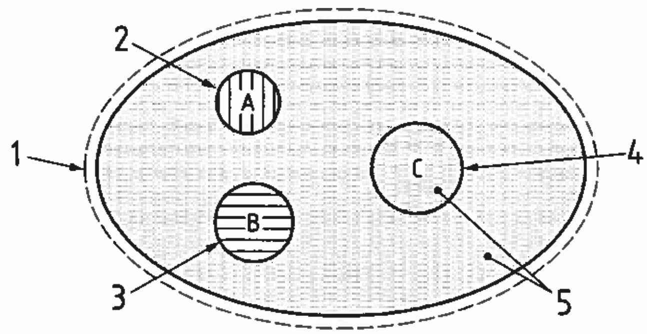
3.4 Sound designations

NOTE See Figure 1.

3.4.1
total sound
totally encompassing sound in a given situation at a given time, usually composed of sound from many sources near and far



a) Three specific sounds A, B, and C under consideration, the residual sound and the total sound



b) Two specific sounds A and B under consideration, the residual sound and the total sound

Key

1 total sound

2 specific sound A

3 specific sound B

4 specific sound C

5 residual sound

NOTE 1 The lowest residual sound level is obtained when all specific sounds are suppressed.

NOTE 2 The dotted area indicates the residual sound when sounds A, B, and C are suppressed.

NOTE 3 In Figure 1 b), the residual sound includes the specific sound C as it is not under consideration.

Figure 1 — Total, specific, and residual sound designations

3.4.2
specific sound
component of the total sound that can be specifically identified and which is associated with a specific source

3.4.3
residual sound
total sound remaining at a given position in a given situation when the specific sounds under consideration are suppressed

3.4.4
initial sound
total sound present in an initial situation before any change to the existing situation occurs

3.4.5
fluctuating sound
continuous sound whose sound pressure level varies significantly, but not in an impulsive manner, during the observation period

3.4.6
intermittent sound
sound that is present at the observer only during certain time periods that occur at regular or irregular time intervals and is such that the duration of each such occurrence is more than about 5 s

EXAMPLE Motor vehicle noise under conditions of small traffic volume, train noise, aircraft noise, and air-compressor noise.

3.4.7
sound emergence
increase in the total sound in a given situation that results from the introduction of some specific sound

Effects of aircraft noise on annoyance and sleep disturbances before and after expansion of Frankfurt Airport - results of the NORAH study, WP 1 'Annoyance and quality of life'

Dirk SCHRECKENBERG[1]; Christin BELKE[2]; Frank FAULBAUM[3]; Rainer GUSKI[4]; Ulrich MOHLER[5]; Jan SPILSKI[6]

[1,2] ZEUS GmbH, Germany

[3] SUZ - Sozialwissenschaftliches Umfragezentrum GmbH, Germany

[4] Ruhr-University Bochum, Germany

[5] Mohler+ Partner Ingenieure AG, Germany

[6] Technische Universitat Kaiserslautern, Germany

ABSTRACT

In October / November 2011 a new runway was opened at Frankfurt Airport and a night curfew from 11 pm to 5am has been implemented. Within the project NORAH (Noise Related Annoyance, Cognition and Health) a longitudinal study on the impact of aircraft noise on annoyance and reported sleep disturbances before and after these changes had been carried out. The study included a survey with a stratified random address sample of residents living near the airport who were interviewed before the runway opening (2011) and in follow-ups in 2012 and 2013. Among others, the source-specific aircraft noise exposure in terms of L_{pAeq} for different times of day were calculated for a 12-months-period for each address and each survey wave. 3508 of 9244 residents interviewed in 2011 took part in all 3 survey waves. Results show that the exposure-response curve for aircraft noise annoyance against the $L_{pAeq,24h}$ shifts after opening of the new runway depending on local changes in sound levels. Reported sleep disturbances were reduced after the introduction of the night curfew except with respect to disturbances while falling asleep or in the early morning. Several non-acoustical factors partly explain the changes in aircraft noise reactions.

Keywords: Aircraft Noise, Annoyance, Sleep disturbances, Change Effect, NORAH

I-INCE Classification of Subjects Number(s): 63.2, 63.4, 66.1, 66.2

1. INTRODUCTION

With about 487'000 movements, 56.4 million passengers and 2.2 million freight ton (year 2011) Frankfurt Airport is the largest airport in Germany. In the year 1997 Frankfurt Airport and the home carrier Deutsche Lufthansa requested an airport expansion including a new terminal and the construction of a 4th runway in order to be able to increase the capacity up to 120 - 126 movements per hour (about 83 - 86 before expansion). During the following years regional planning and zoning procedures were running with the final zoning decision in December 2007, allowing the construction of the 4th runway ('Runway Northwest'). In the same period a stakeholder dialogue process took place, including a mediation process (2000 - 2002), and was followed by the installation of dialogue forums (2000 - 2007 Regionales Dialogforum Flughafen Frankfurt, RDF, since 2008 Forum Flughafen und Region, FFR) on the decision of the Landtag (state parliament) of Hesse.

The new runway has been opened in October 2011 and implies the rerouting of flights. Part of the

[1] schreckenberg@zeusgmbh.de
[2] belke@zeusgmbh.de
[3] frank.faulbaum@uni-due.de
[4] rainer.guski@rub.de
[5] ulrich.moehler@mopa.de
[6] jan.spilski@sowi.uni-kl.de

rerouting (downwind approaches) already started in March 2011. In November 2011 a night curfew from 11pm to 5am has been implemented, following eventually an agreement of the mediation group (2000 - 2002). In 2005, a socio-acoustical survey on the impact of aircraft noise on residents' annoyance and health-related quality (RDF study, 1), has been carried out by commission of RDF. Results of the RDF study showed a considerable shift in the exposure-response-relationship towards a higher percentage of annoyed people per unit of sound level (L_{den}, L_{dn}) as compared to generalized exposure-response curves for aircraft noise annoyance, e.g. by Miedema & Oudshoorn (2). Results of the RDF study revealed that, among others, expectations and fears concerning the future residential life after the expansion of the airport contributed to the explanation of aircraft noise annoyance and perceived health-related quality of life.

The opening of the new runway as well as the implementation of the night curfew means a step change in aircraft noise exposure for residents living in the vicinity of the airport. It is well known that step changes in transportation noise exposure lead to the so-called change effect in human responses to noise exposure. This is defined as "... an excess response to the new noise exposure over that predicted from steady-state exposure-response curves (which predict the exposure effect)" (3, p. 1). With regard to the categorization of environmental noise interventions by Brown and van Kamp (4) the new runway belongs to Type C interventions (new/closed infrastructure), whereas the night curfew is an intervention of Type A (source intervention, time restrictions on source operations).

Janssen & Guski distinguish between low-rate change and high-rate change airports and define high-rate change airports as those with a significant and permanent disruption of the typical trend of aircraft movements. The authors even classify an airport as a high-rate change airport before the step change occurs, "if there has been public discussion about operational plans within 3 years before and after the study" (5, p. 8). According to this definition Frankfurt Airport belongs to the high-rate change airports at the time of the study presented here.

There is evidence that the changes in aircraft noise exposure due to an airport expansion result in a change effect which is not an issue of short duration and can last up to two years (6-7). Whether the change effect is of even longer duration is unknown with regard to aircraft noise as up to now the authors do not know of longitudinal studies covering a longer period of time after the step change in aircraft noise exposure. For changes in noise exposure due to mitigation interventions the evidence for a change effect is mixed. At least, positive changes in terms of a decrement in exposure or respite from noise for respondents lead to a smaller change effect than an increment in noise exposure (3). However, this might depend on the way mitigation measures are implemented.

The expansion of Frankfurt Airport is associated with complex multiple configurations. According to operations predicted for the time after the opening of the new runway areas around the airport would be more exposed by aircraft noise, others less exposed and in other areas there would be no significant change in exposure, i.e. the change is less than or equal to ± 2 dB in $L_{pAeq,24h}$. In addition, the night curfew and other operational measures of noise control since 2011 tested at Frankfurt Airport contribute to multiple and in part opposing changes of the aircraft noise exposure in communities around the airport. Therefore, it is almost impossible to hypothesize about the extent and direction of the change effect in responses to aircraft noise after the opening of the new runway and the implementation of the night curfew.

A longitudinal study has been carried out before and after the introduced changes at Frankfurt Airport (new runway, ban on night flights) in order to (i) update exposure-response curves for aircraft noise annoyance as well as for reported sleep disturbance and (ii) to study the impact of the step changes in aircraft noise exposure on these responses to aircraft noise. In this paper, results of the analysis with regard to the change effect are exemplarily shown for aircraft noise annoyance. The study is part ofworkpackage 1 'Annoyance and quality of life' of the NORAH research program (8).

2. METHODS

2.1 Study design and sampling

The study entails a longitudinal survey design with measurements in 2011 (prior to the opening of the new runway Northwest) and repeated measurements in 2012 and 2013 (after the runway opening and the implementation of the night flight ban). The study region around Frankfurt Airport includes residential areas within the "envelope" of the 40 dB contours of the continuous aircraft sound levels for daytime ($L_{pAeq,06-22h}$) and night-time ($L_{pAeq,22-06h}$). Within this region a panel of residents was randomly sampled from the population registries in 2011 and was stratified by continuous aircraft sound

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level classes (2.5 dB classes of the maximum of $L_{pAeq,06-22h}$ and $L_{pAeq,22-06h}$) and by predicted change in aircraft noise exposure for 2020 in relation to the aircraft noise exposure in 2007 (increase in $L_{pAeq,24h}$ > 2 dB, decrease in $L_{pAeq,24h}$ > 2 dB, no change, i.e. change within the range of ± 2 dB). The sample was then linked to the contact information from the telephone registration to enable telephone interviews as the main mode of survey.

The continuous sound levels used for stratum and to define the perimeter of the study region were calculated for the residential address of each participant by using the German calculation model for aircraft noise exposure, AzB 2008 (9), and refer to the air traffic of the six busiest months of the year 2007. The sound levels predicted for the six busiest months in 2020 used for sampling are based on data modeled by means of the AzB 2008 on the occasion of the zoning procedure.

2.2 Procedure

The sampling of the panel group at Frankfurt Airport was done in the spring of 2011. A cover letter was sent to the sampled residents to inform about the study and invite them to participate in telephone interviews or optional online surveys with the same questionnaire. The first wave of interviews was carried out in summer and autumn of 2011 and finished before the opening of the runway Northwest on 21 October 2011. Repeated interviews were carried out in summer/autumn of 2012 and again in 2013.

Comparative cross-sectional surveys (not further reported here) had been carried out at the airports Berlin-Schoenefeld, Cologne/Bonn and Stuttgart. The sampling and data management was supervised and certified by the responsible agency for data protection.

2.3 Noise exposure

For the residential address of every participant the exposure to source-specific equivalent sound levels, as well as mean maximum sound levels of aircraft, railway and road traffic were calculated for the past 12 months of each survey wave for different times of day (12). For the assessment of aircraft sound levels the calculation method AzB 2008 (9) was used. The average sound levels of railway and road traffic were determined based on the methods for calculation (VBUSCH, VBUS) used for EU noise mapping (10, 11).

2.4 Questionnaire

The questionnaires used in the three survey waves include the assessment of responses to transportation noise (aircraft, railway, road traffic), such as annoyance and disturbances, variables of quality of life, potential moderator variables and co-determinants, variables concerning residential conditions (e.g sound insulation, window type and position) and demographics. The following variables assessed in the questionnaire were used in the analysis in the study described in this paper:

- Aircraft noise annoyance assessed with the ICBEN 5-point scale according to ISO/TS 15666 (13).
- Sleep disturbances assessed with three items which refer to aircraft noise-related disturbances when falling asleep, when sleeping during the night and in the early morning. A 5-point response scale similar to the ICBEN scale was used. The responses to these three items were summarized to a mean score of reported sleep disturbances (Cronbach's alpha t1 (2011) = .91, t2 (2012) = .85, t3 (2013) = .84.
- Self-reported noise sensitivity (1 item) assessed on a 4-point scale ((0: strongly disagree, 1: slightly disagree, 2: slightly agree, 3: strongly agree).
- Coping capacity/perceived control assessed with judgments of six statements on a 5-point scale (agree (1) not to (5) strongly). A mean score of the responses to the six items were calculated (Cronbach's alpha: t1 = .83, t2 = .85, t3 = .84).
- Attitudes towards air traffic: Four items with regard to evaluation of air traffic as useful, comfortable, dangerous, and harmful to the environment (5-point scale: (1) not to (5) very).
- Positive expectations concerning the impact of air traffic at Frankfurt airport on the economic development of the region and the individual (residential) quality of life. Judgments of four items on a 5-point scale (agree (1) not to (5) strongly) were summarized to the mean score 'positive expectations' (Cronbach's alpha: t1 = .71, t2 = .74, t3 = .74).
- Demographics: Age, gender, migration background, period of residence, house ownership, socio-economic status.
- Mode of survey: telephone interview vs. online survey.

2.5 Statistical analysis

Exposure-response relationships for highly aircraft noise annoyed people (%HA) and highly sleep disturbed people (%HSD) were analyzed for each year of measurement by means of multiple logistic regressions with $L_{pAeq,06\_22h}$ (for %HA) and $L_{pAeq,22\text{-}06h}$ (for %HSD), respectively, as acoustical parameters of aircraft noise exposure. The two upper categories of the annoyance scale (very, extremely), i.e. cut-off point = 60% of the response scale, was used to define %HA according to the ICBEN recommendations (14). For %HSD the same cut-off value was used for definition. Noise sensitivity, the judgments of air traffic as useful, comfortable, and environmentally harmful, the demographic variables, the mode of survey, the average road traffic and railway sound levels as well as the interaction between age and mode of survey (because younger participants more often used the online mode than older ones) were included for adjustment.

In order to assess the change effect at Frankfurt from 2011 (prior to the step changes in aircraft noise exposure) to 2013 (after the changes) and to identify factors explaining the effect, Latent Growth Curve Models (LGCM, 15) were used for analysis. The LGCM allows to model a multifactorial change process within a sample as well as individual changes over time. Two aspects are relevant in LGCM: (1) the latent intercept of the dependent variable, in this paper, the initial value in aircraft noise annoyance in 2011 and the factors contributing to it and (2) the latent slope, i.e. the change in the dependent variable, here, aircraft noise annoyance in 2012 and 2013, respectively, and the factors explaining the change. The following variables as ascertained in all survey waves, 2011 (tl), 2012 (t2), and 2013 (t3) were included as indicators: average aircraft sound levels ($L_{pAeq,24h}$), noise sensitivity, coping capacity, the items addressing the attitudes towards air traffic, positive expectations concerning the impact of the air traffic, demographics as described in section 2.4, the interaction of survey mode with age and with the evaluation of air traffic as dangerous and the average sound levels of road traffic and railway traffic.

For each group of participants experiencing either an increase, a decrease or no change above ± 2 dB in $L_{pAeq,24h}$, four LGCM were estimated: (1) a base model without growth, (2) a model with linear growth, (3) a model with curvilinear growth, and (4) a final adjusted model (either linear or curvilinear depending on the goodness of fit of model 2 or 3) including selected indicators of model 2 or 3 (indicators with $p < .20$) to avoid overfitting. For all LGCM for aircraft noise annoyance model 3 (curvilinear growth) provides a better fit to the data and was therefore selected for the adjusted final model.

All final models (exposure-response models, LGCM) included bootstrapping (16) with 5000 'bootstrap'-samples in order to assess the robustness of the models.

3. RESULTS

3.1 Sample and aircraft noise exposure

A sample of 9244 participants took part in the first survey wave in 2011. This is 17% of the total number of available telephone numbers and 7% of those persons invited by letter to participate. A non-responder-analysis, several sensitivity analyses and the bootstrapping applicated for the exposure-response models indicate the robustness of the results (see 8 for more details).

In 2012 4867 of the 9244 participants took part in the repeated measurement and in 2013 the number of remaining participants was 3508. Comparisons of exposure-response curves with the total sample sizes in 2011 and 2012 and with the 3508 participants taking part in all survey waves revealed no significant differences. Therefore, the analyses described in the following were done with the 3508 persons participating in all survey waves. 54% of them were female, age ranged from 18 to 96 years (mean: 53 years).

In 2011, the average aircraft sound levels for 24 hours $L_{pAeq,24h}$ ranged from 36 to 61 dB, mean (M) was 48 dB. In 2012, $L_{pAeq,24h}$ ranged from 35 to 60 dB (M = 48 dB), in 2013, from::, 35 to 60 dB (M = 47 dB). The sound levels for daytime $L_{pAeq,06\_22h}$ ranged from 37 dB to 62 dB in 2011 (M = 50 dB), to 61 dB in 2012 (M = 49 dB), and from 36 dB to 62 dB in 2013 (M = 49 dB). With regard to aircraft noise at night-time, $L_{pAeq,22\_06h}$ levels ranged from::, 35 to 57 dB in 2011 (M = 42 dB) and to 55 dB (M = 42 dB) in 2012 and 2013, respectively. In all cases the standard deviation (SD) of average sound levels was 6 dB.

517 persons (15%) experienced a decrease in aircraft sound levels of more than 2 dB $L_{pAeq,24h}$ in 2012 compared to 2011, 2592 participants (74%) had no change in sound levels above± 2dB and 399 respondents (II%) experienced an increase of more than 2 dB.

With regard to the average sound levels for night-time ($L_{pAeq,22\text{-}06h}$) these were 633 persons (18%)

experiencing a decrease in aircraft sound levels of more than 2 dB, 2617 participants (75%) without a change in sound levels above± 2dB and 258 persons (7%) with an increase of more than 2 dB.

3.2 Percentage of highly annoyed and sleep disturbed people

The average sound levels for daytime and night-time are consistently associated with aircraft noise annoyance and self-reported sleep disturbances, although, for sleep disturbances correlation coefficients are somewhat lower in 2012 and 2013 after implementation of the night flight ban from 11 pm to 5am as compared to the coefficients in 2011. For the respondents taking part in all survey waves $L_{pAeq,06\_22h}$ correlates with aircraft noise annoyance with r = .48 in 2011 and r = .47 in 2012 and 2013. $L_{pAeq,22\_06}$ correlates with self-reported sleep disturbances with r = .41 in 2011 and r = .36 in 2012 and 2013 (for all correlation coefficients $p < .001$).

Figure 1 shows the percentage of highly annoyed people (%HA) in 2011 prior to the opening of the runway Northwest and in the first (2012) and second year (2013) after. There is a shift in %HA in 2012 compared to 2011, in particular below 55 dB $L_{pAeq,06\_22h}$. The %HA-curve in 2013 lies in between the curves from 2012 and 2011. However, the main difference can be seen in comparison of results of the RDF study at Frankfurt Airport in 2005 (1). For comparison, the $L_{pAeq,06\_22h}$ values in the RDF study were re-calculated using the calculation method AzB 2008 and radar track information (STANLY) as input data. %HA was re-defined similar to the definition used in the NORAH study (cut-off= 60%).

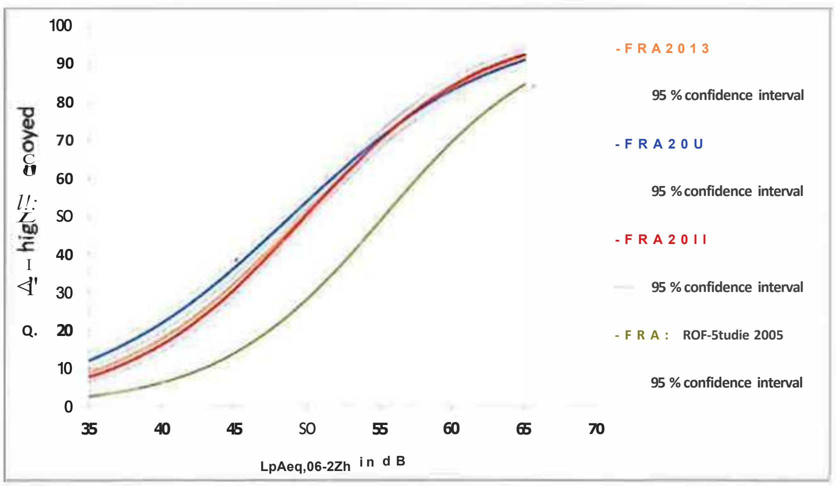

Figure 1 - Percentage of highly annoyed people (%HA) by $L_{pAeq,06-22h}$ in the NORAH study (2011 - 2013) compared to results of the RDF study 2005 (1).

As Figure 2 indicates the percentage of highly sleep disturbed people (%HSD) was considerably decreased after implementation of the night curfew from 11pm to 5am in 2012 and 2013 as compared to %HSD in 2011. Note, that the $L_{pAeq,22-06h}$ values in 2012 and 2013 mainly refer to aircraft sound events in the shoulder hours 10-11pm and 5-6am. However, the shift down of the exposure-response curve for %HSD is in particular true for sleep disturbances during the night. The exposure -response curves for the degree of sleep disturbances when falling asleep is quite similar before and after implementation of the night curfew, whereas for the same average sound level for night-time the sleep disturbances are lower in 2012 and 2013 as compared to sleep disturbances in 2011.

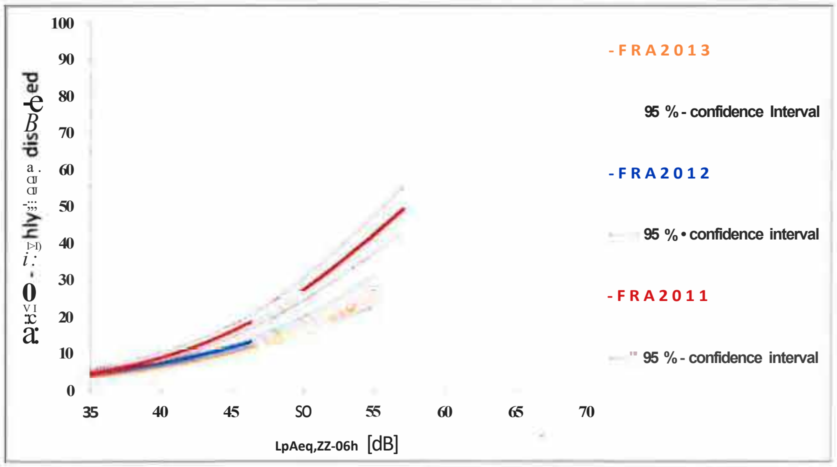

Figure 2 - Percentage of highly sleep disturbed people (%HSD) by $L_{pAeq,22\text{-}06h}$ in 2011, 2012, and 2013

3.3 Estimation of the change effect on aircraft noise annoyance

Table 1 shows the results of the LGCM analysis on the change in aircraft noise annoyance before (201 I) and after (2012, 2013) the step changes at Frankfurt Airport. The exposure-response relations for aircraft noise annoyance in the three years 2011 to 2013 is presented in Figure 3. Beside the base exposure-response model for 2011 the figure shows the expected annoyance for 2012 and 2013 derived from cross-sectional regression analysis with regression coefficients of the base model 2011 and predictor values of2012 and 2013, respectively. Furthermore, the 'occurred' annoyance in 2012 and 2013 was estimated using regression coefficients and predictor values of 2012 and 2013, respectively. The discrepancy between the exposure-response relationship for the expected and the 'occurred' aircraft noise annoyance in 2012 and 2013, respectively, can be interpreted as the change effect.

In the change group *'Reduction of aircraft noise exposure'* aircraft noise annoyance in 2011 is explained by the aircraft sound level. In addition, railway sound level, survey mode, coping capability, positive expectations and the judgment of air traffic as environmentally harmful are associated with aircraft noise annoyance in 2011. Participants interviewed by telephone reported higher noise annoyance than online participants. Railway sound level is somewhat negatively associated with aircraft noise annoyance. Higher coping capacity, positive expectations concerning air traffic and lower degree of evaluation of air traffic as harmful to the environment are positively associated with the annoyance in 2011. Changes in aircraft noise annoyance in 2012 and 2013 after opening ofthe new runway are predicted by aircraft sound levels, coping capability, air traffic-related expectations and the judgment of air traffic as dangerous. Figure 3 shows that in the group 'Reduction in aircraft noise exposure' aircraft noise annoyance has been decreased in 2012 and 2013 as compared to 2011.

In the change group *'Stable aircraft noise exposure'* the aircraft noise annoyance in 2011 is explained by the $L_{pAeq,24h}$ for aircraft, house ownership and noise sensitivity. That is, house owners reported higher noise annoyance than tenants, sound level and noise sensitivity are positively associated with annoyance. Depending on the initial annoyance value in 2011 on average the group shows a decrease in aircraft noise annoyance after the opening of the runway Northwest until 2013. In 2012 the annoyance moves up and in 2013, again, down. The change over time is higher for participants with lower initial aircraft noise annoyance in 2011 (see Figure 3). Beside the aircraft sound levels, particularly coping capacity and positive expectations concerning the air traffic contribute to the explanation of the change in annoyance.

In the change group *'Increase in aircraft noise exposure'* the factors $L_{pAeq,24h}$ for aircraft and for railway, house ownership, coping capability, positive expectations concerning air traffic, and the judgment of air traffic as environmentally harmful contribute significantly to the prediction of aircraft noise annoyance in 201 I. The change in aircraft noise annoyance over time is not explained by changes in the average aircraft sound level $L_{pAeq,24h}$, in the group experiencing an increase in aircraft noise exposure in 2012 and 2013 after the opening of runway Northwest. Instead, annoyance changes are predicted by coping capacity, positive expectations concerning air traffic and judgments of airport as dangerous and environmentally harmful and the interaction between survey mode and the judgment of air traffic as dangerous in 2011. In 2012 the exposure-response relation for aircraft noise annoyance moves up and moves down again in 2013, but is still higher as compared to 2011. The discrepancy between expected and occurred annoyance in 2012 and 2013 is higher in the lower band of sound levels below 55 dB $_{LpAeg,24h}$ (up to 0.70 points of the response scale) than above (about 0.15 points of the response scale).

Table 1: Results of the LGCMs for changes in aircraft noise annoyance 2011, 2012, 2013

Variables	Groups of change in aircraft noise exposure $_{(LpAeq,24h)}$					
	Decrease > 2 dB		Stable± 2 dB		Increase > 2 dB	
	B(SE)	p	B (SE)	p	B (SE)	p
Intercept						
2011 Air $_{(LpAeq,24h)}$	.068 (.007)	<.001	.077 (.003)	<.001	.068 (.013)	< .001
2011 Road $_{(LpAeq,24h)}$	.000 (.005)	.995	-.005 (.002)	.038	-.008 (.006)	.223
2011 Rail $_{(LpAeg,24h)}$	-.014 (.007)	.046	-.006 (.003)	.016	-.019 (.007)	.009
2011 Age			.052 (.016)	.001		
2011 Age^2					-.028 (.033)	.391
2011 Socio-economic status	.055 (.036)	.127			-.015 (.040)	.700
201 1 Migration	-.047 (.039)	.226	-.041 (.015)	.005		
2011 Period ofresidence	.043 (.034)	.210	.112(.021)	<.001		
2011 House ownership					.101 (.037)	.007
2011 Survey mode	.085 (.033)	.010	.112 (.021)	< .001	.055 (.033)	.098
2011 Noise sensitivity			.084 (.022)	<.001		
2011 Coping capability	-.450 (.054)	<.001	-.337 (.025)	< .001	-.368 (.070)	<.001
2011 Positive expectations air traffic	-.354 (.061)	<.001	-.318(.027)	< .001	-.381 (.073)	<.001
2011 Air traffic useful			-.012 (.018)	.526	.052 (.041)	.201
2011 Air traffic dangerous (rec.)			-.098 (.022)	<.001	-.109 (.063)	.085
2011 Air traffic comfortable			.016 (.016)	.323		
2011 Air traffic environm. harmful (rec.)	-.155 (.045)	.001	-.039 (.023)	.084	-.129 (.062)	.039
Slope *Mstopelp*	-0,317	<.001	-0,058	<.001	0,714	<.001
2011 Air $_{(LpAeg,24h)}$	-.155 (.041)	<.001	-.076 (.009)	<.001	-.251 (.163)	.123
2012 Air $_{(LpAeg,24h)}$	.104 (.048)	.029	.029 (.009)	.002	.304 (.348)	.384
2013 Air $_{(LpAeg,24h)}$	.028 (.026)	.290	.038 (.005)	<.001	-.248 (.310)	.425
2011 Road $_{(LpAeg,24h)}$	-.007 (.005)	.160	.001 (.001)	.688	.068 (.058)	.239
2011 Rail $_{(LpAeq,24h)}$	.012 (.007)	.098	.000 (.001)	.899	.071 (.077)	.362
Gender	-.053 (.032)	.097			.093 (.048)	.055
2013 Socio-economic status	-.052 (.037)	.163	.008 (.008)	.322		
2011 Survey mode			-.029 (.011)	.009		
Migration	.055 (.043)	**.198**				
2012 House ownership	-.056 (.033)	.091				
2011 Noise sensitivity			-.037 (.012)	.003	-.043 (.034)	.198
2012 Noise sensitivity			.008 (.003)	.008		

Variables	Groups of change in aircraft noise exposure (LpAeq,z4h)					
	Decrease > 2 dB		Stable± 2 dB		Increase > 2 dB	
	B (SE)	p	B (SE)	p	B (SE)	p
2013 Noise sensitivity					-.042 (.022)	.058
2011 Coping capability	.319 (.057)	<.001	.152 (.016)	<.001	.661 (.163)	<.001
2012 Coping capability	-.159 (.053)	.003	-.081 (.014)	<.001	-.416 (.118)	<.001
2013 Coping capability	-.114 (.046)	.014	-.134 (.015)	< .001	-.488 (.124)	< .001
2011 Positive expectations air traffic	.273 (.075)	< .001	.123 (.017)	<.001	.305 (.115)	.008
2012 Positive expectations air traffic	-.156 (.056)	.005	-.024 (.017)	.159	-.435 (.126)	<.001
2013 Positive expectations air traffic	-.188 (.053)	<.001	-.126 (.016)	< .001		
2011 Air traffic comfortable	.059 (.034)	.082				
2011 Air traffic dangerous (rec.)			.047 (.013)	<.001	.153 (.092)	.095
2012 Air traffic dangerous (rec.)			-.034(.011)	.001	.141 (.072)	.052
2013 Air traffic dangerous (rec.)	-.081 (.040)	.043	-.053 (.01 1)	<.001	-.146 (.065)	.025
2011 Air traffic environm. harmful (rec.)	.081 (.047)	.088	.023 (.013)	.078	.146 (.073)	.046
2012 Air traffic environm. harmful (rec.)			-.026 (.01 1)	.015		
2012 Air traffic useful			.023 (.010)	.019	.116 (.052)	.027
Surv. mode* Air tr. dangerous (rec.) 2011					.140 (.064)	.028
Surv. mode* Air tr. dangerous (rec.) 2012					-.060 (.060)	.312
Surv. mode* Air tr. dangerous (rec.) 2013					.056 (.044)	.202

rec. = item recoded (inverted) in order to get a positive orientation of all response scores addressing the attitudes towards air traffic

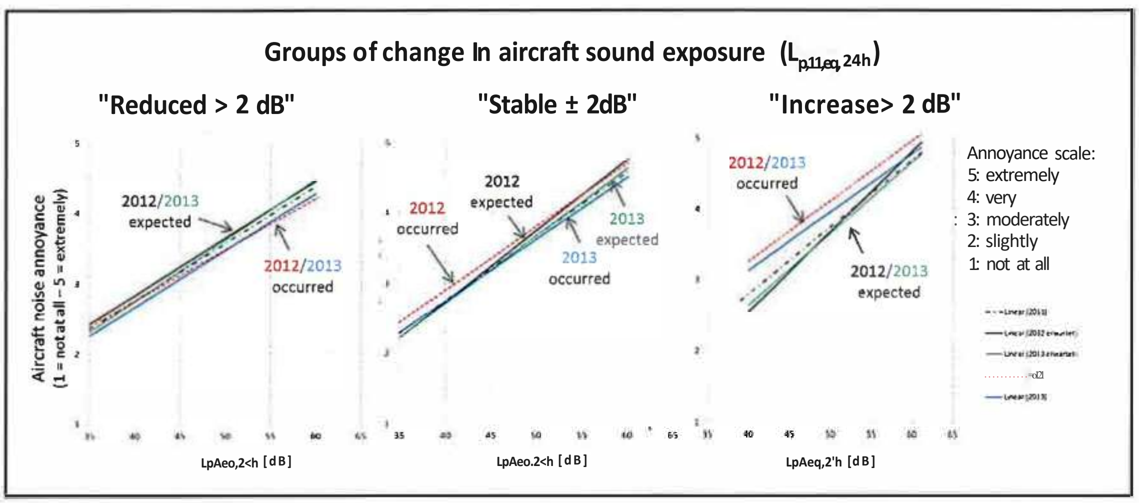

Figure 3 - Exposure-response estimations for aircraft noise annoyance at Frankfurt Airport before (2011) and after (2012/2013) the opening of runway Northwest in different groups of change in LpAeq,24h•

3.4 Change effect for self-reported sleep disturbances

A change effect also occurred for self-reported sleep disturbances due to aircraft noise. It turns out that in 2012 and 2013, after implementation of the night flight ban (in November 2011), the sleep disturbances in participants experiencing a decrease or no change in aircraft sound levels at night-time above 2 dB was lower than expected. In particular, the $L_{pAeq,22-06h}$ for aircraft, age, noise sensitivity, coping capacity, positive expectations concerning the air traffic, and the evaluation of air traffic as dangerous contributed to the explanation of the change effect in sleep disturbances.

All in all, for participants experiencing an increase in aircraft noise exposure at night-time in 2012 as compared to 2011 no statistically significant change effect was found for participants' self-reported sleep disturbances (see 8 for more details).

4. CONCLUSIONS

A longitudinal study was carried out at Frankfurt Airport in order to assess the impact of aircraft noise on annoyance and sleep disturbances prior to the opening of the new runway Northwest in October 2011 and to the implementation of a night flight ban from 11pm to 5am in November 2011 and after that in 2012 and 2013. A total of 3508 residents took part in all repeated measurements in 2011, 2012, and 2013. Telephone interviews (optional online surveys) were carried out and for the address of each participant sound levels of aircraft, railway and road traffic were calculated for the past 12 months of each survey wave for different times of day.

The study revealed a change effect in aircraft noise annoyance and self-reported sleep disturbances due to aircraft noise, i.e. an excess response to the new aircraft sound levels in 2012 and 2013 over that predicted from the exposure-response curves obtained in 2011 and over the expected curves in 2012 and 2013 as estimated in cross-sectional regression analysis. The change effect followed the direction of the local change in aircraft sound levels. For aircraft noise annoyance the change effect was stronger (i) in lower bands of $L_{pAeq,24h}$, (ii) for participants experiencing an increase in aircraft noise exposure in 2012 as compared to 2011, and (iii) in 2012 than one year later in 2013. With regard to self-reported sleep disturbances before and after the implementation of the night curfew the change_ effect occurred in the groups of participants experiencing a reduction and no change above 2 dB $L_{pAeq,22.06h}$. In the group of respondents experiencing an increase in sound levels at night-time the change in sleep disturbances was statistically not significant.

Both, the change in aircraft sound levels as well as non-acoustical factors contributed to the change effect. In the group of participants experiencing an increase in $L_{pAeq,24h}$ after opening of the new runway only the non-acoustical factors contributed to the change effect in aircraft noise annoyance. In particular, those non-acoustical factors turned out to be relevant for the prediction of (the change in) annoyance and sleep disturbances that according to environmental stress-related models (e.g. 17, 18) are supposed to contribute to resources of human beings to cope with noise, i.e. perceived coping capacity/control, attitudes, expectations addressing the noise source, and noise sensitivity.

The study also showed that %HA in all measurements from 2011 to 2013 was considerably higher as compared to %HA in the RDF study carried out at Frankfurt Airport in 2005. This might indicate that the change effect in noise responses due to the expansion of Frankfurt Airport started earlier to 2011 after the announcement of the expansion in 1997 during the following years of debates and regional planning and zoning procedure. On the other hand, the exposure-response curves for %HA at the other airports included in the NORAH study (not presented in this paper) are also higher in comparison to the RDF curve and, thus, higher than the generalized curves of Miedema & Oudshoorn (2). This is in line with results of a recent review on environmental noise annoyance carried out for WHO (19). The review shows evidence that beside annoyance differences between studies at high-rate and low-rate change airports there seem to be a general shift in exposure-response curves for %HA related to average sound level over time even at low-rate change (steady-state) airports.

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Trends in aircraft noise annoyance: The role of study and sample characteristics

Sabine A. Janssen, Henk Vos, Elise E. M. M. van Kempen, Oscar R. P. Breugelmans, and Henk M. E. Miedema

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Trends in aircraft noise annoyance: The role of study and sample characteristics

Sabine A. Janssen[a] and Henk Vos
Department of Environment and Health, Netherlands Organization for Applied Scientific Research (TNO), P.O. Box 49, 2600 AA Delft, The Netherlands

Elise E. M. M. van Kempen and Oscar R. P. Breugelmans
Centre of Environmental Health Research, National Institute for Public Health and the Environment, P.O. Box 1, 3720 BA Bilthoven, The Netherlands

Henk M. E. Miedema
Department of Environment and Health, Netherlands Organization for Applied Scientific Research (TNO), P.O. Box 49, 2600 AA Delft, The Netherlands

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Recently, it has been suggested that the annoyance of residents at a given aircraft noise exposure level increases over the years. The objective of the present study was to verify the hypothesized trend and to identify its possible causes. To this end, the large database used to establish earlier exposure–response relationships on aircraft noise was updated with original data from several recent surveys, yielding a database with data from 34 separate airports. Multilevel grouped regression was used to determine the annoyance response per airport, after which meta-regression was used to investigate whether study characteristics could explain the heterogeneity in annoyance response between airports. A significant increase over the years was observed in annoyance at a given level of aircraft noise exposure. Furthermore, the type of annoyance scale, the type of contact, and the response percentage were found to be sources of heterogeneity. Of these, only the scale factor could statistically account for the trend, although other findings rule it out as a satisfactory explanation. No evidence was found for increased self-reported noise sensitivity. The results are of importance to the applicability of current exposure–annoyance relationships for aircraft noise and provide a basis for decisions on whether these need to be updated.
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I. INTRODUCTION

The human need for transportation by air has been growing rapidly for several decades and is predicted to keep growing in the future. In Europe, more than 2.6 million people are estimated to have been exposed to aircraft noise levels above 55 dB(A) in the year 2007, growing to almost 3.3 million in 2015 (ANOTEC, 2004). Of these, approximately 15% are estimated to be highly annoyed. Furthermore, there is increasing evidence that exposure to aircraft noise contributes to cardiovascular diseases such as hypertension (Babisch and van Kamp, 2009) and may affect children's cognitive functioning (Stansfeld *et al.*, 2005). Annoyance due to aircraft noise has been recognized by policy makers as a harmful effect in itself that should be prevented or reduced. The level of annoyance by aircraft noise in a population can be predicted using exposure–response relations that describe the relationship between aircraft noise exposure and annoyance. The most widely used exposure–response relationships have been presented by Miedema and Vos (1998), and were updated by Miedema and Oudshoorn (2001) using the new standard European noise metric L_{den}. Based on data from 55 cross-sectional surveys carried out between 1967 and 1993 in Europe, North America, and Australia, separate exposure–response curves were established for aircraft, road traffic, and railway noise. These exposure–response relationships have been put forward by the Noise Expert Network of the European Commission to serve as the standard for the European Union (EC, 2002).

Recently, Guski (2004) showed on the basis of the data presented by Miedema and Oudshoorn (2001) that the annoyance of residents at a given aircraft noise exposure level appeared to increase over the years. Van Kempen and van Kamp (2005) reached a similar conclusion based on a review of 28 surveys, indicating that year of the study may be one of the factors underlying the considerable variability in annoyance response between studies. Also, in the Hypertension and Exposure to Noise near Airports (HYENA) study, a large-scale multi-centered study around six European airports, annoyance ratings due to aircraft noise were found to be higher than predicted from the EU standard curve (Babisch *et al.*, 2009). One explanation put forward for an increase over the years concerns the changing noise exposure situations around airports. While the noise emitted by each individual aircraft has been reduced considerably, residents are exposed to an increasing number of overflights. Not all changes in aircraft noise exposure over the years that influence annoyance may be sufficiently reflected in energy

[a]Author to whom correspondence should be addressed. Electronic mail: sabine.janssen@tno.nl

equivalent noise metrics like L_{den}. Also other acoustical factors may play a role, particularly the ambient noise levels due to increased road traffic near airports. Furthermore, the expansion of many airports with new runways causes abrupt and permanently changed noise situations that residents react to in ways that perhaps cannot be predicted by steady-state exposure–response relationships (Fidell, Silvati and Haboly, 2002; Guski, 2004; Brown and van Kamp, 2009a,b). Another possible explanation given for the trend in annoyance concerns differences in the designs of the study, such as exposure assessment, sample selection, data collection methods, and the annoyance scale used (van Kempen and van Kamp, 2005; Brooker, 2009). For instance, decreasing participation rates in questionnaire surveys over the years may have resulted in selection bias. Also, the trend in annoyance may be due to actual changes in the characteristics of the population living in the vicinity of airports (or even the general population), reflecting changes in for instance mean age, noise sensitivity or fear.

The objective of this paper is to thoroughly test whether there is a change over time in annoyance due to aircraft noise and if so, to investigate whether this trend may be explained by differences in study or sample characteristics. To this end the database used by Miedema and Oudshoorn (2001) has been updated with several recent cross-sectional surveys. This updated database includes 34 original datasets from separate airports spanning a period from 1967 to 2005. In contrast to the previous reviews referred to above, the variance of the effect estimates could be determined based on the individual data, allowing more profound statistical analysis of the trend. Furthermore, no extrapolation was needed for determining the effect estimates, and the problem of differences between studies in cut-off criteria for high annoyance was avoided. An adapted version of a multilevel grouped regression as described by Groothuis-Oudshoorn and Miedema (2006) was used to determine effect estimates (and their variance) of the relationship between annoyance and exposure to aircraft noise for each airport. This method allows for correction of the effect on the exposure–response relationship of possible differences among study samples in individual characteristics. Subsequently, a meta-regression (van Houwelingen *et al.*, 2002) was used to investigate whether characteristics of the study may explain the heterogeneity in effect estimates between airports. While the main factor of interest is year of the study, this paper also investigates whether other study characteristics (type of contact, type of annoyance scale applied), sample characteristics (age, number of persons in the household, use or economical dependency of the airport, insulation, noise sensitivity, fear), and acoustical characteristics of the study (number of events) may explain variability in annoyance response. The outcome of the study is of importance to the applicability of current exposure–annoyance relationships for aircraft noise and provides a basis for decisions on whether these need to be updated.

II. DATA

At the Netherlands Organization of Applied Scientific Research (TNO) an archive has been compiled of original datasets from surveys of residents' reactions to transportation noise. The surveys concerning aircraft noise used in the present study were carried out in Europe, North America, and Australia. An overview of the surveys, which often comprised of more than one airport, is given in Table I, with survey ID [code assigned by Fields, see Wyle (2009)], number of respondents, and study characteristics given for each survey. Most surveys previously used to establish exposure–response curves for annoyance due to aircraft noise (Miedema and Vos, 1998; Miedema and Oudshoorn, 2001) were also included here, with the exception of surveys of which the available dataset only contained the average annoyance response per noise exposure category (FRA-016, SWE-035, SWI-053, USA-204, USA-338). In addition, seven more recent surveys (done between 1995 and 2005) were included (NET-371, NET-379, NET-522, SWI-525, NET-533, SWI-534, GER-531). From surveys done in the context of temporary changes such as a closed runway (USA-203), cessation of late-night flights (USA-082), or a military exercise (NOR-366, NOR-328), only the data before the change were used in the analysis. In total, the dataset comprises 34 airports within 22 surveys, with an overall sample size of 48 369. Surveys were carried out between 1967 and 2005, with *Year* defined as the year in which most of the respondents were included. In addition, *Contact* was defined as the type of contact (1 = postal, 2 = telephone, 3 = face-to-face), and *Scale* as the number of categories of the annoyance scale (4, 5, 10, or 11, encoded as dummies with the 4-point scale as a reference). When a survey had applied more than one annoyance scale (see Table I), the scale with the maximum number of categories was used, as this was supposed to give more precise information on annoyance. Furthermore, for part of the surveys the response percentage (*% Resp*) could be obtained from the original reports.

A. Noise exposure measures

In the present study we used L_{den}, the metric for noise mapping in Europe, as the descriptor of noise exposure. L_{den} is defined in terms of L_{Aeq} (average equivalent noise level) during daytime (d), evening (e), and nighttime (n), and applies a 5-dB(A) penalty to noise in the evening and a 10-dB(A) penalty to noise in the night:

$$L_{den} = 10\log\left[(12/24)10^{LD/10} + (4/24)10^{(LE+5)/10} + (8/24)10^{(LN+10)/10}\right].$$

In this formula, *LD*, *LE,* and *LN* are the long-term L_{Aeq} as defined by the ISO (2002) for the day (7:00 a.m. to 7:00 p.m.), the evening (7:00 p.m. to 11:00 p.m.), and the night (11:00 p.m. to 7:00 a.m.), respectively. For the older studies the available information was not always sufficient to directly compute L_{den}, in those cases L_{den} was estimated from metric L_{dn}. The conversion from L_{dn} to L_{den} for the various studies has been described in detail in Miedema and Oudshoorn (2001). The recently added studies either had L_{den} already stored or L_{den} could be estimated from the available noise variables.

TABLE I. Characteristics of the surveys: Study ID [code assigned by fields, see Wyle (2009)], Name of the survey, Reference [report or publication of the survey, Airports (number of airports in survey)], year of the survey (*Year*), N, type of contact (*Contact*: 1 = postal, 2 = telephone, 3 = face-to-face), response percentage (*% Resp*), and number of categories of annoyance scale(s) used in the survey (*Scale*).

Study ID	Name of the survey	Reference	Airports	N	*Year*	*Contact*	*% Resp*	*Scale*
USA-022	U.S.A. Four-Airport Survey (phase I of Tracor Survey)	Hazard (1971)	4	3499	1967	3	79	5
UKD-024	Heathrow Aircraft Noise Survey	Knowler (1971)	1	4515	1967	3	—	4
USA-032	U.S.A. Three-Airport Survey (phase II of Tracor Survey)	Hazard (1971)	3	2883	1969	3	—	5
USA-044	U.S.A. Small City Airports (Small City Tracor Survey)	Pattersen and Connor (1973)	2	1954	1971	3	—	5
USA-082	LAX Airport Noise Study	Fidell and Jones (1975)	1	702	1973	2	—	5
CAN-168	Canadian National Community Noise Survey	Hall *et al.* (1981)	1	631	1978	3	75	11(5)
USA-203	Burbank Aircraft Noise Change Study	Raw and Griffiths (1985)	1	924	1979	3	80	5
AUL-210	Australian Five Airport Survey	Bullen *et al.* (1986)	4	3007	1980	3	82	5
UKD-242	Heathrow Combined Aircraft/Road Traffic Survey	Brooker and Richmond (1985)	4	1993	1981	3	—	4
UKD-238	Glasgow Combined Aircraft/Road Traffic Survey	Diamond and Walker (1986)	1	598	1984	3	—	10(4)
FRA-239	French Combined Aircraft/Road Traffic Survey	Vallet *et al.* (1986)	1	565	1984	3	—	10(4)
NET-240	Schiphol Combined Aircraft/Road Traffic Survey	Diamond *et al.* (1986)	1	573	1984	3	46	10(4)
NOR-311	Oslo Airport Survey	Gjestland *et al.* (1990)	1	1548	1989	2	52	4
NOR-366	Vaernes Military Aircraft Exercise Study	Gjestland *et al.* (1993a)	1	391	1990	2	—	4
NOR-328	Bodo Military Aircraft Exercise Study	Gjestland *et al.* (1993b)	1	702	1992	2	51	4
NET-371	Amsterdam Schiphol Airport Survey (GES 1)	TNO/RIVM (1998)	1	11 150	1996	1	39	11
NET-379	Groningen Airport Eelde Survey	van Dongen *et al.* (1999)	1	407	1998	3	58	11
NET-522	Amsterdam Schiphol Airport Sleep Disturbance Study	Passchier-Vermeer *et al.* (2002)	1	804	2000	1	—	11
SWI-525	Zurich Airport Survey	Brink *et al.* (2008)	1	1787	2001	1	52	11(7)
NET-533	Amsterdam Schiphol Airport Survey (GES 2)	Breugelmans *et al.* (2004)	1	5753	2002	1	46	11
SWI-534	Zurich Airport Survey (Follow-up)	Brink *et al.* (2008)	1	1710	2003	1	52	11(7)
GER-531	Frankfurt Airport Survey	Schreckenberg *et al.* (2010)	1	2273	2005	3	61	11(5)

In line with earlier meta-analyses (Miedema and Vos, 1998; Miedema and Oudshoorn, 2001), people in areas with low L_{den} levels [< 45 dB(A); 5.5%] were excluded from the analyses because the assessment of these low levels is relatively inaccurate. Moreover, in situations with low exposure levels, sources of noise other than aircraft, which are not available for the dataset in the present study, may be more important. Also, people exposed to very high L_{den} levels [> 75 dB(A); 7.5%] were excluded, because particularly in areas with very high noise there is a risk of self-selection of people that are not affected by noise. Although there is no direct evidence for such self-selection, noise sensitive people seem to be more prepared to move to different areas (Nijland *et al.*, 2007). The resulting overall dataset contained 42 078 cases.

B. Annoyance measures

As far as possible, a common set of variables was derived from the datasets, which included annoyance measures, demographic and attitudinal variables, and acoustical variables. Annoyance questions in the different datasets did not contain the same number of response categories. For example, some questions had only four response categories, whereas others had as many as 11 categories. In this study, all sets of response categories were converted into a scale ranging from 0 to 100. This conversion is based on the assumption that a set of categories divides the range of 0–100 in equally spaced intervals. The general rule that gives the position of an inner category boundary on the scale of 0–100 is: $\text{score}_{\text{boundary }i} = 100 \cdot i/m$, where i is the rank number of the category boundary, starting from 1 for the upper boundary of the lowest category, and m is the number of categories. For instance, this means that a respondent in the third category of a 4-point annoyance scale will have an annoyance score with the boundaries 50–75.

C. Possible modifying variables

Demographic or attitudinal variables that have been identified previously as having a smaller or larger influence on noise annoyance are *Age*, *Education*, *Occupation*, number of people in the household *(Household size)*, home ownership *(Ownership)*, economical dependency on airport activities *(Dependency)*, use of the source of noise *(Use)*, self-reported noise sensitivity (*Sensi*), and fear of a plane crash *(Fear)* (Miedema and Vos, 1999; van Gerven *et al.*, 2009). Of these, only the (continuous) variable *Age* was present for all surveys in the dataset. Other variables were known for a subset of the surveys (see Table II for an overview of the variables known for each survey), and were encoded in the following way per airport: *Household size* (mean); *Ownership* (proportion of home owners); *Dependency* (proportion of respondents economically dependent on airport activities); *Use* (proportion of respondents making either low, moderate or high use of the source of noise versus no use at all); *Sensi* (mean; based on various numbers of response categories, converted into a scale ranging from 0 = not sensitive to noise to 100 = very sensitive to noise, with category boundaries given by the same rule as defined above for annoyance); and *Fear* (mean; based on various numbers of response categories, also converted into a scale ranging from 0 = no fear to 100 = very fearful of a plane crash). Since *Education* and *Occupation* may be incompatible between countries over the

TABLE II. Characteristics of the surveys per airport: Study ID [code assigned by fields, see Wiley (2009)], international airport code (Airport), sample size (*N*), year of the study (*Year*), effect estimate (β_{0i}), estimated sampling variance (SE^2), mean age (*Age*), mean number of people in the household (*Household size)*, proportion house owners (*Ownership*), proportion economically dependent (*Dependency*), proportion making use of airport (*Use*), mean noise sensitivity (*Sensi*), mean fear (*Fear*), mean number of overflights per 24 h period (*Events*), and proportion of people with double glazing or special acoustic glazing (*Insulation*).

Study ID	Airport	*N*	*Year*	β_{0i}	SE_i^2	*Age*	*House-hold size*	*Ownership*	*Dependency*	*Use*	*Sensi*	*Fear*	*Events*	*Insulation*
USA-022	DEN	979	1967	19.66	1.95	42	3.6	0.74	0.10	0	—	25.6	85	0.20
—	DFW	898	1967	25.46	2.25	45	3.5	0.59	0.08	0	—	29.8	176	0.14
—	LAX	764	1967	36.32	2.45	42	3.6	0.67	0.12	0	—	37.0	250	0.14
—	ORD	858	1967	18.14	2.21	42	4.0	0.77	0.07	0	—	29.1	263	0.32
UKD-024	LHR	4515	1967	45.15	0.30	48	3.2	0.49	0.07	0.53	—	25.5	73	0.03
USA-032	BOS	1166	1969	48.32	1.68	46	3.7	0.63	0.09	0.49	—	46.1	173	0.13
—	JFK	1042	1969	49.88	3.72	43	4.0	0.82	0.09	0.60	—	51.0	157	0.36
—	MIA	675	1969	27.09	2.58	50	3.2	0.74	0.17	0.72	—	26.6	95	0.01
USA-044	RNO	842	1970	23.28	1.62	44	3.5	0.76	0.06	0.64	—	26.3	32	0.05
—	CHA	1112	1971	18.52	1.34	47	3.3	0.81	0.02	0.41	—	32.0	27	0.16
USA-082	LAX	702	1973	35.41	2.86	45	—	—	—	—	—	48.5	585	—
CAN-168	YYZ	631	1978	37.20	1.57	38	—	0.96	0.07	0.80	43.8	—	—	0.93
USA-203	BUR	924	1979	48.43	1.91	41	—	—	—	—	—	—	364	—
AUL-210	MLB	325	1980	32.71	3.43	36	—	0.88	—	—	—	68.2	50	—
—	PER	635	1980	22.44	1.90	43	—	0.77	—	—	—	61.3	12	—
—	SYD	1401	1980	41.13	0.84	44	—	0.73	—	—	—	71.4	66	—
—	ADL	646	1980	35.28	1.90	46	—	0.77	—	—	—	67.1	27	—
UKD-242	LHR	1223	1981	47.61	0.95	47	—	—	0.07	—	45.3	—	145	0.32
—	LGW	537	1982	27.02	2.23	45	—	—	0.18	—	44.8	—	210	0.59
—	LTN	159	1982	47.41	7.02	47	—	—	0.04	—	44.3	—	41	0.25
—	MAN	74	1982	37.55	15.54	43	—	—	0.01	—	46.9	—	57	0.07
UKD-238	GLA	598	1984	46.44	1.82	45	2.8	0.19	0.01	—	—	32.6	71	0.28
FRA-239	ORY	565	1984	48.97	1.88	41	3.3	0.71	0.08	—	—	28.2	179	0.25
NET-240	AMS	573	1984	38.45	1.81	44	2.7	0.46	0.09	—	—	—	72	0.40
NOR-311	FBU	1548	1989	38.12	0.85	45	2.6	0.80	0.04	0.72	—	29.9	—	0.93
NOR-366	TRD	391	1990	41.46	3.77	45	3.0	—	0.05	—	—	—	—	0.96
NOR-328	BOO	702	1992	20.02	2.10	48	2.4	—	0.05	—	—	—	—	0.97
NET-371	AMS	11150	1996	63.25	0.09	48	2.4	0.58	0.10	0.55	44.9	64.2	158	0.44
NET-379	GRO	407	1998	54.67	6.27	47	3.0	—	0.03	0.39	27.8	54.5	—	0.19
NET-522	AMS	804	2000	60.36	1.32	48	2.7	0.68	0.11	0.55	50.4	27.6	—	0.47
SWI-525	ZRH	1787	2001	53.70	0.72	47	—	0.51	—	0.83	43.2	—	—	0.30
NET-533	AMS	5753	2002	65.60	0.21	51	—	0.58	0.08	—	46.5	48.8	—	0.99
SWI-534	ZRH	1710	2003	55.05	0.81	51	—	0.56	—	0.70	42.1	—	—	0.38
GER-531	FRA	2273	2005	52.21	0.44	52	2.5	0.60	0.06	0.71	42.8	34.0	—	—

years, these were excluded from the present analysis. In addition, for many surveys the possible modifying variables *Events* (mean number of events per 24 h period given per site, although unequal criteria may have been used between surveys for an event) and *Insulation* (proportion of respondents with double glazing or special acoustic glazing) were known.

III. EXPOSURE-EFFECT MODEL

A statistical model developed for analyzing the association between exposures and effects reported with a rating scale was applied here to study the association between L_{den} and self-reported annoyance in the pooled data from the different surveys. This grouped regression model assumes that the dependent variable is randomly distributed with the mean of the distribution being a function (linear combination) of predictor variables. It specifies the probability that someone with exposure level L_{den} has an annoyance level A that exceeds an arbitrary cut-off point C as follows:

$$\begin{aligned} P_C(L_{\mathrm{den}}) &= Prob(\mathrm{A} \geq \mathrm{C}) \\ &= Prob(\beta_0 + \beta_1 L_{\mathrm{den}} + u \geq \mathrm{C}) \\ &= [1 - \mathsf{U}((\mathrm{C} - (\beta_0 + \beta_1 \mathrm{L}_{\mathrm{den}}))/\sigma], \end{aligned}$$

where U represents the cumulative standard normal distribution, β_0 is the intercept and β_1 is the slope coefficient of L_{den}, and u is the random component with standard deviation σ (see Miedema and Oudshoorn, 2001; Groothuis-Oudshoorn and Miedema, 2006, for more details). In addition, other predictor variables than the noise exposure level can be incorporated in the model, allowing correction for individual differences in these variables. By including a dummy variable for each airport (within survey) instead of the overall intercept, a random intercept β_{0i} (with $_i$ as index for airport) and corresponding SE_i^2 was estimated per airport, while the slope of the effect of L_{den} on annoyance β_1 was assumed constant across airports. In this analysis, L_{den} was centered on the overall mean, i.e., the mean L_{den} across all airports within surveys [58.67 dB(A)] was subtracted from it. Consequently, the intercept (β_{0i}) for each airport represents the annoyance level A expected for that particular airport at the overall average level of L_{den}.

IV. META-REGRESSION MODEL

Meta-regression analysis (see van Houwelingen *et al.*, 2002; Viechtbauer, 2006; Thompson and Higgins, 2002) was used to determine the degree of heterogeneity in β_{0i} between airports and to explore the possible causes of such heterogeneity. First, the heterogeneity between airports was estimated (using restricted maximum likelihood estimation) in a model with only the random effect of airport, using the β_{0i}'s and their SE_i^2 as input. Second, *Year* was added to the model as a predictor to estimate which part of the between-airport variance could be attributed to the year of the survey. Subsequently, other survey characteristics (*Contact*, *% Resp*, *Scale*, and *Change*) were used as predictor variables to estimate the variance explained by each of them, first separately and then in combination with *Year* (defined in the analysis as year of the study minus 1967, the year of the oldest survey) to investigate whether they may explain an effect of year of the survey. To investigate whether any heterogeneity between airports is explained by differences in sample characteristics such as *Age* or *Use*, the airport's mean value or proportion of these characteristics was used as a predictor in addition to *Year* in the meta-regression above. All analyses were performed with the statistical package R.

V. RESULTS

A. Study characteristics

Table I presents the surveys in chronological order with the study characteristics per airport. Several study characteristics show a change over the years. While in previous years the type of contact was primarily face-to-face and sometimes through telephone, recent surveys usually involve postal questionnaires. Also, response percentages were higher in some of the older surveys than in later surveys. Another study characteristic that has changed over the years is the type of annoyance scale. While earlier surveys often used scales with 4 or 5 categories, more recent surveys exclusively used scales with 11 categories.

B. Explaining heterogeneity by study characteristics

Table II shows the estimate β_{0i} for the exposure–annoyance relationship (i.e., the annoyance expected at the overall mean exposure level) and the corresponding sampling variance (SE_i^2) for each airport within a survey (see also Fig. 1). A meta-regression analysis with airport as random effect demonstrated considerable heterogeneity between airports in β_{0i} [178.11; Q_E (test for residual heterogeneity) = 7800, df = 33, $p < 0.001$], with a mean (pooled) β_{0i} of 40.09 (95%

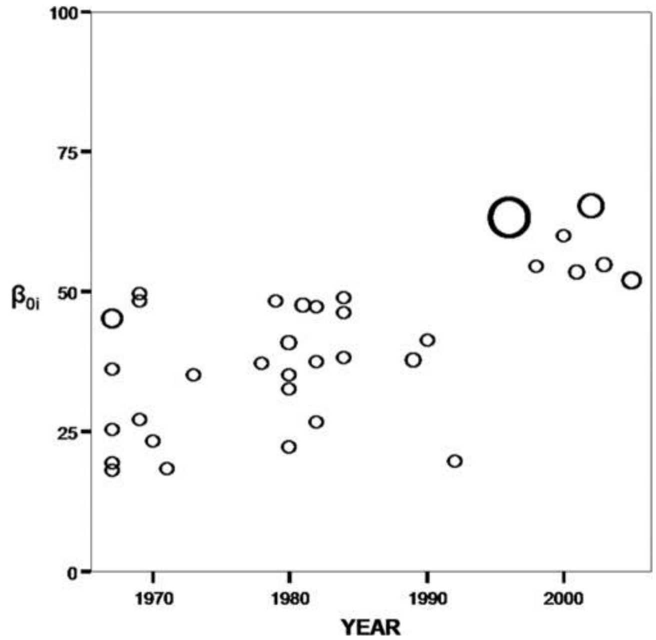

FIG. 1. The effect estimate (β_{0i}) per airport within survey plotted against the year of the survey, with size of the data-points proportional to the inverse variance (SE_i^2) in β_{0i}.

CI = 35.57–44.60). Figure 2 shows the differences in estimated values of β_{0i} according to the differences in study characteristics. *Year* was found to be an important predictor of the observed variability in annoyance response: adding *Year* as a predictor in the meta-regression reduced heterogeneity by 40% (107.32; $Q_E = 3561$, df = 32, $p < 0.001$), with β_{0i} showing a significant increase with *Year* ($z = 4.73$,

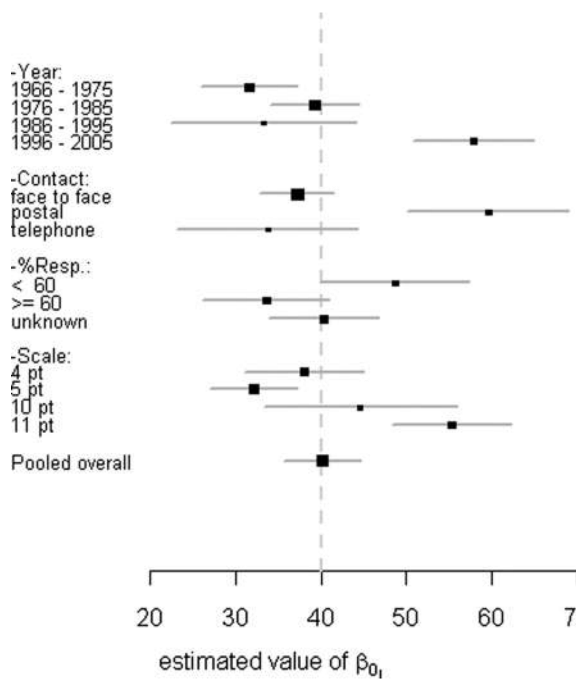

FIG. 2. The estimated mean annoyance on a 100-point scale (β_{0i}) at the overall mean exposure level plotted against study characteristics, with associated 95% confidence intervals and with size of the data-points proportional to the inverse variance (SE_i^2) in β_{0i}.

TABLE III. Estimates (SE) of the meta-regression models with survey characteristics as predictors of the heterogeneity in β_{0i}.

Intercept	*Year (–1967)*	*Contact (tel vs postal)*	*Contact (face-to-face vs postal)*	*% Resp*	*Scale (5 vs 4)*	*Scale (10 vs 4)*	*Scale (11 vs 4)*	(Residual) Heterogeneity
40.09 (2.30)[a]	—	—	—	—	—	—	—	178.11
29.34 (2.90)[a]	0.72 (0.15)[a]	—	—	—	—	—	—	107.32
59.60 (4.81)[a]	—	−25.87 (7.24)[a]	−22.45 (5.28)[a]	—	—	—	—	115.00
41.34 (7.83)[a]	0.55 (0.20)[a]	−18.01 (7.13)[a]	−10.02 (6.52)	—	—	—	—	93.86
77.62 (12.44)[a]	—	—	—	−0.57 (0.18)[a]	—	—	—	146.92
26.89 (20.44)	0.83 (0.29)[a]	—	—	−0.03 (0.24)	—	—	—	102.45
38.02 (3.59)[a]	—	—	—	—	−5.90 (4.43)	6.60 (6.82)	17.27 (5.04)[a]	99.14
34.12 (5.67)[a]	0.24 (0.27)	—	—	—	−3.34 (5.29)	6.38 (6.85)	13.68 (6.47)[a]	99.86

[a] $p < 0.05$.

$p < 0.001$; see Table III). Type of contact also proved to be a source of heterogeneity: both face-to-face interviews ($z = -4.26$, $p < 0.001$) and telephone surveys ($z = -3.57$, $p < 0.001$) were associated with lower effect estimates as compared to postal surveys. When *Contact* was used as a predictor in addition to *Year*, the effect of *Contact* partly disappeared (only an effect of telephone versus postal surveys remained: $z = -2.52$, $p < 0.05$), while the effect of *Year* remained significant. The residual heterogeneity is 93.86 ($Q_E = 2058$, df = 30, $p < 0.001$), indicating that 47% of the heterogeneity could be explained by these predictors together. Also, in those studies for which the response percentage of the study was known ($N = 19$), this was significantly associated with a decrease in reported annoyance ($z = -0.57$, $p < 0.05$). This effect disappeared when *Year* was added as a predictor. Furthermore, when an 11-point scale was used to assess people's annoyance response, higher effect estimates were found than when a 4-point scale was used ($z = 3.42$, $p < 0.001$), while the annoyance response on a 5- or 10-point scale did not differ significantly from that on a 4-point scale. When only *Scale* was used as a predictor, residual heterogeneity was reduced by 44% (99.14; $Q_E = 2190$, df = 30, $p < 0.001$). Adding *Year* as a predictor did not lead to an additional reduction in residual heterogeneity, and no significant effect of *Year* was found, while the effect of the 11-point scale (vs 4-point scale) was still significant ($z = 2.12$, $p < 0.05$).

To check the sensitivity of the results to the choice of the annoyance scale, a further meta-regression was done using β_{0i} based on the alternative (verbal) scales for those studies for which these were available (see Table I). Heterogeneity in β_{0i} (177.14; $Q_E = 7775$, df = 33, $p < 0.001$) was unaffected, with a mean (pooled) β_{0i} of 39.92 (95% CI = 35.41–44.42). *Year* proved to reduce the heterogeneity by 39% (107.86; $Q_E = 3498$, df = 32, $p < 0.001$), with β_{0i} showing a significant increase with *Year* ($z = 4.67$, $p < 0.001$).

C. Sample characteristics

The mean values or proportions of the individual characteristics that may possibly influence annoyance are given per airport in Table II. Some of these sample characteristics show a significant correlation with *% Resp*: lower *% Resp* is associated with an increase in *Age* ($r = -0.66$) and *Use* ($r = -0.71$), and a decrease in *Household size* ($r = 0.92$) and *Ownership* ($r = 0.65$). Furthermore, several characteristics of the surveys' respondents show a change over the years, as shown by meta-regression analyses with *Year* as a predictor of the mean value or the proportion (see Table IV). *Age* shows a significant increase with *Year* ($z = 3.16$, $p < 0.005$), suggesting that the mean age of the studied population has increased with ca. 5 yr. Also, *Household size* shows a significant effect of *Year* (see Table V; $z = -6.39$, $p < 0.001$), with mean *Household size* decreasing from ca. 3.5 to 2.5. Furthermore, an increase in *Use* (the proportion of users; $z = 2.47$, $p < 0.05$) is observed over the years, as well as an increase in *Insulation* (the proportion of respondents with double-glazing or special acoustic glazing; $z = 3.01$, $p < 0.005$). No significant changes over the years were observed in *Ownership*, *Dependency*, *Events*, or *Fear*. Unfortunately, the effect of *Year* on *Sensi* could not be tested in this dataset because this variable was not included in many earlier aircraft noise surveys. To investigate a possible trend in noise sensitivity in the general population, a meta-regression was done involving the TNO archive with all datasets (63) from surveys of residents' response to transportation noise. However, no effect of *Year* on mean noise sensitivity was found ($z = 0.10$, n.s.). Since effects on *Sensi*, *Fear*, *Events*, and *Insulation* could potentially be contaminated by differences in L_{den} between studies, mean L_{den} of the study was used as a covariate in a secondary analysis, but this did not change the significance levels of the effect of *Year*.

TABLE IV. Estimates (SE) of the intercept and the effect of *Year* of the survey on the mean or proportions of the individual characteristics. Significance levels of the effect of *Year* did not change with mean L_{den} as a covariate for *Sensi*, *Fear*, *Events*, and *Insulation*.

	Intercept	*Year (−1967)*
Age	43.07 (0.85)[a]	0.140 (0.044)[a]
Household size	3.55 (0.09)[a]	−0.031 (0.005)[a]
Ownership	0.73 (0.05)[a]	−0.004 (0.002)
Dependency	0.09 (0.05)	0.001 (0.003)
Use	0.34 (0.08)[a]	0.010 (0.004)[a]
Sensi (air, road, rail)	44.38 (2.47)[a]	0.011 (0.101)
Fear	38.12 (4.67)[a]	0.299 (0.261)
Events	163.25 (41.92)[a]	−2.465 (3.485)
Insulation	0.19 (0.08)[a]	0.013 (0.004)[a]

[a] $p < 0.05$.

D. Explaining heterogeneity by sample characteristics

None of the sample characteristics was found to significantly contribute to heterogeneity in annoyance response when mean values or proportions per airport were used as a predictor in addition to *Year* in the meta-regression. To further explore the contribution of sample differences in *Age*, which was available at the individual level for all surveys in the dataset, it was used as an additional predictor in the grouped regression analysis. When new β_{0i}'s were estimated accordingly, the meta-regression showed a reduction in heterogeneity between airports by 2%, but the contribution of study characteristics did not differ from the meta-regression on the β_{0i}'s uncorrected for *Age* described above.

VI. DISCUSSION

On the basis of 34 original datasets from separate airports spanning a period from 1967 to 2005, a significant change over the years was observed in expected annoyance at a given level of noise exposure. This is in accordance with the earlier observations that the level of exposure at which 25% of the population is highly annoyed has decreased over the years (Guski, 2004; van Kempen and van Kamp, 2005). Instead of a gradual increase, annoyance appears to show increased levels particularly from 1996 onward, although this could be due to the limited number of studies included in the preceding years. The advantages of the availability of the original data are that the variance of the effect estimates could be assessed here, allowing more profound statistical analysis, and that changes over the years in individual characteristics could be investigated and corrected for. Another important advantage of the present study is that the interpretation is not limited by the use of different cut-off points for being highly annoyed among studies.

A. Acoustical factors and exposure assessment

One of the possible explanations for a trend in annoyance that was put forward by Guski (2004) concerns changes in aircraft noise exposure over the years that are not reflected by the noise exposure metrics used, particularly the increased number of overflights (events) in combination with a reduction in noise emitted by an individual aircraft. While information on the number of events per site during a 24 h period was available for many studies, the criteria for an event may not have been identical between studies, possibly explaining why the expected increase in number of events over the years was not observed. Therefore, and because of a lack of data for the most recent studies, the possible impact of increased number of events on annoyance could not be adequately investigated. However, on the basis of the data from the Amsterdam Schiphol Airport Survey in 1996 (NET-371), Miedema *et al*. (2000) concluded that noise annoyance, given a certain L_{den} level, was not significantly influenced by the number of events.

Apart from changes over the years in aspects that are not reflected in noise exposure metrics, changes have taken place in the exposure assessment itself. Different assessment methods have been used across countries and over the years, which should also be viewed as a source of heterogeneity. If in earlier years the exposure modeling (or measurement) led to a systematic overestimation of exposure that has (partially) phased out over the years, the observed changes in the exposure–response relationship may be seen as an artifact. Although the influence of this factor could not be tested in the present analysis, there is no obvious reason why there would be systematic exposure measurement errors in earlier surveys as compared to recent surveys.

B. Study design and sample characteristics

Van Kempen and van Kamp (2005) and Brooker (2009) argued that a large part of the heterogeneity between studies may be caused by the study design and sample selection. In particular, decreasing participation rates and resulting selection bias may have contributed to a trend in annoyance. For instance, in the Amsterdam Schiphol Airport Survey in 2002 (NET-533), indications were found for an influence of selective response: respondents had higher levels of annoyance and sleep disturbance than non-respondents (Breugelmans *et al*., 2004), although correcting for non-response still yielded relatively high levels of annoyance (van Kempen and van Kamp, 2005). Indeed, response rates seem to have dropped over time, apparently independent of the type of contact, although surveys were increasingly done by mailed questionnaires or telephone. Lower response rates were associated with an increase in age and use of the airport, a decrease in household size and home ownership, as well as a higher annoyance response. Furthermore, postal surveys were associated with higher annoyance than telephone surveys or face-to-face interviews. However, type of contact only partly explained the effect of year, and response rate did not explain any heterogeneity in addition to year. Still, differences in sample characteristics may have contributed to the heterogeneity between studies. In the present analysis, several changes over time were observed in demographic characteristics of the sample: there was an increase in mean age, a decrease in household size, an increase in insulation measures, and an increase in residents making use of the airport. While some of these changes may be interpreted as indicative of selective response, they may also be explained by trends in the population living in the vicinity of airports or even in the general population. However, none of the changes in individual characteristics that had been identified previously by Miedema and Vos (1999) as factors that modify noise annoyance could explain the observed trend in annoyance over time. Only age and household size show changes in a direction that could possibly contribute to an upward trend in annoyance over the years, whereas increased use of the airport and an increase in insulation measures are rather expected to reduce annoyance (see Miedema and Vos, 1999). While correcting the effect estimates for age differences slightly reduced heterogeneity between studies, it did not affect the trend over time. Furthermore, no evidence was found for a change over time in the attitudinal characteristics fear or noise sensitivity, which seems to rule out the hypothesis that the population under study is getting more sensitive to noise over time.

C. Annoyance scale

Interestingly, an important part of the heterogeneity between surveys in annoyance seems to have been introduced by the type of annoyance scale used, eliminating the effect of year of the survey. In particular, the use of a numerical 11-point scale was associated with higher reported annoyance than a verbal 4-point (or 5-point) scale. This would also explain the counterintuitive finding by van Kempen and van Kamp (2005) that annoyance increased with higher values of the cut-off point for being highly annoyed, since higher cut-off points (72 on the scale of 0–100) are typically used with 11-point scales than with 4- or 5-point scales (often 50–60 on the scale of 0–100, depending on the verbal labels). While earlier surveys mostly used scales with four or five categories, the surveys from 1996 onward included here all used the same scale with 11 categories. This may coincide with the development between 1993 and 2001 of ISO standardized questions by the Community Response to Noise Team of the International Commission on the Biological Effects of Noise (ICBEN, 2001). These findings suggest that the observed trend over time in annoyance due to aircraft noise may be an artifact of changes in the type of annoyance scale used. However, given the high covariance of the scale factor with year of the study, this interpretation should be treated with caution. This is further illustrated by the sensitivity analysis on the data using verbal scales for those studies for which these were used next to a numerical scale. The meta-regression based on these alternative data still showed a clear effect of year and was associated with practically the same residual heterogeneity as when the numerical scales were used. This confirms the suspicion that scale is not a causal factor in the effect of year of the study. While this does not rule out that certain other aspects of the annoyance scale (such as the verbal category labels, or the context in the questionnaire) explain an important part of the variance between studies, it does make the scale explanation based solely on the number of categories (or verbal versus numerical) less plausible. Furthermore, for road traffic noise, applying the same annoyance scales, there is evidence for a stable annoyance response (Guski, 2004; Babisch *et al.*, 2009), although in specific cases higher annoyance than expected was found (Jakovljevic *et al.*, 2008; Klaeboe *et al.*, 2004; Lercher *et al.*, 2008; Öhrström *et al.*, 2007).

D. Cultural differences

While the earliest studies in the present database were from a mixture of countries, all of the survey data from 1980 onward were from studies done in Europe. This raises the question whether the observed increase in annoyance response may have been caused by differences in annoyance response between Europe and other continents. Unfortunately, the dataset did not allow controlling for the possible confounding effect of the continent where the study was done, but the annoyance response also appeared higher in recent as compared to older European studies. Evidence from the HYENA study (Babisch *et al.*, 2009), in which annoyance around six airports was found to be higher than predicted from the exposure–response relationship by Miedema and Oudshoorn (2001), is also based on data from European airports. The present dataset did not allow testing cultural differences or investigating whether the observed increase may be specific to Europe.

E. Expansion of airports

Another important aspect that has been put forward as an explanation for effects of year of the survey is the rate of expansion of airports (Guski, 2004). Many of the later surveys were done in the context of changes raising public discussion, such as expansion of the airport, changed flight procedures, or a new runway, although to a certain extent this may also have been true for some of the older studies. There is evidence that a step change in aircraft noise may be accompanied by disproportionally large increases in annoyance that can (partially) persist for months or even years (Fidell *et al.*, 2002; Houthuijs and van Wiechen, 2006; Breugelmans *et al.*, 2007; Brink *et al.*, 2008; Brown and van Kamp, 2009a,b). Findings around Schiphol Airport as well as Zurich Airport indicate an overreaction in the annoyance response in those people exposed to increased noise levels (Houthuijs and van Wiechen, 2006; Brink *et al.*, 2008). Also, in the HYENA study (Babisch *et al.*, 2009) higher annoyance was found in the relatively new or highly expanded airports Eleftherios Venizelos (Athens, Greece) and Malpensa (Milan, Italy). Although cultural aspects may also play a role, this suggests an overreaction in the annoyance response to aircraft noise in situations with a high rate of expansion, especially since annoyance ratings for road traffic noise in these same areas were not higher than predicted. The question is raised whether the observed trend in annoyance may partly be explained by a larger rate of expansion of airports during recent surveys compared to earlier surveys. Unfortunately, however, the present study did not allow statistical testing of the role of expansion of the airport due to the absence of clear data and criteria on the basis of which the change-status could be attributed to an airport.

VII. CONCLUSION

A significant increase over the years was observed in expected annoyance at a given level of aircraft noise exposure. Several study characteristics can be put forward as possible explanatory factors on the basis of the present analysis. The annoyance scale used, in particular the 11-point scale vs 4- or 5-point scale, was found to be an important source of heterogeneity in annoyance response, which stresses the importance of the use of a uniform annoyance question. However, while the scale factor could statistically account for the year effect, a sensitivity analysis, and other research findings (i.e., Babisch *et al.*, 2009) rule it out as a satisfactory explanation. Two further study characteristics associated with differences in annoyance are the type of contact, with postal surveys showing higher annoyance ratings than telephone or face-to-face surveys, and the response percentage, with higher annoyance in surveys with lower response percentages. However, neither of these factors could explain the effect of the year of the study. Another possible explanation for the year effect, the presumed higher rate of expansion of airports in recent years, could neither be confirmed nor ruled out due to uncertainty in attributing the change-status to an airport. Furthermore, no evidence was found for a sensitization to noise within the population under study as reflected in self-report measures of noise sensitivity.

A limitation of meta-regression analysis is that some of the characteristics which differ between studies can be highly correlated, making it hard to differentiate between their effects (Thompson and Higgins, 2002). Therefore, caution should be taken in the interpretation of the effects, especially since several of the study characteristics mentioned above appear to have changed around the same time. Another limitation is that not all of the included surveys provided information on certain individual characteristics that have been shown to importantly influence annoyance, such as noise sensitivity, fear, or other attitudinal characteristics, preventing proper adjustment for these. Despite the uncertainty with regard to its explanation, it is clear from the observed trend that the applicability of the current exposure–annoyance relationship for aircraft noise (Miedema and Oudshoorn, 2001) should be questioned. Given the large part of the heterogeneity explained by year of the study, it does not seem justifiable to pool recent and older studies into one single relationship. While this could imply that the relationship needs to be updated on the basis of recent studies using similar methodologies, it is important to obtain further insight into the factors responsible for the change and the large heterogeneity found in the annoyance response.

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Review

WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Cardiovascular and Metabolic Effects: A Summary

Elise van Kempen [1,*], Maribel Casas [2], Göran Pershagen [3] and Maria Foraster [2,4]

1 Dutch National Institute for Public Health and the Environment (RIVM), Centre for Sustainability, Environment and Health, P.O.-Box 1, 3729BA Bilthoven, The Netherlands
2 Barcelona Institute for Global Health (ISGlobal), 08036 Barcelona, Spain; maribel.casas@isglobal.org (M.C.); mariafp@gmail.com (M.F.)
3 Institute of Environmental Medicine, Karolinska Institute, SE-171 77 Stockholm, Sweden; goran.pershagen@ki.se
4 Swiss Tropical and Public Health Institute, University of Basel, 4002 Basel, Switzerland
* Correspondence: elise.van.kempen@rivm.nl; Tel.: +31-302-743-601

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Abstract: To update the current state of evidence and assess its quality, we conducted a systematic review on the effects of environmental noise exposure on the cardio-metabolic systems as input for the new WHO environmental noise guidelines for the European Region. We identified 600 references relating to studies on effects of noise from road, rail and air traffic, and wind turbines on the cardio-metabolic system, published between January 2000 and August 2015. Only 61 studies, investigating different end points, included information enabling estimation of exposure response relationships. These studies were used for meta-analyses, and assessments of the quality of evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE). A majority of the studies concerned traffic noise and hypertension, but most were cross-sectional and suffering from a high risk of bias. The most comprehensive evidence was available for road traffic noise and Ischeamic Heart Diseases (IHD). Combining the results of 7 longitudinal studies revealed a Relative Risk (RR) of 1.08 (95% CI: 1.01–1.15) per 10 dB (L_{DEN}) for the association between road traffic noise and the incidence of IHD. We rated the quality of this evidence as high. Only a few studies reported on the association between transportation noise and stroke, diabetes, and/or obesity. The quality of evidence for these associations was rated from moderate to very low, depending on transportation noise source and outcome. For a comprehensive assessment of the impact of noise exposure on the cardiovascular and metabolic system, we need more and better quality evidence, primarily based on longitudinal studies.

Keywords: noise exposure; blood pressure; hypertension; ischaemic heart disease; stroke; diabetes; obesity; meta-analysis

1. Introduction

1.1. Aim

In this paper, we present the main results of a systematic review of the literature dealing with observational studies on the association between environmental noise exposure and the cardiovascular and metabolic systems. The aim was to update some of the existing exposure-response relationships, and to evaluate the overall quality of the evidence. The World Health Organisation (WHO) commissioned this systematic review. Its results form important input for the new environmental noise guidelines for the European Region. The WHO requires that new guidelines should be based on the latest scientific knowledge. The complete review can be found in the report published at the website of RIVM (the Dutch National Institute for Public Health and the Environment) via the following link: http://www.rivm.nl/en/Documents_and_publications/Scientific/Reports/2017/november/Cardiovascular_and_metabolic_effects_of_environmental_noise_Systematic_evidence_review_in_the_framework_of_the_development_of_the_WHO_environmental_noise_guidelines_for_the_European_Region [1].

1.2. Background

During the past decades, several national and international organizations have made recommendations for protecting human health from the adverse effects of environmental noise exposure. In the existing guidelines [2–5], the principal noise source of concern was transportation noise, mainly road and air traffic. The health impact of other noise sources, such as rail traffic and wind turbines, was not addressed in these guidelines. However, with the ongoing extension of railway transport facilities, and the substantial growth of wind energy facilities, the number of studies on the impact of noise from rail traffic noise and on wind turbine noise has increased.

The existing guidelines also contain recommendations that specifically deal with the impact of noise on the cardiovascular system. The most common explanation for the effects of noise on the heart and circulatory system, is stress [2,3]. The cardiovascular effects related to noise exposure may also be the consequence of a decrease in sleep quality, caused by noise exposure during the night, among other additional or interrelated mechanisms. Such reactions may also affect the metabolic system.

The most recent environmental noise guidelines from WHO, date back to 2009, and focus on night-time exposure [3]. Meanwhile, new evidence on the relationship between noise exposure and cardiovascular effects has accumulated. Hypertension and ischaemic heart disease have been the main outcomes of concern in observational studies on the impact of noise on the cardiovascular system. In addition, an increasing amount of studies have recently investigated the impact of noise on *other* cardiovascular end-points such as stroke. Furthermore, hypertension is considered as an important risk factor for other cardiovascular outcomes such as stroke and myocardial infarction. Amongst the newly published studies there were also several studies dealing with the possible effects of noise on the metabolic system, in particular with regard to outcomes such as obesity and type 2 diabetes.

In addition, a number of the newly published studies investigated the combined effects of noise and air pollution. People living close to roads, are exposed not only to traffic noise, but also to air pollution generated by traffic. Previous studies have shown a relationship between air pollution and cardiovascular disease [6,7]. Since air pollution and noise from road traffic share the same source, cardiovascular effects could be attributed to both exposure factors.

The existing environmental noise guidelines also include recommendations that aim to reduce environmental noise exposure in settings where children spend most of their time. However, none of these recommendations takes into account the cardiovascular effects of noise on children. It is possible that people exposed to high levels of noise from an early age, might be at higher risk for cardiovascular problems later in life. Since the publication of the latest environmental noise guidelines in 1999, the number of studies investigating the impact of noise on children's blood pressure has increased substantially.

2. Materials and Methods

2.1. Evaluation of Existing Reviews

The first step in this systematic review was to identify and select reviews of "sufficient" quality, that described the impact of exposure to environmental noise from several sources (air, road, rail and wind turbines) on the cardiovascular or metabolic systems, in different settings (at home, at school), and populations (e.g., adults, children).

After an extended search, we identified 37 reviews evaluating available studies into the impact of exposure to environmental noise on the cardiovascular or metabolic systems. By means of the "Measurement tool for the Assessment of Multiple SysTemAtic Reviews" (AMSTAR) [8] we evaluated their quality, and based on the relevance for this whole systematic review, we selected 15 reviews [9–25]. We carried out the evaluation in duplicate (Elise van Kempen and Maria Foraster, and then discussed the results afterwards.

It appeared that most of the studies covered by the selected reviews, reported on the impacts of road and aircraft noise exposure among adults. Nine reviews included one or more meta-analyses, resulting in more than 13 exposure-response relationships. For most available exposure-response relations, the reviewers were not able to provide a quality judgement of the individual studies. For a number of (new) health end-points (e.g., obesity) and/or noise sources (e.g., rail traffic, no reviews or exposure-response relationships were available.

Following the results of the evaluation of existing reviews, we decided to carry out a new systematic review on the impact of noise on the cardiovascular and metabolic system in order to update some of the existing exposure-response relationships, and to assess the quality of the existing evidence.

2.2. Evaluation of Single Studies

2.2.1. Identification and Selection

We identified observational studies on the impact of noise from air, road, and rail traffic and wind turbines on the cardiovascular or metabolic systems published from 2000 until October 2014 in several literature databases (Medline/PubMed, SCOPUS, EMBASE and SCISCEARCH (see Appendix A for the applied search profiles). To ensure that most of the studies could be identified, we manually scanned reports and proceedings in the fields of epidemiology, and noise and health. We supplemented the results of this search with studies that were already identified by means of the 15 reviews, which we evaluated during the first step of this systematic review (see Section 2.1). Overall, we identified more than 600 publications which were screened in duplicate (Elise van Kempen and Maria Foraster) using predefined criteria. We selected 61 studies for data-extraction [26–135], where detailed quantitative information was available on exposure and health outcomes, enabling estimation of exposure-response relationships. However, conducting a systematic review often takes a lot of time. While working on this review, new results became publically available. In order to keep our results more up to date, it was decided to extend our study material with more recent results beyond the studies that had we already identified for the period 2000–October 2014. However, only updated and new results of studies published between November 2014 and August 2015, were included and processed. Consequently, we were able to include the latest results published between November 2014 and August 2015 of several selected studies: DEBATS [26,46], REGICOR [32,33,43,68], SDPP [29,34,73,78,91,106], HUBRO [30,66] and DCH [27,38,51–53,63,64,136]. In- and exclusion criteria were extensively described in the complete systematic review [1].

2.2.2. Data Extraction

From the selected 61 studies (described in 113 records), we extracted the following data via a structured data extraction form:

- Data on general study characteristics (e.g., study design, study period, study location);
- Population characteristics (sampling of the study population, number of participants, response- and attrition rate, gender, age;
- Exposure assessment and health outcome assessment, and;
- The results of the study.

We carried out the data extraction in duplicate (Elise van Kempen, Maribel Casas and/or Göran Pershagen) and then discussed the results, with the exception of studies on the impact of wind turbine noise (n = 3) and studies on the impact of noise on children's blood pressure. For those studies data, extraction was carried out by one person only (Elise van Kempen).

In the selected studies we evaluated the risk of bias by means of a checklist developed by the WHO [137]: (i) information bias due to exposure assessment; (ii) bias due to confounding; (iii) bias due to selection of participants; (iv) information bias due to non-objective health outcome assessment, and (v) information bias due to non-blinded health outcome assessment. A protocol of how the studies were scored on each of these five items can be found in Section 3.3 of the complete evidence review available via the link specified in Section 1.1. For each study, the evaluation was carried out independently by two or three reviewers (Elise van Kempen, Maribel Casas and Göran Pershagen). From the scores on the different items, we calculated a total risk of bias score (see also Appendix B for an overview of the risk of bias scores per study).

The main effects under investigation were hypertension, IHD, stroke, type 2 diabetes, change in body mass index (BMI), change in waist circumference, and change in mean blood pressure in children. In order to make a comparison between the studies, we expressed their results in a uniform way and calculated the following outcome variables:

- For studies on the impact of noise on hypertension, IHD, stroke or type 2 diabetes, we calculated the natural logarithm of the Relative Risk (RR) and its variance per 10 dB(A);
- For studies on the impact of noise on children's blood pressure, we calculated the blood pressure change (mmHg for a noise level increase of 10 dB(A) and its variance for both systolic and diastolic blood pressure; and
- For studies on the impact of noise on obesity markers BMI and waist circumference, we calculated the change in BMI (kg/m^2) per noise level increase of 10 dB(A) and its variance, and the change in waist circumference (cm) per noise level increase of 10 dB(A) and its variance.

To retain the link with the European Noise Directive (END [138], we expressed noise exposure in L_{DEN}. However, most studies did not report an RR per 10 dB (L_{DEN}). Where noise exposure was expressed by means of another noise indicator than L_{DEN} (e.g., $L_{Aeq,16hr}$ or $L_{Aeq,24hr}$), a conversion to L_{DEN} was needed. Appendix II of the complete review [1] gives an overview of the conversion rules that we applied.

2.2.3. Data Aggregation

For data-aggregation, we included only estimates from studies that were well matched, adjusted, or stratified for at least age and sex. If more than one risk estimate was available for a study, we used the estimates for men and women separately and for separate age-categories, where possible. After selecting the study estimates, we calculated a pooled estimate using the STATA-command METAN to fit a random-effects model [139]. To test consistency of the effect estimates across studies, we used Cochran's Q-test [140]. We calculated the I^2-statistic to reflect the percentage of between-study heterogeneity [141,142]. For some outcomes, we were able to investigate how the summary estimates were affected by sources of heterogeneity. To this end, we carried out a meta-regression analysis using the STATA-command METAREG [141]. Where meta-regression analyses were not possible, we carried out sub-group analyses.

When enough study estimates were available, we attempted to give insight in the extent of publication-bias by means of funnel plots [143]: scatter plots of the studies' effect estimates (RR per 10 dB) against the inverse of the standard error. Also we applied Egger's test of publication bias using the STATA-commands METAFUNNEL and METABIAS [144,145].

2.2.4. Assessment of the Quality of Evidence: GRADE

The WHO required us to assess the quality of the evidence that has been retrieved in this review. In other words, we had to assess to what extent we were confident that an estimate of an association between noise and an outcome is likely or unlikely to be changed by further research.

To this end, we applied a modified version of the GRADE considerations: a systematic and explicit approach to making judgements about quality of evidence [146,147]. In summary, for every outcome, we had to assess the quality of evidence according to several criteria (e.g., study design, study quality, consistency and precision of the results, directness of the evidence, publication bias, whether an exposure-response gradient was present, the magnitude of the effect found, and possible confounding. The scores for the different GRADE criteria are presented in Appendix C to Appendix H as well in Appendices III–VIII of the complete systematic review. How we adapted GRADE for this systematic review is extensively described in Chapter 10 of the complete evidence review [1]. The main divergence from GRADE was that the initial level of certainty was rated "high" for cohort and case-control studies, "low" for cross-sectional studies and "very low" for ecological studies. Furthermore, we upgraded the evidence if the relative risk was 1.5 or higher, but downgraded if based on only one study. GRADE has four levels for the quality of evidence, ranging from "very low" to "high" (see Table 1). The level of the quality of evidence will be linked with the guideline values and recommendations that WHO will include in their environmental noise guidelines.

Table 1. The levels of quality of evidence of the GRADE system (source: [146,147]).

Quality of Evidence	Definition	Examples of When This is the Case
High	Further research is very unlikely to change our confidence in the estimate of effect	Several high-quality studies with consistent results
Moderate	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate	One high-quality study or several studies with some limitations
Low	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate	One or more studies with severe limitations
Very Low	Any estimate of effect is very uncertain	No direct research evidence One or more studies with very severe limitations

3. Results: Main Findings and Weighing the Quality of the Evidence

In this section, for each outcome the main findings of the review and the conclusions of the weighing of the evidence are presented. The report with the complete findings including the systematic evaluation of the included studies, and the reasoning behind the weighing of the evidence, can be found in the complete systematic review [1].

A note for the reader: since we carried out the literature search for this systematic review, new studies have been published that investigate the associations between transportation noise exposure and metabolic and cardiovascular disease. Unfortunately, owing to time constraints, we were not able to carry out a structured and extensive additional search for new studies published in the period November 2014–March 2017. However, in order to identify at least some of the new studies we were missing, we carried out a search on SCOPUS in March 2017. For this, we applied the same SCOPUS-search profile as was used to identify studies for the current review. In an "ideal" systematic review, we should have included the results of these newly identified studies in the results of the current review, and where necessary updated our results. However, due to time constraints, we have not yet been able to systematically evaluate the newly identified studies. Nevertheless, we have decided to present their results in a narrative way, and attempted to assess how they affect the results of the current review. The differences in results with these recent studies and earlier reviews are described in detail for each outcome in the complete systematic review [1].

3.1. Hypertension

We evaluated 40 studies [26,28,30,32,33,35–37,40,43,46,49–51,55–57,60–63,65–68,70,73–78,80–86,88–92,94–99,101,102,105,106,109,110,112,113,117,118,120,123,126,127,130–135,148] that investigated the impact of noise from air, road, and rail traffic and wind turbines on the risk of hypertension. Appendix B presents the separate risk of bias tables. Appendix C presents the different GRADE tables (summarized in Table 2).

Table 2. Noise exposure and the risk of hypertension: summary of findings.

Noise Source	Outcome $	Number of Study Design (s) *	RR per 10 dB (95% CI) †	Number of Participants (Cases)	Quality of Evidence ‡
Air traffic	Prev	9 CS	1.05 (0.95–1.17)	60,121 (9487)	⊕⊕
	Inc	1 CO	1.00 (0.77–1.30)	4721 (1346)	⊕⊕
Road traffic	Prev	26 CS	1.05 (1.02–1.08) **	154,398 (18,957)	⊕
	Inc	1 CO	0.97 (0.90–1.05)	32,635 (3145)	⊕⊕
Rail traffic	Prev	5 CS	1.05 (0.88–1.26)	15,850 (2059)	⊕
	Inc	1 CO	0.96 (0.88–1.04)	7249 (3145)	⊕⊕
Wind turbine	Prev	3 CS	††	1830 (NR)	⊕

$ Outcome: Prev = prevalence of hypertension, Inc = incidence of hypertension; * CS = cross-sectional study, CO = cohort study; †: RR = Relative risk per 10 decibel (dB change in noise level and its 95% confidence interval (CI) after aggregating the results of the evaluated studies. For air, road, –and, rail traffic, noise levels were expressed in L_{DEN}. For wind turbines, noise levels are expressed in Sound Pressure Levels (SPL); ‡ GRADE Working Group Grades of Evidence: High quality (⊕⊕⊕⊕): Further research is very unlikely to change our confidence in the estimate of effect, Moderate Quality (⊕⊕⊕): Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate, Low Quality (⊕⊕): Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate, Very low quality (⊕): We are very uncertain about the estimate. ** The estimate for the association between road traffic noise and the prevalence of hypertension is based on 47 estimates derived from 26 studies. †† We decided not to aggregate the results of the three studies on the impact of wind turbine noise, since too many parameters were unknown and/or unclear. NR = Not Reported.

There were positive associations between noise from air, road, or rail traffic and hypertension in the cross-sectional studies, which formed the largest part (n = 38) of the available evidence (Table 2). After aggregating the results of 26 studies (comprising 154,398 individuals, including 18,957 cases), we derived an RR of 1.05 (95% CI: 1.02–1.08) per 10 dB (L_{DEN}) for the association between road traffic noise and the *prevalence* of hypertension. The studies were carried out within the range of approximately 20–80 dB (L_{DEN}) [28,30,32,33,35–37,43,49,50,55–57,61,62,66–68,70,75,77,80,82,85,88,89,92,96–99,109,110,117,118,120,123,126,127,130–132,135,149]. For aircraft noise (nine studies), we estimated an RR of 1.05 (95% CI 0.95–1.17) per 10 dB (L_{DEN}) (comprising 60,121 residents, including 9487) [28,40,46,50,61,62,74,83,85,94,95,99,102,105,112,113,150]. For rail traffic noise (five studies), we derived an RR of 1.05 (95% CI: 0.88–1.26) per 10 dB (L_{DEN}) (comprising of 15,850 individuals, including 2059 cases of hypertension) [28,56,80,82,135]. Although there was evidence for moderate to high heterogeneity among studies, the meta-regression analyses could not reveal clear sources for this observed heterogeneity.

Despite the fact that most studies were able to adjust for important confounders, and were able to ascertain individual exposure levels, we rated the quality of the evidence from the cross-sectional studies mainly as "very low". This is, among other reasons, because the response rate in many of the studies was lower than 60%. Furthermore, most studies ascertained hypertension by means of self-report only.

In the two evaluated cohort studies that investigated the impact of traffic noise on hypertension, no increased risks were found of hypertension related to traffic noise exposure [51,63,73,78,91,106]. This is confirmed by a recent meta-analysis, including individual data from six cohort studies on the association between road traffic noise and the incidence of hypertension [151]. The reason for this apparent discrepancy in the findings between the cross-sectional and cohort studies is unclear.

Overall, we consider the quality of the evidence *supporting* an association between traffic noise exposure and hypertension as "very low", indicating that any estimate of effect is very uncertain.

3.2. Ischaemic Heart Disease

We evaluated 22 studies [28,42,44,45,47,50,52–54,61,62,69,72,75,79,82,83,85,87,90,97–100,103,107, 109–111,115,118,120–125,128–131,135] that investigated the association between exposure to noise from air, road, and rail traffic and IHD. Appendix B presents the separate risk of bias tables, and Appendix D presents the different GRADE tables (summarized in Table 3). The majority (n = 11) were of cross-sectional design.

Table 3. Noise exposure and the risk of IHD: summary of findings.

Noise Source	Outcome [$]	Number of Study Design (s) *	RR [†] per 10 dB (95% CI)	Participants (Cases)	Quality of Evidence [‡]
Air traffic	Prev	2 CS	1.07 (0.94–1.23)	14,098 (340)	⊕
	Inc	2 ECO	1.09 (1.04–1.15)	9,619,082 (158,977)	⊕
	Mort	2 ECO	1.04 (0.97–1.12)	3,897,645 (26,066)	⊕
		1 CO	1.04 (0.98–1.11)	4,580,311(15,532)	⊕⊕
Road traffic	Prev	8 CS	*1.24 (1.08–1.42)*	25,682 (1614)	⊕⊕
	Inc	1 ECO	1.12 (0.85–1.48)	262,830 (418)	⊕
		3 CO, 4CC	*1.08 (1.01–1.15)*	67,224 (7033)	⊕ ⊕ ⊕⊕
	Mort	1 CC, 2 CO	1.05 (0.97–1.13)	532,268 (6884)	⊕ ⊕ ⊕
Rail traffic	Prev	4 CS	1.18 (0.82–1.68)	13,241 (283)	⊕

[$] Outcome: Prev = prevalence of IHD, Inc = incidence of IHD, Mort = mortality due to IHD; * ECO = ecological study, CS = cross-sectional study, CC = case-control study, CO = cohort study; [†]: RR = Relative Risk per 10 decibel (dB change in noise level, 95% CI = 95% Confidence Interval. For air, road –and, rail traffic, noise levels are expressed in L_{DEN}.; [‡] GRADE Working Group Grades of Evidence: High quality (⊕⊕⊕⊕): Further research is very unlikely to change our confidence in the estimate of effect, Moderate Quality (⊕⊕⊕): Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate, Low Quality (⊕⊕): Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate, Very low quality (⊕): We are very uncertain about the estimate.

The studies that investigated the impact of *air traffic* noise found indications of an increased risk of IHD. Exposure to *aircraft* noise was associated with the *prevalence* of IHD, the *incidence* of IHD, and *mortality* due to IHD [28,42,44,45,47,50,62,69,72,83,85,98,99]. Only the association between *aircraft* noise and the *incidence* of IHD was statistically significant. We estimated an RR of 1.09 (95% CI: 1.04–1.15) per 10 dB (L_{DEN}) after aggregating the results of two studies [42,47] comprising of 9,619,082 participants, including 158,977 *incident* cases of IHD. Since most studies on the impact of aircraft noise were of ecological and cross-sectional design (see Table 3), the quality of the evidence from these studies was mostly rated as "very low". However, the results of the current review are consistent with the results of new longitudinal studies, which reported positive associations between aircraft noise and mortality due to IHD [152,153].

Overall, we rate the quality of the evidence *supporting* an association between *air traffic* noise and IHD as "low", indicating that further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

We found evidence that noise from *road traffic* is associated with an increased risk of IHD. An increase in road traffic noise was associated with significant increases in the *prevalence* of IHD, and the *incidence* of IHD. The evidence for a relationship between noise from road traffic and the *incidence* of IHD was the most robust. After combining the results of three cohort studies and four case-control studies [52,53,75,100,107,111,115,118,120–123,125,130,131] (comprising 67,224 participants, including 7033 *incident* cases of IHD, we found an RR of 1.08 (95% CI: 1.01–1.15) per 10 dB (L_{DEN}) for the association between road traffic noise and the *incidence* of IHD within the range of approximately 40–80 dB L_{DEN}. This means that if road traffic noise levels increase from 40 to 80 dB (L_{DEN}), the RR = 1.36. We rated the quality of the evidence that comes from these studies to be "high". Supporting evidence came from studies on the association between road traffic noise and the prevalence of IHD. We rated the quality of evidence from these studies as low. The results of the current review are strengthened by the results of several recently published longitudinal studies [152,153].

A visualization of the shape of the association between road traffic noise and the *incidence* of IHD, indicated that the risk of IHD increases continuously for road traffic noise levels from about 50 dB (L_{DEN}). This is consistent with the findings of another recent meta-analysis on the association between road traffic noise and IHD [21]. The WHO guidelines of 1999 stated the following: "epidemiological studies show that cardiovascular effects occur after long-term exposure to noise with $L_{Aeq,24hr}$ values of 65–70 dB" [2]. In the WHO Night-noise guidelines, published in 2009, a general threshold of 55 dB (L_{Night}) was recommended for protection of cardiovascular disease [3].

Overall, taking into account all available evidence on the association between road traffic noise on IHD, we rate the quality of the evidence *supporting* an association between *road traffic* noise and IHD to be "moderate", indicating that further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate. However, for road traffic noise and the incidence of IHD, the quality of the evidence was rated as high.

Compared with noise from road and air traffic, we found only a few studies that investigated the impact of noise from *rail traffic*. These had a cross-sectional design. After aggregating the results of the studies on the association between *rail traffic* noise and the *prevalence* of IHD [28,82,90,135], we found a non-significant RR of 1.18 per 10 dB (L_{DEN}).

Overall, we rate the quality of the evidence *supporting* an association between exposure to noise from rail traffic and IHD to be "very low", indicating that any estimate of effect is very uncertain.

3.3. Stroke

Compared with the number of studies on the impact of noise on hypertension and IHD, relatively few studies were available that investigated the impact on stroke (n = 9) [27,42,44,45,47,50,52,54,61,62,64,69,72,79,83,85,98,99]. Appendix B presents the separate risk of bias tables, and Appendix E presents the different GRADE tables (summarized in Table 4).

According to the results of the ecological and cross-sectional studies [28,42,44,45,50,61,62,69,83,85,98,99] an increase in aircraft noise was associated with an increase in the *prevalence* and the *incidence* of stroke. None of these associations was statistically significant (see Table 4). The observations found for the *prevalence* and *incidence* of stroke were supported by the ecological studies [28,42] on the association between air traffic noise and *mortality* due to stroke.

No association between air traffic noise exposure and mortality due to stroke was observed in the evaluated cohort study [72]. This is consistent with the results of new longitudinal studies, which showed no clear indications of an association between aircraft noise and mortality due to stroke [152,153].

The results of the studies [27,28,50,52,54,61,62,64,79,83,85,98,99] that investigated the impact of *road* traffic were not consistent. Only for the association between road traffic noise and the *incidence* of stroke, there was a statistically significant RR of 1.14 (95% CI 1.03–1.25) per 10 dB (L_{DEN}). This result was based on one cohort study [27,52,64], comprising 51,485 participants, including 1881 incident cases of stroke.

Table 4. Noise exposure and the risk of stroke: summary of findings.

Noise Source	Outcome $	Number of Study Design (s) *	RR † per 10 dB (95% CI)	Participants (Cases)	Quality of Evidence ‡
Air traffic	Prev	2 CS	1.02 (0.80–1.28)	14,098 (151)	⊕
	Inc	2 ECO	1.05 (0.96–1.15)	9,619,082 (97,949)	⊕
	Mort	2 ECO	1.07 (0.98–1.17)	3,897,645 (12,086)	⊕
		1 CO	0.99 (0.94–1.04)	4,580,311 (25,231)	⊕⊕⊕
Road traffic	Prev	2 CS	1.00 (0.91–1.10)	14,098 (151)	⊕
	Inc	1 CO	*1.14 (1.03–1.25)*	51,485 (1881)	⊕⊕⊕
	Mort	3 CO	0.87 (0.71–1.06)	581,517 (2634)	⊕⊕⊕
Rail traffic	Prev	1 CS	1.07 (0.92–1.25)	9365 (89)	⊕

$ Outcome: Prev = prevalence of stroke, Inc = incidence of stroke, Mort = mortality due to stroke; * ECO = ecological study, CS = cross-sectional study, CO = cohort study; †: RR = Relative risk per 10 decibel (dB change in noise level, 95% CI = 95% Confidence Interval. The noise levels are expressed in L_{DEN}; ‡ GRADE Working Group Grades of Evidence: High quality (⊕⊕⊕⊕): Further research is very unlikely to change our confidence in the estimate of effect, Moderate Quality (⊕⊕⊕): Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate, Low Quality (⊕⊕): Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate, Very low quality (⊕): We are very uncertain about the estimate.

In the evaluated cross-sectional and ecological studies [27,28,44,45,50,52,54,61,62,64,69,79,83,85,98,99] on the association between road traffic noise and the *prevalence* of stroke or *mortality* due to stroke, no increased risks of stroke due to road traffic noise were observed. This was not consistent with the results of recently published longitudinal studies, which showed that an increase in road traffic noise was statistically significantly associated with an increase in mortality due to stroke [152–154]. As part of the current review, only one cross-sectional study [28] was evaluated, which investigated the association between rail traffic noise and the prevalence of stroke.

Overall, we rate the quality of the evidence *supporting* an association between traffic noise and stroke to be "low". This indicates that further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

3.4. Diabetes

For the current review, we were able to evaluate seven studies [34,38,60,65,75,76,81,84,86,101] that investigated the association between environmental noise and the risk of diabetes. Four studies [28,34,38,75] investigated the possible impact of transportation (air, road, rail traffic noise. Appendix B presents the separate risk of bias tables, and Appendix F presents the different GRADE tables (summarized in Table 5).

We found two studies [28,34] that investigated the impact of *air* traffic noise on the occurrence of diabetes. In a cross-sectional study [28] on the association between air traffic noise and the *prevalence* of diabetes, a non-significant RR of 1.01 per 10 dB (L_{DEN}) was found. In the evaluated cohort study [34] on the association between air traffic noise and the *incidence* of diabetes, no increased risk of diabetes due to air traffic noise was observed (see Table 5).

We found indications that noise from *road traffic* increases the risk of diabetes. The two evaluated cross-sectional studies [28,75] showed an increasing but non-significant trend of the *prevalence* of diabetes with road traffic noise exposure. In the evaluated cohort study [38], an increase in road traffic noise was statistically significantly associated with an increase in the incidence of diabetes. An RR of 1.08 (95% CI: 1.02–1.14) per 10 dB (L_{DEN}) across a noise range of approximately 50–70 dB (L_{DEN}) was estimated.

Table 5. Noise exposure and the risk of diabetes: summary of findings.

Noise Source	Outcome $	Number of Study Design (s) *	RR † per 10 dB (95% CI)	Participants (Cases)	Quality of Evidence ‡
Air traffic	Prev	1 CS	1.01 (0.78–1.31)	9365 (89)	⊕
	Inc	1 CO	0.99 (0.47–2.09)	5156 (159)	⊕⊕
Road traffic	Prev	2 CS	- #	11,460 (242)	⊕
	Inc	1 CO	*1.08 (1.02–1.14)*	57,053 (2752)	⊕ ⊕ ⊕
Rail traffic	Prev	1 CS	*0.21 (0.05–0.82)*	9365 (89)	⊕
	Inc	1 CO	0.97 (0.89–1.05)	57,053 (2752)	⊕ ⊕ ⊕
Wind turbine	Prev	3 CS	**	1830 (NR)	⊕

$ Outcome: Prev = prevalence of diabetes, Inc = incidence of diabetes; * CS = cross-sectional study, CO = cohort study; † RR = Relative risk per 10 decibel (dB change in noise level, 95% CI = 95% Confidence Interval. For air, road –and, rail traffic, noise levels are expressed in L_{DEN}. For wind turbines, noise levels were expressed in Sound Pressure Levels (SPL); ‡ GRADE Working Group Grades of Evidence: High quality (⊕⊕⊕⊕): Further research is very unlikely to change our confidence in the estimate of effect, Moderate Quality (⊕⊕⊕): Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate, Low Quality (⊕⊕): Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate, Very low quality (⊕): We are very uncertain about the estimate; # the data from one cross-sectional study were not included in the table since they were based on a secondary analysis with important information lacking. ** We decided not to aggregate the results of the three studies on the impact of wind turbine noise, since too many parameters were unknown and/or unclear; NR = Not Reported.

Remarkably, an increase in *rail traffic* noise was associated with a decrease in the risk of diabetes in one cross-sectional study [28] while a cohort study [38] found no statistically significant association.

Overall, we rate the quality of the evidence *supporting* an association between traffic noise and diabetes to be "low". This indicates that further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

3.5. Obesity

The number of evaluated studies that investigated the impact of noise on markers of obesity was limited to four [34,136,155,156]: one cohort study and three cross-sectional studies. Appendix B presents the separate risk of bias tables, and Appendix G presents the different GRADE tables (summarized in Table 6). All the studies showed that an increase in traffic noise was associated with an increase in obesity markers, although, according to one study, this was present only in certain subgroups. In the cohort study [34], an increase in aircraft noise of 10 dB (L_{DEN}) was associated with a significant increase in waist circumference of 3.46 (95% CI: 2.13–4.77) cm during 8 to 10 years of follow-up (see Table 6). The evidence of traffic noise affecting obesity markers is strengthened by the results of two recent longitudinal studies [157,158].

Overall, we rate the quality of the evidence *supporting* an association between traffic noise and markers of obesity, respectively, as "low". This indicates that further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Table 6. Noise exposure and the risk of obesity: summary of findings.

Noise Source	Outcome	Number of Study Design (s) *	Change per 10 dB (95% CI) †	Participants	Quality of Evidence ‡
Air traffic	Change in BMI (kg/m^2)	1 CO	0.14 (−0.18–0.45)	5156	⊕⊕
	Change in waist circumference (cm)	1 CO	*3.46 (2.13–4.77)*	5156	⊕⊕⊕
Road traffic	Change in BMI (kg/m^2)	3 CS	0.03 (−0.10–0.15)	71,431	⊕
	Change in waist circumference (cm)	3 CS	0.17 (−0.06–0.40)	71,431	⊕
Rail traffic	Change in BMI (kg/m^2)	2 CS	- **	57,531	⊕
	Change in waist circumference (cm)	2 CS	- **	57,531	⊕⊕

* CS = cross-sectional study, CO = cohort study; † 95% CI = 95% Confidence Interval. Noise levels are expressed in L_{DEN}; ‡ GRADE Working Group Grades of Evidence: High quality (⊕⊕⊕⊕): Further research is very unlikely to change our confidence in the estimate of effect, Moderate Quality (⊕⊕⊕): Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate, Low Quality (⊕⊕): Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate, Very low quality (⊕): We are very uncertain about the estimate. ** We decided not to aggregate the results of the studies on the impact of rail traffic noise, since not all parameters were available to assess a change in BMI or waist circumference per 10 dB; dB = Decibel, BMI = Body Mass Index.

3.6. Blood Pressure in Children

We evaluated eight studies investigating the impact of noise on children's blood pressure [31,39,41,48,58,59,71,93,114,119,159]. Appendix B presents the separate risk of bias tables, and Appendix H presents the different GRADE tables (summarized in Table 7). Seven studies were cross-sectional; one study reported both the results of cross-sectional and longitudinal analyses. With the exception of the association between road traffic noise at school and systolic blood pressure, we observed positive but non-significant associations between exposure to road traffic noise and blood pressure (see Table 7). No combined exposure-response estimate could be computed from the studies on the impact of aircraft noise, since no quantitative results were provided in one of the studies.

Overall, we rate the quality of the evidence *supporting* an association between traffic noise and blood pressure in children, as "very low", indicating that any estimate of effect is very uncertain.

3.7. Wind Turbine Noise

Overall, we evaluated only three cross-sectional studies that investigated the impact of noise from wind turbines on the cardiovascular and metabolic systems [60,65,76,81,84,86,101]. Important limitations of these studies were the low response rates (two studies had response rates of less than 60%) and, the fact that in all studies the cardiovascular or metabolic endpoint was ascertained by questionnaire or interview. In these studies, we observed that an increase in wind turbine noise was associated with non-significant increases in self-reported hypertension and non-significant decreases in self-reported cardiovascular disease. For self-reported diabetes, the results appeared inconsistent.

Overall, we rate the quality of the studies *supporting* an association between exposure from wind turbine noise and adverse effects in the cardiovascular or metabolic system as "very low", indicating that any estimate of effect is very uncertain.

Table 7. Noise exposure and the impact on children's blood pressure: summary of findings.

Noise Source	Setting	Outcome	Number of Study Design (s) *	Change in Blood Pressure (mmHg) per 10 dB (95% CI) †	Participants	Quality of Evidence ‡
Air traffic	School	Systolic blood pressure (mmHg)	2 CS	-	2013	⊕
		Diastolic blood pressure (mmHg)	2 CS	-	2013	⊕
	Home	Systolic blood pressure (mmHg)	2 CS	-	2013	⊕
		Diastolic blood pressure (mmHg)	2 CS	-	2013	⊕
Road traffic	School	Systolic blood pressure (mmHg)	5 CS	−0.60 (−1.51–0.30)	4520	⊕
		Diastolic blood pressure (mmHg)	5 CS	0.46 (−0.60–1.53)	4520	⊕
	Home	Systolic blood pressure (mmHg)	6 CS	0.08 (−0.48–0.64)	4197	⊕
		Diastolic blood pressure (mmHg)	6 CS	0.47 (−0.30–1.24)	4197	⊕

* CS = Cross-sectional study; † 95% CI: 95% confidence interval. Blood pressure is expressed in millimeters of mercury (mmHg). Noise levels are expressed in L_{DEN}; ‡ GRADE Working Group Grades of Evidence: High quality (⊕⊕⊕⊕): Further research is very unlikely to change our confidence in the estimate of effect, Moderate Quality (⊕⊕⊕): Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate, Low Quality (⊕⊕): Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate, Very low quality (⊕): We are very uncertain about the estimate; mmHg: millimeters of mercury.

4. Discussion

The current review shows that a large number of studies have investigated the impact of noise on the cardiovascular system, but applying the GRADE, the quality of the evidence is often rated as relatively low. This does *not* mean that exposure to noise has no effect on the cardiovascular system, but encourages further research to improve the quality of the evidence. After all, there is a strong biological plausibility that noise affects human health. Furthermore, in many of the evaluated studies, we observed statistically significant associations between noise and cardiovascular endpoints. The most robust were the effects of road traffic noise in relation to IHD. Combining the results of 7 longitudinal studies, revealed an RR of 1.08 (95% CI: 1.01–1.15) per 10 dB (L_{DEN}) for the association between road traffic noise and the *incidence* of IHD. We rated the quality of the evidence from these longitudinal studies as high. Supporting evidence came from studies on the association between road traffic noise and the *prevalence* of IHD.

Several recent reviews have been published on cardiovascular effects of environmental noise exposure, which are described in detail in the full systematic review [1]. The quantitative results regarding exposure-response relationships following meta-analyses agree well with our review. However, most earlier reviews did not include a detailed quality assessment of individual studies.

This review also addressed the possible impact of noise on the metabolic system. In comparison with the studies on the impact of noise on the cardiovascular system, the number of available studies was rather limited. The results of these studies were not always consistent. In addition, the quality of the evidence was rather low. It is therefore, at this moment too early to draw definite conclusions with regard to the impact of noise on the metabolic system.

5. Conclusions

The results of the current review shows that at this moment, not enough studies of good quality are available that investigated the impact of noise on the cardiovascular and metabolic system. The plausibility of an association calls for further efforts with improved research. In order to improve the quality of the existing evidence, more studies with a cohort or case-control design are needed.

In order to improve the quality of the existing evidence, we also recommend that more well designed studies on health effects in relation to exposure to wind turbines and rail traffic noise are set up and carried out.

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Author Contributions: Elise van Kempen and Maria Foraster conducted the study selection. Elise van Kempen, Maribel Casas, Göran Pershagen, and Maria Foraster conducted the study evaluation. Elise van Kempen, Maribel Casas and Göran Pershagen conducted the data-extraction and meta-analyses. Elise van Kempen wrote the paper. All authors read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Applied Search Profiles

In order to identify "Observational studies such as ecological studies, cross-sectional studies, case control studies or cohort studies involving the association between aircraft and/or rail traffic noise exposure and hypertension and/or high blood pressure, and/or ischemic heart disease (including angina pectoris and/or myocardial infarction) in adults published from 2000 until October 2014 with no language restriction", the following search profiles were applied in:

MEDLINE 1950 to present, MEDLINE In-Process & Other Non-Indexed Citations 20141021

1 *((rail* or aircraft or airport* or air traffic*) adj5 noise.tw. (504)*
2 *Aircraft/or Airports/or Railroads/(9486)*
3 **Transportation/(3419)*
4 *(rail* or aircraft or airport* or air traffic.tw. (11,558)*
5 **Noise/(10,029)*
6 *Noise, transportation/(1017)*
7 *exp Blood pressure/(254,113)*
8 *exp Hypertension/(217,361)*
9 *Myocardial ischemia/(33,403)*
10 *exp Cardiovascular diseases/or exp Vascular diseases/or exp Heart diseases/(1,944,605)*
11 *(hypertension or blood pressure.tw. (445,550)*
12 *(isch?emic heart disease* or coronary heart disease* or angina pectoris or myocard* infarct*or cardiovascular disease* or heart disease*).tw. (368,878)*
13 *(1 or 2 or (3 and 4)) and (1 or 5 or 6) (860)*
14 *13 and (7 or 8 or 9 or 10 or 11 or 12) (119)*
15 *14 not child*.ti. (112)*
16 *limit 15 to yr = 2000 − current (83)*

Scopus, 20141022
((TITLE-ABS-KEY((rail OR aircraft OR airport* OR air-traffic*) W/5 noise) AND*

(TITLE-ABS-KEY(hypertension OR blood-pressure OR ischemic-heart-disease OR coronary-heart-disease* OR angina-pectoris OR myocard*-infarct* OR cardiovascular-disease* OR heart-disease*)) AND PUBYEAR > 1999) AND NOT (TITLE(child*))*

In order to identify "Observational studies such as ecological studies, cross-sectional studies, case-control studies or cohort studies involving the association between aircraft and/or rail traffic and/or road traffic noise exposure and stroke and/or diabetes type II, and/or obesity in adults, published until October 2014 with no language restriction", the following search profiles were applied in:

Medline 20141023 MEDLINE 1950 to present, MEDLINE In-Process & Other Non-Indexed Citations

1 *((rail* or aircraft or airport* or road* or traffic* or automobile* or vehicle*) adj5 noise.tw.(1188)*
2 *exp *Transportation/(35,715)*
3 *Aircraft/or Airports/or Railroads/or Motor Vehicles/(12,387)*
4 **Noise/(10,039)*
5 *Noise, transportation/(1023)*
6 *(1 or 2 or 3) and (1 or 4 or 5) (1774)*
7 *exp Cerebrovascular disorders/(290,152)*
8 *exp Diabetes Mellitus/(328,383)*
9 *exp Obesity/or exp Overweight/or exp Body Mass Index/(208,810)*
10 *(stroke or cerebrovascular* or cva or brain vascular accident* or brain vascular disorder*).tw. (187,910)*
11 *(diabetes or obesit* or overweight or bmi or body mass index).tw. (556,663)*
12 *7 or 8 or 9 or 10 or 11 (1,065,975)*
13 *6 and 12 (54)*
14 *13 not child*.ti. (51)*
15 *limit 14 to yr = 2000 — current (47)*

Scopus 20141023
((TITLE-ABS-KEY((rail OR aircraft OR airport* OR road* OR traffic* OR automobile* OR vehicle*) W/1 noise) AND (TITLE-ABS-KEY(stroke OR cerebrovascular OR cva OR brain-vascular OR diabetes OR obesit* OR overweight OR bmi OR body-mass-index)) AND PUBYEAR > 1999) AND NOT (TITLE(child*))*

In order to identify "Observational studies such as ecological studies, cross-sectional studies, case control studies or cohort studies involving the association between road traffic noise exposure and hypertension and/or high blood pressure published from 2010 until October 2014 with no language restriction", the following search profiles were applied in:

Medline 20141017 MEDLINE 1950 to present, MEDLINE In-Process & Other Non-Indexed Citations

1 *((road* or traffic* or automobile* or vehicle* or motor cycle* or motorcycle* or transport*) adj5 noise.tw.(993)*
2 *exp *Transportation/(35,698)*
3 *Motor Vehicles/(2962)*
4 **Noise/(10,029)*
5 *Noise, transportation/(1017)*
6 *(1 or 2 or 3) and (1 or 4 or 5) (1714)*
7 *exp Blood pressure/(254,113)*
8 *exp Hypertension/(217,361)*
9 *(blood pressure or hypertension).tw. (445,404)*
10 *6 and (7 or 8 or 9) (134)*
11 *10 not child*.ti. (120)*

12 *limit 11 to yr = 2010 − current (46)*

PubMed 20141024
((traffic[ti] OR road*[ti] OR automobile*[ti] OR vehicle*[ti] OR motorcycle*[ti] OR transport*[ti]) AND noise[ti]*

Scopus 20141024
(TITLE-ABS-KEY((rail OR aircraft OR airport* OR road* OR traffic* OR automobile* OR vehicle*) W/1 noise) AND (TITLE-ABS-KEY(hypertension OR blood-pressure) AND PUBYEAR > 2009 AND NOT TITLE(child*)*

In order to identify "Observational studies such as ecological studies, cross-sectional studies, case-control studies or cohort studies involving the association between road, rail and air traffic noise exposure and blood pressure in children published until October 2014 without any language restriction", the following search profiles were applied in:

Medline 20141017 MEDLINE 1950 to present, MEDLINE In-Process & Other Non-Indexed Citations

1 *((rail* or aircraft or airport* or road* or traffic or automobile* or vehicle*) adj5 noise.tw. (1185)*
2 *exp *Transportation/(35,698)*
3 *Aircraft/or Airports/or Railroads/or Motor Vehicles/(12,379)*
4 **Noise/(10,029)*
5 *Noise, transportation/(1017)*
6 *(1 or 2 or 3) and (1 or 4 or 5) (1770)*
7 *exp Blood pressure/(254,113)*
8 *exp Hypertension/(217,361)*
9 *(blood pressure or hypertension).tw. (445,404)*
10 *6 and (7 or 8 or 9) (144)*
11 *10 and (child* or infant* or adolescent*).mp. (43)*

Scopus 20141024
TITLE-ABS-KEY((rail OR aircraft OR airport* OR road* OR traffic* OR automobile* OR vehicle*) W/1 noise AND TITLE-ABS-KEY(blood-pressure OR hypertension) AND TITLE-ABS-KEY(child* OR infant* OR adolescent*)*

In order to identify "Observational studies such as ecological studies, cross-sectional studies, case-control studies or cohort studies involving the association between audible noise (greater than 20 Hz) and infrasound and low-frequency noise (less than 20 Hz) from wind turbines or wind farms and blood pressure and/or cardiovascular disease published from October 2012 until October 2014 without any language restriction", the following search profiles were applied in:

PubMed 20141024
(((((wind turbine OR wind farm*[Title/Abstract]))) AND ((noise[MeSH Terms]) OR noise[Title/Abstract]))) AND (((health*[Title/Abstract]) OR blood pressure OR cardiovascular)) 2012–current*

Medline 20141027 MEDLINE 1950 to present, MEDLINE In-Process & Other Non-Indexed Citations

1 *((wind adj3 turbine*) or (wind adj3 farm*) or windturbine* or windfarm*).tw. (271)*
2 *Wind/(2794)*
3 *Renewable energy/(273)*
4 *Power Plants/(5234)*
5 *Electric Power Supplies/(4979)*
6 *Energy-Generating Resources/(1684)*
7 *2 and (3 or 4 or 5 or 6) (183)*
8 *1 or 7 (362)*

9 *Noise/or Sound/(26,842)*
10 *(infrasound* or noise or low frequenc*).tw. (131,959)*
11 *(blood pressure or cardiovascular).tw. (474,959)*
12 *Blood Pressure/(243,394)*
13 *Cardiovascular Physiological Phenomena/or Cardiovascular Diseases/or Cardiovascular System/(129,880)*
14 *health*.ti. (532,337)*
15 *8 and (9 or 10) and (11 or 12 or 13 or 14) (19)*
16 *limit 15 to yr = 2012–current (14)*

Scopus 20141027
TITLE-ABS-KEY((wind W/3 turbine) OR windturbine* OR (wind W/3 farm*) OR windfarm*) AND TITLE-ABS-KEY(noise OR infrasound* OR low-frequenc*) AND (TITLE-ABS-KEY(blood-pressure OR cardiovascular*) OR TITLE(health*) OR KEY(health*)) AND PUBYEAR > 2011*

Embase and SciSearch:
same search profile used as in Medline.

Appendix B. Risk of Bias

This appendix presents the risk of bias tables. They are presented per exposure outcome combination. An extensive description and the reasoning behind these tables can be found in Chapters 4–9 of the complete review.

Table A1. Reviewer's judgement about risk of bias for each of the studies on aircraft noise and hypertension that were selected for data extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
SDPP [73,78,91,106]	Low	Low	High	Low	Low	Low
HYENA [50,61,62,83,85,98,99]	Low	Low	High	Low	High	High
SEHS [112]	Low	Low	Low	High	Low	Low
DEBATS-pilot [46]	Low	Low	High	Low	Unclear	High
DEBATS-main [26]	Low	Low	Unclear	Low	Unclear	Unclear
AWACS [28]	Low	Low	High	High	Low	High
Okinawa [40,102,113]	High	Low	Unclear	Low	Low	High
Knipschild-1 [133,134]	High	High	High	Low	Low	High
SERA [74]	Low	Low	High	Low	Unclear	High
GES-2 [94,95,105]	Low	Low	High	High	Low	High
GES-3 [94,95,105]	Low	Low	High	High	Low	High
SPANDAU [97,109,110]	Low	Low	Low	High	Low	Low

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age and sex; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60% (cross-sectional studies) and attrition rate is less than 20% (follow-up studies).

Table A2. Reviewer's judgement about risk of bias for each of the studies on road traffic noise and hypertension that were selected for data extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
Amsterdam [132]	High	Low	Low	Low	Low	Low
Caerphilly [130,131]	High	High	Low	Low	Low	High
Luebeck [126,127]	High	Low	Low	Low	Unclear	High
BCC3 [118,120,123]	Low	Low	High	High	Low	High
SHEEP [75]	Low	Low	Low	Low	Low	Low
Tokyo [117]	Unclear	Low	Low	High	Unclear	Unclear
StockholmRoad [92]	Low	High	Low	High	Low	High
Groningen [88,89]	Low	Low	High	High	Low	High
PREVEND [88,89]	Low	Low	High	Low	Low	Low
UIT1 [135]	Low	High	Low	High	Unclear	High
SPANDAU [97,109,110]	Low	Low	Low	High	Low	Low
Skane-1 [96]	Low	Low	High	High	Unclear	High
Lerum [80]	Low	Low	Low	High	High	High
Skane-2 [77]	Low	Low	Low	High	Low	Low
BBT-1 (phone [82,135]	Low	Low	Low	High	Unclear	High
BBT-2 (face-to-face [82,135]	Low	Low	Low	High	Unclear	High
HYENA [50,61,62,83,85,98,99]	Low	Low	High	Low	High	High
KORA [37,49]	Low	Low	Low	Low	Low	Low
Berlin-IV [36,149]	Low	Low	High	Low	Low	Low
Taiwan [35,70]	High	Low	Unclear	High	Unclear	High
REGICOR [32,33,43,68]	Low	Low	Low	Low	Low	Low
Heinz-Nixdorf Recall Study [67]	Low	Low	Low	Low	Low	Low
Oslo Health Study [30,66]	Low	Low	Low	Low	Low	Low
DCH [51,63]	Low	Low	High	High	Low	High
SAPALDIA-2 [55,57]	Low	Low	Low	High	Low	Low
Roadside [56]	Low	High	High	High	Low	High
ALPNAP [82,90,135]	Low	Low	High	High	Unclear	High
AWACS [28]	Low	Low	High	High	Low	High

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age and sex; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%.

Table A3. Reviewer's judgement about risk of bias for each of the studies on rail traffic noise and hypertension that were selected for data extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
Lerum [80]	Low	Low	Low	High	High	High
AWACS [28]	Low	Low	High	High	Low	High
Roadside [56]	Low	High	High	High	Low	High
DCH [51,63]	Low	Low	High	High	Low	High
SAPALDIA-2 [55,57]	Unclear	Low	Low	High	Low	High
ALPNAP [82,90,135]	Low	Low	High	High	Unclear	High
BBT-1 [82,135]	Low	Low	Low	High	Unclear	High
BBT-2 [82,135]	Low	Low	Low	High	Unclear	High

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age and sex; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%.

Table A4. Reviewer's judgement about risk of bias for each of the studies on noise from wind turbines and hypertension that were selected for data extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
NL-07 [60,65,76,84]	High	Low	High	High	Low	High
SWE-00 [65,81,101]	High	Low	Low	High	Low	High
SWE-05 [65,81,86]	High	Low	High	High	Low	High

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age and sex; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%.

Table A5. Reviewer's judgement about risk of bias for each of the studies on aircraft noise and IHD that were selected for data extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
HYENA [44,45,50,61,62,69, 83,85,98,99]	Low	Low	High	High	High	High
USAairports [47]	High	High	Low	Low	Low	High
SPANDAU [97,109,110]	Low	High	Low	High	Low	High
LSAS [42]	High	Unclear	Low	Low	Low	High
SNC [72]	Unclear	High	Low	Low	Low	High
AWACS-1 [28]	Low	Low	High	High	Low	High
AWACS-2 [28]	Unclear	High	Low	Low	Low	High
IVEM [124,128,129]	High	High	Low	Low	Low	High

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age, sex, and smoking; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. Studies with a purposeful sample also scored "low".

Table A6. Reviewer's judgement about risk of bias for each of the studies on road traffic noise and IHD that were selected for data extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
Caerphilly-a [122,125,130,131]	High	High	Low	Low	Low	High
Caerphilly-b [111,115,122,125,130,131]	High	Low	Low	Low	Low	Low
Speedwell-a [121,122,125,131]	High	High	Low	Low	Low	High
Speedwell-b [111,115,121,122,125,131]	High	Low	Low	Low	Low	Low
SPANDAU [97,109,110]	Low	High	Low	High	Low	High
ALPNAP [82,90,135]	Low	Low	High	High	Unclear	High
NAROMI [100,107]	Low	Low	Low	Low	Low	Low
BCC1 [118,120,123]	Low	Low	Low	Low	Low	Low
BCC2 [118,120,123]	Low	Low	Low	Low	Low	Low
BCC3 [118,120,123]	Low	Low	Low	High	High	High
Kaunus-1 [87,103]	High	High	Low	Low	Low	High
BBT-Phone [82,135]	Low	High	Low	High	Unclear	High
BBT-Face [82,135]	Low	High	Low	High	Unclear	High
IVEM [124,128,129]	High	High	Low	Low	Low	High
SHEEP [75]	Low	Low	Low	Low	Low	Low
NCSDC [79]	Low	Low	Low	Low	Low	Low
AWACS1 [28]	Low	Low	High	High	Low	High
HYENA [44,45,50,61,62,69,83,85,98,99]	Low	Low	High	High	High	High
DCH [52,53]	Low	Low	Low	Low	Low	Low
Canada1 [54]	Low	High	Low	Low	Low	Low

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age, sex, and smoking; † In order to score "low", participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. Studies with a purposeful sample also scored "low".

Table A7. Reviewer's judgement about risk of bias for each of the studies on rail traffic noise and IHD that were selected for data extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to not Blinded Outcome Assessment	Total Risk of Bias
BBT-1 [82,135]	Low	High	Low	High	Unclear	High
BBT-2 [82,135]	Low	High	Low	High	Unclear	High
ALPNAP [82,90,135]	Low	Low	High	High	Unclear	High
AWACS [28]	Low	Low	High	High	Low	High

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age, sex, and smoking; † In order to score "low", participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. Studies with a purposeful sample also scored "low".

Table A8. Risk of bias: reviewer's judgements about each risk of bias item for each of the six studies on the association between aircraft noise and stroke that were selected for data extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
HYENA [44,45,50,61,62,69, 83,85,98,99]	Low	Low	High	High	High	High
LSAS [42]	High	High	Low	Low	Low	High
SNC [72]	Unclear	High	Low	Low	Low	High
AWACS-1 [28]	Low	Low	High	High	Low	High
AWACS-2 [28]	Unclear	High	Low	Low	Low	High
USAairports [47]	High	High	Low	Low	Low	High

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age, sex, and smoking; † In order to score "low", participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. Studies with a purposeful sample also scored "low".

Table A9. Reviewer's judgement about risk of bias for each of the studies on road traffic noise and stroke that were selected for data-extraction.

Study [Ref.]	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
HYENA [44,45,50,61,62,69, 83,85,98,99]	Low	Low	High	High	High	High
NCSDC [79]	Low	Low	Low	Low	Low	Low
DCH [27,52,64]	Low	Low	Low	Low	Low	Low
AWACS1 [28]	Low	Low	High	High	Low	High
Canada1 [54]	Low	High	Low	Low	Low	Low

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age, sex, and smoking; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. Studies with a purposeful sample also scored "low".

Only the AWACS1 study [28] investigated the impact of rail traffic noise on stroke. See Table A9 for the quality assessment.

Table A10. Reviewer's judgement on risk of bias in studies on aircraft noise and diabetes.

Study	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
SDPP [34]	Low	Low	High	Low	Low	Low
AWACS-1 [28]	Low	Low	High	High	Low	High

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age, sex, and smoking; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. Studies with a purposeful sample also scored "low".

Table A11. Reviewer's judgement on risk of bias in studies on road traffic noise and diabetes.

Study	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to Not Blinded Outcome Assessment	Total Risk of Bias
SHEEP [75]	Low	Low	Low	High	Low	Low
DCH [38]	Low	Low	Low	Low	Low	Low
AWACS1 [28]	Low	Low	High	High	Low	High

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age, sex, and smoking; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. Studies with a purposeful sample also scored "low".

Table A4 also presents the results of the evaluation of the quality of the studies that investigated the association between audible noise (greater than 20 Hz) from wind turbines and self-reported diabetes [60,65,76,81,84,86,101].

Table A10 also presents the results of the evaluation of the quality of the study that investigated the association between aircraft noise and obesity [34].

Table A11 also presents the results of the evaluation of the quality of the studies that assessed railway noise and diabetes: DCH [38], AWACS1 [28].

Table A12 also presents the results of the evaluation of the quality of the two studies that investigated the association between railway noise and obesity [136,155].

Table A12. Reviewer's judgement on risk of bias in studies on road traffic noise and obesity.

Study	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to not Blinded Outcome Assessment	Total Risk of Bias
HUBRO [30,156]	Low	Low	High	Low	Low	Low
SDPP [155]	Low	Low	High	Low	Low	Low
DCH [136]	Low	Low	High	Low	Low	Low

* In order to score "low", the study should contain information that can be used to derive effect estimates that are at least adjusted for age, sex, and smoking; † In order to score "low" participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. Studies with a purposeful sample also scored "low".

Table A13. Risk of bias: reviewer's judgements on risk of bias in studies on noise and children's blood pressure.

Study	Bias Due to Exposure Assessment	Bias Due to Confounding *	Bias Due to Selection of Participants †	Bias Due to Health Outcome Assessment	Bias Due to not Blinded Outcome Assessment	Total Risk of Bias
RANCH [58,93]	Unclear	Low	High	Unclear	Unclear	High
ICCBP-a [114,159]	Low	Low	High	Unclear	Unclear	High
ICCBP-b [114]	Low	Low	High	Unclear	Unclear	High
PIAMA [48]	Unclear	Low	High	Unclear	Low	High
GINIplus [31,41]	Unclear	Low	High	Unclear	Low	High
LISAplus [31,41]	Unclear	Low	High	Unclear	Low	High
BELGRADE1 [39]	High	Low	High	Unclear	Unclear	High
REGECOVA [119]	High	High	Low	Unclear	Unclear	High
USA1 [59,71]	High	High	Low	Unclear	Unclear	High

* In order to score "low" the study should contain information that can be used to derive effect estimates that are at least adjusted for age and sex. † In order to score "low", participants had to be randomly sampled from a known population and the response rate of the study had to be higher than 60%. An additional condition for cohort studies was that the attrition rate had to be at least 20%.

Appendix C. Summary of Findings Tables Dealing with Studies on the Impact of Noise on Hypertension

This appendix presents the summary of findings tables dealing with the studies on the impact of noise on hypertension. An extensive description and the reasoning behind these tables can be found in the complete review in Section 11.1.

Table A14. Summary of findings table for the association between aircraft noise exposure and the prevalence of hypertension.

Question	Does Exposure to Aircraft Noise Increase the Risk of Hypertension			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities (general population) located around airports in Europe and Japan			
Outcome	The prevalence of hypertension			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		1.05 (95% CI: 0.95–1.17) per 10 dB	
	Number of participants (# evaluated studies)		60,121 (9)	
	Number of cases		9487	
			Rating	Adjustment to rating
Quality assessment	Starting rating		9 cross-sectional studies [a]	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [b]	Downgrading
		Inconsistency	Serious [c]	Downgrading
		Indirectness	None [d]	No downgrading
		Imprecision	None [e]	No downgrading
		Publication bias	None [f]	No downgrading
	Factors increasing confidence	Strength of association	Small [g]	No upgrading
		Exposure-response gradient	Non-significant exposure-response gradient [g]	Upgrading
		Possible confounding	No serious bias [h]	Upgrading
	Overall judgement of quality of evidence			0 (low)

[a] Since only cross-sectional studies were available, we started with a grading of "low" (2); [b] Methods used to select the population: In six studies, the participants were randomly selected, taking into account aircraft noise exposure; three studies were originally not designed to investigate the impact of aircraft noise exposure, but still participants were randomly selected. In six studies, participants were probably not aware of the fact that they participated in a study investigating the impact of noise; for three studies, this was unclear. For one study, it was likely that participants were aware of the fact that they participated in a study investigating the impact of noise. In six studies, response rates were below 60%; for two studies, the response rate was unclear and only in one study response rate was higher than 60%; [c] Results across studies differed in magnitude and direction of effect estimates (see Figure 4.1 of the complete review). This was confirmed by the results of the heterogeneity analyses, demonstrating moderate heterogeneity ($I^2_{residual}$ = 72.1%); [d] The studies assessed population, exposure, and outcome of interest; [e] We considered

the results to be precise, since the number of participants and the number of cases was large enough. The 95% confidence interval was sufficiently narrow; [f] There was little reason to believe that there is major publication bias or small study bias (see also Figure 4.2). The Egger test did not provide evidence for small-study effects; [g] Most studies found that the risk of hypertension increased when aircraft noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.05 per 10 dB. The noise range of the studies under evaluation was 35–75 dB. This means that if air traffic noise level increases from 35 to 75 dB, the RR = 1.22. We found indications for an effect of exposure duration: The effect estimates turned out to be larger for the sample that lived for a longer period in the same house; [h] We did not find evidence that suggests that possible residual confounders or biases would reduce our effect estimate.

Table A15. Summary of findings table for the association between road traffic noise exposure and the prevalence of hypertension.

Question	**Does Exposure to Road Traffic Noise Increase the Risk of Hypertension**			
People	Adult population (men and women)			
Setting	Residential setting: people living several cities in Europe			
Outcome	The prevalence of hypertension			
Summary of findings	**RR per 10 dB increase in road traffic noise level (L_{DEN})**		1.05 (95% CI: 1.02–1.08) per 10 dB *	
	Number of participants (# evaluated studies)		154,398 (26)	
	Number of cases		18,957	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		26 cross-sectional studies [a]	2 (low)
	Factors decreasing confidence	**Risk of bias**	Serious [b]	Downgrading
		Inconsistency	Serious [c]	Downgrading
		Indirectness	None [d]	No downgrading
		Imprecision	None [e]	No downgrading
		Publication bias	Small probability of publication bias [f]	Downgrading
	Factors increasing confidence	**Strength of association**	Small [g]	No upgrading
		Exposure-response gradient	Evidence of an exposure-response gradient [g]	Upgrading
		Possible confounding	No serious bias [h]	Upgrading
	Overall judgement of quality of evidence			1 (very low)

* The estimate was based on 47 effect estimates; [a] Since only cross-sectional studies were available, we started with a grading of “low” (2); [b] In 12 studies, the participants were randomly selected taking into account exposure to road traffic noise; although the participants of these studies were randomly selected, 14 studies were originally not designed to investigate the impact of road traffic noise exposure; In 2 studies it was likely that participants were aware of the fact that they participated in a study investigating the impact of noise. In 8 studies, the participation rate was below 60%; for 16 studies, the participation rate was larger than 60%; [c] Results across studies differed in magnitude and direction of effect estimates (see Figure 4.3 of the complete review). This was confirmed by the results of the heterogeneity analyses, demonstrating “moderate” heterogeneity ($I^2_{residual}$ = 52.4%); [d] The evaluated studies assessed population, exposure, and outcome of interest; [e] We considered the results to be precise: the number of participants and the number of cases was large enough, and the 95% CI was sufficiently narrow; [f] There was reason to believe that there is some publication bias or small study bias (result of the Egger test provided evidence for small-study effects) (see also Figure 4.4 of the complete review); [g] Most studies found that the risk of hypertension increased when road traffic noise level increased (RR per 10 dB > 1). There was evidence of a significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a significant effect size of 1.05 per 10 dB. The noise range of the studies under evaluation was 20–85 dB. This means that if road traffic noise level increases from 20 to 85 dB, the RR = 1.34. We found indications for an effect of exposure duration: The effect estimates turned out to be larger for the sample that lived for a longer period in the same house; [h] We did not find evidence to suggest that possible residual confounders or biases would reduce our effect estimate.

Table A16. Summary of findings table for the association between rail traffic noise exposure and the prevalence of hypertension.

Question	**Does Exposure to Rail Traffic Noise Increase the Risk Of Hypertension**			
People	Adult population (men and women)			
Setting	Residential setting: people living in several cities in Europe			
Outcome	The prevalence of hypertension			
Summary of findings	**RR per 10 dB increase in rail traffic noise level (L_{DEN})**		1.05 (95% CI: 0.88–1.26) per 10 dB	
	Number of participants (# evaluated studies)		15,850 (5)	
	Number of cases		2059	
			Rating	**Adjustment to rating**
Quality assessment		**Starting rating**	5 cross-sectional studies #	2 (low)
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	**Strength of association**	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (Very low)

Since only cross-sectional studies were available, we started with a grading of "low"(2); [a] In three studies, the participants were randomly selected taking into account road- and/or rail traffic noise exposure; although the participants of these studies were randomly selected, two other studies were originally not designed to investigate the impact of (rail) traffic noise exposure; In one study there is a chance that the participants were aware that they took part in a study investigating the impact of noise; in two other studies it is not very likely that participants were aware that they took part in a study investigating the impact of noise, since they were not originally set up to investigate the impact of noise. For one study, it was unclear whether participants were aware of taking part in a noise study. In two studies, response rates were below 60%; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 4.5 of the complete review). This was confirmed by the results of the heterogeneity analyses, demonstrating "moderate" heterogeneity ($I^2_{residual}$ = 57.6%); [c] The evaluated studies assessed population, exposure, and outcome of interest; [d] We considered the results to be precise: the number of cases was large enough, and the 95% CI was sufficiently narrow; [e] Due to the low number of available effect estimates it was not possible to test for publication bias or small study bias; [f] Most studies found that the risk of hypertension increased when rail traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.05 per 10 dB. The noise range of the studies under evaluation was 30–80 dB (L_{DEN}). This means that if rail traffic noise level increases from 30 to 80 dB, the RR = 1.28; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A17. Summary of findings table for the association between exposure to wind turbines and the prevalence of hypertension.

Question	**Does Exposure to Noise from Wind Turbines Increase the Risk of Hypertension**	
People	Adult population (men and women)	
Setting	Residential setting: people in the neighbourhood of wind turbines in The Netherlands and Sweden	
Outcome	The prevalence of hypertension	
Summary of findings	**RR per 10 dB increase in wind turbine noise level (SPL)**	-
	Number of participants (# evaluated studies)	1830 (3)
	Number of cases	NR

Table A17. *Cont.*

			Rating	Adjustment to rating
Quality assessment		Starting rating	3 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Very serious [a]	Downgrading
		Inconsistency	None [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Limited [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	Serious bias cannot be ruled out [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] Methods used to select the population: response rates were in two of the three studies below 60%. The participants were randomly selected taking into account the distance between their house and a wind turbine (park); hypertension was in all cases measured by means of a questionnaire; [b] Although results across studies differed in the magnitude of effect estimates (see Figure of the complete review 4.6), all studies found a positive association between exposure to wind turbine noise and the prevalence of hypertension; [c] The evaluated studies assessed population, exposure, and outcome of interest; [d] We considered the results to be imprecise: we assessed that the number of cases was less than 200, which is small. The 95% CIs of the separate studies contained values below 0.5 and above 2.0; [e] Due to the low number of available effect estimates it was not possible to test for publication bias or small study bias; [f] We decided not to carry out a meta-analysis; [g] Although we did not find evidence to suggest that possible residual confounders or biases would reduce our effect estimate, the studies were unable to adjust for important confounders.

Table A18. Summary of findings table for the association between aircraft noise exposure and the incidence of hypertension.

Question	Does Exposure to Aircraft Noise Increase the Risk of Hypertension			
People	Adult population (men and women, 35–56 years)			
Setting	Residential setting: people living around Stockholm Arlanda airport in Sweden			
Outcome	The incidence of hypertension			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		1.00 (0.77–1.30) per 10 dB	
	Number of participants (# studies)		4712 (1)	
	Number of cases		1346	
			Rating	Adjustment to rating
Quality assessment	Starting rating		1 cohort study #	4 (high)
	Factors decreasing confidence	Risk of bias	Serious limitations [a]	Downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	No evidence of an exposure-response gradient [f]	Nu upgrading
		Possible confounding	Non-residual misclassification of disease	No upgrading
	Overall judgement of quality of evidence			2 (Low) [g]

Since a cohort study was available, we started with a grading of "high" (4); [a] Participants were a (partly) random selection from people participating in the Stockholm Preventive Programm. Hypertension was ascertained by both a clinical examination and a questionnaire; although it was not possible to exactly assess the attrition rate, it was probably > 20%; [b] Since only one study was evaluated, this criterion was not applied; [c] The study assessed population, exposure, and outcome of interest; [d] We considered the results to be precise: the sample was sufficiently large, and the 95% CI was sufficiently narrow; [e] Since only one study was evaluated, we were not able to test for publication bias; [f] We found a non-significant effect size of 1.00 per 10 dB. The noise range of the evaluated study was 45–65 dB (L_{DEN}); [g] The overall judgement of the quality of evidence was graded as "moderate" (3). Since only one study was available, we downgraded the overall level of evidence to "low" (2).

Table A19. Summary of findings table for the association between road traffic noise exposure and the incidence of hypertension.

Question	Does Exposure to Road Traffic Noise Increase the Risk of Hypertension			
People	Adult population (men and women, 50–64 years)			
Setting	Residential setting: people living in Aarhus or Copenhagen (Denmark)			
Outcome	The incidence of hypertension			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN})		0.97 (0.90–1.05) per 10 dB	
	Number of participants (# studies)		43,635 (1)	
	Number of cases		3145	
			Rating	Adjustment to rating
Quality assessment	Starting rating		1 cohort study #	4 (high)
	Factors decreasing confidence	Risk of bias	Serious limitations [a]	Downgrading
		Inconsistency	Na [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	No evidence of exposure-response gradient [f]	No upgrading
		Possible confounding	None	No upgrading
	Overall judgement of quality of evidence			2 (low) [g]

Since a cohort study was available, we started with a grading of “high” (4); [a] Participants were people participating in the DCH cohort. For this cohort, people living in Aarhus or Copenhagen, aged 50–64 years, and who were cancer-free, were randomly selected and invited. Attrition rate was > 20% after three years of follow-up time. Hypertension was ascertained by a questionnaire; [b] Since only one study was evaluated, this criterion was not applied; [c] The study assessed population, exposure, and outcome of interest; [d] We considered the results to be precise: the sample was sufficiently large, and the 95% CI was sufficiently narrow; [e] Since only one study was evaluated, we were not able to test for publication bias; [f] We found a non-significant effect size of less than 1.00 per 10 dB; [g] The overall judgement of the quality of evidence was graded “moderate”(3). Since only one study was available, we downgraded the overall level of evidence to “low” (2).

Table A20. Summary of findings table for the association between rail traffic noise exposure and the incidence of hypertension.

Question	Does Exposure to Rail Traffic Noise Increase the Risk of Hypertension	
People	Adult population (men and women, 50–64 years)	
Setting	Residential setting: people living in Aarhus or Copenhagen (Denmark)	
Outcome	The incidence of hypertension	
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN})	0.96 (0.88–1.04) per 10 dB
	Number of participants (# studies)	7249 (1)
	Number of cases	3145

Table A20. *Cont.*

			Rating	Adjustment to rating
Quality assessment	Starting rating		1 cohort study #	4 (high)
	Factors decreasing confidence	Risk of bias	Serious limitations [a]	Downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	No evidence of an exposure-response gradient [f]	No upgrading
		Possible confounding	None	No upgrading
	Overall judgement of quality of evidence			2 (low) [g]

Since a cohort study was available, we started with a grading of "high" (4); [a] Participants were people participating in the DCH cohort. For this cohort, people living in Aarhus or Copenhagen, aged 50–64 years. and who were cancer-free, were randomly selected and invited. Attrition rate was > 20% after three years of follow-up time. Hypertension was ascertained by a questionnaire; [b] Since only one study was evaluated, this criterion was not applied; [c] The study assessed population, exposure, and outcome of interest; [d] We considered the results to be precise: the sample was sufficiently large, and the 95% CI was sufficiently narrow; [e] Since only one study was evaluated, we were not able to test for publication bias; [f] We found a non-significant effect size of less than 1.00 per 10 dB; [g] The overall judgement of the quality of evidence was graded as "moderate"(3). Since only one study was available, we downgraded the overall level of evidence to "low" (2).

Appendix D. Summary of Findings Tables Dealing with Studies on the Impact of Noise on Ischaemic Heart Disease

This appendix presents the summary of findings tables dealing with the studies on the impact of noise on IHD. An extensive description and the reasoning behind these tables can be found in the complete review in Section 11.2.

Table A21. Summary of findings table for the association between aircraft noise exposure and the prevalence of ischaemic heart disease.

Question	Does Exposure to Aircraft Noise Increase the Risk of IHD			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in Europe			
Outcome	The prevalence of IHD			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		1.07 (95% CI: 0.94–1.23)	
	Number of participants (# studies)		14,098 (2)	
	Number of cases		340	
			Rating	Adjustment to rating
Quality assessment	Starting rating		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	None [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			1 (very low)

Since only cross-sectional studies were available, we started with a grading of “low” (2); [a] In both studies, the population was selected randomly. Response rates were in both studies below 60%. In the studies, IHD was ascertained by means of a questionnaire only; one of the studies was not able to adjust for smoking; [b] Although results across studies differed in the magnitude if effect estimates, both studies found a positive association between exposure to aircraft noise and the prevalence of IHD (see Figure 5.1 of the complete review); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be precise: the number of cases was large enough, and the 95% CI was sufficiently narrow; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] Both studies found that the risk of IHD increased when air traffic noise level increased (RR per 10 dB > 1).There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.07 per 10 dB. The noise range of the studies under evaluation was 30–70 dB (L_{DEN}); [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A22. Summary of findings table for the association between road traffic noise exposure and the prevalence of ischaemic heart disease.

Question	**Does Exposure to Road Traffic Noise Increase the Risk of IHD**			
People	Adult population (men and women)			
Setting	Residential setting: people living several cities in Europe			
Outcome	The prevalence of IHD			
Summary of findings	**RR per 10 dB increase in road traffic noise level (L_{DEN})**		1.24 (95% CI: 1.08–1.42) per 10 dB	
	Number of participants (# studies)		25,682 (8)	
	Number of cases		1614	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		8 cross-sectional studies #	2 (low) #
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Minor [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	**Strength of association**	Large [f]	Upgrading
		Exposure-response gradient	Evidence of an exposure-response gradient [f]	Upgrading
		Possible confounding	Possible bias [g]	No upgrading
	Overall judgement of quality of evidence			2 (low)

Since only cross-sectional studies were available, we started with a grading of “low” (2); [a] Methods used to select the population: In 6 studies, the participants were randomly selected taking into account road traffic noise exposure. The response rates were below 60%. In four of the eight studies. In three of the included studies, exposure was assessed by noise models incorporated in GIS. The noise models used were able to estimate the noise levels at individual level. In four of the studies, IHD was ascertained by means of a questionnaire only; [b] Results across studies differed only in the magnitude of effect estimates (see Figure 5.2 of the complete review). This was confirmed by the results of the heterogeneity analyses, indicating “moderate” heterogeneity ($I^2_{residual}$ = 51.4%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be less precise: the number of cases was large enough, and although the 95% CI contained values > 1.25, we considered the sample size as sufficiently large; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] All studies found that the risk of IHD increased when road traffic noise level increased (RR per 10 dB > 1). There was evidence of a significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a significant effect size of 1.24 per 10 dB. The noise range of the studies under evaluation was 30–80 dB. This means that if road traffic noise level increases from 30 to 80 dB, the RR = 2.93; [g] Adjustment for smoking and indicators of air pollution were found to be important sources of heterogeneity.

Table A23. Summary of findings table for the association between rail traffic noise exposure and the prevalence of ischaemic heart disease.

Question	Does Exposure to Rail Traffic Noise Increase the Risk of IHD			
People **Setting** **Outcome**	Adult population (men and women) Residential setting: people living several cities in Europe The prevalence of IHD			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN})		1.18 (95% CI: 0.82–1.68) per 10 dB	
	Number of participants ([#] studies)		13,241 (4)	
	Number of cases		283	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		4 cross-sectional studies	2 (low) [#]
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Minor [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	**Strength of association**	Large, but non-significant [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

[#] Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] Response rates were in two of the four studies below 60%. In all studies, IHD was ascertained by means of a questionnaire only; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 5.7 of the complete review). This was confirmed by the results of the heterogeneity analyses, indicating "moderate" heterogeneity ($I^2_{residual}$ = 57.4%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be less precise: the 95% CI contained values > 1.25; however, we considered the sample size to be sufficiently large; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] Most studies found that the risk of IHD increased when rail traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.18 per 10 dB. The noise range of the studies under evaluation was 30–80 dB. This means that if rail traffic noise level increases from 30 to 80 dB, the RR = 2.29; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A24. Summary of findings table for the association between aircraft noise exposure and the incidence of ischaemic heart disease.

Question	Does Exposure to Aircraft Noise Increase the Risk of IHD			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in the UK and USA			
Outcome	The incidence (hospital admissions) of IHD			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		1.09 (95% CI: 1.04–1.15)	
	Number of participants ([#] studies)		9,619,082 (2)	
	Number of cases		158,977	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 ecological studies	1 (very low) [#]
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA	No downgrading
	Factors increasing confidence	**Strength of association**	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a significant exposure-response gradient [f]	Upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			1 (very low)

[#] Since only ecological studies were available, we started with a grading of "very low" (1); [a] Both ecological studies worked with a purposeful sample; so randomization and response rate is not an issue. Studies were not able to adjust for important confounders at individual level. Studies were unable to apply individual exposure estimates; [b] Although results across studies differed in the magnitude of effect estimates, both found a positive association between exposure to aircraft noise and the incidence of IHD (see Figure 5.1 of the complete review). This was confirmed by the results of the heterogeneity analyses, indicating "low" heterogeneity ($I^2_{residual}$ = 48.4%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be precise: the number of participants, as well as the number of cases were much larger than 200, and the 95% CI did not contain values below 0.75 or above 1.25; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] There was evidence of a significant exposure-response gradient: We found a significant effect size of 1.09 per 10 dB across a noise range of 45 to ~65 dB, this means that if the aircraft noise level increases from 45 to 65 dB, the RR = 1.19; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A25. Summary of findings table for the association between road traffic noise exposure and the incidence of ischaemic heart disease: ecological studies.

Question	**Does Exposure to Road Traffic Noise Increase the Risk of IHD**			
People	Adult population (men and women)			
Setting	Residential setting: people living in Kaunas (Lithuania)			
Outcome	The incidence of IHD			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN})		1.12 (95% CI: 0.85–1.48) per 10 dB	
	Number of participants ([#] studies)		262,830 (1)	
	Number of cases		418	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		1 ecological study	1 (very low) [#]
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Na [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	Downgrading
	Factors increasing confidence	**Strength of association**	NA [f]	No upgrading
		Exposure-response gradient	Evidence of non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low) [h]

[#] Since only one ecological study was available, we started with a grading of "very low" (1); [a] Ecological studies worked with a purposeful sample; so randomization and response rate is not an issue. The study was not able to adjust for important confounders at individual level, and was unable to apply individual exposure estimates; [b] Only one study was evaluated, so inconsistency was not an issue; [c] The study assessed population, exposure and outcome of interest; [d] Although the 95% CI contained values above 1.25, we considered the results to be precise: the number of participants, as well as the number of cases were much larger than 200; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias. However, when combining this study with the other case-control and cohort studies that investigated the association between road traffic noise and the incidence of IHD, the number of estimates became large enough to test for publication bias. The funnel plot (Figure 5.6 of the complete review) was somewhat a-symmetric, but the Egger test provided only weak evidence for small-study effects; [f] There was evidence of a non-significant exposure-response gradient: We found a non-significant effect size of 1.12 per 10 dB across a noise range of 55–75 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] The overall judgement of the quality of the evidence was "very low"(0). Downgrading of the overall level of evidence, because only one study was available, made no sense.

Table A26. Summary of findings table for the association between road traffic noise exposure and the incidence of ischaemic heart disease: cohort and case-control studies.

Question	**Does Exposure to Road Traffic Noise Increase the Risk of IHD**			
People	Adult population (men and women)			
Setting	Residential setting: people living several cities in Europe			
Outcome	The incidence of IHD			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN})		1.08 (95% CI: 1.01–1.15) per 10 dB	
	Number of participants (# studies)		67,224 (7)	
	Number of cases		7033	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		3 cohort studies, 4 case-control studies	4 (high) #
	Factors decreasing confidence	**Risk of bias**	Limited [a]	No downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	Small probability of publication bias [e]	Downgrading
	Factors increasing confidence	**Strength of association**	Small [f]	No upgrading
		Exposure-response gradient	Evidence of an exposure-response gradient [f]	Upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			4 (high)

Since cohort and case-control studies were available, we started with a grading of "high" (4); [a] In all the studies, the participants were randomly selected. For six studies, the response rate was higher than 60%; in all the cohort studies, the loss to follow-up was less than 20%. Methods to assess exposure: In three of the included studies, exposure was assessed by noise models incorporated in GIS. The noise models used were able to estimate the noise levels at individual level. In three other studies, noise exposure assessment was based on noise measurements in the direct living area of the participant; [b] Results across studies differed only in the magnitude of effect estimates (see Figure 5.3 of the complete review). The results of the heterogeneity analyses demonstrated no clear evidence for heterogeneity; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results as precise: The number of participants and cases were much larger than 200, and the 95% CI did not contain values below 0.75 or above 1.25; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias. However, when combining these studies with the ecological study that investigated the association between road traffic noise and the incidence of IHD, the number of estimates became large enough to test for publication bias. The funnel plot (Figure 5.6) was somewhat a-symmetric, but the Egger test provided only weak evidence for small-study effects; [f] Most studies found that the risk of IHD increased when road traffic noise level increased (RR per 10 dB > 1). There was evidence of a significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a significant effect size of 1.08 per 10 dB. The noise range of the studies under evaluation was 40–80 dB. This means that if road traffic noise level increases from 40 to 80 dB, the RR = 1.36; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A27. Summary of findings table for the association between aircraft noise exposure and mortality due to ischaemic heart disease: ecological studies.

Question	**Does Exposure to Aircraft Noise Increase the Risk of IHD**	
People	Adult population (men and women)	
Setting	Residential setting: people living in cities located around airports in the UK and The Netherlands	
Outcome	Mortality due to IHD	
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})	1.04 (95% CI: 0.97–1.12)
	Number of participants (# studies)	3,897,645 (2)
	Number of cases	26,066

Table A27. *Cont.*

			Rating	Adjustment to rating
Quality assessment	Starting rating		2 ecological studies	1 (very low) #
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only ecological studies were available, we started with a grading of "very low" (0); [a] Both ecological studies worked with a purposeful sample; so randomization and response rate is not an issue. Studies were not able to adjust for important confounders at individual level. Studies were unable to apply individual exposure estimates; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 5.1 of the complete review). This was not confirmed by the results of the heterogeneity analyses, demonstrating "low" heterogeneity ($I^2_{residual}$ = 39.7%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be precise: Both the number of participants and cases were much larger than 200; the 95% CI did not contain values below 0.75 or above 1.25; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] One of the two studies found that the risk of IHD increased when air traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.04 per 10 dB. The noise range of the studies under evaluation was 40–65 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A28. Summary of findings table for the association between aircraft noise exposure and mortality due to ischaemic heart disease: cohort studies.

Question	Does Exposure to Aircraft Noise Increase the Risk of IHD			
People	Adult population (men and women)			
Setting	Residential setting: people living in Switzerland			
Outcome	Mortality due to IHD			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		1.04 (95% CI: 0.98–1.11) per 10 dB	
	Number of participants (# studies)		4,580,311 (1)	
	Number of cases		15,532	
			Rating	Adjustment to rating
Quality assessment	Starting rating		1 cohort study	4 (high) #
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	Na [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			2 (low) [h]

Since a cohort study was available, we started with a grading of "high" (4); [a] Aircraft noise levels were available at 100 × 100 m grids and the study suffered from a lack of information about important life style factors; [b] Only one study was evaluated, so inconsistency was not an issue (see Figure 5.1 of the complete review); [c] The study assessed population, exposure and outcome of interest. [d] We considered the results to be precise: Both the number of participants and cases were much larger than 200. The 95% CI did not contain values below 0.75 or above 1.25; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] There was evidence of a non-significant exposure-response gradient: We found a non-significant effect size of 1.04 per 10 dB across a noise range of 40 to 60 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of evidence as "moderate". Since only one study was available, we downgraded the overall level of evidence to "low" (2).

Table A29. Summary of findings table for the association between road traffic noise exposure and mortality due to ischaemic heart disease: cohort and case-control studies.

Question	**Does Exposure to Road Traffic Noise Increase the Risk of IHD**			
People	Adult population (men and women)			
Setting	Residential setting: people living several cities in Europe			
Outcome	Mortality due to IHD			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN}) Number of participants (# studies) Number of cases		1.05 (95% CI: 0.97–1.13) per 10 dB 532,268 (3) 6884	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		1 cohort studies, 2 case-control studies	4 (high) #
	Factors decreasing confidence	**Risk of bias**	Limited [a]	Downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	**Strength of association**	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			3 (moderate)

Since cohort and case-control studies were available, we started with a grading of "high" (4); [a] For the largest of the three studies, there was a possible risk of bias since there were worries with regard to exposure assessment, and one was not able to adjust for smoking; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 5.5 of the complete review). This was not confirmed by the heterogeneity analyses, demonstrating "low" heterogeneity ($I^2_{residual}$ = 34.9%); [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be precise: Both the number of participants and cases were much larger than 200. The 95% CI did not contain values below 0.75 or above 1.25; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] Most studies found that the risk of IHD increased when road traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.05 per 10 dB. The noise range of the studies under evaluation was 42–70 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Appendix E. Summary of Findings Tables Dealing with Studies on the Impact of Noise on Stroke

This appendix presents the summary of findings tables dealing with the studies on the impact of noise on stroke. An extensive description and the reasoning behind these tables can be found in the complete review in Section 11.3.

Table A30. Summary of findings table for the association between aircraft noise exposure and the prevalence of stroke.

Question	Does Exposure to Aircraft Noise Increase the Risk of Stroke			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in Europe and The Netherlands			
Outcome	The prevalence of stroke			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		1.02 (95% CI: 0.80–1.28)	
	Number of participants (# studies)		14,098 (2)	
	Number of cases		151	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	**Strength of association**	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non- significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] Response rates were in both studies below 60%. In the studies, stroke was ascertained by means of a questionnaire only; one of the two studies was not able to adjust for smoking; [b] Results between studies differed in the magnitude and direction of effect estimates (see Figure 6.1 of the complete review). This was not confirmed by the result of the heterogeneity analysis, demonstrating "low" heterogeneity ($I^2_{residual}$ = 0.0%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The number of cases was smaller than 200, and the 95% CI was judged as not sufficiently narrow; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] One the two studies found that the risk of stroke increased when air traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.02 per 10 dB. The noise range of the studies under evaluation was 30–75 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A31. Summary of findings table for the association between road traffic noise exposure and the prevalence of stroke.

Question	Does Exposure to Road Traffic Noise Increase the Risk of Stroke			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in Europe and The Netherlands			
Outcome	The prevalence of stroke			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN})		1.00 (95% CI: 0.91–1.10) per 10 dB	
	Number of participants (# studies)		14,098 (2)	
	Number of cases		151	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	**Strength of association**	NA [f]	No upgrading
		Exposure-response gradient	No evidence of an exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] Response rates were in both studies below 60%. In the studies, stroke was ascertained by means of a questionnaire only; one of the two studies was not able to adjust for smoking; [b] Results between studies differed in the magnitude and direction of effect estimates (see Figure 6.2 of the complete review). This was not confirmed by the result of the heterogeneity analysis, demonstrating "low" heterogeneity ($I^2_{residual}$ = 0.0%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise since the number of cases was smaller than 200. The 95% CI was judged as sufficiently narrow; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] One the two studies found that the risk of stroke increased when road traffic noise level increased (RR per 10 dB > 1). There was no evidence of an exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.00 per 10 dB. The noise range of the studies under evaluation was 30–75 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A32. Summary of findings table for the association between rail traffic noise exposure and the prevalence of stroke.

Question	**Does Exposure to Rail Traffic Noise Increase the Risk of Stroke**			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities around airports in The Netherlands			
Outcome	The prevalence of stroke			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN})		1.07 (95% CI: 0.92–1.25) per 10 dB	
	Number of participants (# studies)		9365 (1)	
	Number of cases		89	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		1 cross-sectional study #	2 (low)
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	**Strength of association**	Small, but non-significant [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low) [h]

Since one cross-sectional study was available, we started with a grading of "low" (2); [a] Response rate was below 60%, and stroke was ascertained by means of a questionnaire only; [b] NA; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: Although the 95% CI was considered as sufficiently narrow, we considered the number of cases to be small; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] The evaluated study found that the risk of stroke increased when rail traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: We found a non-significant effect size of 1.07 per 10 dB. The noise range of the study under evaluation was 30–65 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of the evidence to be "very low" (0). Grading the overall judgement of the quality of evidence down with one level was not considered to be useful. Despite the fact that only one study was available, we did not downgrade the overall level of evidence. The overall judgement of the quality of evidence was already judged as "very low".

Table A33. Summary of findings table for the association between aircraft noise exposure and the incidence of stroke: ecological studies.

Question	Does Exposure to Aircraft Noise Increase the Risk of Stroke			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in the UK and USA			
Outcome	The incidence (hospital admissions) of stroke			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		1.05 (95% CI: 0.96–1.15)	
	Number of participants (# studies)		9,619,082 (2)	
	Number of cases		97,949	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 ecological studies	1 (very low)
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA	No downgrading
	Factors increasing confidence	**Strength of association**	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

[#] Since only ecological studies were available, we started with a grading of "very low" (1); [a] Both ecological studies worked with a purposeful sample; so randomization and response rate is not an issue. Studies were not able to adjust for important confounders at individual level. Studies were unable to apply individual exposure estimates; [b] Results between studies differed in the magnitude and direction of effect estimates (see Figure 6.1 of the complete review). This was confirmed by the result of the heterogeneity analysis, indicating "strong" heterogeneity ($I^2_{residual}$ = 82.7%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be precise: Both the number of participants and cases were much larger than 200. The 95% CI did not contain values below 0.75 or above 1.25; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] One the two studies found that the risk of stroke increased when air traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.05 per 10 dB. The noise range of the studies under evaluation was 40 to approximately 65 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A34. Summary of findings table for the association between road traffic noise exposure and the incidence of stroke.

Question	Does Exposure to Road Traffic Noise Increase the Risk of Stroke			
People	Adult population (men and women)			
Setting	Residential setting: people living in several cities in Denmark			
Outcome	The incidence of stroke			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN})		1.14 (95% CI: 1.03–1.25) per 10 dB	
	Number of participants (# studies)		51,485 (1)	
	Number of cases		1881	
			Rating	**Adjustment to Rating**
Quality assessment	**Starting rating**		1 cohort study	4 (high)
	Factors decreasing confidence	**Risk of bias**	Limited [a]	No downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	**Strength of association**	Small [f]	No upgrading
		Exposure-response gradient	Evidence of an exposure-response gradient [f]	Upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			3 (moderate) [h]

[#] Since one cohort study was available, we started with a grading of "high" (4); [a] No limitations in study design found; [b] Only one study was evaluated, so inconsistency was not an issue; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results of the study to be precise: Both the number of participants and cases were much larger than 200. The 95% CI did not contain values below 0.75 or above 1.25; [e] The number of available effect estimates was too small to test for publication bias; [f] The evaluated study found that the risk of stroke increased when road traffic noise level increased (RR per 10 dB > 1). There was evidence of a significant exposure-response gradient: We found a significant effect size of 1.14 per 10 dB. The noise range of the study under evaluation was approximately 50 to 70 dB. This means that if the road traffic noise level increases from 50 to 70 dB, the RR = 1.30; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of the evidence to be "high" (4). Since only one study was available, we downgraded the overall level of evidence to "moderate" (3).

Table A35. Summary of findings table for the association between aircraft noise exposure and mortality due to stroke: ecological studies.

Question	**Does Exposure to Aircraft Noise Increase the Risk of Stroke**			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in the UK and The Netherlands			
Outcome	Mortality due to stroke			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN}) Number of participants ([#] studies) Number of cases		1.07 (95% CI: 0.98–1.17) 3,897,645 (2) 12,086	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 ecological studies	1 (very low)
	Factors decreasing confidence	**Risk of bias**	Serious [a]	Downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA	No downgrading
	Factors increasing confidence	**Strength of association**	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non- significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

[#] Since we only ecological studies were available, we started with a grading of "very low" (1); [a] Both ecological studies worked with a purposeful sample; so randomization and response rate is not an issue. Studies were not able to adjust for important confounders at individual level. Studies were unable to apply individual exposure estimates; [b] Results between studies differed in the magnitude of effect estimates (see Figure 6.1 of the complete review). The result of the heterogeneity analysis demonstrated "low" heterogeneity ($I^2_{residual}$ = 28.5%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be precise: Both the number of participants and cases were much larger than 200. The 95% CI did not contain values below 0.75 or above 1.25; [e] Due to the low number of available effect estimates, it was not possible to test for publication bias or small study bias; [f] Both studies found that the risk of stroke increased when air traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: After aggregating the results of the evaluated studies, we found a non-significant effect size of 1.07 per 10 dB. The noise range of the studies under evaluation was approximately 40 to 65 dB. This means that if the aircraft noise level increases from 40 to 65 dB, the RR = 1.18; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A36. Summary of findings table for the association between aircraft noise exposure and the mortality due to stroke: cohort studies.

Question	Does Exposure to Air Traffic Noise Increase the Risk of Stroke			
People	Adult population (men and women)			
Setting	Residential setting: people living in several cities near airports in Switzerland			
Outcome	Mortality due to stroke			
Summary of findings	RR per 10 dB increase in air traffic noise level (L_{DEN}) Number of participants (# studies) Number of cases		0.99 (95% CI: 0.94–1.04) per 10 dB 4,580,311 (1) 25,231	
			Rating	Adjustment to rating
Quality assessment	Starting rating		1 cohort study	4 (high)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	None [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	No evidence of an exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			3 (moderate) [g]

[#] Since one cohort study was available, we started with a grading of "high" (4); [a] No limitations in study design found; [b] Only one study was evaluated, so inconsistency was not an issue; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be precise: Both the number of participants and cases were much larger than 200. The 95% CI did not contain values below 0.75 or above 1.25; [e] The number of available effect estimates was too small to test for publication bias; [f] The evaluated study did not find that the risk of stroke increased when air traffic noise level increased (RR per 10 dB < 1). There was no evidence of a gradient: We found a non-significant effect size of 0.99 per 10 dB. The noise range of the study under evaluation was approximately 40 to 65 dB; [g] We graded the overall quality of the evidence to be "high". Since only one study was available, we downgraded the overall level of evidence "moderate" (3).

Table A37. Summary of findings table for the association between road traffic noise exposure and mortality due to stroke.

Question	Does Exposure to Road Traffic Noise Increase the Risk of Stroke			
People	Adult population (men and women)			
Setting	Residential setting: people living in several cities in Denmark, The Netherlands and Canada			
Outcome	Mortality due to stroke			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN}) Number of participants (# studies) Number of cases		0.87 (95% CI: 0.71–1.06) per 10 dB 581,517 (3) 2634	
			Rating	Adjustment to Rating
Quality assessment	Starting rating		3 cohort studies	4 (high)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Limited [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	No evidence of an exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			3 (moderate)

Since cohort studies were available, we started with a grading of "high" (4); [a] No limitations in study design found; [b] Results across studies differed in the magnitude and direction of effect estimates (see also Figure 6.2). This was confirmed by the results of the heterogeneity analysis, demonstrating "strong" heterogeneity ($I^2_{residual}$ = 78.0%); [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be precise enough: Both the number of participants and cases were much larger than 200. However, the 95% CI did contain values below 0.75; [e] The number of available effect estimates were too small to test for publication bias; [f] Only one of the evaluated studies found that the risk of stroke increased when road traffic noise level increased (RR per 10 dB > 1). There was no evidence of an exposure-response gradient: After aggregating the results of the studies, a non-significant effect size of 0.87 per 10 dB across a noise range of ~50 to 70 dB was found; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Appendix F. Summary of Findings Tables Dealing with Studies on the Impact of Noise on Diabetes

This appendix presents the summary of findings tables dealing with the studies on the impact of noise on diabetes. An extensive description and the reasoning behind these tables can be found in the complete review in Section 11.4.

Table A38. Summary of findings table for the association between aircraft noise exposure and the prevalence of diabetes.

Question	**Does Exposure to Aircraft Noise Increase the Risk of Diabetes**			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in The Netherlands			
Outcome	The prevalence of diabetes			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		1.01 (95% CI: 0.78–1.31)	
	Number of participants (# studies)		9365 (1)	
	Number of cases		89	
			Rating	**Adjustment to Rating**
Quality assessment	**Starting rating**		1 cross-sectional study #	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non- significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low) [h]

Since only one cross-sectional study was available, we started with a grading of "low" (2); [a] The response rates was below 60%. Diabetes was ascertained by means of a questionnaire only; the study was not able to adjust for smoking; [b] Since only one study is available, this criterion is not applicable; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The number of cases was small, and the 95% CI was not sufficiently narrow; [e] Since the results of only one study were available it was not possible to test for publication bias or small study bias; [f] The evaluated study found that the risk of diabetes increased when air traffic noise level increased (RR per 10 dB > 1). There was evidence of a non-significant exposure-response gradient: we found a non-significant effect size of 1.01 per 10 dB. The noise range of the studies under evaluation was 30–65 dB. this means that if the air traffic noise level increases from 30 to 65 dB, the RR = 1.04; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded overall quality of the evidence to be "very low" (0). Despite the fact that only one study was available, it was not useful to downgrade the overall quality of evidence.

Table A39. Summary of findings table for the association between road traffic noise exposure and the prevalence of diabetes.

Question	Does Exposure to Road Traffic Noise Increase the Risk of Diabetes			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in The Netherlands and Stockholm			
Outcome	The prevalence of diabetes			
Summary of findings	RR per 10 dB increase in road noise level (L_{DEN}) Number of participants (# studies) Number of cases		NR 11,460 (2) 242	
			Rating	**Adjustment to Rating**
Quality assessment	**Starting rating**		2 cross-sectional study #	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] In one of the studies, the response rate was below 60%. In the studies, diabetes was ascertained by means of a questionnaire only; [b] Results of the studies differed in the magnitude of effect estimates; [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results of the studies to be imprecise: Although the number of cases was > 200, the 95% CIs of the separate studies were not sufficiently narrow; [e] Since the results of only two studies were available it was not possible to test for publication bias or small study bias; [f] Both studies found that the risk of diabetes increased when road traffic noise level increased (RR per 10 dB > 1). A meta-analysis was not carried out; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A40. Summary of findings table for the association between rail traffic noise exposure and the prevalence of diabetes.

Question	Does Exposure to Rail Traffic Noise Increase the Risk of Diabetes			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities located around airports in The Netherlands			
Outcome	The prevalence of diabetes			
Summary of findings	RR per 10 dB increase in rail noise level (L_{DEN}) Number of participants (# studies) Number of cases		0.21 (95% CI: 0.05–0.82) 9365 (1) 89	
			Rating	**Adjustment to Rating**
Quality assessment	**Starting rating**		1 cross-sectional study #	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low) [h]

Since only one cross-sectional study was available, we started with a grading of "low" (2); [a] The response rate was below 60%. Diabetes was ascertained by means of a questionnaire only; [b] Since only one study is available, this criterion is not applicable; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The number of cases was small, and the 95% CI was not sufficiently narrow; [e] Since the results of only one study were available, it was not possible to test for publication bias or small study bias; [f] In the evaluated study a health promoting effect of noise was found; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of the evidence to be "very low"(0). Despite the fact that only one study was available, it was not useful to downgrade the overall quality of evidence.

Table A41. Summary of findings table for the association between exposure to noise from wind turbines and the prevalence of diabetes.

Question	**Does Exposure to Noise from Wind Turbines Increase the Risk of Diabetes**			
People	Adult population (men and women)			
Setting	Residential setting: people in the neighbourhood of wind turbines in The Netherlands and Sweden			
Outcome	The prevalence of diabetes			
Summary of findings	RR per 10 dB increase in wind turbine noise level (SPL)		-	
	Number of participants (# evaluated studies)		1830 (3)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		3 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Very serious [a]	Downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious[d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	Serious bias cannot be ruled out [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] Methods used to select the population: response rates were in two of the three studies below 60%. The participants were randomly selected, taking into account the distance between their house and a wind turbine (park); diabetes was in all cases measured by means of a questionnaire; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 7.1 of the complete review); [c] The evaluated studies assessed population, exposure, and outcome of interest; [d] We considered the results to be imprecise: We assessed that the number of cases is probably lower than 200. The 95% CIs of the separate studies contained values below 0.5 and above 2.0; [e] Due to the low number of available effect estimates it was not possible to test for publication bias or small study bias; [f] Only one of the evaluated studies found that We decided not to carry out a meta-analysis; [g] The studies were unable to adjust for important confounders.

Table A42. Summary of findings table for the association between aircraft noise exposure and the incidence of diabetes.

Question	**Does Exposure to Aircraft Noise Increase the Risk of Diabetes**			
People	Adult population (men and women)			
Setting	Residential setting: people living in Stockholm (Sweden)			
Outcome	The incidence of diabetes			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN})		0.99 (95% CI: 0.47–2.09)	
	Number of participants (# studies)		5156 (1)	
	Number of cases		159	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		1 cohort #	4 (high)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	No evidence of an exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			2 (low) [h]

Since we have a cohort study, we start at 4 (high evidence; [a] The loss-to-follow-up was estimated as > 20%; [b] Since only one study is available, this criterion is not applicable; [c] The study assessed population, exposure and outcome of interest; [d] Although the number of cases was large, the 95% CI was judged as not sufficiently narrow; [e] Since the results of only one study were available it was not possible to test for publication bias or small study bias; [f] The evaluated study found that the risk of diabetes decreased when air traffic noise level increased (RR per 10 dB < 1). No evidence of an exposure-response gradient was found: the evaluated study found an non-significant effect size of 0.99 per 10 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of the evidence to be "moderate" (3). Since only one study was available, we downgraded the overall level of evidence to "low" (2).

Table A43. Summary of findings table for the association between road traffic noise exposure and the incidence of diabetes.

Question	Does Exposure to Road Traffic Noise Increase the Risk of Diabetes			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities in Denmark			
Outcome	The incidence of diabetes			
Summary of findings	RR per 10 dB increase in road traffic noise level (L_{DEN}) Number of participants (# studies) Number of cases		1.08 (95% CI: 1.02–1.14) 57,053 (1) 2752	
			Rating	Adjustment to rating
Quality assessment	Starting rating		1 cohort #	4 (high)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Limited [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a significant exposure-response gradient [f]	Upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			3 (moderate) [h]

Since one cohort study is available, we started with a grading of "high" (4); [a] The quality of the study was judged as high; [b] Since only one study is available, this criterion is not applicable; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results of the study to be precise: The number of cases was large, and the 95% CI was sufficiently narrow; [e] Since the results of only one study were available it was not possible to test for publication bias or small study bias; [f] The evaluated study found that the risk of diabetes increased when road traffic noise level increased (RR per 10 dB < 1). There was evidence of a significant exposure-response gradient: In the evaluated study a statistically significant RR of 1.08 per 10 dB across the noise range of 50–70 dB was found. This means that if the road traffic noise level increases from 50 to 70 dB, the RR = 1.17; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of the evidence to be "high" (4). Since only one study was available, we downgraded the overall level of evidence to "moderate" (3).

Table A44. Summary of findings table for the association between rail traffic noise exposure and the incidence of diabetes.

Question	Does Exposure to Rail Traffic Noise Increase the Risk of Diabetes			
People	Adult population (men and women)			
Setting	Residential setting: people living in cities in Denmark			
Outcome	The incidence of diabetes			
Summary of findings	RR per 10 dB increase in aircraft noise level (L_{DEN}) Number of participants (# studies) Number of cases		0.97 (95% CI: 0.89–1.05) 57,053 (1) 2752	
			Rating	Adjustment to rating
Quality assessment	Starting rating		1 cohort #	4 (high)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Limited [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	No evidence of an exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			3 (moderate) [h]

Since, a cohort study is available, we started with a grading of "high" (4); [a] The quality of the study was judged as high; [b] Since only one study is available, this criterion is not applicable; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results of the studies as precise: the number of cases was large, and the 95% CI was judged as sufficiently narrow; [e] Since the results of only one study were available it was not possible to test for publication bias or small study bias; [f] The evaluated study found that the risk of diabetes decreased when rail traffic noise level increased (RR per 10 dB < 1). No evidence of an exposure-response gradient was found: the evaluated study found a non-significant effect size of 0.97 per 10 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of the evidence to be "high" (4). Since only one study was available, we downgraded the overall level of evidence to "moderate" (3).

Appendix G. Summary of Findings Tables Dealing with Studies on the Impact of Noise on Obesity

This appendix presents the summary of findings tables dealing with the studies on the impact of noise on obesity. An extensive description and the reasoning behind these tables can be found in the complete review in Section 11.5.

Table A45. Summary of findings table for the association between aircraft noise exposure and the change in Body Mass Index.

Question	Does Exposure to Aircraft Noise Increase the Risk of Obesity			
People	Adult population (men and women)			
Setting	Residential setting: people living in Stockholm in areas located around the airport			
Outcome	Change in BMI (kg/m^3)			
Summary of findings	Change in BMI per 10 dB increase in aircraft noise level (L_{DEN})		0.14 (95% CI: −0.18–0.45) kg/m^2	
	Number of participants (# studies)		5156 (1)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		1 cohort study #	4 (high)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non- significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			2 (low) #

Since a cohort study was available, we started with a grading of "high" (4); [a] The quality of the study was judged as high; [b] Since only one study is available, this criterion is not applicable; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The standard deviation of the reported effect size was larger than the mean difference in BMI; [e] Since the results of only one study were available, it was not possible to test for publication bias or small study bias; [f] In the evaluated study, a harmful effect of noise was found. There was evidence of a non-significant exposure-response gradient: we found a non-significant effect size of 0.14 kg/m^2 per 10 dB. The noise range of the study under evaluation was 48–65 dB. This means that in case the air traffic noise level increases from 48 to 65 dB, the BMI increased with 0.24 kg/m^2 (this is less than 3–5% change in BMI, which is considered clinically significant); [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of the evidence to be "moderate" (3). Because only one study was available, we downgraded the overall quality of evidence to "low" (2).

Table A46. Summary of findings table for the association between road traffic noise exposure and the change in Body Mass Index.

Question	Does Exposure to Road Traffic Noise Increase the Risk of Obesity			
People	Adult population (men and women)			
Setting	Residential setting: people living in Stockholm in areas located around the airport (Sweden), people living in Oslo (Norway), People living in Aarhus or Copenhagen (Denmark)			
Outcome	Change in BMI (kg/m^3)			
Summary of findings	Change in BMI per 10 dB increase in road traffic noise level (L_{DEN})		0.03 (95% CI: −0.10–0.15) kg/m^2	
	Number of participants (# studies)		71,431 (3)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		3 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non- significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as high; [b] Results across studies differed in the magnitude and direction of effect estimate (see Figure 8.1 of the complete review). This was confirmed by the results of the heterogeneity analysis, demonstrating "strong" heterogeneity ($I^2_{residual}$ = 84.4%); [c] The study assessed population, exposure and outcome of interest. [d] We considered the results to be imprecise: The standard deviation of the reported effect size was larger than the mean difference in BMI; [e] Since the number of available estimates was small, it was not possible to test for publication bias or small study bias; [f] In one of the evaluated studies, a harmful effect of noise was found. There was evidence of a non-significant exposure-response gradient: After aggregating the results of the studies, we found a non-significant effect size of 0.03 kg/m^2 per 10 dB. The noise range of the studies under evaluation was ~40–65 dB. This means that if the road traffic noise level increases from 40 to 65 dB, the BMI increased with 0.08 kg/m^2 (this is probably less than 3–5% change in BMI, which is considered clinically significant); [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A47. Summary of findings table for the association between rail traffic noise exposure and the change in Body Mass Index.

Question	**Does Exposure to Rail Traffic Noise Increase the Risk of Obesity**			
People	Adult population (men and women)			
Setting	Residential setting: people living in Stockholm in areas located around the airport (Sweden), and people living in Aarhus or Copenhagen (Denmark)			
Outcome	Change in BMI (kg/m^3)			
Summary of findings	Change in BMI per 10 dB increase in rail traffic noise level (L_{DEN})		-	
	Number of participants (# studies)		57,531 (2)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Limited [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			1 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as high; [b] Results varied between the studies; [c] Results across studies differed in the magnitude of effect estimates. The direction of the effects was consistent; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be precise: For both studies, the standard deviations of the reported effect were smaller than the reported effect size; [e] Since the number of available estimates was small, it was not possible to test for publication bias or small study bias; [f] Both studies found a harmful effect of rail traffic noise. We decided not to carry out a meta-analysis; [g] Residual confounding primarily due to the way exposure was assessed, cannot be ruled out. For the other factors, we were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A48. Summary of findings table for the association between aircraft noise exposure and the change in waist circumference.

Question	**Does Exposure to Aircraft Noise Increase the Risk of Obesity**	
People	Adult population (men and women)	
Setting	Residential setting: people living in Stockholm in areas located around the airport	
Outcome	Change in waist circumference (cm)	
Summary of findings	Change in waist circumference per 10 dB increase in aircraft noise level (L_{DEN})	3.46 (95% CI: 2.13–4.77) cm
	Number of participants (# studies)	5156 (1)
	Number of cases	NR

Table A48. *Cont.*

			Rating	Adjustment to rating
Quality assessment	**Starting rating**		1 cohort study #	4 (high)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	NA [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Limited [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Large [f]	Upgrading
		Exposure-response gradient	Evidence of a significant exposure-response gradient [f]	Upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			3 (moderate) [h]

Since a cohort study was available, we started with a grading of "high" (4); [a] The quality of the study was judged as high; [b] Since only one study is available, this criterion is not applicable; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results of the study to be precise: The standard deviation of the reported effect size was smaller than the mean difference in waist circumference; [e] Since the results of only one study were available, it was not possible to test for publication bias or small study bias; [f] The study found a harmful effect of aircraft noise. There was evidence of a significant exposure-response gradient: we found a significant effect size of 3.46 cm per 10 dB. The noise range of the study under evaluation was 48–65 dB. This means that if the air traffic noise level increases from 48 to 65 dB, the waist circumference increased more than 5.88 cm; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate; [h] We graded the overall quality of the evidence to be "high" (4). Because only one study was available, we downgraded the overall quality of evidence to "moderate" (3).

Table A49. Summary of findings table for the association between road traffic noise exposure and the change in waist circumference.

Question	**Does Exposure to Road Traffic Noise Increase the Risk of Obesity**			
People	Adult population (men and women)			
Setting	Residential setting: people living in Stockholm in areas located around the airport (Sweden), people living in Oslo (Norway), People living in Aarhus or Copenhagen (Denmark)			
Outcome	Change in waist circumference (cm)			
Summary of findings	Change in waist circumference per 10 dB increase in road traffic noise level (L_{DEN})		0.17 (95% CI: −0.06–0.40) cm	
	Number of participants (# studies)		71,431 (3)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		3 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	Small [f]	No upgrading
		Exposure-response gradient	Evidence of a non- significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			1 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as high; [b] Results across studies differed in the magnitude and direction of effect estimate (see Figure 8.1 of the complete review). This was confirmed by the results of the heterogeneity analysis, demonstrating "strong" heterogeneity ($I^2_{residual}$ = 84.4%); [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be precise enough: The standard deviation of the reported effect size was smaller than the mean difference in waist circumference; [e] Since the number of available estimates was small, it was not possible to test for publication bias or small study bias; [f] Two studies found a harmful effect of road traffic noise. There was evidence of a non- significant exposure-response gradient: After aggregating the results of the three evaluated studies, we found a non-significant effect size of 0.17 per 10 dB. The noise range of the study under evaluation was ~40–65 dB. This means that if the road traffic noise level increases from 40 to 65 dB, the waist circumference increased with 0.43 cm (this is probably less than 3-5% change in waist circumference, which is considered clinically significant); [g] Residual confounding primarily due to the way exposure was assessed cannot be ruled out. For the rest we were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A50. Summary of findings table for the association between rail traffic noise exposure and the change in waist circumference.

Question	Does Exposure to Rail Traffic Noise Increases the Risk of Obesity			
People	Adult population (men and women)			
Setting	Residential setting: people living in Stockholm in areas located around the airport (Sweden), and people living in Aarhus or Copenhagen (Denmark)			
Outcome	Change in waist circumference (cm)			
Summary of findings	Change in waist circumference per 10 dB increase in rail traffic noise level (L_{DEN})		-	
	Number of participants (# studies)		57,531 (2)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Limited [a]	No downgrading
		Inconsistency	Limited [b]	No downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Limited [d]	No downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			2 (low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as high; [b] Results across studies only differed in magnitude of effect estimates; [c] The study assessed population, exposure and outcome of interest; [d] We considered the results to be precise: For both studies, the standard deviations of the reported effect were smaller than the reported effect size; [e] Since the number of available estimates was small, it was not possible to test for publication bias or small study bias; [f] Both studies found a harmful effect of rail traffic noise. We decided not to carry out a meta-analysis; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Appendix H. Summary of Findings Tables Dealing with Studies on the Impact of Noise on Children's Blood Pressure

This appendix presents the summary of findings tables dealing with the studies on the impact of noise on children's blood pressure. An extensive description and the reasoning behind these tables can be found in the complete review in Section 11.6.

Table A51. Summary of findings table for the association between aircraft noise exposure at home and the change in systolic blood pressure in children.

Question	Does Exposure to Aircraft Noise Affect Blood Pressure			
People	Children (boys and girls)			
Setting	Residential setting: Children (aged 6–11 years) living in cities around Schiphol Amsterdam airport (The Netherlands), London Heathrow (United Kingdom) and Kingsford-Smith airport (Australia)			
Outcome	Change in systolic blood pressure (mmHg)			
Summary of findings	Change in systolic blood pressure level per 10 dB increase in aircraft noise level (L_{DEN})		-	
	Number of participants (# studies)		2013 (2)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	A lot is unclear [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as low, since response rates in both studies were higher than 60%, and because of the difficulty to judge the quality of the blood pressure measurements; [b] One study found a positive effect; the other found a negative effect (see Figure 9.1 of the complete review); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The standard deviation of the reported effect size was larger than the mean difference in blood pressure; [e] Since the results of only two studies were available it was not possible to test for publication bias or small study bias; [f] One of the studies found a harmful effect of noise. It was not possible to combine the results of both studies. A meta-analysis was not carried out; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A52. Summary of findings table for the association between aircraft noise exposure at home and the change in diastolic blood pressure in children.

Question	Does Exposure to Aircraft Noise Affect Blood Pressure			
People	Children (boys and girls)			
Setting	Residential setting: Children (aged 6–11 years) living in cities around Schiphol Amsterdam airport (The Netherlands), London Heathrow (United Kingdom) and Kingsford-Smith airport (Australia)			
Outcome	Change in diastolic blood pressure (mmHg)			
Summary of findings	Change in diastolic blood pressure level per 10 dB increase in aircraft noise level (L_{DEN})		-	
	Number of participants (# studies)		2013 (2)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	A lot is unclear [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as low, since response rates in both studies were higher than 60% and because of the difficulty to judge the quality of the blood pressure measurements; [b] One study found a positive effect; the other found a negative effect (see Figure 9.2 of the complete review); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The standard deviation of the reported effect size was larger than the mean difference in blood pressure; [e] Since the results of only two studies were available it was not possible to test for publication bias or small study bias; [f] One of the evaluated studies found a harmful effect of noise. It was not possible to combine the results of both studies. A meta-analysis was not carried out; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A53. Summary of findings table for the association between aircraft noise exposure at school and the change in systolic blood pressure in children.

Question	Does Exposure to Aircraft Noise Affect Blood Pressure	
People	Children (boys and girls)	
Setting	Educational setting: Children (aged 6–11 years) visiting primary schools in cities around Schiphol Amsterdam airport (The Netherlands), London Heathrow (United Kingdom) and Kingsford-Smith airport (Australia)	
Outcome	Change in systolic blood pressure (mmHg)	
Summary of findings	Change in systolic blood pressure level per 10 dB increase in aircraft noise level (L_{DEN})	-
	Number of participants (# studies)	2013 (2)
	Number of cases	NR

Table A53. *Cont.*

			Rating	Adjustment to rating
Quality assessment	Starting rating		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	A lot is unclear [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started the grading with "low" (2); [a] The quality of the studies was judged as low, since response rates in both studies were higher than 60% and because of the difficulty to judge the quality of the blood pressure measurements; [b] One study found a positive effect; the other found a negative effect (see Figure 9.1 of the complete review); [c] The studies assessed population, exposure and outcome of interest; [d] The standard deviation of the reported effect size was larger than the mean difference in blood pressure; [e] Since the results of only two studies were available it was not possible to test for publication bias or small study bias; [f] It was not possible to combine the results of both studies. A meta-analysis was not carried out; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A54. Summary of findings table for the association between aircraft noise exposure at school and the change in diastolic blood pressure in children.

Question	Does Exposure to Aircraft Noise Affect Blood Pressure			
People	Children (boys and girls)			
Setting	Educational setting: Children (aged 6–11 years) visiting primary schools in cities around Schiphol Amsterdam airport (The Netherlands), London Heathrow (United Kingdom) and Kingsford-Smith airport (Australia)			
Outcome	Change in diastolic blood pressure (mmHg)			
Summary of findings	Change in diastolic blood pressure level per 10 dB increase in aircraft noise level (L_{DEN})		-	
	Number of participants (# studies)		2013 (2)	
	Number of cases		NR	
			Rating	Adjustment to rating
Quality assessment	Starting rating		2 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	A lot is unclear [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	NA [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as low, since response rates in both studies were higher than 60% and because of the difficulty to judge the quality of the blood pressure measurements; [b] One study found a positive effect; the other found a negative effect (see Figure 9.2 of the complete review); [c] The studies assessed population, exposure and outcome of interest; [d] The standard deviation of the reported effect size was larger than the mean difference in blood pressure; [e] Since the results of only two studies were available it was not possible to test for publication bias or small study bias; [f] It was not possible to combine the results of both studies. A meta-analysis was not carried out; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A55. Summary of findings table for the association between road traffic noise exposure at home and the change in systolic blood pressure in children.

Question	**Does Exposure to Road Traffic Noise Affect Blood Pressure**			
People	Children (boys and girls)			
Setting	Residential setting: Children (aged 6–11 years) living in cities in The Netherlands, the United Kingdom, Germany, Croatia, Serbia and the United States of America			
Outcome	Change in systolic blood pressure (mmHg)			
Summary of findings	Change in systolic blood pressure level per 10 dB increase in road traffic noise level (L_{DEN})		0.08 (95% CI: −0.48–0.64) mmHg	
	Number of participants (# studies)		4197 (6)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		6 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as low, since response rates in both studies were higher than 60% and because of the difficulty to judge the quality of the blood pressure measurements. Also studies were not always able to adjust for confounding or were able to attribute individual exposure estimates; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 9.1 of the complete review). This was not confirmed by the results of the heterogeneity analysis, demonstrating only "low" heterogeneity ($I^2_{residual}$ = 8.9%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The standard deviation of the reported effect size was larger than the mean difference in blood pressure; [e] Since the number of available effect estimates was less than 10, it was not possible to test for publication bias or small study bias; [f] Three of the evaluated studies found a harmful effect of noise. There was evidence of a non-significant exposure-response gradient: after combining the results of the evaluated studies, we found a non-significant effect size of 0.08 mmHg per 10 dB. The noise range was ~35–80 dB. This means that if the road traffic noise level increases from 35 to 80 dB, the blood pressure increased with 0.36 mmHg; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A56. Summary of findings table for the association between road traffic noise exposure at home and the change in diastolic blood pressure in children.

Question	**Does Exposure to Road Traffic Noise Affect Blood Pressure**			
People	Children (boys and girls)			
Setting	Residential setting: Children (aged 6–11 years) living in cities in The Netherlands, the United Kingdom, Germany, Croatia, Serbia and the United States of America			
Outcome	Change in diastolic blood pressure (mmHg)			
Summary of findings	Change in diastolic blood pressure level per 10 dB increase in road traffic noise level (L_{DEN})		0.47 (95% CI: −0.30–1.24) mmHg	
	Number of participants (# studies)		4197 (6)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		6 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	Evidence of a non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as low, since response rates in both studies were higher than 60%, and because of the difficulty to judge the quality of the blood pressure measurements. Also studies were not always able to adjust for confounding or were able to attribute individual exposure estimates; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 9.2 of the complete review). This was confirmed by the results of the heterogeneity analysis, demonstrating "strong" heterogeneity ($I^2_{residual}$ = 76.0%); [c] The studies assessed population, exposure and outcome of interest; [d] The results were considered to be imprecise: The standard deviation of the reported effect size was larger than the mean difference in blood pressure; [e] Since the number of available effect estimates was less than 10, it was not possible to test for publication bias or small study bias; [f] Three of the evaluated studies found a harmful effect of noise. There was evidence of a non-significant exposure-response gradient: After combining the results of the evaluated studies we found a non-significant effect size of 0.47 mmHg per 10 dB. The noise range was ~35–80 dB. This means that if the road traffic noise level increases from 35 to 80 dB, the blood pressure increased with 2.1 mmHg; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A57. Summary of findings table for the association between road traffic noise exposure at school and the change in systolic blood pressure in children.

Question	**Does Exposure to Road Traffic Noise Affects Blood Pressure**			
People	Children (boys and girls)			
Setting	Educational setting: Children (aged 6–11 years) living in cities in The Netherlands, the United Kingdom, Croatia, Serbia and the United States of America			
Outcome	Change in systolic blood pressure (mmHg)			
Summary of findings	Change in systolic blood pressure level per 10 dB increase in road traffic noise level (L_{DEN})		−0.60 (95% CI: −1.51–0.30) mmHg	
	Number of participants (# studies)		4520 (5)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		5 cross-sectional studies #	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	No evidence of an exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since we only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as low, since response rates in both studies were higher than 60% and because of the difficulty to judge the quality of the blood pressure measurements. Also studies were not always able to adjust for confounding or were able to attribute individual exposure estimates; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 9.1 of the complete review). This was confirmed by the results of the heterogeneity analysis, demonstrating "moderate" heterogeneity ($I^2_{residual}$ = 61.6%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The standard deviation of the reported effect size was larger than the mean difference in blood pressure; [e] Since the number of available effect estimates was less than 10, it was not possible to test for publication bias or small study bias; [f] Three studies found a harmful effect. There was no evidence of an exposure-response gradient: after combining the results of the evaluated studies, we found a non-significant effect size of −0.60 mmHg per 10 dB; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

Table A58. Summary of findings table for the association between road traffic noise exposure at school and the change in diastolic blood pressure in children.

Question	**Does Exposure to Road Traffic Noise Affect Blood Pressure**			
People	Children (boys and girls)			
Setting	Educational setting: Children (aged 6–11 years) living in cities in The Netherlands, the United Kingdom, Croatia, Serbia and the United States of America			
Outcome	Change in diastolic blood pressure (mmHg)			
Summary of findings	Change in diastolic blood pressure level per 10 dB increase in road traffic noise level (L_{DEN})		0.46 (95% CI: −0.60–1.53) mmHg	
	Number of participants (# studies)		4520 (5)	
	Number of cases		NR	
			Rating	**Adjustment to rating**
Quality assessment	**Starting rating**		5 cross-sectional studies#	2 (low)
	Factors decreasing confidence	Risk of bias	Serious [a]	Downgrading
		Inconsistency	Serious [b]	Downgrading
		Indirectness	None [c]	No downgrading
		Imprecision	Serious [d]	Downgrading
		Publication bias	NA [e]	No downgrading
	Factors increasing confidence	Strength of association	NA [f]	No upgrading
		Exposure-response gradient	Evidence of a statistically non-significant exposure-response gradient [f]	No upgrading
		Possible confounding	No conclusions can be drawn [g]	No upgrading
	Overall judgement of quality of evidence			0 (very low)

Since only cross-sectional studies were available, we started with a grading of "low" (2); [a] The quality of the studies was judged as low, since response rates in both studies were higher than 60% and because of the difficulty to judge the quality of the blood pressure measurements. Also studies were not always able to adjust for confounding or were able to attribute individual exposure estimates; [b] Results across studies differed in the magnitude and direction of effect estimates (see Figure 9.1 of the complete review). This was not confirmed by the results of the heterogeneity analysis, demonstrating "low" heterogeneity ($I^2_{residual}$ = 16.0%); [c] The studies assessed population, exposure and outcome of interest; [d] We considered the results to be imprecise: The standard deviation of the reported effect size was larger than the mean difference in blood pressure; [e] Since the number of available effect estimates was less than 10, it was not possible to test for publication bias or small study bias; [f] There was evidence of a statistically non-significant exposure-response gradient: after combining the results of the evaluated studies, we found a non-significant effect size of 0.46 mmHg per 10 dB. The noise range was ~35–80 dB. This means that if the road traffic noise level increases from 35 to 80 dB, the blood pressure increased with 2.1 mmHg; [g] We were not able to draw any conclusions whether possible residual confounders or biases would reduce our effect estimate.

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Emissions from an International Airport Increase Particle Number Concentrations 4-fold at 10 km Downwind

Neelakshi Hudda,[†] Tim Gould,[‡] Kris Hartin,[§] Timothy V. Larson,[‡] and Scott A. Fruin*[,†,∥]

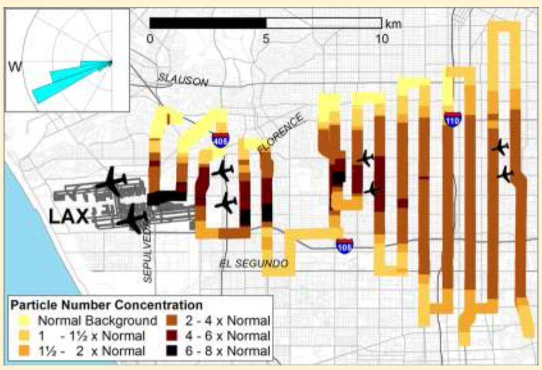
[†]Keck School of Medicine, Department of Preventive Medicine, University of Southern California, Los Angeles, California 90089, United States

[‡]Department of Civil and Environmental Engineering, University of Washington, Seattle, Washington 98195, United States

[§]Department of Environmental and Occupational Health Sciences, University of Washington, Seattle, Washington 98195, United States

Supporting Information

ABSTRACT: We measured the spatial pattern of particle number (PN) concentrations downwind from the Los Angeles International Airport (LAX) with an instrumented vehicle that enabled us to cover larger areas than allowed by traditional stationary measurements. LAX emissions adversely impacted air quality much farther than reported in previous airport studies. We measured at least a 2-fold increase in PN concentrations over unimpacted baseline PN concentrations during most hours of the day in an area of about 60 km^2 that extended to 16 km (10 miles) downwind and a 4- to 5-fold increase to 8–10 km (5–6 miles) downwind. Locations of maximum PN concentrations were aligned to eastern, downwind jet trajectories during prevailing westerly winds and to 8 km downwind concentrations exceeded 75 000 particles/cm^3, more than the average freeway PN concentration in Los Angeles. During infrequent northerly winds, the impact area remained large but shifted to south of the airport. The freeway length that would cause an impact equivalent to that measured in this study (i.e., PN concentration increases weighted by the area impacted) was estimated to be 280–790 km. The total freeway length in Los Angeles is 1500 km. These results suggest that airport emissions are a major source of PN in Los Angeles that are of the same general magnitude as the entire urban freeway network. They also indicate that the air quality impact areas of major airports may have been seriously underestimated.



INTRODUCTION

Previous studies that directly measured the impact of aviation activity on air quality have mostly conducted measurements in close proximity of airports. Few studies have reported significant air quality impacts extending beyond a kilometer.[1−4] Carslaw et al. 2006[1] analyzed differences in pollutant concentrations by wind speed and direction along with differences in aircraft and ground traffic activity at Heathrow Airport in London. They found airport contributions of up to 15% of total oxides of nitrogen (NO_x) at a site 1.5 km downwind of the nearest runway. At Hong Kong International Airport, Yu et al. 2004[2] used nonparametric regression analysis on pollutant concentrations by wind speed and direction. They calculated that aircraft nearly doubled sulfur dioxide concentrations 3 km away and also increased concentrations of carbon monoxide and respirable suspended particles under similar wind speeds and directions. Fanning et al. 2007[3] measured particle numbers concentrations in the 10−100 nm range and found significant increases above background at 1.9, 2.7, and 3.3 km downwind of the Los Angeles International Airport (LAX) blast fence. Although measurements were stationary and not concurrent, they also noted that takeoffs produced high concentrations and downwind gradients within 600 m of the blast fence. Dodson et al. 2009[4] found that aircraft activity at a regional airport in Warwick, RI contributed 24−28% of the total black carbon (BC) measured at five sites 0.16−3.7 km from the airport.

Several other airport and aviation emissions studies focused on quantifying the air quality impacts from jet takeoffs[5,6] and measured air pollutant concentrations very close to runways. Of particular relevance to this study, Hsu et al. 2013[7] linked flight activity at LAX with 1 min average PN concentrations. Their models suggested that aircraft produced a median PN concentration of nearly 150 000 particles/cm^3 at the end of the departure runway. PN concentrations decreased rapidly with distance to 19 000 particles/cm^3 at a location 250 m downwind and to 17 000 particles/cm^3 at a location 500 m further downwind. The rapid drop-off in concentration, however, may have reflected an increasing offset from the centerline of impacts with greater downwind measurement distance. Similar magnitude PN concentrations and correlations

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with departures were reported by Westerdahl et al. 2008[8] and Zhu et al. 2011[9] at sites located within 100−200 m of the Hsu et al. 2013[7] measurements.

Our study was motivated by mobile monitoring platform (MMP) based observations of large but gradual increases in PN concentrations as we approached locations under LAX jet landing trajectories on multiple transects up to 10 km downwind of LAX. We hypothesized that emissions from LAX activities were increasing PN concentrations over much larger areas and longer downwind distances than previously observed in studies that focused on near freeway and jet takeoff impacts to air quality. An extensive monitoring campaign confirmed that LAX-related emissions increased PN concentrations downwind at least 2-fold to 16 km. This large, previously undiscovered spatial extent of the air quality impacts downwind of major airports may mean a significant fraction of urban dwellers living near airports likely receive most of their outdoor PN exposure from airports rather than roadway traffic.

MATERIALS AND METHODS

Monitoring Area. LAX is the sixth busiest airport in the world and third busiest in the United States. About 95% of flights take off and land into the prevailing westerly/west-southwesterly (W/WSW) onshore winds[10] (i.e., 263 degrees, the direction of runway alignment[2]) using two sets of parallel runways separated by about 1.5 km. In the busiest hours, 40−60 jets per hour arrive during hours 0700−1900 and depart during hours 0800−2100. Reduced activity is typical for the early morning and late evening hours. 20−40 jets per hour arrive during hours 0600 and 1000−0100 and depart during hours 0700 and 2200−2300. During other hours typically fewer than five jets per hour arrive or depart.[10]

The airport complex is about 4.5 km east to west (E-W) and about 2.5 km north to south (N−S) and is surrounded by major roadways and freeways, as highlighted in Figure 1 (Figure S.1 in Supporting Information (SI) shows a map of this area with street name labels). The Federal Aviation Administration noise contours of the modeled annual 65 dB A-weighted equivalent (L_{Aeq}) noise threshold are shown[11] extending eastward along the predominant downwind direction and reflect the jet trajectories used for landing. They also extend west of the airport over the Pacific Ocean (not shown).

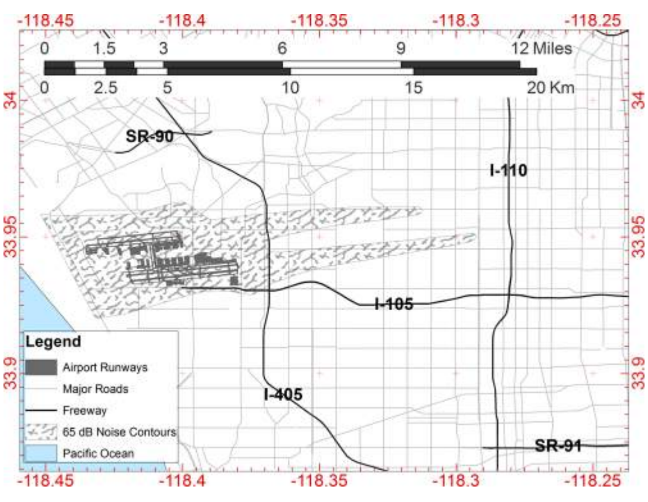

Figure 1. Los Angeles International Airport and 65 dB noise contours indicating eastern jet trajectories.

Mobile Monitoring. Monitoring consisted of transects 4−16 km in length, nearly perpendicular (i.e., N−S) to the direction of the prevailing winds, at varying downwind distances. Different monitoring routes were required to fully capture the changes in impact locations due to shifts in wind direction. A general downwind direction was chosen based on meteorological predictions but transect lengths and locations were determined during the monitoring run based on observations of the rate of change of PN concentrations. For each transect, monitoring was extended several hundred meters beyond the location where baseline PN concentrations appeared stable.

Measurements were conducted over 29 days with the University of Southern California (USC) MMP, a gasoline-powered hybrid vehicle. A second MMP, the University of Washington (UW) MMP, a gasoline-powered minivan, joined the monitoring on 3 days (June 22, 27 and July 1, 2013). Table 1 gives monitoring dates and times.

Most measurements were conducted during times of onshore westerly winds, typically strongest during 1100−1600, but we also conducted measurements during early morning and late night hours when air traffic was low and onshore winds were reduced (August 13, 16, 23, 24 and 25, December 03, 09, 15 and 16, 2013). Monitoring focused on the area east of LAX (i.e., the predominant downwind direction) but included several runs along the boundary of the airport in the upwind direction and south of the airport complex during occasions of northerly winds in winter months.

Instrumentation. Concentration measurements included PN, BC, NO, NO_2, NO_x, and particle surface UV-photo-ionization potential (measured using Ecochem Photoelectric Aerosol Sensor [PAS] that responds to elemental carbon and particle-bound polycyclic aromatic hydrocarbons [PB−PAH]). Instrument details are provided in SI (Table S.1 and S.2). Instruments were powered by two deep-cycle marine batteries via DC-to-AC inverter. Our power arrangement allowed for 5 h of run time if all instruments were running. For sampling runs that were anticipated to exceed 5 h, several instruments were shut down to extend battery life and the Condensation Particle Counter (CPC) was run on the vehicle's 12 V cell phone power outlet. If other instruments were turned on later, the required warm-up time was 25 min.

Instrument clock times were regularly synchronized to be within 1 s of the global positioning system device time, which also recorded speed and location. Measurements from instruments with a delayed response time were advanced to match the instantaneous instruments and the GPS time and location recorded at 1 s intervals. For pollutant measurements recorded at 10 s intervals, all locations within the recording interval were assigned the pollutant value reported for that interval.

Meteorological Data. Minute and hourly wind speed and wind direction data were obtained from the Automated Surface Observing Systems monitor at LAX airport (latitude 33.943 and longitude −118.407). Due to the 16 km distance between eastern edge of the study area and the meteorological station located at LAX, we could not assume that wind speed and direction were identical to those measured at LAX, but wind direction in this region of Los Angeles tends to be similar over large areas during daytime.[12]

The average wind direction at LAX is WSW (252°).[12] Daytime southwesterly sea breezes typically occur 16 h per day in the summer (0900−0100 for June−August), decreasing to 6

Table 1. Sampling Days, Time Periods and Meteorological Conditions during Sampling

date[a]	time	sampling distance from LAX (km)	WD[b]	WS (m/s)	urban background PN[c]	ratio of impacted to unimpacted baseline PN, 10 km downwind
4/6/2011	14:30–16:45	8–12	WSW, **W**	5.0 ± 1.8	15 000	2.0
4/10/2011	15:00–17:30	8–12	**W**	6.9 ± 1.2	10 000	4.5
5/24/2011	09:00–11:00	8–12	**Calm**, W	1.0 ± 2.5	10 000	3.0
5/27/2011	12:15–14:45	8–12	WSW, **W**	6.3 ± 1.3	10 000	4.7
1/26/2012	17:28–20:22	8–12	WSW, **W**	2.9 ± 2.1	20 000	6.0
9/29/2012	13:30–17:30	0–8	**W**	6.1 ± 1.1	10 000	3.7
9/30/2012	15:45–18:30	0–8	**W**	6.1 ± 0.4	5000	5.2
6/11/2013	14:14–15:14	2.5–8.5	**WSW**, W	6.7 ± 0.0	15 000	5.0
6/12/2013	13:30–16:30	2.5–10.5	**W**	4.0 ± 0.4	15 000	4.0
6/22/2013	11:47–18:50[d]	0–8	WSW, **W**	5.7 ± 0.4	10 000	4.4
6/27/2013	11:49–18:00[d]	0–8	WSW, **W**	5.3 ± 0.7	10 000	4.0
7/01/2013	10:30–18:30[d]	0–8	**W**, ESE	3.8 ± 1.0	15 000	3.8[e]
8/6,7/2013	23:56–02:45	0–8	WSW, W, S	3.3 ± 0.7	10 000	3.3
8/13/2013	06:30–15:00	0–8	Calm, WSW, **W**, NNE, NE, ENE, E, ESE[f]	3.0 ± 2.0	10 000	4.0
8/15/2013	08:30–15:30	0–16	Calm, WSW,**W**	2.5 ± 2.1	20 000	3.8
8/16/2013	09:45–20:50	0–16	SW, WSW,**W**, WNW	4.4 ± 1.3	10 000	3.0
8/23,24/2013	12:00–01:30	0–16	SSW, WSW,**W**	4.4 ± 2.2	20 000	4.0, 5.0
8/24,25/2013[g]	17:30–01:00	0–16	Calm, SSW, SW, WSW,**W**, ESE	3.1 ± 2.1	15 000	6.0
11/1/2013	16:00–19:50	0–12	SSE, W, **WSW**	3.7 ± 0.7	10 000	3.8[e]
12/3/2013	19:45–00:20	0–12	**WSW, W, WNW**	8.8 ± 1.4	5000	6.0
12/5/2013	13:00–18:30	0–12	WSW, **W**, WNW	5.5 ± 0.6	10 000	2.8
12/9/2013	16:00–00:00	0–10	**N**, NNE	2.7 ± 0.6	20 000	n/a
12/10/2013	15:30–21:30	0–10	**WNW,N**, NW	3.1 ± 1.1	20 000	5.0
12/14/2013	17:00–20:30	0–10	W, Calm	2.1 ± 0.5	20 000	data lost
12/15,16/2013	22:00–02:00	0–10	N, **NE**, ESE	2.9 ± 1.0	17 500	n/a
12/16/2013	10:00–16:00	0–12	**N, W**	2.8 ± 1.6	10 000	4.5
12/18/2013	17:30–20:30	0–10	**WSW**, SSW, SSE	3.3 ± 1.3	10 000	6.0
12/20/2013	16:30–20:00	0–10	**WSW, Calm**, E	2.6 ± 1.3	15 000	4.0
12/23/2013	15:15–19:00	0–12	**W**, Calm, E	2.8 ± 1.3	10 000	11.0

[a]The runs for which maps are presented are formatted in bold. [b]Predominant wind direction is formatted as bold. [c]Urban background value concentrations are reported to nearest 2500 particles/cm^3 and are the average baseline values in the unimpacted areas away from local traffic sources [d]Concurrent MMP sampling times: June 22:1320–1720, June 27:1325–1510, July 1:1240–1640. [e]Monitoring route did not cover the full N–S extent of the impact on Western Av (10 km downwind) on these days, values have been reported for Crenshaw Blvd. (8 km downwind). [f]Easterly flow was recorded in morning hours (until 1000) and westerly later morning to afternoon [g]08/25/2013 was not counted as an additional monitoring day because only 1 h of monitoring (0000–0100) was conducted on this date

h in the winter (1200–1800 in December). Only during the winter months (November–February, 0000–0900) are light easterly off-shore winds common.[12] Wind speed and direction during the monitoring periods are summarized in Table 1. Wind roses based on 1 min data are shown in Figure S.2 and S.3 of the SI.

Data Processing. MMP measurements included a localized traffic emissions signal representing microscale and middle scale variations (10–100 m and 100–500 m, respectively) and an underlying "baseline" pollutant concentration that varied gradually over the neighborhood scale (500 m–4 km).[13] Watson et al. 1997[13] derived these categories by considering the spatial scales of impact of various types of air pollution sources. We adopted a smoothing methodology to estimate baseline PN concentrations that excluded the microscale and middle scale impacts due to local sources, usually specific vehicles.

Baseline PN concentrations were derived from our mobile measurements by taking a rolling 30-s fifth percentile value of the 1-s concentration time series, and assigning that value to the measured location. This removed the microscale and middle scale impacts from traffic sources such as specific vehicle plumes. Baseline concentrations for a run were relatively spatially uniform outside of the LAX impact areas, with coefficients of variation (CV) of less than 5%. In comparison, the raw PN concentrations on roadways outside the LAX impact areas had CVs on the order of 40%. On rare occasions, the MMP was behind a high emitter for longer than 30 s. Such events, only if verifiable by video and field notes, were censored. However, less than 0.5% of data were censored in this manner, generated from about a dozen instances of prolonged influence from high emitting vehicles. An illustration of both raw and smoothed concentration time series is presented in the SI (Figures S.4–S.7). The figures in this text are based on smoothed data.

RESULTS AND DISCUSSION

Spatial Pattern and Extent of Elevated PN Concentrations. Downwind of LAX we observed gradual but large increases in baseline PN concentrations occurring over transect distances of multiple kilometers. PN concentrations were elevated 4-fold or more above nearby unimpacted baseline concentrations up to 10 km in the downwind direction from

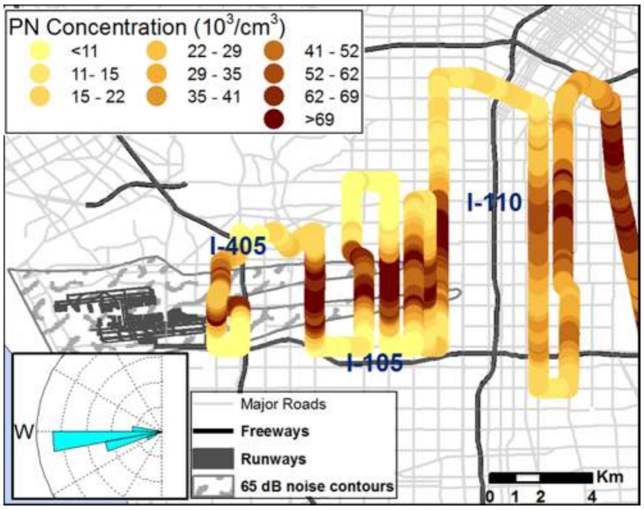

Figure 2. Spatial pattern of PN concentration (colored by deciles) for the afternoon and evening hours of August 23, 2013.

LAX. Figure 2 shows an example of the spatial pattern of the elevated PN concentrations.

The size of the impacted areas with high PN concentration increases was remarkable. At 16 km downwind, a 2-fold increase in PN concentration over baseline concentrations was measured across 6.5 km. Assuming a trapezoidal shaped plume with parallel edges of length 1.5 and 6.5 km, PN concentrations were at least doubled over an area of 60 km^2. Eight km downwind, a 5-fold increase in PN concentrations over baseline concentrations extended across 3 km and covered a total area of 24 km^2. (Concentrations in this large area exceeded 71 000 particles/cm^3, the average concentration on Los Angeles freeways.[14]) Within 3 km of the airport boundary, concentrations were elevated nearly 10-fold, exceeding 100 000 particles/cm^3, with concentrations of 150 000 particles/cm^3 occurring over a several km^2 area.

This pattern of elevated PN concentrations over large areas east of LAX was consistently observed during periods when there were both westerly winds and high air traffic volumes, typically all daylight hours and well into the night. Figure 3

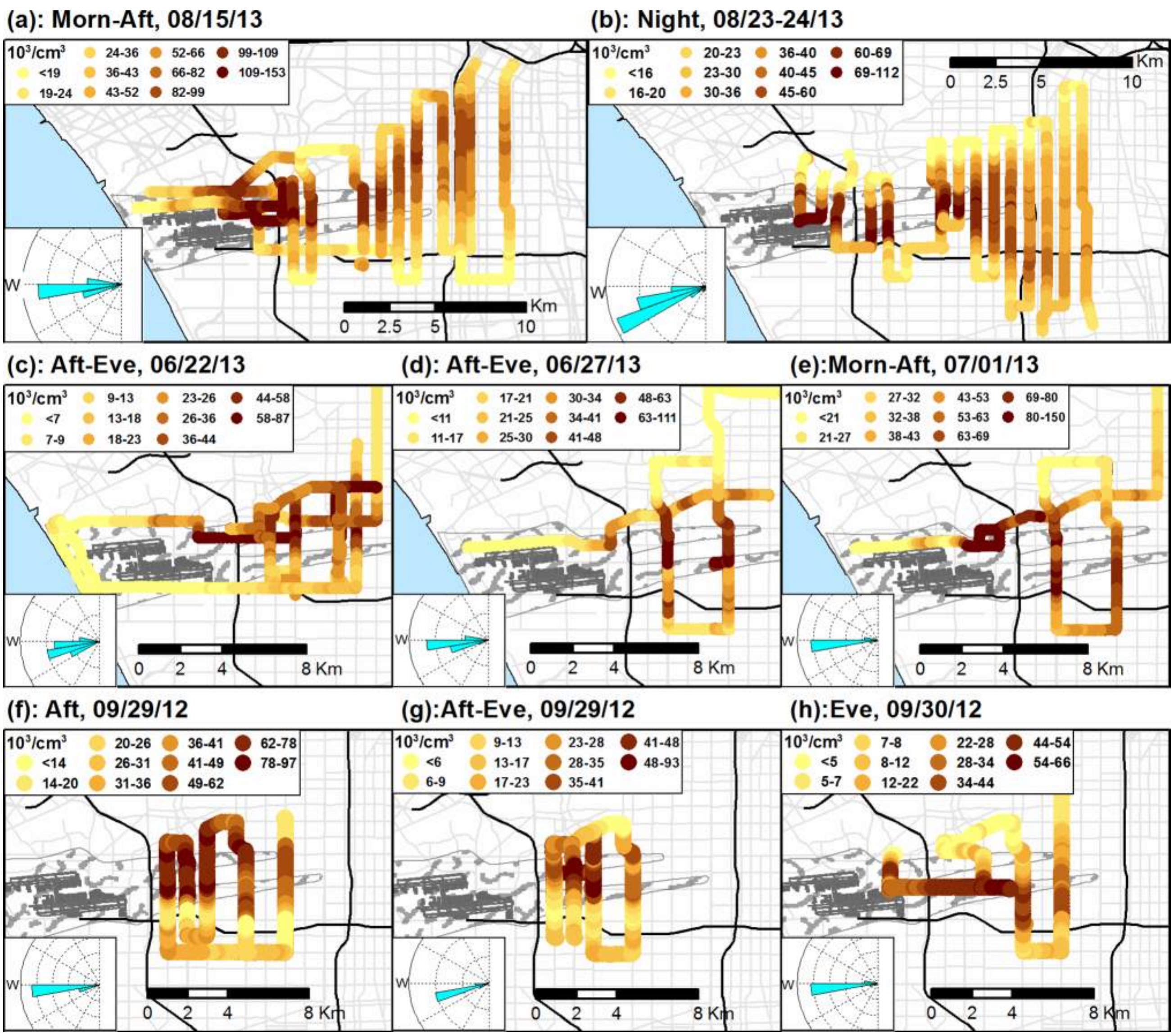

Figure 3. Spatial pattern of impact during different monitoring events. Wind direction during monitoring is shown in insets on bottom left. PN concentrations are classified and colored by deciles.

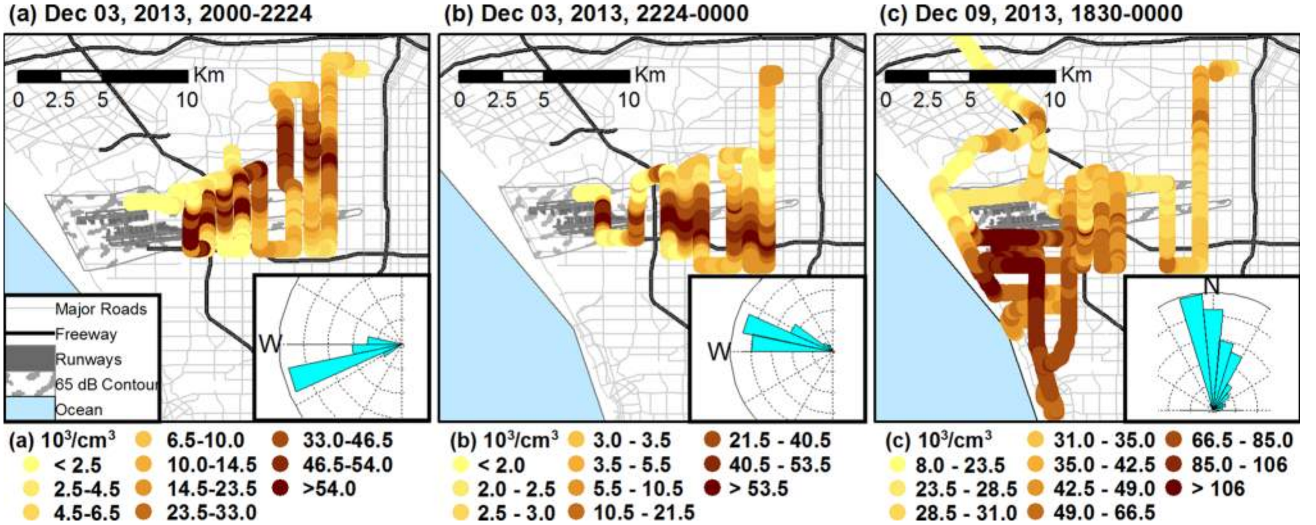

Figure 4. Change in location of impact due to shift in wind direction. Wind direction during monitoring is shown in insets on bottom left. PN concentrations are classified and colored by deciles.

shows the consistency of the patterns over eight monitoring runs at various times of day, displayed in each row by similarity of spatial scale.

In directions other than the downwind direction, no large areas of elevated PN concentrations were observed. Figures 3(c)−(e) include concentrations measured upwind of the LAX boundary (these are indicated by faint yellow lines within the noise contour); the concentrations recorded were typical of the coastal baseline concentrations, less than 10 000 particles per cm^3 (also see Figure S.8 in SI). Of possible other PN sources, a large refinery is located south of the airport but we did not observe elevated PN or other pollutant concentrations directly downwind of this source. In general, industrial point sources of pollution in the Los Angeles Air Basin are very tightly regulated by the South Coast Air Quality Management District.

We did not observe distinct day versus night differences, as might be expected based on the large change in meteorologically driven dilution between day and night for ground level sources. It appeared that the distant impacts we observed downwind of LAX required sufficient wind speeds for the jet climbing and landing emissions to reach the ground, as observed in Yu et al., 2004[2] at LAX and Hong Kong International Airports and Carslaw et al. 2006[1] at Heathrow Airport. At LAX, this probably corresponded to the development of the on-shore sea breezes that typically started 4−6 h after sunrise and lasted until 3−6 h after sunset.[12]

We also did not see the impacts of individual jets at the distances monitored, but the merging of individual jet impacts is not unexpected at distances of multiple km. Considering the frequency of landings and takeoffs (>90 per hour from 0900−2100[10]), at an average wind speed of 4 m/s, for example, an incoming parcel of air will travel only about 160 m before another jet landing or takeoff occurs. Under normal daytime air turbulence and the enhanced turbulence produced by jets,[15,16] significant mixing is expected over a 5−10 km distance (20−40 min). The generally smooth increases and decreases observed across the length of transects at such distances are additional evidence that mixing of plumes occurs. Examples of these smooth concentration increases for individual transects are shown in Figures S.6 and S.7 in the SI.

The consistent and distinctive spatial pattern of elevated concentrations was aligned to prevailing westerly winds and landing jet trajectories, and roughly followed the shape of the contours of noise from landing jets, indicating that landing jets probably are an important contributor to the large downwind spatial extent of elevated PN concentrations. As defined by the International Civil Aviation Organization, typical engine thrust during landing is 30%, as compared to 100% for takeoff and 85% for the climbing phase.[6] Stettler et al. 2011[6] calculated 18% of total NO_x emissions from landings, with 12% from taxiing and holding, 18% from takeoff, and 52% from the climb and climb out phases, respectively. When the extra upwind distance of the climb and climb out phases are taken into account, the landing approach emissions likely produce a significant fraction of the increased PN concentrations observed downwind.

Influence of Wind Direction on Location of Impact. The downwind location of the impact changed with shifts in the prevailing wind direction, although significant shifts in wind direction during the daytime are not typical of this area of Los Angeles.[12] Figure 4(a) and (b) illustrate one such change in impacted locations due to a shift in wind direction on a gusty day with frontal weather that also resulted in cleaner upwind baseline PN concentrations of less than 5000 particles/cm^3. The impacted locations were aligned along the NE direction during 2000−2220 h when winds were from W to WSW (250−280°). The impact then moved southwards between 2220−0000 h as winds turned more W to WNW (280−330°). During this shift, the impact centerline moved by 5.5 km on transects 8−10 km east of LAX.

Monitoring was also conducted during N to NE prevailing winds that tend to occur late at night in November and December (2100−2300).[12] This N to NE wind direction resulted in impacts that were centered south of the airport (Figure 4(c)). The PN concentrations in this southerly impact were roughly twice as high as on other days, in part because the baseline PN concentrations reflected urban air from northerly winds instead of marine air from westerly winds.

Diurnal wind patterns change little by season in Los Angeles basin.[12] Onshore westerly winds are common during midday hours, even in winter. As a result, areas of elevated PN

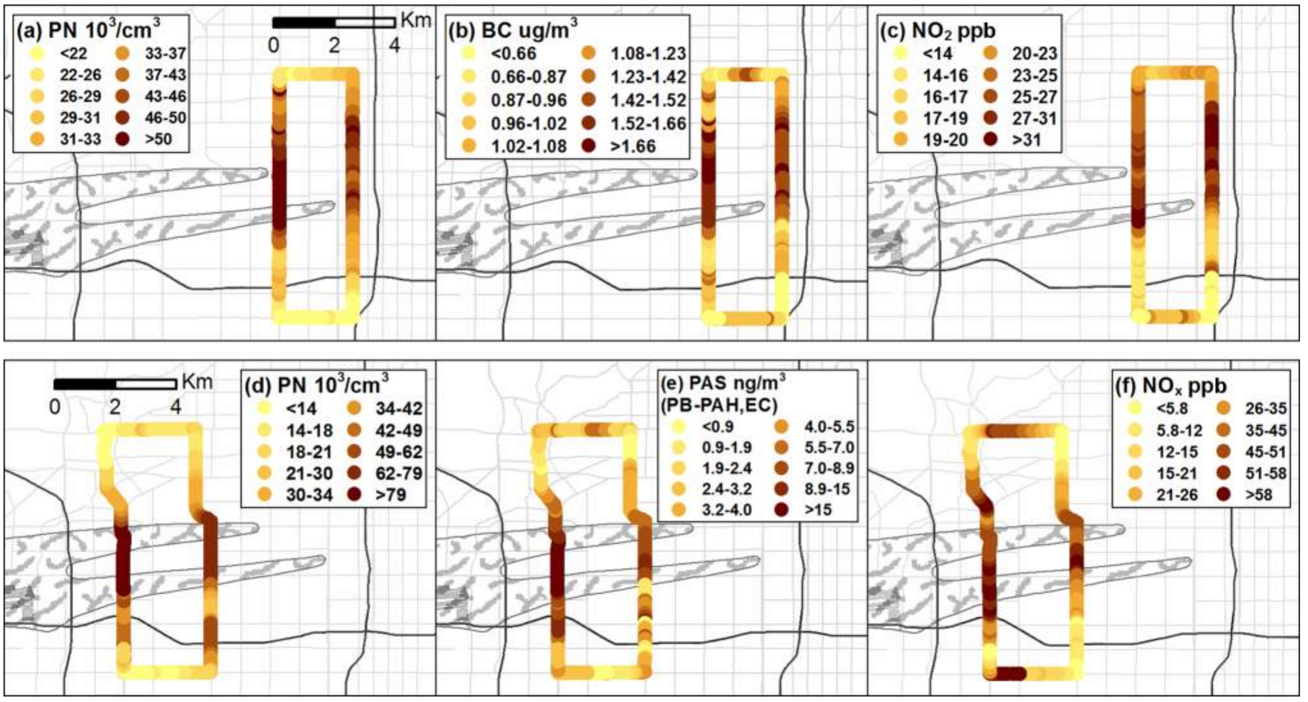

Figure 5. Spatial pattern of simultaneously measured pollutants during 1400−1530 on June 27, 2013. Concentrations are classified and colored by deciles. Panels (a)−(c) show data measured by the UW MMP and (d)−(f) show data measured by the USC MMP.

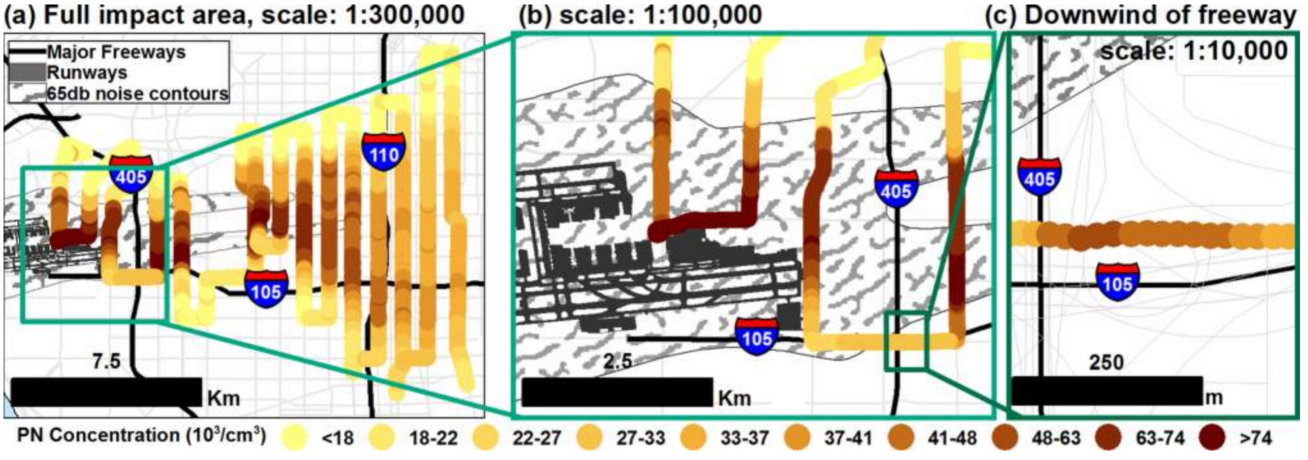

Figure 6. Comparison of the spatial scale of freeway impacts compared to airport impacts for monitoring during nighttime on August 23−24, 2013.

concentrations downwind and east of LAX likely occur in all seasons. Monitoring in different seasons demonstrated the consistent year round presence of this impact. Examples of similarly extensive impacts in non-summer months are shown in the SI (Figures S.8 and S.9).

Other Pollutants. Over large areas downwind of LAX, concentrations of pollutants other than PN were also elevated. Figure 5(a)−(c) show nearly indistinguishable spatial patterns for PN, BC, and NO_2 concentration measured simultaneously at distances of 9.5−12 km from LAX. This suggests a common source for these pollutants, although the BC concentration increases were not large when compared to PN and NO_x, about 0.5−1 $\mu g/m^3$ at 8−10 km downwind. While jet aircraft are not known to produce large amounts of BC, two studies found elevated BC from plane takeoffs at LAX. Zhu et al. 2011[9] measured an increase of about 1 $\mu g/m^3$ of BC due to plane activity 140 m downwind of the runway. Westerdahl et al. 2008[8] measured increases in BC concentration of several $\mu g/m^3$ during takeoff events near the eastern LAX boundary, but also observed elevated BC concentrations at all times. At a smaller airport, Dodson et al. 2009[4] found median contributions of about 0.1 $\mu g/m^3$, about one-quarter of total BC measured at five sites ranging in downwind distance from 0.3−3.7 km, and also observed departures producing about twice the impact as arrivals. Therefore, it appears some jets at LAX are capable of producing measurable increases in BC, particularly at takeoffs.

Spatial patterns of simultaneously measured PN and PAS response (PB−PAH and EC) were also similar on transects 4.5−7.5 km from LAX (Figure 5(d)−(e)). The NO_X elevation pattern was less regular (Figure 5(f)). This was likely due to smaller LAX related contributions compared to baseline concentrations, thus reducing the signal-to-noise ratio.

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Overall, the top quartile concentrations (highly impacted) of all pollutants were about three times higher than the lowest quartile within 7.5 km from LAX and two times higher at 12 km distance. In addition, concurrent sampling with the two mobile platforms demonstrated high temporal (SI Figure S.10) and spatial consistency (SI Figure S.11) for PN measurements.

Comparison of LAX and Freeway PN Impacts. PN concentration increases from ground level line sources such as freeways, under conditions of daytime crosswind dilution, decrease exponentially with increasing downwind distance and return to baseline concentrations within 200−300 m.[17] The two N−S freeways (I-405 and I-110 that run perpendicular to the prevailing winds) did not contribute appreciably to elevated PN concentrations in areas where we observed large impacts from LAX on PN concentrations. This is illustrated in Figure 6, which contains two enlargements to show the increase in PN number concentrations over approximately 250 m distance downwind of I-405, a distance and an increase in PN concentration that is not discernible at the scale of Figures 2 and 3. The panel in Figure 6(c) at 1:10 000 scale shows the PN concentration increase of about 24 000/cm^3. The maximum PN concentration was not immediately downwind of the freeway because at this location there is an elevated overpass and some distance is needed for emissions to reach the ground.

To put into further perspective the extent of the elevated PN concentrations observed downwind of LAX, we estimated the freeway length necessary to produce an equivalent impact in terms of PN concentration-weighted area of impact assuming typical daytime dilution conditions for freeways.

For the days we captured the fullest downwind extent of the impact under typical daytime wind conditions (August 15, 23, and 24), we calculated an integrated PN impact above baseline PN concentrations of 2.3, 1.6, and 1.1 × 10^6 (particles/cm^3) × km^2, respectively. See Table S.3(a)−(c) of SI for calculations. Impacted areas were calculated using ArcGIS spatial analysis tools and were conservatively defined as areas where increased PN concentration were at least double the baseline concentrations measured north and south of the impact zone. The resulting impact areas were 30−65 km^2. For comparison, a less conservative criterion for defining the impact area such as a 50% or 33% increase over baseline PN concentrations increased the impacted area by 40% and 80%, respectively.

To calculate PN impacts downwind of freeways, we combined the exponential regression fit of near-freeway measurements made downwind of I-405 by Zhu et al. 2002a[18] with updated average daytime on-freeway PN concentrations taken from Li et al. 2013[14] (71 000 particles/cm^3). PN concentrations were at least double the baseline PN concentrations of 15 000−20 000 particles/cm^3 for 90−130 m downwind.[3] This resulted in a concentration-weighted impact area of 2930−3930 (particles/cm^3) × km^2 per km of freeway length.

Based on these concentration-weighted impact areas, 280−790 km of freeway are needed to produce the equivalent PN-concentration-weighted impact area of LAX. (The less conservative criteria resulted in ranges of freeway length of 340−1000 km and 430−1100 km for thresholds of 50% and 33%, respectively.) There are only about 1500 km of freeways and highways in Los Angeles County.[19] Therefore, LAX should be considered one of the most important sources of PN in Los Angeles. For comparison, within the 60 km^2 area of elevated PN concentrations downwind and east of LAX, the 15−25 km of freeways contributed less than 5% of the PN concentration increase.

Recommendations for Other Studies. LAX is in a region of Los Angeles with highly consistent wind direction. This provided the several hours necessary for a single mobile platform to monitor a sufficient number of transects to cover the large area impacted by LAX emissions. At airport locations where the prevailing wind direction frequently shifts during the day, multiple platforms would be necessary to quickly capture the full spatial extent of emissions impacts to surrounding air quality.

The emissions from LAX are likely not unique on a per-activity basis. The large area of impact from LAX suggests that air pollution studies involving PN, localized roadway impacts, or other sources whose impacts are in the influence zone of a large airport should carefully consider wind conditions and whether measurements are influenced by airport emissions.

Source apportionment of specific airport sources or activities was beyond the scope of our study but would be necessary to evaluate the effectiveness of possible mitigation options. Differing NO_2 to NO_x ratios at different levels of engine thrust[20] might be used to distinguish the contributions of jet landing, idling or takeoff activities. Takeoff and idling emission also differ in surface properties (i.e., the ratio of active surface area to surface bound photoionizable species)[21] and particle size distributions differ between aircraft and ground support equipment emissions.[21]

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

Map of monitoring area (Figure S.1), the instruments used (Tables S.1−S.2), wind roses (Figures S.2 and S.3), illustration of data processing (Figures S.4−S.7), additional maps illustrating the spatial pattern (Figures S.8 and S.9), concurrent sampling with two mobile measurement platforms (Figures S.10 and S.11) and calculations for comparing freeway impact (Table S.3 (a)−(c)) are presented in the Supporting Information. This material is available free of charge via the Internet at http://pubs.acs.org.

■ AUTHOR INFORMATION

Corresponding Author

*Phone: 323-442-2870; fax: 323-442-3272; e-mail: fruin@usc.edu.

Present Address

‖S.A.F.: Keck School of Medicine, Department of Preventive Medicine, University of Southern California, 2001 North Soto Street, Los Angeles, CA 90089-9013, United States.

Notes

The authors declare no competing financial interest.

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Aviation-Related Impacts on Ultrafine Particle Number Concentrations Outside and Inside Residences near an Airport

N. Hudda,*[,†] M.C. Simon,[†,‡] W. Zamore,[§] and J. L. Durant[†]

[†]Department of Civil and Environmental Engineering, Tufts University, 200 College Ave, 204 Anderson Hall, Medford, Massachusetts 02155, United States

[‡]Department of Environmental Health, Boston University, 715 Albany Street, Boston, Massachusetts 02118, United States

[§]Somerville Transportation Equity Partnership, 13 Highland Ave, #3, Somerville, Massachusetts 02143, United States

S *Supporting Information*

ABSTRACT: Jet engine exhaust is a significant source of ultrafine particles and aviation-related emissions can adversely impact air quality over large areas surrounding airports. We investigated outdoor and indoor ultrafine particle number concentrations (PNC) from 16 residences located in two study areas in the greater Boston metropolitan area (MA, USA) for evidence of aviation-related impacts. During winds from the direction of Logan International Airport, that is, impact-sector winds, an increase in outdoor and indoor PNC was clearly evident at all seven residences in the Chelsea study area (∼4−5 km from the airport) and three out of nine residences in the Boston study area (∼5−6 km from the airport); the median increase during impact-sector winds compared to other winds was 1.7-fold for both outdoor and indoor PNC. Across all residences during impact-sector and other winds, median outdoor PNC were 19 000 and 10 000 particles/cm^3, respectively, and median indoor PNC were 7000 and 4000 particles/cm^3, respectively. Overall, our results indicate that aviation-related outdoor PNC infiltrate indoors and result in significantly higher indoor PNC. Our study provides compelling evidence for the impact of aviation-related emissions on residential exposures. Further investigation is warranted because these impacts are not expected to be unique to Logan airport.

INTRODUCTION

Aircraft engine exhaust emissions are a significant source of ultrafine particles (UFP; aerodynamic diameter <100 nm) and can cause several-fold increases in ground-level particle number concentrations (PNC) over large areas downwind of airports.[1−4] The spatial extent and magnitude of the impact varies depending on factors including wind direction and speed, runway use pattern, and flight activity but encompasses large populations in cities where airports are located close to the urban residential areas. For example, in Amsterdam, PNC (a proxy for UFP) were found to be elevated 7 km downwind of Schiphol Airport[2] while in Los Angeles, PNC were reported to be elevated 18 km downwind of Los Angeles International Airport.[1,3] Thus, it is important to characterize aviation-related UFP.

Previous studies have shown that UFP can cross biological boundaries (entering the circulatory system) due to their extremely small size.[5−7] Exposure to UFP is of particular concern because it is associated with inflammation biomarkers, oxidative stress and cardiovascular disease.[6] Recent exposure assessment studies have started testing airport variables in UFP predictive models,[8−12] but epidemiological studies that incorporate airports in the exposure assessment are lacking; currently, they primarily focus on traffic-related UFP. To better inform UFP exposure assessment efforts, it is also important to distinguish aviation-related contributions from other urban sources and to characterize them independently. This is particularly challenging in urban areas with pervasive and dense road networks. Furthermore, studies have shown that residing in the vicinity of airports is significantly associated with hospitalization for cardiovascular disease;[13,14] however, there the focus has been on association between cardiovascular health effects and increased noise around airports, which can be confounded by UFP. To date, no studies described in the literature investigate the health effects of UFP, or of noise controlling for UFP, around airports.

In a previous study, we found that during winds from the direction of the Logan International Airport (Boston, MA) PNC at two long-term, central monitoring stations located 4 km and 7.5 km downwind of the airport were 2-fold and 1.33-fold higher, respectively, compared to average for all other winds.[4] In the current study, we investigated residential data sets from wider areas surrounding those two central sites. Our primary objectives were (1) to investigate short-term residential PNC monitoring data for evidence of aviation-related impacts that could be identified despite the influence of other urban sources of UFP, and (2) to analyze the data for evidence of indoor infiltration of aviation-related PNC. To our knowledge,

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this is the first study to report the impact of aviation-related emissions inside residences.

■ MATERIALS AND METHODS

Logan International Airport and Central and Residential Monitoring Sites. The General Edward Lawrence Logan International Airport is located 1.6 km east of downtown Boston (Figure 1(a)). It has six runways and supports about

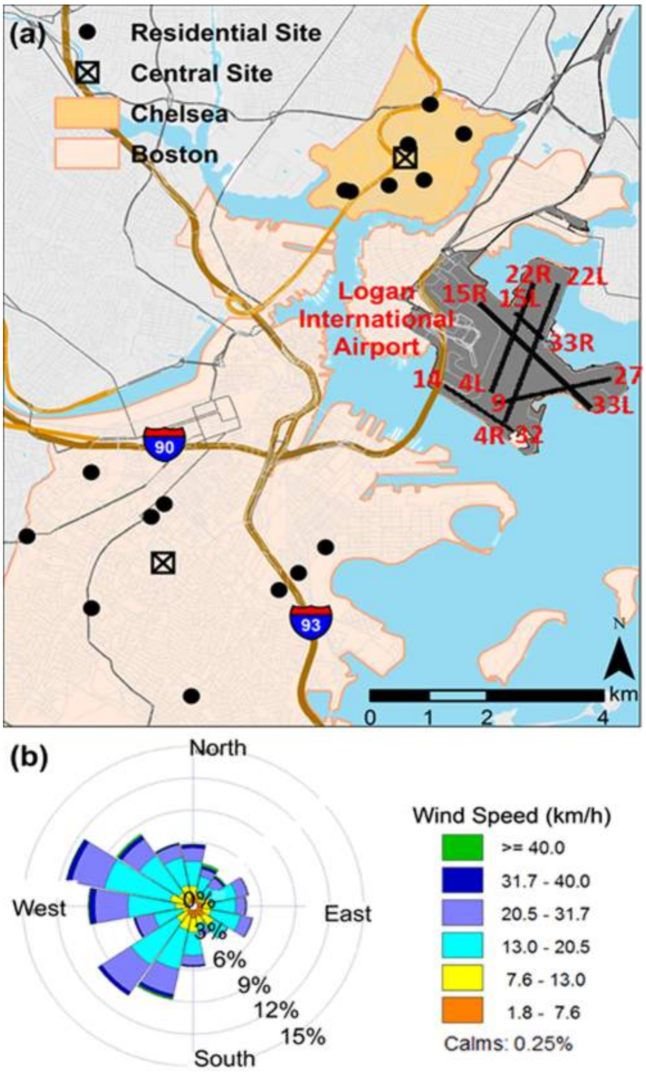

Figure 1. (a) Map of the runways at Logan International Airport and the locations of the central and residential monitoring sites in Chelsea and Boston. Base layers were obtained from mass.gov. (b) Windrose is based on 1 min data for 2014 reported by National Weather Service Automated Surface Station located at the airport.

1000 flights per day. Flight statistics are shown in the Supporting Information (SI) Figure S1. Prevailing winds in the Boston region are westerly (northwest in winter and southwest in summer, combined annual frequency 56%, see Figure 1(b)). The downwind advection of airport-related emissions occurs largely over urban areas located east and northeast of the airport as well as over the ocean during prevailing winds. During easterly winds, several other urban areas are downwind of the airport. We studied two of these areas: Chelsea and Boston.

In Chelsea, outdoor (i.e., ambient) and indoor monitoring was conducted at seven residences that were located 3.7—4.9 km downwind from the airport along 133°—165° azimuth angles measured to the geographic center of the airport (Figure 1(a)). Each residence was monitored for six consecutive weeks between February — December 2014. Ambient monitoring was also conducted continuously at a central site in Chelsea (located on top of a three-story building) during the entire 11-month period (Figure 1(a)). In Boston, monitoring was conducted at nine residences between May 2012 and October 2013. The residences were located 5.0—10.0 km downwind from the airport along 43°—74° azimuth angles measured to the geographic center of the airport. Monitoring was also conducted continuously during this 18-month period at a central site in Boston—the U.S. Environmental Protection Agency Speciation Trends Network site (ID: 25−025−0042). Central sites were selected based on their proximity to the geographic center and representativeness for the study area. Residential sites were selected based on their proximity to highways and major roads (the latter defined as annual average daily traffic >20 000): four sites were <100 m, seven between 100 and 200 m, and five >200 m from highways or major roads. Monitoring schedule, meteorological parameter summary, residence characteristics, and distance to major roadways are shown in SI Tables S1−S6.

During the six-weeks of monitoring at each residence, a HEPA filter (HEPAirX, Air Innovations, Inc., North Syracuse, NY) was operated in the room where the condensation particle counter (CPC) was located for three consecutive weeks followed by three consecutive weeks of sham filtration or vice versa. Only nonsmoking residences were recruited and we found no evidence of smoking in residences. Residences were monitored one or two at a time with limited overlap between monitoring periods. For further details of residential monitoring and filtration, see Simon et al.[15] and Brugge et al.,[16] respectively.

Instruments and Data Acquisition. PNC were monitored using four identical water-based CPCs (model 3783, TSI Inc., Shoreview MN), which recorded 30 s or 1 min average concentrations. The CPCs were annually calibrated at TSI and measured to within ±10% of one another, consistent with manufacturer-stated error. Ambient PNC were monitored continuously at the central-sites. At residences, a solenoid valve connected to the inlet switched the air flow between outdoor and indoor air every 15 min. Thus, residential outdoor and indoor PNC were monitored for 30 min per hour. To ensure that the sampling lines (1-m-long conductive silicon tubing for both indoor and outdoor carrying transport flow of 3 L per minute) were fully flushed, the first and last data points per switch were discarded (7−13% of the total). Any data that were flagged by the instruments (<1% of the total) and hours with <50% data recovery were not included in the analysis.

Flight records for individual aircraft were obtained from the Massachusetts Port Authority (East Boston, MA) and counted to obtain hourly totals for landings, takeoffs and the sum of the two (LTO). Meteorological data (a 2 min running average at 1 min resolution for wind direction and speed) were obtained from the National Weather Service station at the airport and processed through AERMINUTE[17] (a meteorological processor developed by EPA for use in AERMET and AERMOD) to obtain hourly values.

Data and Statistical Analysis. Each PNC data set (residential indoor, residential outdoor, and central-site) was

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Table 1. Impact Sector Definitions and Summary of Particle Number Concentration Statistics for Residential Sites

ID	distance to airport (km)	impact sector definition (WD°)	impact sector winds frequency, hours	impact-sector winds hourly PNC statistics: outdoor median	indoor median	indoor minimum	other winds hourly PNC statistics: outdoor median	indoor median	indoor minimum
Chelsea Residences									
D1	4.3	111−155	4.7%, 47	36 000	11 100	7600	13 200	4400	3700
D2	4.4	111−154	5%, 50	37 100	14 600	7500	16 200	5100	3500
U1	4.9	142−176	5.3%, 53	14 900	2300	1400	7800	1900	1600
U2	4.0	117−164	11.8%, 119	18 600	2500	1800	10 700	2400	1800
C1	4.2	145−182	5.2%, 50	12 800	3500	2800	8100	2500	1900
C2	4.4	130−171	5.4%, 54	19 700	1900	1300	9700	2200	1700
C3	3.7	124−173	10.8%, 111	26 600	6400	4700	8900	2800	2200
Boston Residences									
D1	6.1	31−59	6.9%, 63	27 800	8400	4300	10 700	5300	4000
U1	5.0	28−61	8.4%, 79	25 100	22 700	17 500	14 700	7400	6100
U2	5.6	30−59	8.2%, 70	19 700	10 900	6900	9700	6100	3700
C1	6.8	53−79	9.6%, 97	9400	3700	2600	8000	2300	1800
C2	7.1	53−78	3%, 30	11 900	7900	6400	10 000	4100	2800
C3	7.8	62−86	9.6%, 94	21 000	7700	5800	14 300	3900	3300
B1	10.0	33−53	3.4%, 34	13 500	4900	4200	10 100	4500	3400
B2	8.8	48−67	6%, 65	8200	4900	3200	7200	4500	3000
B3	9.2	60−78	4%, 39	12 900	15 400	11 600	8100	6300	5100

aggregated separately to calculate hourly medians. Hourly medians were further aggregated by 10°-wide wind-direction sectors, and medians were calculated for each sector. Wind-direction sectors were centered on even 10° and spanned ±5°. Data were also classified as impact-sector versus other based on the wind direction. Winds that positioned monitoring sites downwind of the airport were called *impact-sector* winds. Impact-sector boundaries (Table 1) correspond to the azimuth angles measured from a monitoring site to the widest distance across the airport complex (SI Figure S2).

For indoor data we also calculated the hourly minimum in addition to hourly medians. Indoor data were also classified by filtration scenario (HEPA or sham). Indoor measurements reflect contributions from both particles generated indoors and particles of outdoor origin that infiltrate indoors. We did not quantify fraction of indoor- versus outdoor-origin particles. Instead, we compared hourly indoor minimums (less likely to be influenced by indoor-generated PNC spikes) with outdoor PNC to determine if higher indoor PNC occurred during impact-sector winds. During periods of elevated outdoor concentrations, indoor concentrations are also expected to be elevated due to air exchange between residences and their surroundings.

Spearman's rank correlation (coefficients reported as r_S) was calculated between PNC and wind speed and PNC and LTO. Inferences based on Spearman's rank correlation were limited to ordinal associations. Correlations were considered significant if p-values were <0.05. Bootstrapped 95% confidence intervals for the correlation coefficients were also calculated. Further, impact-sector wind data sets at residences were relatively small; they ranged from 30 to 119 h or 3.0−11.8% of the total data. To take the resulting uncertainty into account, we compared distributions of correlation coefficient estimates − generated using bootstrap resampling methods (1×10^4 random samples with replacement) − for impact-sector winds to other winds. Subsamples (1×10^4 random samples without replacement) from other-wind data sets but of size comparable to impact-sector-winds were also compared where appropriate.

■ RESULTS AND DISCUSSION

We found strong evidence of aviation-related particle infiltration. Outdoor and indoor PNC were statistically significantly higher during impact-sector winds compared to other winds. Wilcoxon rank sum tests indicated that the median of 10°-wide-sector medians from all residences for impact sector winds was higher than other winds for outdoor concentrations (p-value <0.0001, z-value = −8.1) as well as for indoor concentrations during both sham filtration (p-value <0.0001, z-value = −5.1) and HEPA filtration (p-value = 0.0037, z-value = −2.7). Table 1 summarizes indoor and outdoor concentrations.

We present detailed results in the following sections where we have organized our lines of reasoning as follows: first, we demonstrate elevated outdoor PNC during different impact-sector winds in the two study areas (each showing an impact when it was oriented downwind of the airport) including sites upwind and downwind of a highway; second, we discuss correlation of outdoor PNC with wind speed and flight activity, which indicated the aviation-related origin of elevated PNC during impact-sector winds; and third, we report indoor trends at all residences and discuss indoor infiltration of aviation-related, elevated, outdoor PNC for two residences in detail.

Wind Direction and Ambient PNC Patterns at Residences. Higher ambient PNC were observed during winds that positioned the sites downwind of the airport (i.e., impact-sector winds). Impact sector differed by study area and from residence to residence within the study areas. In Chelsea (located NW of the airport) PNC were elevated during SE winds and in Boston (located SW of the airport) PNC were elevated during NE winds (Figure 1). This impact is thus spatially widely distributed in the Boston area.

Chelsea. During impact-sector winds in the Chelsea study area (ESE-S, 111°−182°), PNC were elevated at the central site and all seven residences. Residences that were upwind of the highway during impact-sector winds are denoted with a U, residences that were downwind of the highway during impact-sector winds are denoted as D, and community sites that are

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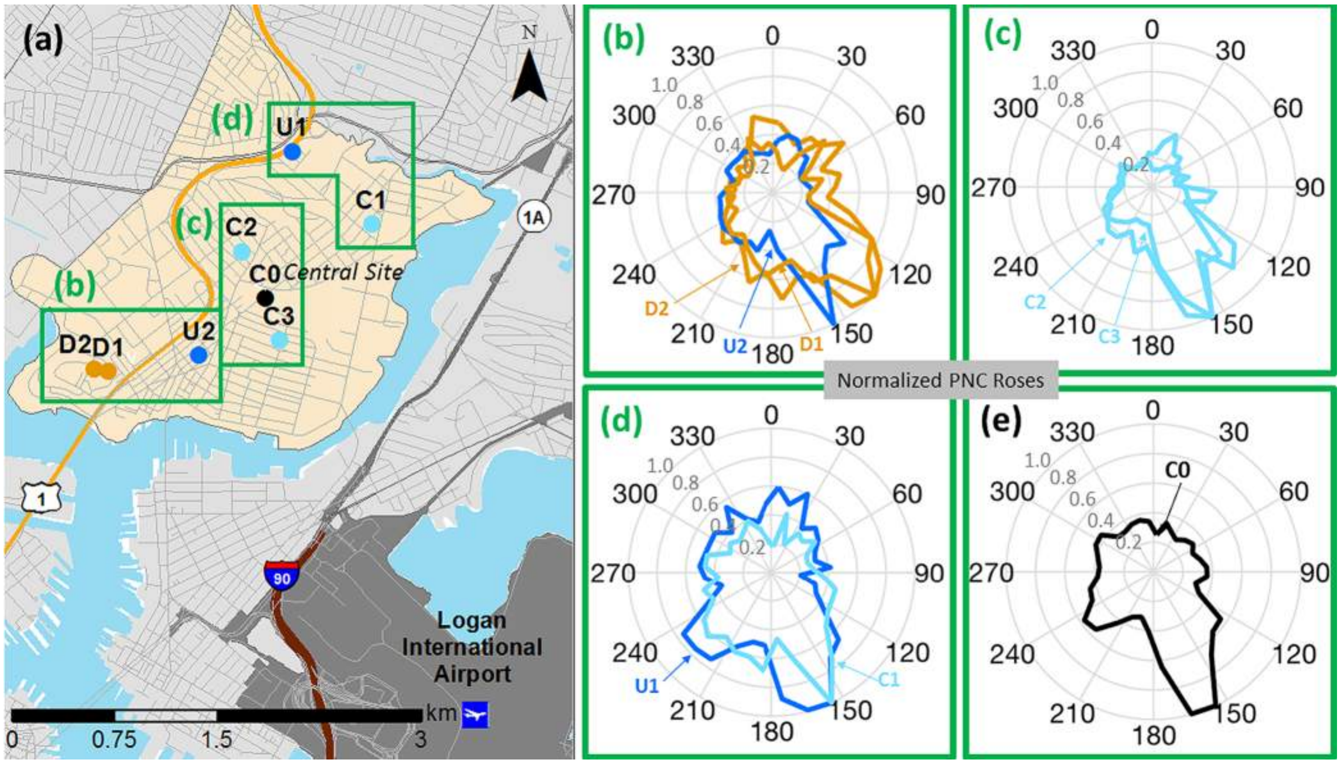

Figure 2. (a) Locations of the central site (C0, black) and seven residences monitored in Chelsea. Residences were classified as upwind (U, dark blue) of the highway during impact-sector winds, downwind of the highway (D, orange) during impact-sector winds and community sites that were not in proximity of the highway (C, light blue). (b)−(e) Normalized (by the maximum) PNC roses are based on hourly medians; concentric circles are increments of 0.2 on a 0−1 scale.

not in proximity of a highway are denoted as C (Figure 2). Median PNC during impact-sector winds were 1.6- to 3.0-fold higher than the medians for all other winds (Table 1). Highest and lowest residential impact-sector medians were 37 000 and 13 000 particles/cm^3, respectively, as compared to 16 000 and 8000 particles/cm^3 during all other winds.

Impact-sector winds occurred for 4.7−11.8% of the time (annually, ∼ 7% in 2014) during the residential monitoring, but their weighted contributions to the monitoring averages were 8−26%. It should be noted that these contributions likely include some input from other sources in impact sectors, such as, traffic. Heatmaps of PNC by wind direction and hour of the day for the central site and all seven residences studied in Chelsea (SI Figure S3 (a) and (c)) indicate PNC peaks coincided with morning and evening vehicular and aviation traffic rush-hours. However, these peaks were highly elevated during impact-sector winds even though traffic impacts are not particularly concentrated in the impact sector; only two of the seven residences (D1 and D2) were downwind of major roadways and highways during impact-sector winds.

Boston. In the Boston study area, a pronounced increase in PNC during impact-sector winds was evident at three sites 5.0−6.1 km downwind of the airport (Figure 3). At residences U1 and U2 (NNE-ENE, 28°−61°), which were both also upwind of Interstate 93 (I-93) (Figure 3(b)), median PNC during impact-sector winds were 25 000 and 20 000 particles/cm^3, respectively, as compared to 15 000 and 10 000 particles/cm^3 during all other winds. At site D1, which was 6.1 km downwind of the airport and 200 m downwind of I-93 during impact-sector (NE) winds, but impacted by the highway during both NE (31°−59°) and SE (115°−145°) winds, median PNC were greater during NE winds than during SE winds (29 000 vs 19 000 particles/cm^3, respectively; means were 29 000 ± 46% vs 21 000 ± 70% particles/cm^3, respectively) for similar I-93 traffic volume (hourly traffic flow was 7000 ± 47% during times of NE vs 8000 ± 39% during SE winds).

At the other six sites in Boston, which were 6.8−10.0 km from the airport, increases in PNC during impact-sector winds were not as distinct (Figure 3(c)). Ambient median PNC during impact-sector winds, which likely included considerable contributions from upwind sources including busy roadways and highways in Boston, were 1.1- to 1.6-fold higher at these six residences than the medians for all other winds (Table 1). Heatmaps for PNC by wind direction and time of day for the central site and all residences (SI Figure S3 (b) and (d)) indicate PNC peaks coincided with morning and evening vehicular and aviation traffic rush-hours. The impact-sector PNC were lower in Boston compared to Chelsea.[15]

Correlations between PNC and Wind Speed. Because higher wind speeds generally promote greater dispersion and mixing, PNC and wind speed are typically negatively correlated. However, for buoyant aviation emissions plumes, higher wind speeds promote faster ground arrival counterbalancing the increased dilution.[18] Thus, a distinct feature of aviation emissions impacts (unlike road traffic emissions impacts) is a lack of negative correlation between PNC and wind speed.[4,19,20] We too observed this phenomenon. During impact-sector winds at Chelsea and Boston central-sites, the negative correlation between PNC and wind speed was lacking; correlation coefficients were r_S = 0.17 and 0.19, n = 435 and 408 h, respectively, and p-value < 0.001. In contrast, during other winds, the expected negative correlation between PNC and wind speed was observed (r_S = −0.24 and −0.05, n = 7552 and 10 537 h, respectively, and p-value < 0.001). Similar trends

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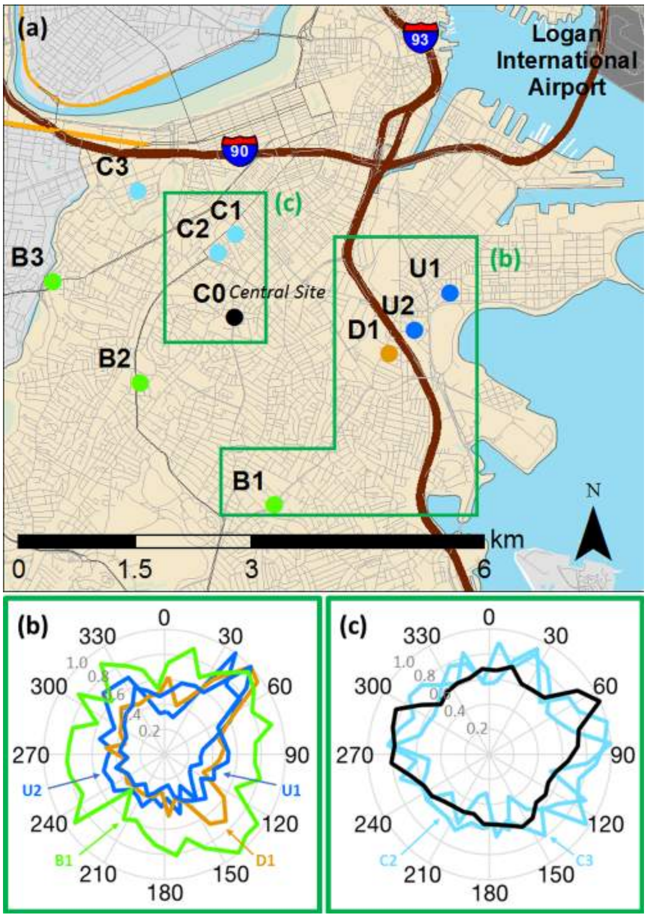

Figure 3. (a) Locations of the central site (C0, black) and nine residences monitored in Boston. Residences were classified as upwind (U, dark blue) of the highway during impact-sector winds, downwind of the highway (D, orange) during impact-sector winds, community sites (C, light blue) and background sites (B, green). (b)−(c) Normalized (by the maximum) PNC roses are based on hourly medians; concentric circles are increments of 0.2 on a 0−1 scale.

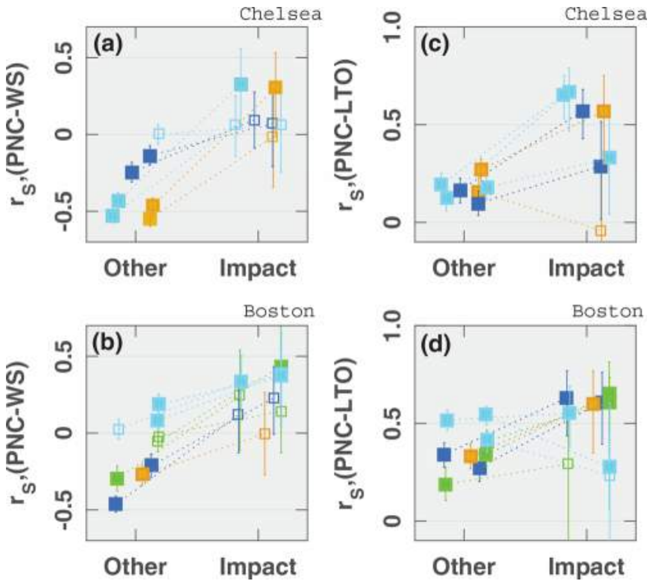

Figure 4. Correlation coefficients between outdoor PNC and wind speed (a, b) and LTO (c, d) for seven Chelsea and nine Boston residences during impact-sector and other winds. Filled squares represent significant correlation (*p*-value <0.05) and unfilled squares represent insignificant correlations. *X*-axis is categorical but points have been jittered to enhance visual clarity by reducing overlap. For description of colors, see captions for Figures 2 and 3.

were found at the residences in both study areas: correlation between PNC and wind speed was either lacking or even positive during impact-sector winds but it was negative during other winds. Correlation coefficients for residences are shown in Figure 4 where points have been jittered along the categorical *x*-axis to reduce overlap.

Because impact-sector winds were a small fraction of all winds (3−12% of the total data set) we conducted bootstrap resampling of correlation estimates (r_S) and bootstrap subsampling of a similarly small data set from other wind conditions to ensure that the lack of negative correlation was not by chance. The correlation estimates during impact-sector winds were different from the negative estimates obtained for other winds; results are shown in SI Figure S4−S19. The contrast in correlation was most evident in Chelsea and sites upwind of I-93 in Boston. Notable exceptions were sites downwind of both a highway and the airport during impact-sector winds likely because they were dominantly impacted by highway emissions given their proximity to the highways. For example, at site D1 in Boston, we observed no difference in correlation estimates between impact-sector and other winds (SI Figure S11). In comparison, at sites U1 and U2 in Boston, which were upwind of the highway during impact-sector winds but still downwind of the airport, correlation estimates were positive during impact-sector winds and negative during other winds (SI Figure S12−S13).

Correlations between PNC and Flight Activity. PNC at both central sites were previously reported to be positively correlated with aviation activity (measured as LTO, the hourly total landings and takeoffs) after controlling for traffic volume, time of day and week, and meteorological factors (wind speed, temperature, and solar radiation).[4] Because the central sites both had relatively large data sets (several years of monitoring), we were able to control for these factors; however, the relatively small PNC data sets for residences and the lack of local traffic volume information limited meaningful controls in the current analysis. Also, because the temporal patterns of flight activity and vehicle traffic are similar, some confounding was observed between PNC and LTO irrespective of the wind direction. For example, Pearson's correlation coefficient for hourly LTO and traffic volume on I-93 in 2012 was 0.85. Nonetheless, Spearman's correlations and the bootstrap analysis (SI Figure S20−S35) indicate that PNC versus LTO correlation estimates during impact-sector winds were generally higher than during other winds; that is, r_s ranged from 0.29 to 0.67 during impact-sector winds compared to 0.10−0.54 during other winds, but there were exceptions (see discussion in SI).

Indoor Infiltration of PNC during Impact-Sector Winds. *Overall Trend at Residences.* Infiltration of aviation-related outdoor PNC was evident in the data as higher indoor concentrations during impact-sector winds compared to other winds. The median increase in indoor concentrations during impact-sector winds compared to other winds was 1.7-fold (range: 0.9−3.1-fold). PNC measurements (median and minimums) are summarized in Table 1 for all residences. For trends with respect to wind direction for individual residences see SI Figures S36−S51, which show an increase in indoor medians coincident with impact-sector winds is more apparent for residences in Chelsea and Boston closer to the airport, while

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some residences located farthest away (like B1 and B2) showed no trend with respect to wind direction for either outdoor or indoor PNC.

HEPA filtration lowered the indoor concentrations; indoor-to-outdoor PNC ratios were 0.33 ± 0.17 lower during HEPA filtration as compared to sham filtration (see Brugge et al.[16]). Figure 5 compares 10°-wide-sector PNC medians for impact-sector and other winds separately for sham and HEPA filtration scenarios in all 16 homes. Because filtration efficiency is not preferential to ambient wind direction, higher concentrations (despite lower indoor-to-outdoor ratios) were still observed during impact-sector winds. Further, this trend was apparent in both the hourly medians and hourly minimums (range: 0.8–2.9-fold) of indoor PNC even though hourly medians are more likely to be skewed by contributions from indoor sources than the hourly minimums (SI Figure S52).

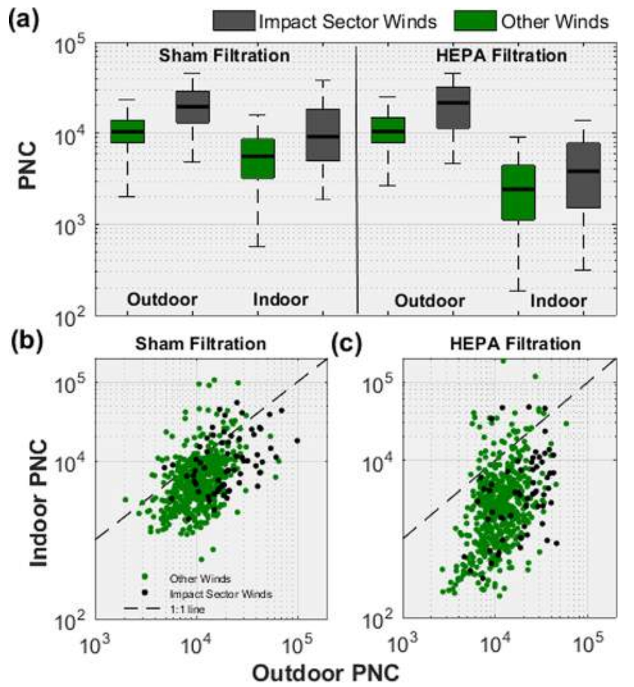

Figure 5. (a) Tukey's boxplots of indoor and outdoor PNC data during sham and HEPA filtration from all 16 homes. The horizontal line inside each box is the median; the boxes extend from the 25th to the 75th percentile and the whiskers extend to 1.5*interquartile range. In (b) and (c) each point in the scatterplots represents the median of hourly medians classified into 10-degree-wide wind sectors.

Previous studies have shown that ambient PNC infiltrate indoors via multiple pathways such as forced air ventilation systems, open windows, or cracks in the building envelope.[21] Infiltration factors vary from 0.03 to 1.0[21,22] in the ultrafine range, the size range for the majority of the aviation-related particulate emissions.[3] Infiltration of aviation-related PNC and, resultantly, an increase in indoor PNC and residential exposures can thus be expected in near-airport residences. Our results clearly indicate that to be the case; particles of aviation-related origin infiltrate residences. Two cases are illustrated in detail in the following section.

Illustration of Infiltration at Select Residences. Infiltration of PNC is illustrated for residence C3 in Chelsea in Figure 6 (a). Time series of indoor PNC closely followed the same pattern as outdoor PNC during an 18-h period of consistent impact-sector winds (from 1900 h on Oct 6 to 1200 h on Oct 7, 2014). During hours of minimal flight activity (0100–0500 h; LTO = 1.5 h^{-1}), PNC indoors and outdoors at C3 and the central site were all low but increased as flight activity resumed after ~0500 h. Residential outdoor PNC was also remarkably highly correlated (Pearson's r = 0.96) with the central site located 1 km away indicating the spatial homogeneity of the aviation-related impact over a large area. Further, even though it was past the evening traffic rush-hour period (and thus traffic would have contributed minimally to the observations or for that matter particle formation) when the winds shifted (at ~1900 h) to the impact sector, outdoor and central-site concentrations increased to high levels (1 min averages were between 50 000 and 100 000 particles/cm^3), which underscores the magnitude of this impact. In comparison, Simon et al.[15] reported mean 1 min on-road PNC from 180 h of mobile monitoring across Chelsea including traffic rush-hours was 32 000 particles/cm^3 which was about one third to one half of the observed PNC at C3 during impact-sector winds. Overall, at C3, the median indoor PNC was nearly 3-fold higher for impact-sector winds compared to other winds (8900 versus 2800 particle/cm^3) (Figure 6(c), SI Figure S42).

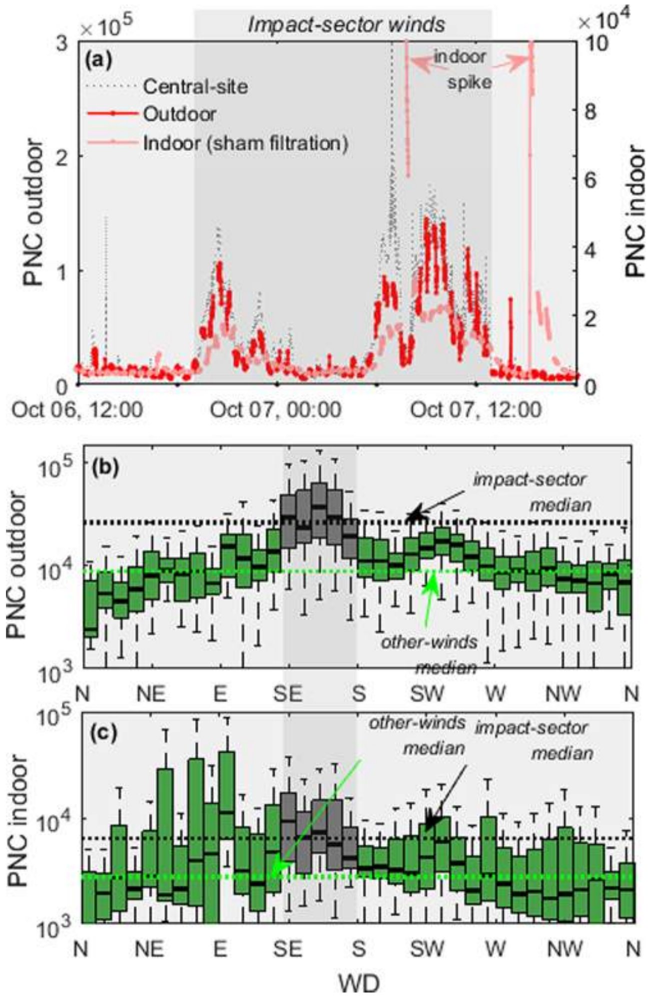

Figure 6. PNC time series for October 6–7, 2014 for site C3 in Chelsea is shown in (a). Impact-sector winds are highlighted in gray. Tukey's boxplots in (b) and (c) show outdoor and indoor PNC. The horizontal line inside each box is the median, the boxes extend from the 25th to the 75th percentile and the whiskers extend to 1.5*interquartile range.

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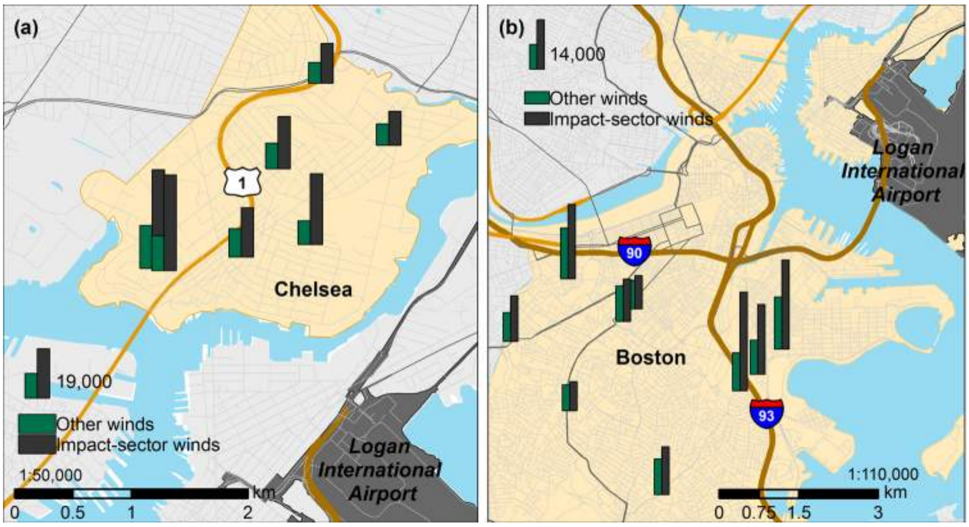

Figure 7. Outdoor PNC at residences during six-week monitoring periods in Chelsea (a) and Boston (b). Median of hourly medians classified as impact-sector and other winds are shown.

Another example of infiltration is shown in Figure S53(a) where a 22-h period of generally consistent impact-sector winds is highlighted (from 1900 h on Nov 6 to 1700 h on Nov 7, 2012) for residence U1 from the Boston study area. U1 is relatively close to I-93 but it is upwind of the highway during impact-sector winds. Outdoor concentrations during impact-sector winds from 1900 h to as late as midnight on Nov 6–7, 2012 were ~40 000 particles/cm^3 but then decreased to as low as 2000 particles/cm^3 during the hours of low flight activity at the airport (LTO decreased from 32 h^{-1} to 2.8 h^{-1} during 1900–0000 h to 0000–0500 h). The indoor PNC time series was consistent with the outdoor concentration during these hours. Both outdoor and indoor concentration started increasing again around 0500 h when flight activity resumed at the airport; however, around 0800 h indoor PNC spiked, likely from an indoor particle-generation event that dominated indoor PNC during the following hours despite impact-sector winds. Overall, the median indoor PNC was 2-fold higher for impact-sector winds compared to other winds (15 000 versus 7400 particles/cm^3) (Figure S53(c) and Figure S44).

Strength and Limitations. To our knowledge this is the first investigation of the impacts of aviation-related emissions at residences around airports. Our results show an increase in outdoor as well as indoor PNC. These findings point to the need for studies to provide further characterization of these impacts (e.g., measure additional pollutants in a greater number and variety of residences both near and far from airports and under a greater diversity of meteorological conditions and indoor activities).

Our study also had limitations. The foremost is that monitoring was not specifically designed for quantifying the impacts of aviation-related emissions on indoor and outdoor PNC. Data were collected as part of the Boston Puerto Rican Health Study (a study of exposure to urban air pollution and cardiovascular health effects in a Puerto Rican cohort[23]), but it allowed for the reported analysis because of the residences' proximity to and distribution around the airport. Ideally, for quantifying the aviation-related impacts and distinguishing them from other outdoor sources (such as traffic) and indoor sources (such as cooking), continuous indoor and outdoor monitoring at several locations in carefully characterized residences with indoor time-activity records would be necessary. In addition, the study was not designed to characterize the air exchange rates or infiltration factors for ambient particles. As a result, we could not quantify the contribution of indoor- versus outdoor-origin PNC to total indoor observations, or more pertinently the contribution from aviation-related outdoor PNC to indoor observations. Further, the lack of concurrent data from all or even multiple residences precluded spatial analysis. Residence-to-residence differences in outdoor and indoor PNC (Figure 7 and Table 1) were observed. For example, at sites closer to the airport PNC were generally higher than farther away, but at sites immediately downwind of highways, even though they were farther downwind of the airport, PNC were even higher, likely due to impacts from both aviation-related and traffic emissions. Such spatial differences were not investigated. Observed outdoor concentration differences were likely not solely due to the differences in spatial location with respect to the airport or other sources; temporal differences (e.g., meteorological and seasonal factors) likely also contributed significantly, but they could not be controlled for due to lack of concurrent data.

Significance of the Results. Altogether, our results make a compelling case for further investigation of aviation-related air pollution impacts and resulting exposures because these impacts are not expected to be unique to Logan airport. Extrapolating from Correia et al.[13], we estimate that in the United States ~40 million people live near 89 major airports (i.e., within areas with ≥45 dB noise levels near airports). Inclusion of aviation-related impacts may also improve predictive models for exposure assessments. Future studies of this impact with concurrently located sites that allow analysis of the spatial gradient and comparison with traffic impacts could be very informative for ultrafine particle epidemiology.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.est.7b05593.

Information related to flight activity at Logan International Airport (Figure S1), details of monitoring schedule residence characteristics, and summary statistics of the

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data (Table S1−S6, Figure S2), heatmaps of PNC by wind direction and time of the day (Figure S3), correlation coefficient estimates from bootstrap subsampling and resampling (Figure S4−S35), additional graphics related to particle number concentration trends with respect to wind direction at monitoring sites (Figure S36−S52) and an example of infiltration (Figure S53) (PDF)

AUTHOR INFORMATION

Corresponding Author

*Phone: 617.627.5489; fax: 617.627.3994; e-mail: neelakshi.hudda@tufts.edu.

ORCID

N. Hudda: 0000-0002-2886-5458

Notes

The authors declare no competing financial interest.

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Article

Impacts of Aviation Emissions on Near-Airport Residential Air Quality

Neelakshi Hudda,* Liam W. Durant, Scott A. Fruin, and John L. Durant

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ABSTRACT: Impacts of aviation emissions on air quality in and around residences near airports remain underexamined. We measured gases (CO, CO_2, NO, and NO_2) and particles (black carbon, particle-bound aromatic hydrocarbons, fine particulate matter ($PM_{2.5}$), and ultrafine particles (reported using particle number concentrations (PNC) as a proxy)) continuously for 1 month at a residence near the Logan International Airport, Boston. The residence was located under a flight trajectory of the most utilized runway configuration. We found that when the residence was downwind of the airport, the concentrations of all gaseous and particulate pollutants (except $PM_{2.5}$) were 1.1- to 4.8-fold higher than when the residence was not downwind of the airport. Controlling for runway usage and meteorology, the impacts were highest during overhead landing operations: average PNC was 7.5-fold higher from overhead landings versus takeoffs on the closest runway. Infiltration of aviation-origin emissions resulted in indoor PNC that were comparable to ambient concentrations measured locally on roadways and near highways. In addition, ambient NO_2 concentrations at the residence exceeded those measured at regulatory monitoring sites in the area including near-road monitors. Our results highlight the need for further characterization of outdoor and indoor impacts of aviation emissions at the neighborhood scale to more accurately estimate residential exposures.

INTRODUCTION

In 2018, 10 million flights carrying one billion passengers flew into or out of airports in the United States (US).[1] Over the next 25 years, flight operations and enplanements in the US are projected to grow annually at the rate of 1 and 2%,[2] respectively, and a similar outlook is expected worldwide.[3] To meet this growing flight demand, in the last two decades over half of the 35 busiest airports in the US have undergone airfield expansions to increase their capacity.[4] These trends are of significance to the health of millions of people who live or work near airports and are thereby regularly exposed to noise and air pollution originating from aviation activity. For example, increased rates of adverse health outcomes ranging from hypertension,[5−13] cardiovascular disorders,[6,14−16] birth outcomes,[17,18] respiratory diseases,[19] and learning deficit in children[20−22] have been observed near airports. Furthermore, implementation of the Next Generation Air Transportation System,[23] which guides airplanes on precise paths via satellites, has narrowed the flight paths and lowered landing altitudes, concentrating the impacts further in certain communities.

Recently, the impacts of aviation emissions on ground-level ambient ultrafine particle (UFP; aerodynamic diameter < 100 nm) concentrations were found to extend over unexpectedly large areas near airports and in particular along flight paths.[24] For example, elevated particle number concentrations (PNC) were reported downwind of major international airports as far as 7 km near Amsterdam, 7.3 km in Boston, 18 km in Los Angeles, and 22 km in London.[25−29] UFPs are emitted at high rates by jet aircraft[30] and linked to increased rates of hypertension and cardiovascular morbidities.[31,32] However, UFPs do not contribute significantly to mass in the fine particle range and are not routinely monitored, in part due to a lack of ambient air quality standards. Therefore, they present the possibility of being an additional important confounder for near-airport epidemiological investigations.[33,34] For example, Wing et al.[35] found that UFP exposure was. independently associated with adverse birth outcomes in the vicinity of Los Angeles International Airport. Similarly, black carbon (BC) and oxides of nitrogen, which are also emitted at high rates by aircraft[30,36−38] and have recognized adverse cardiovascular effects,[39] are also elevated near airports.[24,25] Some near-airport epidemiological studies have accounted for confounding pollutants, like fine ($PM_{2.5}$[16]) and coarse particulate matter (PM_{10}[15,40,41]), ozone,[16] and NO_2,[41] but by using regional-scale central monitor data or predictive models that only account for larger-scale spatial patterns and ground-transportation emissions. Confounding co-exposure to aviation-origin emissions

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themselves remains unaccounted for, limiting the causal interpretation of the epidemiological results.

Moreover, research on near-airport air quality has been limited to ambient (outdoor) observations to date.[24] The extent and conditions under which aviation emissions infiltrate residences and impact indoor air quality remain largely unaddressed. We found only one study that reported on residential infiltration of aviation emissions.[42] In that study, 16 homes in Boston (MA), which were selected primarily for assessment of highway impacts on indoor air quality, were found to contain higher PNC indoors when the residences were downwind of the Logan International Airport. This study did not quantify infiltration rates due to the lack of concurrent outdoor and indoor measurements. Further, no studies have investigated the influence of meteorology and aviation activity on infiltration or quantified impacts of aviation emissions on indoor air quality.

In this study, we concurrently monitored outdoor and indoor air pollutant concentrations in a near-airport residence to assess the influence of temporal factors including time of day, meteorology and aviation activity intensity, and operation type (landings and takeoffs). We studied a residence of a common architectural style and vintage in Winthrop, MA, a community that is significantly impacted by the Logan International Airport. About a third of the Winthrop's population of 17 500 lives within the 60 dB noise impact zone (an annual average of cumulative 24 h day and night noise exposures with a 10 dB night-time penalty).Ours is the first study to detail the disproportionate impact of overhead landing jets on residential outdoor and indoor air quality.

■ METHODS

Airport Description. The General Edward Lawrence Logan International Airport is located 1.6 km east of downtown Boston (Figure 1). It has six runways and supports ~1000 operations per day (combined landings and takeoffs [LTO]). For each wind-direction quadrant, the airport has a '*preferred runway configuration*' consisting of a subset of runways (three out of the six runways), as shown in the Supporting Information (SI), Figure S1, to which operations are preferentially directed. In the US, the naming convention on runways is such that they represent the numerical heading in tens of degrees of the planes using the runways. For example, planes taking off or landing on runway 27 at the Logan airport head ~270° true north, while planes taking off or landing on runway 4 head ~40° true north.

Residential Air Quality Monitoring and Instruments. Monitoring was conducted from August 23 to September 23, 2017, at a residence in Shirley Point, Winthrop located 1.3 km from the eastern end of runway 9/27 (Figure 1). Jets descend overhead of the residence at an elevation of ~75−100 m. The residence is located in a suburban neighborhood with only one major collector/arterial road within a 1 km radius, and the road leads to a dead end and thus has very limited vehicular traffic (Figure S2a). Outdoor monitoring was performed using the Tufts Air Pollution Monitoring Laboratory (described in detail elsewhere[43]), which was parked in the driveway on the northern side of the property. Outdoors, a suite of gaseous and particulate pollutants were measured including particle number concentrations (PNC, measured at 1 s resolution using a TSI (MN) Condensation Particle Counter 3783 [CPC, d_{50} = 7 nm]), black carbon (BC), fine particulate matter ($PM_{2.5}$), particle-bound polycyclic aromatic hydrocarbons (PBPAH) for

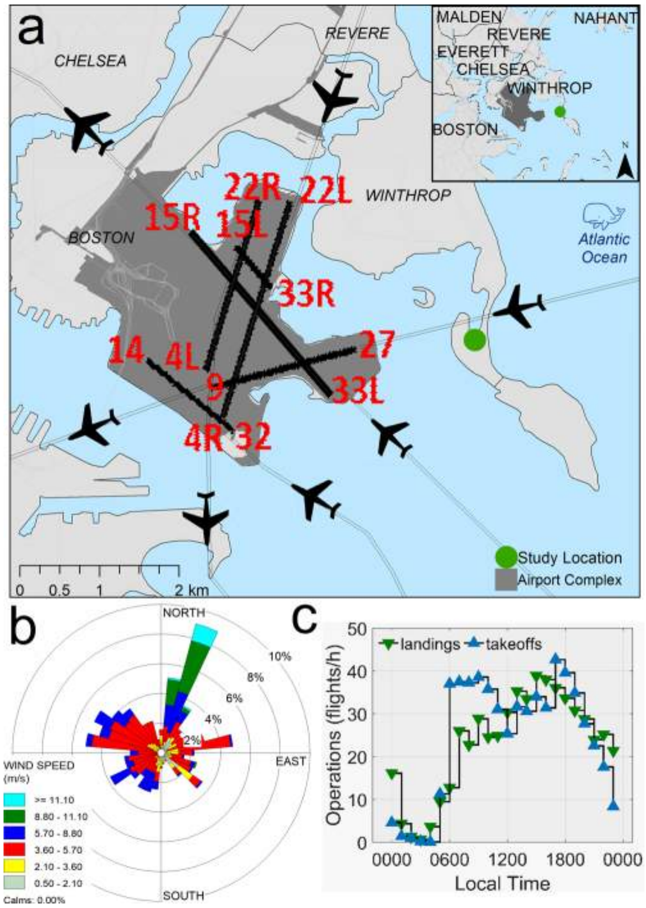

Figure 1. (a) Monitoring the site location and flight trajectories for preferred runway configurations for jets during SW and NW winds at the Logan Airport. (b) Windrose and (c) diurnal flight activity for the study period.

PAH-containing particles ≤1.0 μm), carbon monoxide (CO), and oxides of nitrogen (NO, NO_2, and NO_X) (see Table S1 for details of the instruments used). To limit disturbance to the residents (i.e., due to noise from the monitoring equipment), indoor measurements were restricted to PNC using the same make and model CPC as outside. It was placed in the first-floor living room. Weekly maintenance of the instruments included flow checks, clock resets, and data download.

Residence Characteristics and Ventilation Practices. The residence, built in 1920, is a two-story, two-bedroom, 1700 ft^2 colonial wood-frame house that is typical of the architectural style of the neighborhood. It does not have a centralized ventilation system (neither AC nor fans) and neither the kitchen nor the single bathroom is equipped with exhaust fans. It has eight double-hung windows, four picture windows, two inoperable windows, a front door, a back door, and a sliding glass door. In the early 1990s, all of the windows, the front door, and the sliding glass door were replaced with new, tighter versions as part of Massport's Residential Sound Insulation Program.[44] This is a voluntary program where owners of residences located within the 65 dB DNL threshold area can apply for noise reduction measures. Therefore, this residence may have lower air exchange rates under closed window conditions than residences without soundproofing. New storm windows and storm doors were also added at this time.

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Prior to the start of monitoring, we deliberately did not discuss ventilation practices (or instruct residents to modify or not modify current practices) so as not to influence their behavior during the month of monitoring. Following the monitoring period, the residents were surveyed *post hoc*[45] on cooking practices, fan and air conditioner use, and window openings during the month-long study. On the survey, the residents indicated that on weekdays windows were opened minimally during the day (~2 h) and in the evening (~1 h), while on weekends, 3−5 windows were typically opened for 2−5 h during the day and 1−2 h in the evening (1800−2300 h). At night (after 2300 h) on both weekdays and weekends, all windows were closed and as many as three window-mounted AC units were operated to provide cooling. Also, the residents (two full-time working adults) indicated that they cooked infrequently.

Regulatory Monitoring Sites and Other Sites. To provide perspective on near-airport observations, we also compare concentrations of pollutants measured near the airport with those measured at regulatory monitoring sites and in near-highway neighborhoods in the Boston area. Data from five proximal regulatory monitoring sites operated by the Massachusetts Department of Environmental Protection[46] in Suffolk and Essex counties were obtained. For ease of interpretation, we refer to these sites by their distinguishing features. The sites are as follows: (a) a site on the shoulder of Interstate I-93N and 6 km SW of the airport (referred to as *adjacent-highway*); (b) a near-roadway site at the intersection of five streets and 100 m N from Interstate I-90 and ~6 km W of the airport (*near-roadway*); (c) a site in downtown Boston 3.5 km W of the airport (*downtown*); (d) a site located 7.5 km WSW of the airport that is considered indicative of the neighborhood scale (*urban-background*); and (e) a site 13 km NNE of the airport in Lynn, MA, that is considered indicative of regional-scale air quality (*regional-background*). Traffic volumes (annual average daily traffic estimated from the regional planning commission[47]) in the 1 km area around these sites are shown in Figure S2b−f in Table S2.

The air quality monitoring instruments used at regulatory sites are listed in Table S2. We used federal equivalent method instruments to measure CO and oxides of nitrogen at the near-airport site. For $PM_{2.5}$, we used an optical sensor instead of federal reference/equivalent methods; this nephelometer tends to read higher than federal reference/equivalent methods, is sensitive to relative humidity, which we do not correct for, and requires gravimetric calibration to local aerosol for data to be comparable to regulatory data.[48] Thus, we do not discuss absolute $PM_{2.5}$ concentration differences between the near-airport residence and the regulatory sites and limit interpretation to broad trends.

Because ultrafine particles are not a regulated air pollutant in the US, PNC is not routinely monitored at the regulatory sites by state or federal agencies. Comparable PNC data were available from the Tufts UFP Monitoring Network (TUMN), which uses the same CPCs as we used at the near-airport residence (TSI model 3783). Data were available from two locations: first, the roof of a three-story building in Chelsea, 4.0 km northwest from the airport, for the entire study duration (August 23−September 23, 2017) and second, from a station collocated at the urban-background regulatory site for August 23−September 09, 2017.

Data Acquisition and Statistical Analysis. Meteorological data collected at the airport (KBOS) were obtained from the National Centers for Environmental Information[49] and aggregated to hourly resolution. Regulatory monitoring site data was obtained from EPA's AirData websites https://www.epa.gov/airdata and https://aqs.epa.gov/api at hourly average resolution. Measured pollutant data were aggregated to hourly resolution and aligned with the meteorological and regulatory data.

Data on flight activity at the airport were web-scraped from https://secure.symphonycdm.com, a public portal for tracking flight activity at the airport. A coordinate grid was established for each runway, and when a plane entered or exited, a grid, it was counted as having landed or taken off, respectively. Data was extracted at 30 s intervals and aggregated to the hour. To check for errors in the automated methodology, flight activity was also replayed and tracked manually for 5 h (three busy hours with >2 operations/minute and two more hours with <0.5 operations/minute) (Table S3); scraping/automated extraction underestimated operations by 0−3% in busy hours and 0% in other hours. Detailed flight activity logs including idling and taxiing times for airplanes on the tarmac were unavailable to us.

Statistical analysis was conducted in MATLAB 2018. Nonparametric statistics were used because the pollutant data were non-normally distributed; differences were tested using the Wilcoxon rank-sum test (significance threshold $p < 0.05$), and the Spearman's rank correlation coefficients (r_s) are reported. Extreme outliers were defined using Tukey's fences,[50] i.e., three times the interquartile range, and excluded from indoor-to-outdoor (I/O) ratio analysis (amounting to 0.007% of data during impact sector and 4.9% of the data during other winds). As a check, all extreme outliers were found to exceed unity, indicating that indoor concentrations exceeded outdoor concentrations likely due to indoor sources.

RESULTS AND DISCUSSION

Flight Activity Patterns. SW-NNW winds orient the residence downwind of the airport. During these winds, landings occurred mostly over the water and takeoffs occurred mostly over the land (Figure 1a shows flight trajectories). For example, when winds are from the S-W (180−270°), the predominant wind direction (WD) in the Boston area during summer, jets are preferentially directed to land on 22L (heading 214.6°) and 27 (heading 271.5°) and takeoffs are directed to occur on 22L and 22R (heading 214.6°). When winds are from the W-N (270−360°), flights are preferentially directed to land on runways 27, 32 (heading 320.6°) and 33L (heading 330.1°) and takeoff from 27 and 33L. During the study, 100% landings and 100% takeoffs occurred on preferred runways for 62 and 48% of the hours, respectively, and >50% of the operations occurred on preferred runways 70% of the hours. Takeoffs were far more frequently directed to nonpreferred runways than landings (e.g., during SW and NW winds, ~15% of takeoffs occurred on nonpreferred runways compared to <5% of landings). The windrose and flight activity for the study duration are shown in Figure 1b,c. Overall, we observed 1.2 times as many flights during evening peak rush hour (1700−1800) than during morning peak rush hour (0900−1000). The hours of 0100−0600 were the least busy due to night-time flight restrictions (Figure 1c).

Wind Direction and Pollutant Patterns. The WSW-N sector (247.5−360°) stands out in the bivariate polar plots as the sector associated with the highest PNC (Figure 2a,b), a trend also reflected by most of the other pollutants (Figure

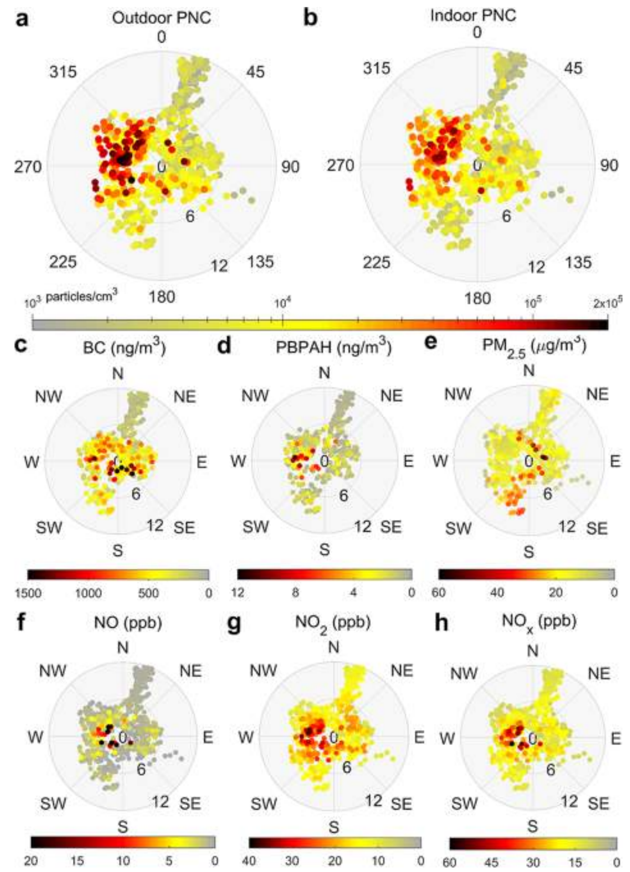

Figure 2. Polar plots of hourly average pollutant concentrations versus wind direction and speed. (a) Outdoor and (b) indoor particle number concentrations (particles/cm^3) and (c–h) hourly average outdoor concentrations of other pollutants. Radial axis labels placed along 135°show wind speed in m/s.

2c–h). During these winds, the residence was downwind of the airport complex as well as flight trajectories for the runways preferred during westerly winds. We identified this sector as the impact sector (247–360°), similar to other works.[27,42,51,52] Non-impact-sector winds (i.e., winds from 0 to 246.9°) oriented the monitoring site upwind of the airport and were further subdivided into winds from over-the-ocean (0–112.5°) and over-the-land (112.6–246.9°).

Significantly higher concentrations of PNC, oxides of nitrogen (NO, NO_2, and NO_X), CO, BC, and PBPAH were observed during impact-sector winds compared to non-impact-sector winds (Table 1). Fold elevation, or the ratio of mean concentration for all hours of impact-sector winds to the mean concentration for all hours of non-impact-sector winds, was highest for PNC (Table 1): PNC were 4.8-fold elevated outside and 4.2-fold elevated inside the residence. Fold elevation was lower for other pollutants. BC was 1.3-fold elevated and PBPAH was 1.8-fold elevated. NO, NO_2, and NO_X were 1.9, 1.2, and 1.2-fold elevated, respectively (n.b., the difference between means was much greater for NO_2 (2.7 ppb) than for NO (0.8 ppb)). Fold elevation was lowest for CO, 1.1-fold. Only $PM_{2.5}$ concentrations were not elevated during impact-sector winds relative to non-impact-sector winds. Higher $PM_{2.5}$ concentrations were observed when winds were from the S–SW, a pattern consistent with that observed at vicinal regulatory monitoring sites (Figure S3a) and associated with long-range transport of aerosols from regional sources upwind.

Generally, when winds were from over-the-ocean, pollutant concentrations were lower; the lowest levels occurred during a 3.5-day-long storm event (mid-day 19 September–23 September, 2017), during which winds were high and from the NNE (see Figures 1c and 2). Table S4 summarizes concentrations for non-impact-sector winds further split into over-the-ocean and over-the-land winds.

Diurnal Patterns. PNC diurnal patterns during impact-sector winds were very distinct from those for other pollutants and distinct from PNC diurnal patterns during non-impact-sector winds. As shown in Figure 3, PNC increased steadily from 1600 to 2300 h to levels that were far higher than those at any other time of the day and decreased precipitously with a drop in flight activity, in particular, after 0100 h. The late-evening (2000–2300 h) average exceeded the morning (0600–1100 h) average by a factor of three (80 000 ±

Table 1. Statistics for Hourly Averaged Pollutant Concentrations during Monitoring (23 August–23 September, 2017)

	n (hours of data)		mean (± st. dev.)			median (IQR)		Wilcoxon rank-sum test statistics[a]	
pollutant	impact sector	non-impact sector	impact sector	non-impact sector	fold elevation	impact sector	non-impact sector	*p*-value	*z*-value
PNC indoors (number/cm^3)	261	469	25000 ± 27000	6000 ± 8000	4.2	13 000 (6000–32 000)	4000 (2000–7000)	<0.05	14.1
PNC outdoors (number/cm^3)	255	484	38000 ± 42000	8000 ± 15000	4.8	17 000 (7000–55 000)	4000 (3000–7000)	<0.05	15.0
PNC I/O ratio	255	469	0.77 ± 0.27	0.83 ± 0.23		0.78 (0.60–0.91)	0.81 (0.69–0.95)	<0.05	−3.7[b]
BC (ng/m^3)	141	370	390 ± 230	300 ± 250	1.3	330 (230–530)	250 (130–390)	<0.05	5.0
PBPAH (ng/m^3)	159	229	1.8 ± 1.9	1 ± 1.1	1.8	1.1 (0.7–2)	0.6 (0.4–1.2)	<0.05	6.9
$PM_{2.5}$ (μg/m^3)[c]	251	419	11 ± 4	15 ± 7		11 (8–13)	13 (11–17)	1	−7.1
NO (ppb)	252	419	2 ± 3	1 ± 2	1.9	1 (0–2)	0 (0–1)	<0.05	7.3
NO_2 (ppb)	252	419	17 ± 7	14 ± 5	1.2	15 (12–21)	13 (11–16)	<0.05	5.2
NO_X (ppb)	252	419	18 ± 8	15 ± 6	1.2	16 (13–22)	14 (11–17)	<0.05	5.6
CO (ppb)	196	401	220 ± 50	200 ± 60	1.1	210 (180–240)	180 (150–230)	<0.05	5.3

[a]One-sided hypothesis test, where the alternative hypothesis states that the median of the impact sector is greater than the median of other winds.
[b]One-sided hypothesis test, where the alternative hypothesis states that the median of other winds is greater than the median of the impact sector.
[c]Factory calibration based.

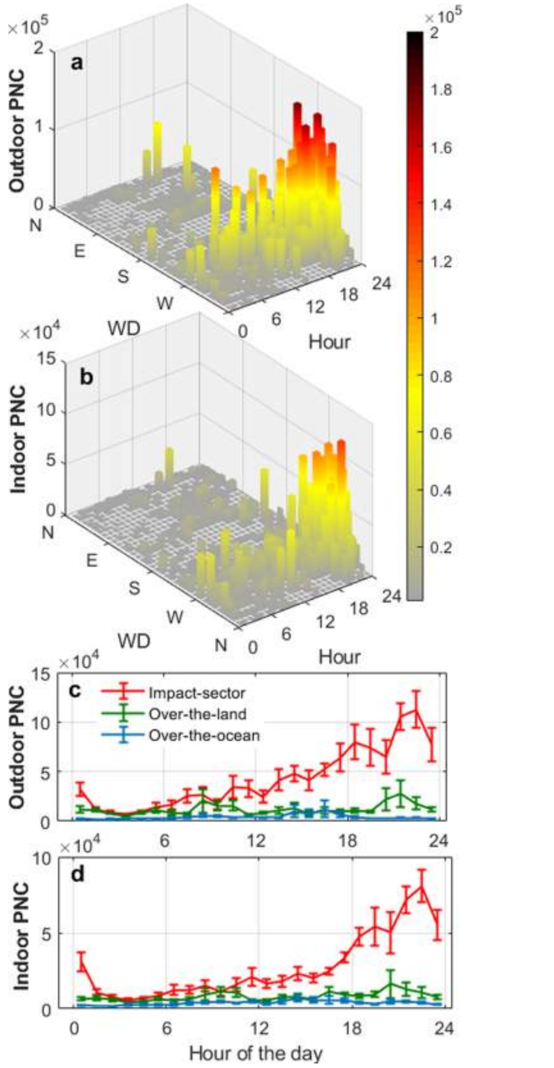

Figure 3. Outdoor (a) and indoor (b) PNC patterns with respect to wind direction (WD) and hour of the day; data were binned into 36 10°-wide WD and 24 hourly bins, resulting in an unequal distribution of data per bin but reflecting the natural frequency of WD during the monitoring period. Diurnal trends of outdoor (c) and indoor (d) PNC for impact-sector and other winds. Error bars show the standard error. Note the difference in the y-axis scale for outdoor versus indoor PNC.

51 000 versus 25 000 ± 26 000 particles/cm^3) even though total flight operations were only 15% higher in the evening relative to the morning. This indicates that the late-evening PNC increase was promoted by factors other than a proportional increase in flight activity. We also observed a pronounced late-evening PBPAH peak during impact-sector winds. PBPAH are emitted directly in aircraft exhaust, but they can also form due to condensation of semivolatile PAH on particles in the atmosphere.[37] The highest ratio of PBPAH concentration to BC concentration (BC is also emitted directly in aircraft exhaust and is a relatively inert pollutant) also occurred in the late evening hours during impact-sector winds (Figure S5). Lack of detailed tarmac-level activity data (idling and taxiing times) and chemical composition precludes an explanation for the late-evening PNC increase we observed. For example, the increase could have derived from greater airplane idling and other low-thrust operations during evening hours; low-thrust operations like idling have a higher PNC emission index (number of particles/kg fuel burnt) than high-thrust operations.[53] Greater knowledge of how plumes chemically evolve as they are transported from airplanes to downwind receptor areas near airports could help to better explain our findings.

Other than PNC, all of the pollutants had bimodal diurnal concentration profiles during impact-sector winds and the magnitude of morning and evening peaks were comparable except for NO, where the morning peak concentration was about 3-fold higher than the evening peak concentration, and NO_2, where the average concentration in late-evening exceeded the morning average by 1.3-fold (Figure 4).

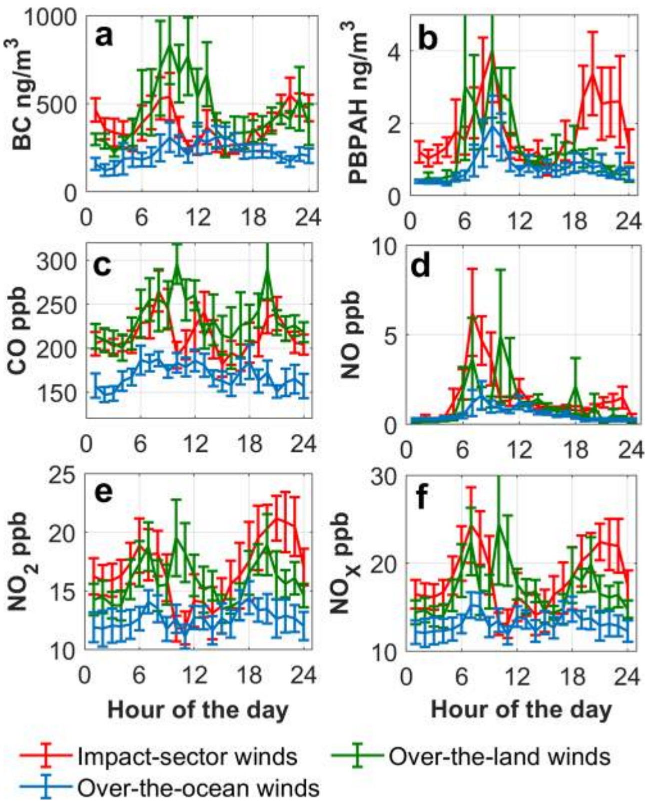

Figure 4. Diurnal trends of hourly averages of outdoor pollutant concentrations for the monitoring period during impact-sector and other winds. Error bars show the standard error. See Figure S3b for $PM_{2.5}$ and Figure S6 for CO_2.

In comparing non-impact-sector/over-the-land winds, non-impact-sector/over-the-ocean winds, and impact-sector winds, several key observations emerge. First, during over-the-ocean winds, the concentrations of pollutants were consistently and expectedly the lowest compared to other wind sectors. Also, upon examination of over-the-ocean diurnal patterns, there were small coincident peaks of PBPAH, BC, NO, and NO_2 in the morning. The few upwind air pollution sources in this sector include marine vessels, activities at Deer Island where the Deer Island Wastewater Treatment Plant is located, and traffic on roadways near the monitoring site; it is possible that these sources were responsible. Second, during over-the-land winds, the concentrations of pollutants were lower than impact-sector winds, except BC and CO. During morning to mid-day hours (0500−1300), BC concentrations during over-the-land winds were substantially higher than during impact-

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sector winds (650 ± 120 versus 390 ± 110 ng/m^3). The diurnal profiles for CO during over-the-land and impact-sector winds were similar and concentrations were only moderately different (230 ± 60 versus 220 ± 50 ppb); the evening peak coincided with the ground-traffic rush-hour period (1700–2000 h), indicating the influence of primary vehicular emissions from the Boston area at this monitoring site. Third, no distinct diurnal pattern was observed for $PM_{2.5}$ (Figures S3b and S7). Fourth, the diurnal pattern for CO_2 was similar for all three wind sectors (Figure S6). Finally, during both impact-sector and non-impact-sector winds, the lowest concentrations of pollutants were observed during 0200–0500 h when flight activity was minimal (Figure 1c) and during the warm afternoon hours when convective mixing was greatest. Correlations between pollutants at hourly time resolution are discussed in the SI (Figure S7).

Particle Infiltration. Indoor diurnal PNC patterns were nearly identical to outdoor PNC patterns (Figure 3), indicating that there was substantial infiltration of outdoor particles into the residence. Time-series plots based on 1 s measurements indicate that infiltration occurred rapidly, on the order of minutes (Figure S8). Overall, indoor PNC during both impact-sector and non-impact-sector winds were only ∼25% lower than outdoor PNC but there were modest wind-sector differences in the I/O ratios. I/O ratios were significantly ($p < 0.001$) lower during impact-sector winds compared to other winds: 0.77 ± 0.27 during impact-sector winds compared to 0.82 ± 0.23 during other winds (Figure S9a). In addition, the I/O ratios were generally negatively correlated with outdoor concentrations (Figure S9e), but more strongly so for impact-sector winds ($r_s = -0.49$, $p < 0.0001$) than non-impact-sector winds ($r_s = -0.32$, $p < 0.001$). These results are consistent with the expectation that the I/O ratios should be lower for particle mixtures dominated by smaller particles (like aircraft emissions[26,54]) because they have lower penetration rates or higher diffusional losses through cracks.[55] But the differences are modest, and coincidental influence of unquantified factors, like irregular window opening, cannot be ruled out.

Flight Activity on Preferred Runways and Pollutant Patterns during Impact-Sector Winds. Pollutant concentrations and correlations with flight activity strongly depended on the operational runway configuration. The highest correlations between ambient pollutant concentrations and total flight activity (combined landings and takeoffs per hour; LTO/h) occurred when the preferred runway configuration for impact-sector winds was used. For these conditions, all pollutants except $PM_{2.5}$ were positively correlated with total flight activity (r_s ranged from 0.31 to 0.57 for landings and 0.28–0.54 for takeoffs (Figure S12)). In contrast, flight activity on nonpreferred runways, even during impact-sector winds, was negatively correlated with pollutant concentrations although the monitored residence was still downwind of the airport (r_s ranged from −0.48 to −0.17 for landings and −0.45 to −0.22 for takeoffs). Correlation coefficients for all pollutants are shown in Figure S12.

Further, whether jets were landing or taking off at a particular runway made a remarkable difference on the downwind impacts. This point is illustrated in Figure 5a, which shows outdoor and indoor PNC (1 s resolution data) and the fraction of hourly flight activity on runways 27 and 33L. These are the two closest runways to our monitoring site. They are also preferred for operations during impact-sector winds (Figure 1a) and the majority of flight operations were

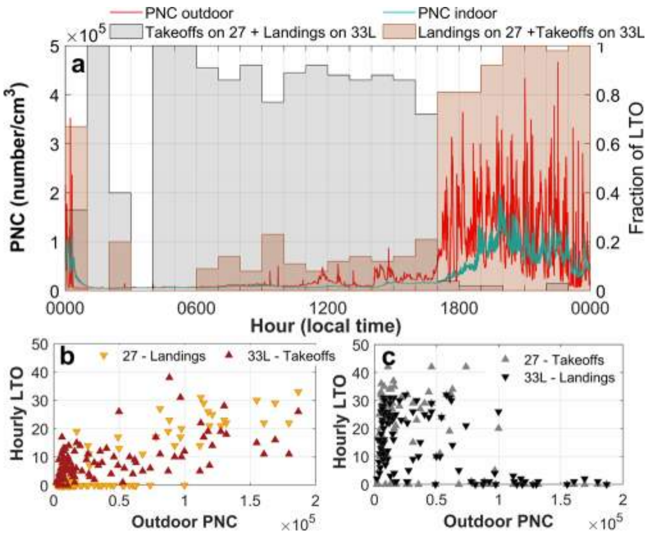

Figure 5. (a) 24-h time series of PNC and fraction of flight activity on runways 27 and 33L for a day of sustained impact-sector winds. (b, c) Scatter plots of hourly operations exclusively on runways 27 and 33L and outdoor PNC during impact-sector winds over the entire study period (n = 103 h). Figures S13–S16

conducted on these two runways during the 24-h period shown in Figure 5a. One key difference over the course of this day was that between 0400 and 1700 h, 70–100% of operations/hour occurred such that landings were on 33L and takeoffs on 27, but between 1700 and 0000 h the runway configuration switched and 80–100% of operations/hour occurred such that landings were on 27 (i.e., overhead of our monitoring site) and takeoffs on 33L. Concurrent with this switch at 1700 h, we observed recurrent PNC spikes that exceeded 100 000 particles/cm^3 and an overall increase in both outdoor and indoor PNC. Average outdoor PNC were 7.5-fold higher (121 000 ± 74 000 versus 16 000 ± 10 000 particles/cm^3) during 1700–0000 h than during 0400–1700 h. Likewise, average indoor PNC were similarly 7.7-fold higher (73 000 ± 31 000 versus 9 500 ± 3 400 particles/cm^3) during 1700–0000 h than during 0400–1700 h. Time series for other pollutants from the same 24-h period Figure 5 are shown in Figures S13–S16. Our results are consistent with reported observations of ground-level PNC spikes from descending plumes of landing jets under the landing trajectory up to 2.75 km from the runway.[26] It is noteworthy that pollutants are known to be entrained in the descending vortices from the jet wingtips[56] and the altitude of descending overhead jets at this residence (75–100 m) is below the expected planetary boundary layer height in summer. Examination of the hours in which flight activity occurred exclusively on runways 27 and 33L, i.e., n = 103 h, 40% of the impact-sector data set yielded similar results; data is shown in Figure 5b,c and statistics are discussed in the SI.

Comparison with Regulatory and Other Data sets. We compared our measurements from the near-airport residence to measurements collected during the month-long study period at five regulatory monitoring and two UFP monitoring locations in the Boston area. Locations for all sites are shown in Figure S17a, diurnal trends are shown in Figure S17b–h, and concentrations are summarized in Table S8.

The most interesting intercomparison was observed for oxides of nitrogen. Jet-engine exhaust emissions are highly

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enriched in NO_2[38] relative to NO, while exhaust emissions from ground-transportation gasoline engines are primarily in the form of NO. NO can be oxidized within minutes to NO_2 in the presence of high ozone concentrations.[57] NO_2 concentrations at the near-airport residence were higher than those recorded at all of the regulatory monitoring sites including the ones adjacent to highways and busy roadways. Study-duration ambient average NO_2 at the residence was 15 ± 6 ppb (17 ± 7 ppb during impact-sector winds). This is ~40% higher than at the adjacent-highway (11 ± 7 ppb) and near-roadway (12 ± 8 ppb) sites, which are purposefully monitored to account for the highest exposures as part of EPA's and MassDEP's near-roadway network.[58] It was also nearly 2-fold higher than at the urban-background site (8 ± 7 ppb) and 7.5-fold higher than at the regional-background site (2 ± 3 ppb). In contrast, NO concentrations at the near-airport residence were lower than those at all regulatory sites except the regional-background site. Expectedly, the highest NO concentrations were observed at sites in close proximity to traffic emissions, i.e., the adjacent-highway (8 ± 10 ppb) and near-roadway (5 ± 6 ppb) sites. The study-duration average NO concentration at the near-airport residence (1 ± 2 ppb overall and 2 ± 3 ppb during impact-sector winds) was 5-fold higher than at the regional-background site (0.2 ± 1 ppb), comparable to the urban-background site (2 ± 4 ppb), and many-fold lower than at the adjacent-highway and near-roadway sites. It is noteworthy that our study site is also farther downwind of the airport than the near-roadway regulatory sites are to traffic emission sources; thus, we likely measured a more aged plume with greater NO_2 relative to NO. See discussion in SI (Section S2.7) for other pollutants.

The study-duration average outdoor PNC as well as indoor PNC at the near-airport residence exceeded the outdoor PNC at the two UFP monitoring sites for all hours of the day (Figure 5h). The near-airport residence study-duration average concentrations were 18 000 ± 31 000 particles/cm^3 outdoors and 13 000 ± 20 000 particles/cm^3 indoors with the impact-sector averages being 38 000 ± 42 000 and 25 000 ± 27 000 particles/cm^3, respectively. In comparison, the ambient average PNC at the Chelsea site was 11 000 ± 9700 particles/cm^3 and 12 000 ± 5900 particles/cm^3 at the urban-background site. Near-airport indoor averages were comparable to the median 8000−27 000 particles/cm^3 concentrations measured on-road with a mobile lab in Boston and Chelsea[59] and to the 25 000 particles/cm^3 median concentration reported within 0−50 m of I-93 during summer; all-season median was 37 000 particles/cm^3, which was comparable to the outdoor median concentration during impact-sector winds at the near-airport residence.[43]

■ IMPLICATIONS

Our results show that when jet airplanes used preferred runways during impact-sector winds, particularly when such a configuration included overhead descents, outdoor and indoor PNC were remarkably elevated at our residential monitoring site ~1 km from the Logan Airport. Temporally, the highest PNC coincided with the periods of highest noise co-exposures (i.e., overhead landing flight hours). This finding is consistent with previous studies that have investigated the spatial patterns of pollutants around airports and have shown that PNC is significantly elevated downwind,[24] but especially under landing jet trajectories coinciding with the highest noise impact contours.[25] Our work underscores the need to account for both aviation-origin air pollution and noise co-exposures to avoid potential confounding of health risk associations to airport proximity.

Further, by clearly demonstrating the relationships between meteorological forcings (e.g., wind direction and wind speed) and aviation activity on UFP infiltration, our results add to the nascent body of knowledge of airport impacts on surrounding neighborhoods. These findings have implications for exposure assessment: exposure monitoring campaigns should be designed to include adequate coverage of the times of day (and times of high flight activity) with specific meteorological conditions of concern, especially wind direction. Our results also show that in the vicinity of airports, exposure to pollutants, particularly UFP and NO_2, is as significant in magnitude as that observed in the vicinity of highways. Also, we observed that indoor PNC were comparable to on- and near-highway PNC and that ambient NO_2 concentrations exceeded those observed at regulatory monitoring sites near an interstate highway and major arterial roadways. It is noteworthy that at this residence (and nearby areas),[60] PNC were highest during the evening and night-time hours (1700−2300 h), the times that people spend most of their time at home. In contrast, the lowest PNC in near-highway homes and on-road in the Boston metropolitan area occur during the late evening to overnight hours.[59,61] Compared to investigations of near-highway exposures to UFP and other traffic-related air pollutants, near-airport exposures remain essentially unaddressed in the literature.[16]

While our results provide a basis for better characterizing exposures to air pollutants of aviation origin at near-airport residences, additional work is needed to assess generalizability. For example, further work is needed to quantify the impact of housing stock characteristics (age, architectural style, and degree of sound insulation) on infiltration. Likewise, studying a greater range of behaviors that impact infiltration and indoor air quality (e.g., air conditioner use, in-home filtration, and ceiling fans) could help to identify practices that reduce indoor exposures. In addition, because we conducted our study in summer, it would be informative to repeat it in winter to quantify seasonal differences in both outdoor air quality and indoor infiltration; both are expected to differ seasonally. Similarly, because we only measured PNC infiltration, it would be useful to measure additional pollutants indoors (e.g., NO_2 and BC) to determine whether other pollutants infiltrate to the same extent as PNC. Finally, the chemical composition of aviation-related particulate air pollution at the neighborhood or community scale (i.e., few to tens of kilometers from the airport) remains unaddressed in the literature. Studies of the chemical composition of particles may shed light on the relative contributions from landings, takeoffs, idling, and taxiing at this scale and may also provide insights into mitigating these impacts (e.g., benefits derived from reducing idling times).

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.est.0c01859.

Maps showing preferred runway configurations, traffic around the near-airport site and regulatory sites, details of instruments, summary of concentrations, diurnal trends for pollutants and meteorological parameters, correlations between pollutants and between pollutants and flight activity, illustration of particle infiltration and trends of the I/O ratios with respect to the temporal and meteorological parameters, and comparison of near-airport concentrations to those at regulatory sites including the diurnal patterns and their discussion and a concentration summary table (PDF)

AUTHOR INFORMATION

Corresponding Author

Neelakshi Hudda − *Department of Civil and Environmental Engineering, Tufts University, Medford, Massachusetts 02155, United States;* orcid.org/0000-0002-2886-5458; Email: neelakshi.hudda@tufts.edu

Authors

Liam W. Durant − *Department of Electrical and Computer Engineering, Tufts University, Medford, Massachusetts 02155, United States*

Scott A. Fruin − *Department of Preventive Medicine, Keck School of Medicine, University of Southern California, Los Angeles, California 90033, United States*

John L. Durant − *Department of Civil and Environmental Engineering, Tufts University, Medford, Massachusetts 02155, United States*

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.est.0c01859

Notes

The authors declare no competing financial interest.

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Preterm Birth among Infants Exposed to *in Utero* Ultrafine Particles from Aircraft Emissions

Sam E. Wing,[1] Timothy V. Larson,[2] Neelakshi Hudda,[3] Sarunporn Boonyarattaphan,[2] Scott Fruin,[4]* and Beate Ritz[1]**

[1]Department of Epidemiology, University of California, Los Angeles, Los Angeles, California, USA
[2]Departments of Civil & Environmental Engineering and Occupational & Environmental Health Sciences, University of Washington, Seattle, Washington, USA
[3]Department of Civil & Environmental Engineering, Tufts University, Medford, Massachusetts, USA
[4]Division of Environmental Health, University of Southern California, Los Angeles, California, USA

Introduction: Ambient air pollution is a known risk factor for adverse birth outcomes, but the role of ultrafine particles (UFPs) is not well understood. Aircraft-origin UFPs adversely affect air quality over large residential areas downwind of airports, but their reproductive health burden remains uninvestigated.

Objectives: This analysis evaluated whether UFPs from jet aircraft emissions are associated with increased rates of preterm birth (PTB) among pregnant mothers living downwind of Los Angeles International Airport (LAX).

Methods: This population-based study used birth records, provided by the California Department of Public Health, to ascertain birth outcomes and a novel, validated geospatial UFP dispersion model approach to estimate *in utero* exposures. All mothers who gave birth from 2008 to 2016 while living within 15 km of LAX were included in this analysis ($N = 174{,}186$; including 15,134 PTBs).

Results: *In utero* exposure to aircraft-origin UFPs was positively associated with PTB. The odds ratio (OR) per interquartile range (IQR) increase [9,200 particles per cubic centimeter (cc)] relative UFP exposure was 1.04 [95% confidence interval (CI): 1.02, 1.06]. When comparing the fourth quartile of UFP exposure to the first quartile, the OR for PTB was 1.14 (95% CI: 1.08, 1.20), adjusting for maternal demographic characteristics, exposure to traffic-related air pollution, and airport-related noise.

Conclusion: Our results suggest that emissions from aircraft play an etiologic role in PTBs, independent of noise and traffic-related air pollution exposures. These findings are of public health concern because UFP exposures downwind of airfields are common and may affect large, densely populated residential areas. https://doi.org/10.1289/EHP5732

Introduction

Approximately 1 in 10 births in the United States are preterm (Martin et al. 2018), increasing the infant's risk for developing complications, such as respiratory problems, infections, developmental delays, and vision or hearing impairments (WHO 2018). Prematurity is also the leading cause of neonatal mortality (Harrison and Goldenberg 2016) and generates an annual economic burden in the United States of ∼\$26 billion [Institute of Medicine (U.S.) 2007].

Exposure to ambient air pollution during pregnancy has previously been identified as a risk factor for adverse birth outcomes, including preterm birth (PTB) (Maisonet et al. 2004; Ponce et al. 2005; Ritz et al. 2000, 2002; Ritz and Yu 1999; Šrám et al. 2005; Stillerman et al. 2008; Wilhelm and Ritz 2003, 2005). The effect of ambient air pollution from ground-transportation emissions on birth outcomes has been extensively studied, but the effects of aircraft emissions have not. During landing, takeoff, and taxiing, aircraft generate pollutant plumes that are blown downwind of airports, potentially adversely affecting the health of residents. The pollutants include particulate matter (PM), especially ultrafine particles (UFPs) from jet engines; volatile organic compounds; oxides of sulfur; and oxides of nitrogen (Carslaw et al. 2006; Ratliff et al. 2009; Valotto and Varin 2016; Yu et al. 2004). PM has traditionally been measured and regulated in terms of mass concentration of particles with aerodynamic diameter less than 10 lm (PM_{10}) or less than 2.5 lm ($PM_{2.5}$). Ultrafine or nanoparticles, which are less than 0.1 lm in diameter, are not routinely monitored or regulated. They account for little mass, but make up the majority of particles in terms of number and surface area (Hinds 1999). On an equal mass basis, UFPs may have more impact on health than do particulates with larger aerodynamic diameters, such as $PM_{2.5}$ (Hyder et al. 2014; Lamichhane et al. 2015; Lee et al. 2013) and PM_{10} (Ritz et al. 2000; Wilhelm and Ritz 2005), due to their greater mobility in the body and greater surface area.

Recent studies report adverse air quality impacts from landing jets over large areas downwind of major airports (Hudda et al. 2016, 2018, 2014; Keuken et al. 2015; Masiol et al. 2017b, 2017a; Riley et al. 2016). For example, jets approaching Los Angeles International Airport (LAX) in Los Angeles, California, produce ground-level UFP concentrations more than twice the nearby ambient levels at distances up to 16 km away from the airport (Hudda et al. 2014). Here, we evaluated whether UFPs from jet aircraft emissions increase rates of PTB near LAX based on an AERMOD dispersion model for UFPs that we built and validated with spatially extensive ground-level measurements.

Address correspondence to Beate Ritz, University of California, Los Angeles, Department of Epidemiology, 650 Charles E. Young Dr. South, Los Angeles, CA 90095 USA. Email: britz@ucla.edu

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*Co-senior authors.

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Materials and Methods

Sample Population and Health Outcome

We identified all mothers who gave birth from 2008 through 2016 while living within 15 km of LAX using birth certificates obtained from the California Department of Public Health. Our health outcome, PTB, was defined as a live birth occurring before 37 wk gestation (yes/no). We excluded birth records with implausible gestational ages (<20 or >50 wk, $n = 686$), implausible birth weights (<500 g or >5,000 g, $n = 1{,}181$), nonsingleton pregnancies ($n = 6{,}407$), or missing data on any covariates ($n = 14{,}236$) leaving 174,186 births. This study was approved by the University of California Los Angeles Institutional Review Board and the California Health and Human Services Agency's Committee for the Protection of Human Subjects. This study used routinely collected administrative data only and thus required no contact with research participants. Therefore, a waiver of informed consent was granted because it would not affect the rights of the participant nor could this research be practicably carried out without the waiver. Privacy and confidentiality were assured by using an encrypted and secure, internet-disabled computer for all data storage and analysis.

Exposure Assessment—UFPs

The U.S. Environmental Protection Agency (U.S. EPA) AERMET model was used first to generate relevant meteorological parameters from surface measurements available at LAX. Hourly vector averages of 10-m wind speed and direction were compiled from raw 5-min average measured values. Figure S1 shows the hourly directional and speed frequency distributions (wind rose) during the modeling period. We then used U.S. EPA's AERMOD meteorological dispersion model to predict air quality impacts downwind of the airport, assuming two steady-state, volumetric line sources, 50 m $\times$ 50 m in cross-section, to represent the emissions from descending aircraft approaching both runways. These two volume line sources were aligned in the same direction as the runways, which closely matched the predominant wind directions shown in Figure S1. One end of each source was placed at ground level on the eastern edge of each corresponding runway to account for the approximately 100-m induced downward plume travel from the interacting rotational energy of the vortices, which lowers the effective source positions relative to the actual position of the landing aircraft (Graham and Raper 2006). The other ends of the line sources were located at 1,000-m elevation to match the 3-degree approach angle as shown in Figure S2.

Due to the lack of regulation or standards for particle number, UFP emissions have not been well characterized historically and estimating UFP emission rates from jets involves high uncertainty (Durdina et al. 2017). For this reason, we initially assumed a nominal daily average total emission rate from both sources of 1 g/s. These emissions were then allowed to vary on a relative basis by hour of the day, based on reported flight activity patterns, with nearly all flight activity occurring between 0700 and 2300 hours (7 A.M. and 11 P.M.), as shown in Figure S3 (LAWA 2014).

To determine and validate adjustments to this emission rate, we regressed the resulting AERMOD predictions against direct downwind measurements made along the transects shown in Figure S4 on seven days, five in summer and two in winter (Figure 1) (Hudda et al. 2014). The average values for all days along each transect were then compared with the volume line source model relative predictions, based on the nominal 1 g/s emissions rates and scaled to match observed values during the same hourly time periods using a simple linear regression model. We included an intercept in the model to account for any residual background not included in the prior adjustments. Predicted vs. measured values are shown in Figure S5. The model R^2 was 0.71 with an root mean square error (RMSE) of 2,300 particles per cc and a mean absolute percentage error of 6%. The intercept was statistically significant with a value of 13,900 [standard deviation (SD) = 4,800] particles per cc.

For sensitivity tests, we compared results from modeling UFP concentrations from an area source representing the ground-level emissions from the airport runway and tarmac. We also tested a 10-degree angle of ascent (Yim et al. 2013). Neither of these configurations predicted UFP concentrations that were significantly correlated with the observations.

The 3-degree, dual volume line source model was then run for the period January 2008 through December 2016. Average values were computed for each month during that period at the receptor locations shown in Figure S6. We assumed that the meteorology derived from the LAX data applied over the entire modeling region. The monthly activity patterns shown in Figure S7 relative to the overall average were then used to adjust the monthly average model predictions at each receptor location. Particle number concentrations reported here are based on an AERMOD conversion factor of 2.3×10^6.

Using the UFP dispersion model, we linked average per trimester and per pregnancy period UFP exposures within the 15-km buffer to geocoded maternal addresses reported on the birth certificate. Additionally, we evaluated noncircular, ellipsoid exposure buffers with semiminor axes of 10, 12, and 14 km and semimajor axes of 22.5, 18.8, and 16.1 km, respectively, to preserve the original exposure buffer area of $\sim 707\ km^2$. These ellipses were aligned with the prevailing daytime wind direction of 263 degrees, the angle at which the runways are oriented.

Covariates

We controlled for NO_2 concentrations as a ground-level vehicle traffic surrogate for combustion emissions similar to methods used in previous studies (Ritz et al. 2009; Singer et al. 2004). Briefly, with a Land Use Regression (LUR) model we estimated annual NO_2 exposures for Los Angeles County using data collected over 2 wk from 201 passive air samplers (part number PS-100; Ogawa & Company USA). Final predicted concentration surfaces explained 85% of the variation of measured NO_2 concentrations. Mothers were assigned the annual average concentrations of the year during which the majority of their pregnancy occurred.

The analysis also included the known PTB risk factors (Campbell et al. 2017; Fuchs et al. 2018; Kyrklund-Blomberg and Cnattingius 1998; Luo et al. 2006; Ruiz et al. 2015) listed in the birth certificates, including parental age; mother's race/ethnicity [Hispanic (any race), non-Hispanic black, non-Hispanic white, and non-Hispanic Asian and non-Hispanic Other (including Native American and Hawaiian/Pacific Islander); maternal educational attainment; maternal nativity (U.S.- or foreign-born); and maternal smoking (ever/never during pregnancy)].

Thirty-nine noise monitors in the communities surrounding the airport routinely record noise from overhead flights and generate publicly reported community noise equivalent levels (CNELs). These monitors are deployed and managed by the airport authority and are certified by the California Department of Transportation, Division of Aeronautics. Monitors are located up to ~ 1 km north and south and 7 km east of the airport boundary, roughly following the usual approach pattern to LAX. Almost no monitoring occurs west of the airport because its western edge abuts the Pacific Ocean (LAWA 2015). Monitored data are the input into the Federal Aviation Administration's Integrated Noise Model to generate estimated annual noise impact areas due to aircraft activity. The areas affected above an annual average of 65 decibels (dB), the acceptable CNEL limit for individuals living near an airport, according to the California Department of Transportation (California Department of Transportation Division of Aeronautics) and the day–night average noise level threshold used by the Federal Aviation Administration (FAA) to make policy assessments (FAA 2018) are shown in Figure S8. We included CNEL values at each mother's residence as a dichotomous variable, either above or below 65 dB.

To further control for confounding by neighborhood socioeconomic status (nSES), we also adjusted for a composite score of nSES based on a principal component analysis selection of seven indicator variables generated from United States census data. Mothers were assigned a quintile nSES index (5 = high, 1 = low), based on the ranking of their census tract's median household income, median rent, median house value, percent living 200% below poverty level, percent of blue-collar workers, percent unemployed, and education index (Yost et al. 2001).

Statistical Analysis

We assessed the association between quartiles of residential location-specific aircraft UFP concentrations during pregnancy and PTB using logistic regression (SAS version 9.3; SAS Institute, Inc.). Quartiles were defined by cut points at 5,300 particles/cc, 8,600 particles/cc, and 14,600 particles/cc. These cut points remained consistent across all models. In covariate-adjusted models, we estimated the odds ratio (OR) for PTB in each quartile of UFP exposure relative to the lowest quartile. To evaluate the role of maternal nativity and race/ethnicity, we conducted jointly stratified analyses because the health outcomes of some recent immigrant groups may differ from native-born individuals with the same race/ethnicity (Hoggatt et al. 2012; McDonald and Kennedy 2004). We also evaluated a continuous measure of UFP, examining a linear, per-IQR increase in relative UFP exposure and sensitivity analyses using a mixture of exposure quantiles. Additionally, we analyzed the association between quartiles of UFP exposure and very PTB (<32 wk gestation) using an adjusted logistic regression model.

Further sensitivity analyses included stratifying by nSES (quintiles) and educational attainment (high school education or less, some college to bachelor's degree, or more than a bachelor's degree) to estimate the association between UFP and PTB in population subgroups. Using monthly estimates of UFP exposure, per-trimester exposure estimates were generated. Per-trimester exposure models were modeled to assess potential periods of greater sensitivity to pollutants during gestation. Pearson correlations across trimesters and with other pollutants, nSES, and UFP exposures were also analyzed. To isolate aircraft movements at LAX from activities at a nearby municipal airport [Santa Monica Municipal Airport (SMO)], we additionally excluded in some sensitivity analyses residents living within a 2-km and 5-km buffer distance from the SMO airport. Subjects for whom any covariate data were missing were excluded from analyses.

Results

Demographic factors by PTB status for the infants born within a 15-km radius of LAX between 2008 and 2016 are shown in Table 1. Most mothers were Hispanic with a high school degree or less. Mean age at delivery was 29 y (SD = 6.4 years). PTB occurred in 8.7% of all births and was more common in black and Hispanic mothers and mothers with less education and among male births. Demographic factors are also shown by quartile of UFP exposure in Table S1. In higher quartiles of exposure, mothers tended to be younger, more frequently Hispanic or black, and had less education than mothers in lower exposure quartiles. The mean UFP exposure concentration was 12,000 particles/cc (SD = 11,000 particles/cc), with a minimum of 2,500 particles/cc and maximum of 120,000 particles/cc. The IQR was 9,200 particles/cc.

In unadjusted logistic regression models, the highest quartile of pregnancy average UFP exposure was associated with a 1.32 OR of giving birth to a preterm baby in comparison with the lowest quartile. Controlling for demographic factors as well as traffic pollution and noise, the OR for PTB in the upper quartile of UFP exposure was 1.14 (95% CI: 1.08, 1.20) (Table 2), with the odds increasing monotonically with each increase in exposure quartile. When we stratified by maternal race/ethnicity and nativity when comparing the fourth quartile of UFP exposure to the first, we found the strongest associations among foreign-born women, particularly for Asian and Hispanic women (Table S2). By contrast, stronger associations were found in U.S.-born black women relative to foreign-born black women, though the sample size among black women was markedly smaller (Table S3). Exposure to the highest quartile of traffic-related NO_2 (>25.5 ppb) relative to the lowest (<21.8 ppb) was associated with an OR of 1.15 (95% CI: 1.09, 1.22). Additionally, exposure to noise >65 dB CNEL was associated with an OR of 1.10 (95% CI: 1.01, 1.19) (Table 2). Of note, maternal exposure with high airport noise was only moderately correlated with aircraft-origin UFPs (Pearson correlation coefficient $r = 0.56$) and weakly inversely correlated with traffic-related NO_2 ($r = -0.18$) (Table S4).

In additional sensitivity analyses using different quantiles of UFP exposure, the results remained consistent (Table S5). A monotonic dose–response of increasing risk of PTB with increasing exposure to UFP was evident for all exposure categorizations we examined. For UFPs using a continuous variable we estimated the OR of PTB to be 1.04 (95% CI: 1.02, 1.06) per IQR increase

Table 1. Maternal and infant demographics by gestational age.

Total *N* = 174,186	<37 wk (*n* = 15,134)	≥37 wk (*n* = 159,052)
Gestational age, mean weeks (SD), missing = 0	34.5 (2.8)	39.7 (1.4)
Birth weight, mean grams (SD), missing = 6	2,598 (752)	3,348 (444)
Parity, mean children (SD), missing = 0	2.3 (2.3)	2.1 (2.4)
Quintile of nSES Index,[a] mean (SD), missing = 0	1.9 (1.3)	2.2 (1.4)
Infant sex [*n* (%)]		
Male	8,282 (54.7)	80,774 (50.8)
Female	6,850 (45.3)	78,278 (49.2)
Missing (*n*)	2	0
Maternal age [*n* (%)]		
<20	1,322 (8.7)	11,658 (7.3)
20–24	2,980 (19.7)	30,731 (19.3)
25–29	3,440 (22.7)	38,339 (24.1)
30–34	3,702 (24.5)	43,372 (27.3)
35+	3,690 (24.4)	34,952 (22.0)
Missing (*n*)	1	2
Maternal Race [*n* (%)]		
White	1,842 (12.2)	29,749 (18.7)
Black	3,027 (20.0)	22,487 (14.1)
Hispanic	8,997 (59.5)	89,592 (56.3)
Asian	916 (6.1)	13,670 (8.6)
Others	352 (2.3)	3,554 (2.2)
Missing (*n*)	216	2,526
Maternal education [*n* (%)]		
High school graduate or less	8,909 (58.9)	81,542 (51.3)
Some college to bachelor's degree	4,928 (32.6)	57,883 (36.4)
More than a bachelor's degree	1,297 (8.6)	19,627 (12.3)
Missing (*n*)	435	4,584
Maternal nativity [*n* (%)]		
U.S.-born	10,802 (71.4)	111,087 (70.0)
Foreign-born	4,332 (28.6)	47,965 (30.2)
LUR modeled NO_2 exposure, mean ppb (SD), missing = 0	23.8 (2.6)	23.6 (2.7)
High noise at residence [*n* (%)]		
≥65 dB CNEL	779 (5.2)	6,685 (4.2)
<65 dB CNEL	14,355 (94.8)	152,367 (95.8)
Cigarette smoking [*n* (%)]		
Ever during pregnancy	157 (1.0)	923 (0.6)
Never during pregnancy	14,977 (99.0)	158,129 (99.4)
Missing	1,686	11,681

Note: Data are complete unless otherwise indicated. CNEL, community noise equivalent level; dB, decibels; LUR, land use regression.
[a]nSES measured as a composite index of seven indicator variables based on U.S. census data at the census tract level.

Table 2. Adjusted odds ratios (ORs) [95% confidence intervals (CIs)] of preterm birth.[a]

	95% CI			
Variable	Unadjusted model	Adjusted model 1[b]	Adjusted model 2[c]	Adjusted model 3[d]
UFP				
Quartile 1 (<5,340 particles/cc)	Ref	Ref	Ref	Ref
Quartile 2 (5,340–8,600 particles/cc)	1.17 (1.11, 1.22)	1.01 (0.96, 1.07)	1.03 (0.98, 1.08)	1.03 (0.98, 1.08)
Quartile 3 (8,600–14,600 particles/cc)	1.27 (1.22, 1.33)	1.05 (1.00, 1.10)	1.08 (1.02, 1.13)	1.08 (1.02, 1.13)
Quartile 4 (>14,600 particles/cc)	1.32 (1.27, 1.39)	1.11 (1.05, 1.16)	1.16 (1.10, 1.22)	1.14 (1.08, 1.20)
NO_2				
Quartile 1 (<21.8 ppb)	—	—	Ref	Ref
Quartile 2 (21.8–23.8 ppb)	—	—	1.10 (1.05, 1.15)	1.10 (1.05, 1.16)
Quartile 3 (23.9–25.5 ppb)	—	—	1.10 (1.05, 1.16)	1.11 (1.05, 1.15)
Quartile 4 (>25.5 ppb)	—	—	1.15 (1.09, 1.21)	1.15 (1.09, 1.22)
Exposed to noise >65 dB CNEL	—	—	—	1.10 (1.01, 1.19)

Note: —, Data not available; CNEL, community noise equivalent level; dB, decibels; ppb, parts per billion; Ref, reference.
[a]PTB cases $n = 15{,}134$.
[b]Adjusted for maternal age, maternal educational attainment, SES, maternal race, and cigarette smoking. Educational attainment was recorded in 9 ordinal categories: No formal education, 8th grade or less, 9th grade through 12th grade with no diploma, high school graduate or GED, some college credit with no degree, associate's degree, bachelor's degree, master's degree, doctorate or professional degree.
[c]Adjusted for all variables in Adjusted Model 1 and NO_2.
[d]Adjusted for all variables in Adjusted Model 2 and airport noise.

in UFP. When we explored exposure to UFP at different times during pregnancy, we found that the per-trimester effect estimates were nearly identical to those for the entire pregnancy (Table S6). However, the UFP averages for trimesters and the whole pregnancy were highly correlated (Table S3); hence, our ability to detect differences between trimester-specific exposures was diminished. When we modified the aspect ratio of the exposure area, generating an ellipsoid buffer, we observed only minor changes in effect estimates (Table S7).

We also conducted stratified analyses to assess potential effect measure modifiers. When we stratified by quintile of nSES, we observed a modest increase in the odds of PTB associated with UFP exposure with decreasing nSES when comparing the fourth quartile of UFP exposure to the first, though estimates were not behaving strictly monotonically (Table S8). We also found nSES and UFP exposures to be negatively correlated [Pearson correlation coefficient: $-.27$, $p < .0001$ (Table S9)]; i.e., mothers living in areas with the lowest nSES tended to be exposed to higher levels of aircraft-origin UFPs relative to women living in areas with higher nSES. Stratifying by education suggested an increased risk of PTB due to UFP exposure in all quartiles of exposure among women with less than a high school education (OR 1.19, 95% CI: 1.10, 1.28). On the other hand, for those with some college education, the estimated effect sizes for UFP exposure were smaller (OR 1.10, 95% CI: 1.00, 1.21) (Table S10).

We also estimated the association between UFPs and very PTB ($n = 2{,}805$), and the OR for the highest quartile (1.13) of exposure was very similar to the overall estimate, but the CI was wider (95% CI: 0.98, 1.31) (Table S11). When excluding mothers living close to a nearby municipal airport (SMO), overall effect estimates changed only slightly. Specifically, after excluding mothers living within 2 km and 5 km of SMO, the ORs for the highest quartile of UFP exposure relative to the lowest quartile increased to 1.15 (95% CI: 1.09, 1.21) and 1.18 (95% CI: 1.11, 1.25), respectively (Table S12).

Discussion

We found *in utero* exposures to jet-specific UFP emissions, estimated using a spatially validated AERMOD dispersion model, to be associated with increased odds of PTB among mothers living within 15 km of LAX. This is the first study to report such associations for an adverse birth outcome among residents living in the incoming flight paths and downwind of a major airport. We also found associations between PTB and vehicular traffic-related air pollution NO_2, modeling with an LUR as reported previously in a study of births between 1997 and 2006 in Los Angeles (Wu et al. 2009), but the effect sizes were slightly weaker than those we estimated for LAX UFPs. These results suggest an association between traffic-related air pollution and PTB that has been previously reported for other population-based birth outcome studies (Ji et al. 2019; Ritz et al. 2007, 2000; Wilhelm et al. 2011) and was consistent across different categorizations of the UFP exposure variable.

Our results suggest that exposure to aircraft-origin UFP may be independently associated with PTB after accounting for coexposure to traffic-related air pollution and aircraft noise. Whether noise was included or excluded from models, the effect estimates for UFP exposure remained the same. Although previous research found some evidence for an etiological role of noise in PTB (Argys et al. 2019), other research has not consistently detected this link (Ristovska et al. 2014). In our cohort, although exposure to airport-related noise does appear to be associated with an increased risk for PTB for those living very close to the airport (Figure S8), aircraft-origin UFPs were associated with PTB in an area downwind of the LAX airfield that is much larger than the one affected by high noise levels. In fact, in 2010, more than 1.9 million residents lived within the 15-km buffer we studied (U.S. Census Bureau 2010). For comparison, aircraft activity at LAX has been previously estimated to generate an average particle number concentration equivalent to 280 km–790 km of freeway emissions, which represents emissions equivalent to 19%–53% of the total freeway length in all of Los Angeles County (Hudda et al. 2014).

An important aspect of this study is that it distinguishes aircraft-origin UFPs from traffic-origin UFPs. A previous study in California implicated vehicle traffic UFPs in PTBs from 2000 to 2008 (Laurent et al. 2016). However, the CALINE4 traffic model used to estimate exposures did not include the contributions of aircraft-origin UFP. In comparison with the sharp UFP gradients resulting from vehicle traffic that are limited to a few hundred meters from roadways, UFP emissions from jets, particularly landing planes, show unusually large impact areas with relatively little small-scale spatial variability (e.g., almost no change over hundreds of meters) (Hudda and Fruin 2016). This characteristic allowed for more accurate exposure estimates compared to with ground-source UFP concentrations from roadways, which typically have sharp downwind concentrations gradients (Kaur et al. 2006).

There is a relatively rapid downward transport of these aircraft-origin UFPs and thus very little time for physical aging of these UFP particles due to coagulation with larger particles. This downward transport is due to a combination of large-scale daytime, convective velocities of up to 1 m/s that are enhanced by local-scale jet wingtip vortices that can extend vertically downward for several hundred meters at similar, superimposed velocities (Graham and Raper 2006). This combination results in plumes from descending aircraft reaching ground level in approximately a few minutes near the airport and up to 15–20 min at 15 km downwind from the airport. At these plume transport times, 10–20 nm UFPs emitted by jet engines have a characteristic coagulation half-life of about an hour, assuming that they are emitted into a background aerosol with a number concentration of 1×10^4 particles per cubic centimeter and count mean diameter of 0.2 lm (Seinfeld and Pandis 2006). These half-lives depend on the number concentration and size of the surrounding background particles. However, the smaller UFPs that are transported downward from this elevated source spend even less time interacting with potentially higher concentrations of existing particles that occur at ground level, such as those found on or near major roadways. It is therefore not surprising that the typical size of these UFPs in the downwind footprint shown in Figure 2 are typically very small 10–30 nm, indicating minimal coagulation losses (Hudda and Fruin 2016; Hudda et al. 2014; Riley et al. 2016; Shirmohammadi et al. 2016). Furthermore, due to the consistency of daytime onshore breeze directions at LAX, the location of elevated, ground-level UFPs concentrations downwind and to the east of LAX is very stable (Hudda and Fruin 2016; Hudda et al. 2014), producing relatively large contrasts in concentrations between residences inside the area of impact in comparison with those located outside.

An interesting finding is that the effect estimates for UFPs and PTB were somewhat stronger among foreign-born Hispanic and Asian women, possibly because those women are less likely to be employed during pregnancy in comparison with U.S.-born mothers (von Ehrenstein et al. 2013, 2014); thus, they could have spent more time at their residences during pregnancy, which may have resulted in greater exposure and/or reduced exposure misclassification, which could possibly explain the stronger effect sizes we estimated. Alternatively, the foreign-born women may have been at increased risk for PTB due to decreased utilization of prenatal care (Heaman et al. 2013)—possibly driven by several barriers, including language comprehension (Edwards 1994) and access to health care (Gagnon 2004)—or working in physically demanding occupations that adversely affect birth outcomes (von Ehrenstein et al. 2013).

Several aspects of UFP could contribute to the estimated effects on PTB. Inhaled UFPs penetrate the lung mucosa and can translocate to other parts of the body because their size facilitates movement across cell barriers, entrance into the bloodstream, and relocation to distal tissues (Baldauf et al. 2016), including the placenta (Bové et al. 2019). Additionally, UFPs escape the usual clearance mechanisms by phagocytes, which remove larger particles like PM_{10} and $PM_{2.5}$ (Li et al. 2016). Murine cell–based experiments have linked UFP exposures with an increased oxidative stress response and inflammation (Li et al. 2003; Nel et al. 2001), mechanisms that have been implicated in PTB (Ferguson et al. 2015; Romero et al. 1991; Vadillo-Ortega et al. 2014). For example, at concentrations occurring in ambient Los Angeles air, one experiment found large increases in measures of oxidative stress, such as heme oxygenase expression, intracellular glutathione depletion, and reactive oxygen species generation (via dithiothreitol assay) in exposure to quasi-UFP size fractions (<0.15 lm) in comparison with fine or coarse PM fractions (Li et al. 2003). In humans, intrauterine inflammation is common in PTB (Üstün et al. 2001), and PTB is associated with an unusually large presence of proinflammatory immune cells and tumor necrosis factor-α (Romero et al. 1989).

Another important physiochemical property of UFPs that may increase their pathogenic potential is their large particle surface area. Depending on their sources, they may carry adsorbed or condensed air toxics, such as polycyclic aromatic hydrocarbons (PAHs) (Sioutas et al. 2005). In fact, UFPs are responsible for up to 30% of the PAHs deposited in the lung (Kawanaka et al. 2009). UFP plumes from aircraft emissions are highly enriched in particle-bound PAHs (Kinsey 2009) and an order of magnitude higher than background particle-bound PAH levels reported up to 6 km downwind of LAX (Hudda et al. 2014). Other research in the Los Angeles area has found that UFPs contain much

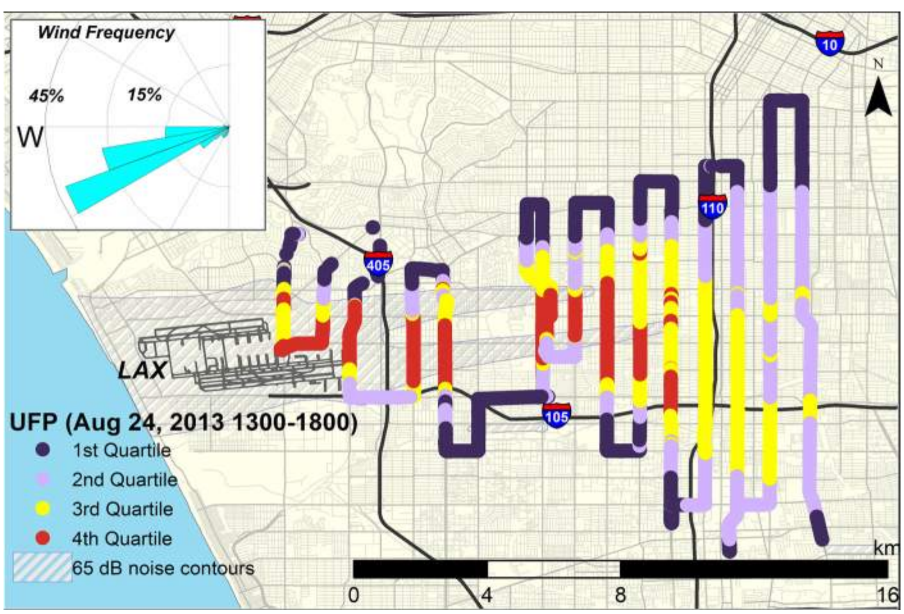

Figure 1. Measured ultrafine particles (UFP) concentrations downwind of Los Angeles International Airport (LAX) on 3 December 2013 with area above 65 decibels (dB) average noise in gray. Base layers obtained from USGS.gov (USGS 2019).

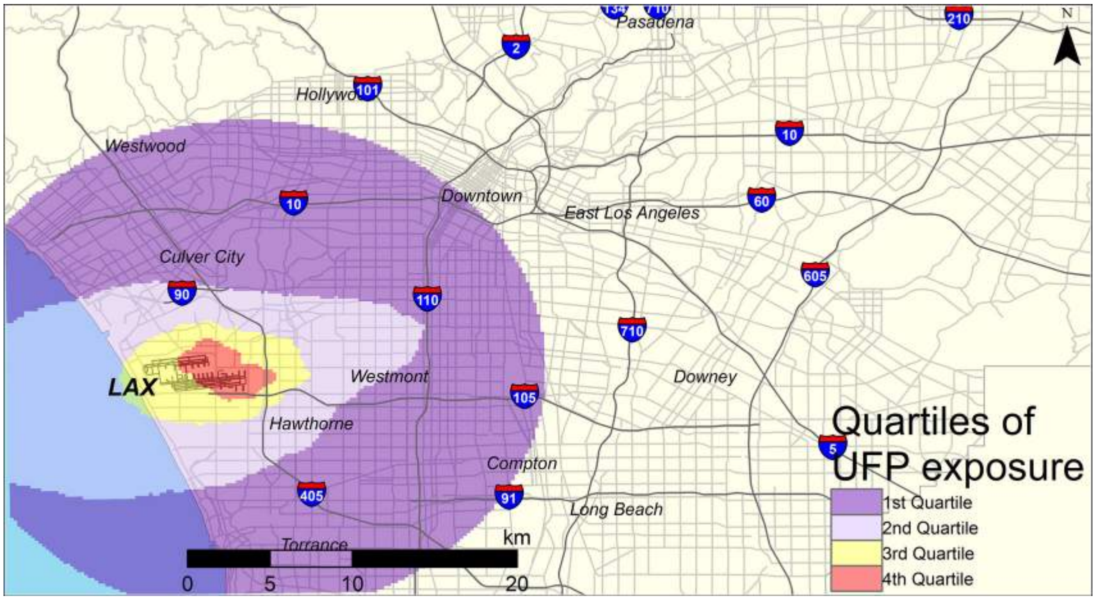

Figure 2. Estimated UFP exposure quartiles from AERMOD results. Base layers obtained from USGS.gov (USGS 2019).

higher PAH content than fine (<2.5-lm) particles and coarse (2.5–10-lm) particles (Li et al. 2003). With respect to aircraft-based PAHs, a study of emissions within the plane loading area of a major airport showed that the particle-bound PAHs were composed of ~80% high-molecular-weight compounds with high toxicity (Lai et al. 2013). Altogether, there is evidence suggesting that UFPs, especially those of aircraft-origin, carry pathogenic PAHs linked to inflammation (den Hartigh et al. 2010; Schober et al. 2007) and PTB (Wilhelm et al. 2011).

Another source of aviation emissions located in the study area is the general aviation airport SMO (~7.5 km north of LAX), but the aircraft using this airfield are smaller, using Avgas, which contains tetraethyl lead (ASTM International 2017). *In utero* lead exposure is a known cause of adverse birth outcomes (Andrews et al. 1994). To account for potential lead exposures in areas near this municipal airport, we excluded births within a 2- and 5-km distance from SMO, but this exclusion did not change our effect estimates for UFPs.

Our study has several strengths. The UFP dispersion model allowed us to assess exposure profiles in a large population encompassing tens of thousands of births. Due to the daytime wind directions at LAX being very consistent throughout the entire year, the locations at which UFP exposures occur downwind of LAX are quite stable (Hudda and Fruin 2016; Hudda et al. 2014). Such consistency allows for accurate exposure estimation at residences across the years due to improved AERMOD exposure model generalizability. Further, the outcome data were derived from birth records, reported and recorded in a uniform manner in California.

Another strength of our study is its public health importance. UFP exposures have received limited research attention, and this project addresses impacts of aircraft movements that could have profound public health impacts, given the ever-growing demand for air travel. In the United States, more than 40,000 daily flights (FAA 2017) service nearly 400 primary airports (FAA 2013). UFP emissions from these aircraft are spread across large residential areas. For example, in the United States, ~40 million people live near 89 major airports (i.e., in areas with ≥45 dB noise levels). Due to the noise from airports, many of the UFP affected areas are low nSES with especially vulnerable populations. In analyses by nSES, PTB was associated with higher levels of aircraft-origin UFP exposures only in low nSES areas (Table S8). Low nSES communities are overrepresented in housing stock located directly downwind of this highly trafficked airport. In addition, because lower household income has been shown to be inversely correlated with air conditioner use (Malig et al. 2010), the proximity might be magnifying air pollution exposures due to the opening of windows in homes lacking air conditioning, which can result in increased indoor UFP concentrations (Rim et al. 2013). Although we cannot confirm this hypothesis in our data, it is one possible explanation for this observation. Another explanation is increased susceptibility to PTB among low-nSES pregnant women, possibly due to differences in health care access.

This study has some limitations, including a semiecological exposure assessment because we are estimating UFP exposures only at the home address provided on the birth certificate, and we cannot account for time spent by mothers at work, in transit, or at other residences prior to birth. A previous study estimated that 9%–32% of mothers move during their pregnancy (Bell and Belanger 2012). We were not able to adjust for exposure to $PM_{2.5}$ in our analyses because only a single government-operated $PM_{2.5}$ monitor is located in the area of interest and does not provide spatial variation in measures. However, our adjustment for LUR modeled NO_2, a valid marker for traffic-related air pollution in the region (Su et al. 2009), helped control for spatially distinct traffic-related pollutants that may act as confounders on a fine spatial scale. Future studies of this type would benefit from greater temporal coverage of UFP measurements for dispersion model validation, perhaps via fixed monitors. Finally, our assumption of a constant per-aircraft UFP emission rate did not account for possible changes in relative emission factors over the study period. Unfortunately, adequate information to quantify historical trends for aircraft UFP emission factors is not available.

Conclusion

An increased risk of PTB was estimated with *in utero* exposure to higher concentrations of aircraft-origin UFPs in women living near LAX. Although *in utero* air pollution exposure from particulate matter—especially from traffic-related combustion sources—are known risk factors for PTB, our results suggest that emissions from aircraft might play an independent etiological role in adverse birth outcomes. These findings are of great public health concern because UFP exposures downwind of airfields are common and may affect large densely populated residential areas.

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Distinct Ultrafine Particle Profiles Associated with Aircraft and Roadway Traffic

Elena Austin,* Jianbang Xiang, Timothy R. Gould, Jeffry H. Shirai, Sukyong Yun, Michael G. Yost, Timothy V. Larson, and Edmund Seto

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ABSTRACT: The Mobile ObserVations of Ultrafine Particles study was a two-year project to analyze potential air quality impacts of ultrafine particles (UFPs) from aircraft traffic for communities near an international airport. The study assessed UFP concentrations within 10 miles of the airport in the directions of aircraft flight. Over the course of four seasons, this study conducted a mobile sampling scheme to collect time-resolved measures of UFP, CO_2, and black carbon (BC) concentrations, as well as UFP size distributions. Primary findings were that UFPs were associated with both roadway traffic and aircraft sources, with the highest UFP counts found on the major roadway (I-5). Total concentrations of UFPs alone (10−1000 nm) did not distinguish roadway and aircraft features. However, key differences existed in the particle size distribution and the black carbon concentration for roadway and aircraft features. These differences can help distinguish between the spatial impact of roadway traffic and aircraft UFP emissions using a combination of mobile monitoring and standard statistical methods.

1. INTRODUCTION

The health effects associated with $PM_{2.5}$ [particles with diameters less than 2.5 μm (μm)] mass concentrations have been well studied, leading to established standards and routine monitoring.[1] However, $PM_{2.5}$ consists of a mixture of particles of varying sizes from a variety of sources, with the most numerous particles by count usually falling within the ultrafine size range (<100 nm). Typical reported urban background concentrations of ultrafine particles (UFPs), ranging from 5000 to 40,000 particles/cubic centimeter (#/cm^3), are impacted by weather and proximity to roadways and airports.[2−11] The total mass concentration associated with these UFPs is typically less than 2 μg/m^3. Thus, the UFP is not considered an important contributor to the mass of $PM_{2.5}$. In the ambient environment, the spatial and temporal variation of UFPs tends to differ significantly from that of $PM_{2.5}$ or PM_{10}.[12]

Early toxicological studies suggested that UFPs may be more relevant to health than larger-sized particles due to the larger surface area relative to the mass of UFPs and the ability for smaller sized particles to penetrate within the body.[13,14] While the epidemiologic evidence for UFP health effects is still limited, there exist some studies to inform quantitative concentration−response functions for all-cause mortality,[15] and recent large epidemiologic studies have considered UFP exposure estimates for a variety of outcomes, including breast cancer,[16] ischemic heart disease,[17−21] prostate cancer,[22] asthma, and COPD.[23]

Although much research on environmental variations in UFP concentrations has focused on roadway vehicle emissions of UFPs,[10,24−30] recent research identifies a previously underappreciated source of UFPs, which may be responsible for large population exposures globally. Monitoring campaigns conducted in communities near the Los Angeles,[31−33] Atlanta,[34] Boston,[35,36] New York,[37] and Amsterdam[38] airports have all identified elevated levels of total UFPs in proximity to international airports. The work in LAX demonstrated significant downwind exposures (∼10 km) of UFP but did not have information on upwind community exposures.[35,39] This has led to difficulty in determining community impacts and differential exposures during aircraft takeoffs versus landings. Previous work, using near-source fixed-site sampling at one location[38,40] or nonsimultaneous upwind and downwind locations, has not yielded consistent results with respect to the relative impact of landing versus takeoff flight activity.[41] Previous work has highlighted the compositional differences between aircraft and roadway traffic sources,[37,40,42−45] as well as documenting uniquely different fuel-based emissions of roadway and roadway traffic-based sources.[39] To our knowledge, exploiting these known differences to derive spatially resolved exposures zones within a mobile monitoring framework is unique to the work presented here.

The Mobile ObserVations of Ultrafine Particles (MOV-UP) study[45] was a two-year project, funded by the State of

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Washington, aiming to study air quality impacts of air traffic for communities located near and below the flight paths of the Seattle-Tacoma International (Sea-Tac) Airport. The study assessed UFP concentrations within 10 miles upwind and downwind of the airport under the flight trajectories. The goals of this study were to demonstrate the ability to distinguish between aircraft and other sources of UFPs and compare levels of UFPs in areas impacted by high volumes of air traffic with those areas that are much less impacted.

To our knowledge, this work is significant and novel in that:

1 mobile monitoring was simultaneously performed at a significant distance (~10 km) both upwind and downwind of a major airport to examine the relative impacts of takeoffs versus landings (Stacey et al.[40] and Keuken et al.[38] used near-source fixed-site sampling at one location coupled with the wind direction; Lopes et al.[41] used fixed-site sampling at both locations but did not sample simultaneously upwind and downwind; and Shirmohammadi et al.[39] and Hudda et al.[33] did not sample upwind at LAX);

2 multivariate analysis was conducted on purely mobile monitoring data to separate traffic sources from aircraft sources (Tessum et al.[42] conducted PCA in the Los Angeles study, but relied on both mobile and fixed-site data; others using only fixed-site data include Rivas et al.[43] and Masiol et al.,[37,44] who conducted PMF and analyses on fixed-site data); and

3 PCA-based predictions were used to derive spatially resolved independent estimates of fuel-based emission factors (Shirmohammadi et al.[39] assessed emissions based on a more spatially limited sampling scheme), demonstrating clear separation in emissions between roadway traffic and aircraft, as well as between landing and takeoff conditions.

2. METHODS

Sampling for the MOV-UP study was conducted seasonally from February 2018 through March 2019. The study was conducted using a mobile sampling design, with two hybrid-electric vehicles equipped with sampling instruments and an isokinetic probe, which sampled ambient air as the vehicles moved through defined routes. All measurements were conducted after an initial vehicle warmup period of at least 30 min. This sampling platform has been previously described in detail.[29]

2.1. Study Area. The study domain included the areas to the north and south of the Sea-Tac International Airport. Mobile monitoring occurred along defined routes termed *transects*, which were designed to sample perpendicular to the flight path in an east-west direction at fixed latitudes north and south of the airport.

Because of terrain and roadway considerations, some transects deviated slightly from the target latitude. We monitored transects 10 miles north (five transects) and 10 miles south (six transects) of the airport (Figure S1, Supporting Information). The campaign was designed to capture multiple repeated samples of each transect. Please see a summary description of each route in the Supporting Information, Table S1.

Sampling occurred during the mid-day and afternoon hours to increase comparability between the different sampling repeats and to minimize the effect of a changing height of the atmospheric mixing layer. In the interest of decreasing confounding by weather patterns and other time-varying changes in UFP concentration, most sampling days consisted of two simultaneous sampling vehicles north and south of the airport.

2.2. Mobile Monitoring Measurements. A detailed description of the mobile platform is given elsewhere.[29] In summary, each mobile monitoring platform consisted of a Toyota Prius hybrid-electric vehicle from University of Washington Fleet Services and several portable monitors for air pollution measurements.

Location and speed were captured using a GPS logger on the dash of the vehicle. The sampling inlet was mounted on the roof of the vehicle pointing forward and positioned above the vehicle boundary layer, the zone of turbulence directly associated with vehicle motion. Airflow entered the vehicle through the otherwise sealed left rear window from where they were connected to the instruments. Particle loss was minimized using stainless steel, copper, and conductive flexible tubing for the particle sampling inlet and connecting tubing. The exhaust pipe from the vehicle's gasoline engine was discharged on the right side low to the ground, away from the elevated, left-side air monitoring inlet. To further minimize the potential for self-pollution, the vehicle's gasoline engine would typically shut off when stopped at red traffic lights.

As summarized in Table S2, each mobile platform was equipped with a CPC (model 3007, TSI Inc., MN), two P-Trak (model 8525, TSI Inc., MN) condensation nucleus particle counters (one with inlet diffusion screens to increase the minimum detected particle size), a black carbon aerosol monitor (microAeth AE51, AethLabs, CA), a CO_2 analyzer (Li-850, LI-COR, NE), and a GPS receiver (DG-500, GlobalSat WorldCom Corporation, TW). Additionally, a NanoScan SMPS nanoparticle sizer (model 3910, TSI Inc., MN) was rotated between the two platforms. All these instruments measured and recorded data at one-second intervals except the NanoScan (1 min intervals).

2.3. Flight and Meteorological Data. We requested flight data from the Federal Aviation Administration (FAA) western regional office using a data-disclosure request. The data covered 2018 and included track data for all the flights in the Seattle metropolitan region. The density of flights with an altitude of lower than 750 m was gridded in cells of 70 × 100 m by hour of the year for the study domain. We used the single-aircraft track data to calculate the predominant landing direction and the number of flights landing per hour. The flight data included flights arriving and departing from all local airports.

The Washington Automated Surface Observing System (ASOS) network[46] provided us with wind speed and direction, temperature, and relative humidity based on 15 min data from Sea-Tac.

2.4. Instrument Calibration and Colocation. All instruments were calibrated for flow, zero, and span in the factory before we received them. The full calibration process is described in detail elsewhere.[47] The Li-850 CO_2 analyzer was calibrated for zero and span in the lab with certified standard CO_2 gas. We conducted mobile colocation with all sets of UFPs and/or BC monitors deployed in one vehicle, using the average reading of all instruments as a reference. Since there are no traceable standards for calibration of UFPs and BC monitors, we used the averaged measured results of all sets of duplicate monitors as the reference. See Table S3 for the

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summary of calibration coefficients and R^2. Note that five P-Trak monitors, four P-Trak screened monitors, two CPC monitors, and three AE51 monitors were rotated between the two vehicles.

2.5. Data Integration. At the end of each sampling day, we collected raw data from each instrument on a secure server. There were 2,876,538 individual time points collected. We developed a merging script to

1 compute 30 s center-aligned rolling means to smooth concentrations of CO_2 and 1 s particle numbers;
2 smooth the BC data using an optimized noise-reduction averaging (ONA) algorithm (with the attenuation coefficient (ATN) threshold set to ΔATN = 0.06) to reduce potential instrumental optical and electronic noise;[48]
3 apply a common 1 min time basis for all sampling instruments;
4 calculate short-term 30 min background concentrations for black carbon and particle count, based on the method presented elsewhere;[29]
5 apply between-instrument calibration factors as discussed in the "Quality Control" section; and finally,
6 merge meteorological parameters and flight data per 1 h metric.

2.6. Quality Control. We also performed data quality control and applied the following criteria. We first excluded GPS coordinates from the analysis which were outside of the study zone presented in Figure S1. We flagged them as erroneous zero readings across all NanoScan 60 s samples (57 measurements). We excluded data with black carbon concentrations exceeding 27,000 ng/m^3 (0.01% of the data). We based one of our particle metrics between 10 and 20 nm on the difference in short-term measures of the CPC and P-Trak instruments. In instances where this difference was negative (<1.2% of the collected data), we replaced the negative value with a random normal distribution of data centered around 1 particle/cm^3, eliminating negative values in the data. The maximum negative difference before this transformation was −32, the mean was −0.25, and the median was −0.11. Next, automated flagging routines censored data corresponding to instrument error codes and instruments operating out of specified parameters or data otherwise missing (instrument rebooted itself, lost power, etc.). We then manually inspected the time series for each pollutant for anomalies and cross-checked with field technician notes. Finally, we combined the resulting mobile monitoring data into a final data file. All data management was performed in R version 3.5.1.

2.7. Descriptive Statistics. We computed descriptive statistics of the collected data including mean, median, interquartile range, and range and performed graphical representation of the data using the ggplot2 library in R.

We calculated some informative pollutant ratios for descriptive purposes. These measures are based on differences in the cut point of the CPC, Ptrak, and screened PTrak instruments. To potentially account for the prevalence of various particle sizes and contribution of black carbon soot originating from different emission source types, we computed ratios for the proportion of 10−20 nm particles relative to total measured particles, the proportion of 20−36 nm particles relative to total measured particles, and the proportion of 10−20 nm particles to black carbon concentration.

Also, we calculated the concentration of particles above the background concentration of total particles as the quantity above the 5th percentile of the 30 min concentration of particles. This approach has been successfully employed in previous mobile monitoring campaigns to account for neighborhood-level concentrations.[26,34]

2.8. Principal Component Analysis. Principal component analyses (PCA) were performed using the "psych" and "GPA rotation" packages in R. Factors with eigenvalues greater than 1 being retained and a Varimax rotation applied to improve factor interpretability.

Input variables beyond the directly measured variables were included in the PCA analysis to capture a variety of composition and size information on the particles collected over the mobile monitoring campaign. These are described in the Descriptive Statistics section.

A sensitivity analysis was developed based on a subset of the data containing NanoScan data. This second PCA solution was used to interpret and validate the full model. Results of the two PCA analyses were compared using both correlations of the scores and composition information. Principal component features were interpreted based on composition and spatially described based on GPS data collected during the mobile monitoring drives.

2.9. Spatial Mapping. We performed mapping of pollutants, principal components, and flight patterns on a grid of 0.001 degrees of longitude (∼70 m) and 0.002 degrees of latitude (∼100 m). We represented the distribution of pollutant concentrations on a quantile scale and performed plotting using the R implementation of the leaflet JavaScript tool.

2.10. Fuel-Based Emission Factors. Fuel-based emissions factors are typically computed as a concentration of emissions produced per gram of fuel burned. The emission factor of particular interest in this study is the very smallest range of UFPs that we termed "ultra-ultrafine particles" (Ultra-UF), defined by eq 1

$$\text{emission factor (EF)} = \frac{\text{\# of ultra-UF particles } (10-20 \text{ nm})}{\text{fuel (kg)}} \quad (1)$$

We do not know the total kilograms of fuel burned for the traffic and aircraft sources. However, we can use the change in measured ambient CO_2 concentration over a short period as a proxy for changes in fuel consumption. The change in CO_2 relates to fuel consumption by estimating the weight fraction of carbon (ω_c) in the traffic and aircraft fuel. We reported these weights in the literature measuring between 0.85 and 0.87 for traffic and 0.86 for Jet A fuel.[49]

Based on a previously developed method,[39] we estimated the fuel-based emissions factors (eq 2) for quantiles of locations we identified as "high aircraft impact" and "high traffic impact" through the PCA analysis. Urban background concentrations are defined as the 5th percentile of the data collected during each hour of monitoring,[26,29] for both the Ultra-UF and CO_2 concentrations.

$$EF_P = \left(\frac{[P]_i - [P]_{bg}}{[CO_2]_i - [CO_2]_{bg}} \right) \omega_c \times \alpha \quad (2)$$

where $[P]_i$ represents the concentration of Ultra-UF particles at the impact area (#/cm^3); $[P]_{bg}$ represents the hourly

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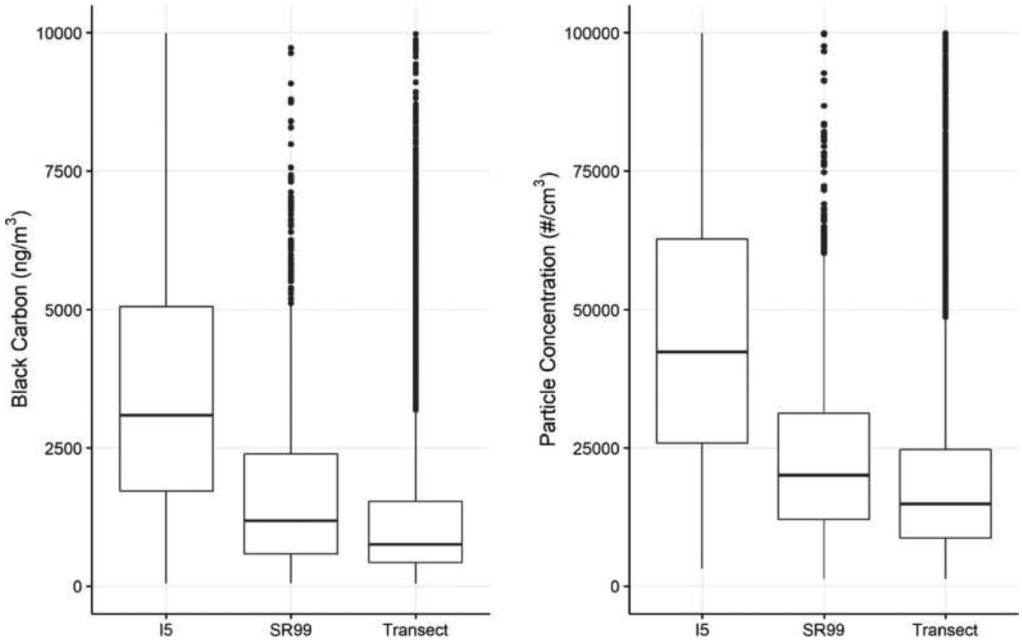

Figure 1. Major roadway (Interstate 5 and State Route 99) and mobile monitoring transect concentrations of traffic-related pollutants: (A) black carbon mass and (B) total particle (>10 nm) number. This figure includes all the data collected on all transects north and south of the airport.

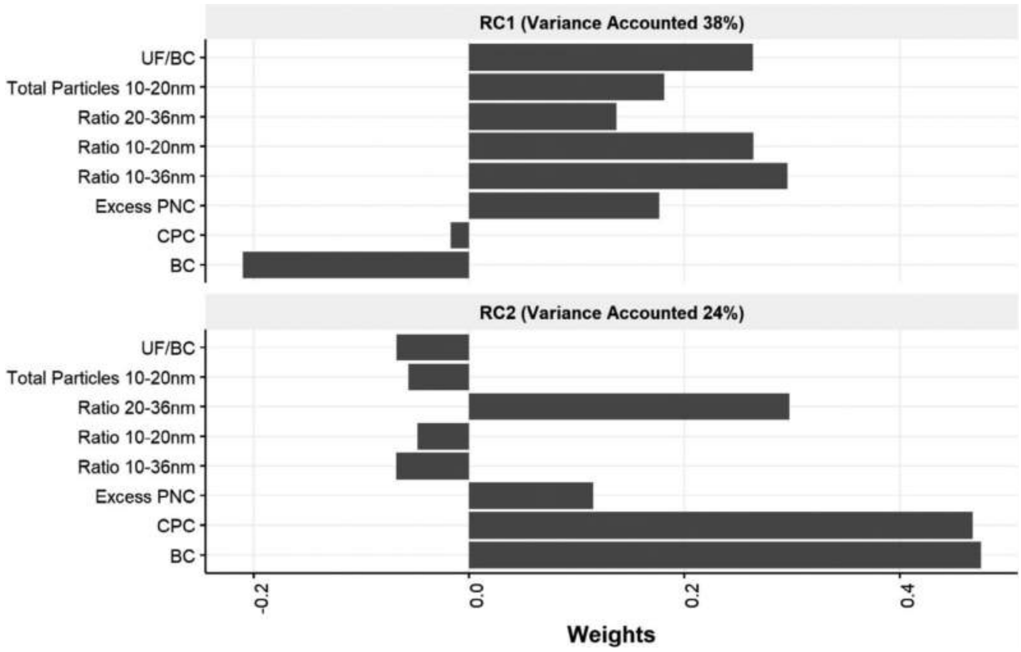

Figure 2. Principal component factor loadings for each feature.

background concentration of Ultra-UF particles (#/cm^3); $[CO_2]_i$ represents the concentration of CO_2 at the impact area (g/m^3); $[CO_2]_i$ represents the hourly background concentration of CO_2 (kg/m^3); ω_c is the weight fraction of traffic and aircraft fuel; and α is the unit conversion factor (10^{15}). The nonparametric Wilcoxon rank sum test was used for comparison of EF between different locations and landing conditions.

3. RESULTS

3.1. Descriptive Summary. We conducted mobile monitoring with either one or two vehicles for 63 days during the time domain of our study between February 7, 2018, and January 11, 2019. Typically, the two vehicles were sampled for 5 h within the interval from approximately 11:00 to 17:00 on different routes—either along five transects to the north or along five transects (or six during the summer season) to the south of Sea-Tac. Overall, the airport was in south flow operation (planes taking off to the south and landing from the north), 67% of our sampling times. This is comparable to the overall yearly proportion of the south flow operation of 65% (Table S4). The wind-rose plots (Figure S2) are separated by north and south flow operating conditions derived from the flight-track data. As expected, during north flow operation, winds are predominantly from the north and northwest, whereas during south flow operation, winds are from the south

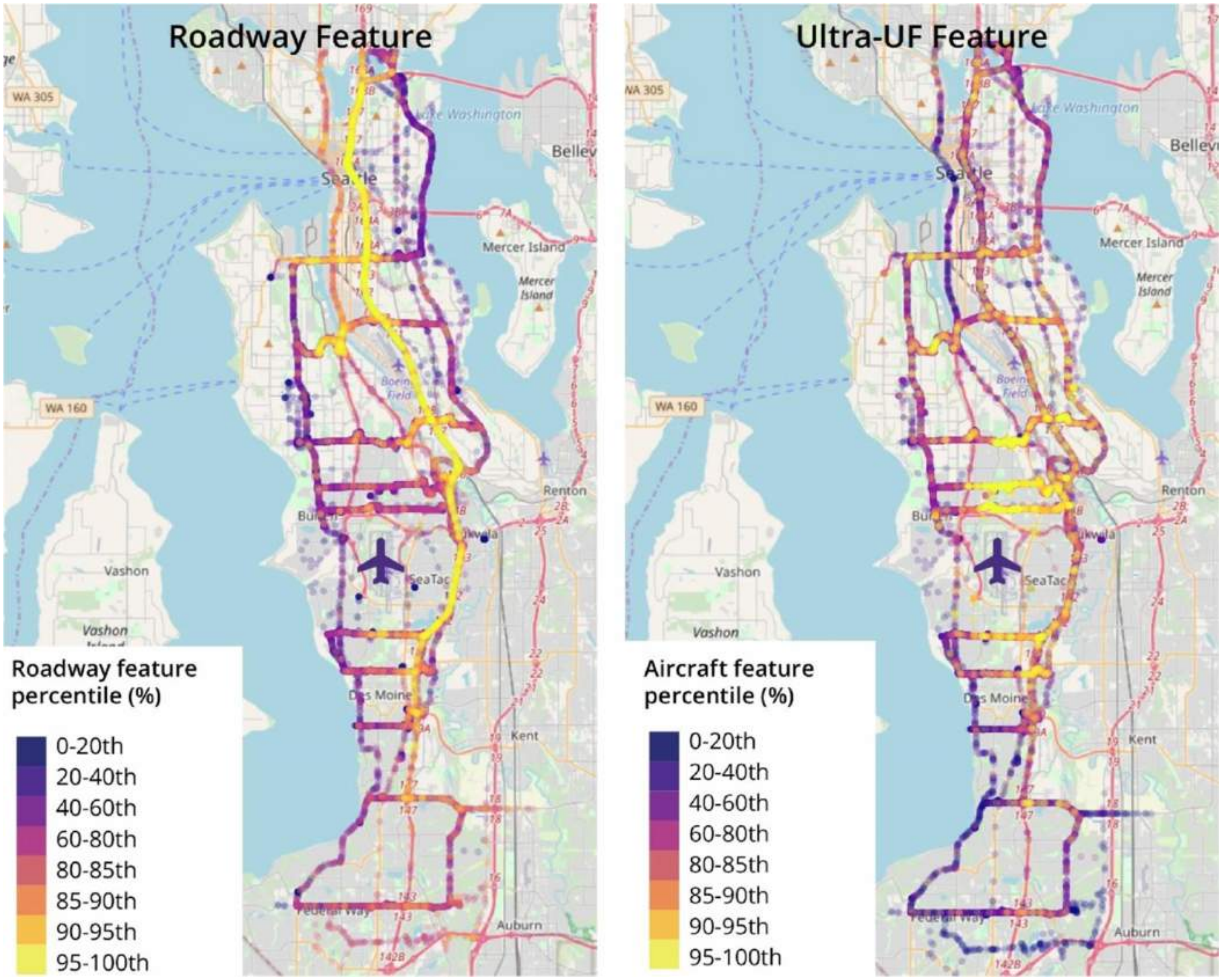

Figure 3. Spatial distribution of the "Ultra-UF" and "roadway" features. Colors correspond to percentile values for each factor score. Percentiles range from 0th percentile representing the smallest observed value to 100th representing the largest observed value.

and southwest. There are fewer time periods with winds exceeding 6 m/s during the north flow operations for our sampled data.

We compared the overall concentration of roadway pollutants, on our transects, on I-5, and on SR-99 (Table S5), along with the total sampling time (in minutes) along each route segment. For the particles and gases measured, we reported the highest mean values on roads, both I-5 and SR 99.

The mean concentration of black carbon observed on I-5 was 5.0 $\mu g/m^3$ with a standard deviation (SD) of 4.3 $\mu g/m^3$, whereas on transect N1 and S1, directly adjacent to the airport on north and south ends, respectively, the mean concentration of black carbon was 1.0 (SD = 1.0) $\mu g/m^3$ and 1.5 (SD = 5.1) $\mu g/m^3$, respectively. The total particle concentration measured on I-5 was 59,896 (37,704) $\#/cm^3$, which is significantly higher than concentrations observed along transects.

It is important to consider that each transect traverses along its east-west length from areas below low aircraft volume to high flight volume. Therefore, summary statistics across the entire transect may not capture peak variations. Typically, the highest SD values are found on the road, although there are some transects that demonstrate more change in pollutant measures.

There was a distinction between the distribution of black carbon and the total particle number (>10 nm) obtained from the two roadway locations and I-5 (Figure 1). Traffic-related pollutants most heavily impacted the high traffic interstate location; however, extreme values (>than the 95th percentile of the data) are common on both the transect and SR 99 sites.

The spatial distribution of traffic-related pollutants confirms that their locations are primarily on and near the major roadways. There is a clear decrease in traffic-related concentrations as the mobile monitoring platform moves away from the high-traffic locations (Figure S3).

3.2. Principal Component Analysis. The PCA yielded two features that together accounted for 61% of the variability in the mobile monitoring data. Figure 2 shows the factor loadings for each feature. These loadings correspond to the correlation coefficients between the pollutant variables and PCA factors. The squared factor loading is the percent of the variance in that variable explained by the factor. Large positive loadings correspond to variables that have a large proportion of

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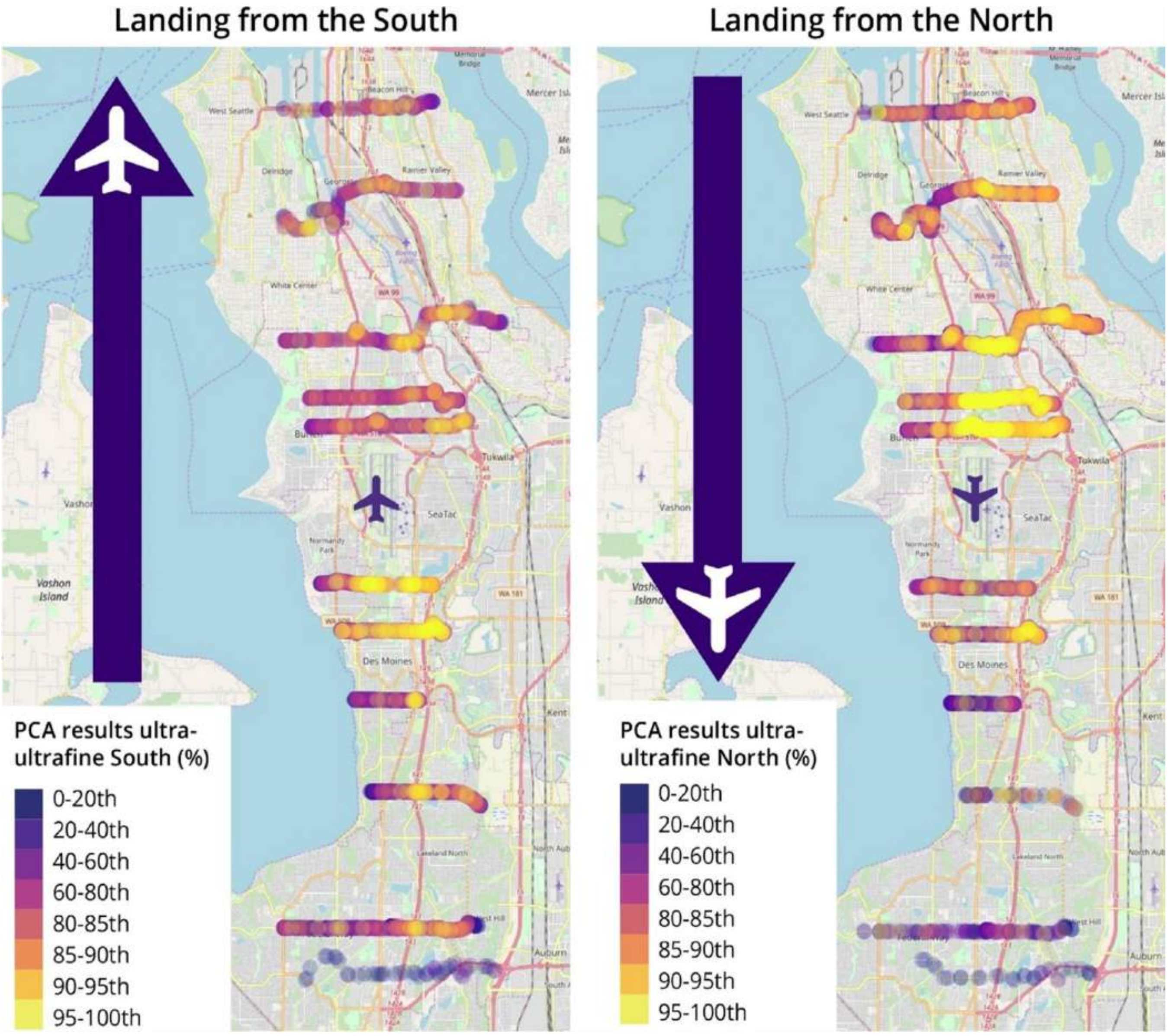

Figure 4. Spatial distribution of the "Ultra-UF" PCA feature, separated by the landing direction. Colors correspond to percentile values for the Ultra-UF factor score. Map layer OpenStreetMap contributors.

their variability captured within the factor. Negative loadings correspond to factors that vary inversely with the factor.

The first feature (RC1) was positively correlated with particles between 10 and 36 nm in diameter. In addition, this feature had a negative correlation with black carbon, a pollutant primarily emitted from diesel combustion, as well as other urban sources such as rail, maritime, manufacturing, and wood heating. When compared to a restricted analysis that included size-resolved information from the NanoScan (Figure S4), there was a correlation of 0.82 between this feature and the NanoScan-based feature with a high proportion of 11.5 and 15.4 nm particles. This same feature had a poor association with particles greater than 20.4 nm. Based on these characteristics, we describe this as the "Ultra-UF feature".

The second feature (RC2) from this analysis has a high correlation with particles between 20 and 36 nm and BC and total UFP concentrations. In contrast, this feature is inversely correlated with particles with a diameter smaller than 20 nm. When compared to a restricted analysis that included size-resolved information (Figure S4), we demonstrated a correlation of 0.79 between this feature and the feature composed of a high proportion of particles between 20 and 36 nm. Based on these characteristics, we described this feature as the "roadway feature".

Figure 3 shows the spatial distribution of these distribution factors and plots the percentile values of the PCA scores computed over the year of sampling for each location we sampled during the mobile monitoring campaign. We can see that the roadway feature, characterized by strong correlations with roadway related pollutants, is the highest overall on I-5 and at major junctions with SR-99. The Ultra-UF feature is not characterized by high concentrations on roadway. This feature shows high values north and south of the airport.

This PCA analysis suggests that based on a mobile monitoring campaign, we can distinguish between roadway-related UFP sources and a distinct UFP source composed primarily of particles less than 20 nm in diameter. Based on the previous literature,[32] this fraction is likely associated with

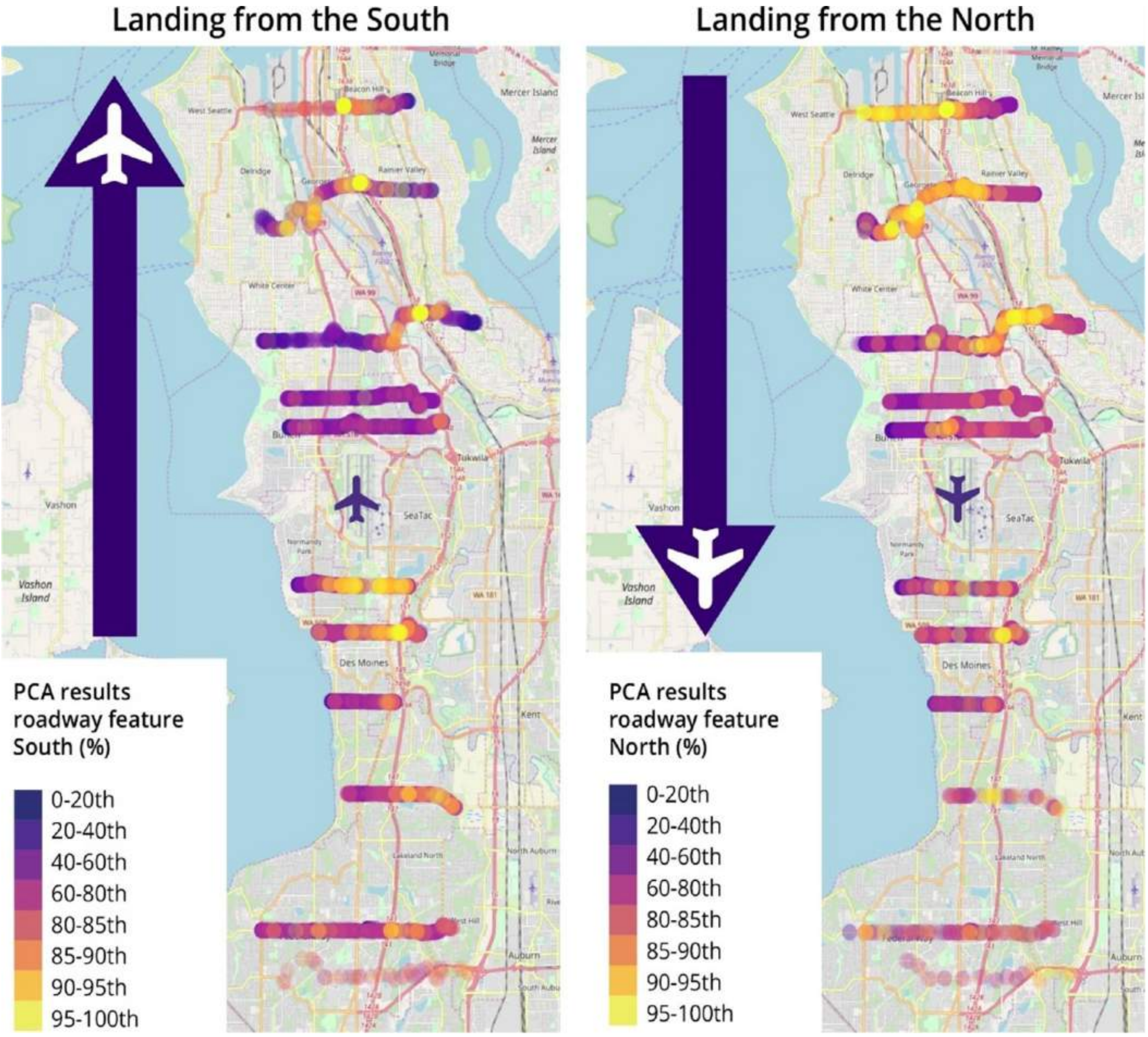

Figure 5. Spatial distribution of the "roadway" feature, separated by the landing direction. Colors correspond to percentile values for the roadway factor score. Map layer OpenStreetMap contributors.

aircraft emissions when aircraft engines are relatively under light load, such as landing. To test the hypothesis that the Ultra-UF feature was associated with periods of time when aircrafts were landing overhead, we separated the data set by the aircraft landing direction.

A high percentage of mobile monitoring measurements underneath the landing path of aircraft were consistent with the Ultra-UF feature (Figure 4). There are still some areas opposite to the landing that show some high PCA scores; these may be due to emissions from aircraft takeoffs or sometimes from a poor separation between traffic and aircraft emissions by the PCA.

In contrast, plotting the scores of the roadway feature by the aircraft landing direction shows (Figure 5) that there is no significant impact of the landing direction on the spatial distribution of this PCA score. A clear spatial gradient east and west of high-traffic roadways in this mapping also emerges. Because of the association with the aircraft landing paths, rather than roadways, the Ultra-UF is likely due to pollution from aircraft emissions.

3.3. Emission Factors. We calculated fuel-based emission factors and grouped them by quantiles of the roadway and Ultra-UF PCA features. This emission factor represents the concentration of particles emitted per kg of fuel burned. In this study, we estimated the emission factor by the ratio of the change in particle number (10−20 nm) to the change in CO_2 associated with each feature. The Methods section describes this calculation in detail. Over the study area, the calculated EF for the roadway feature does not significantly change (Figure 6A). However, the EF at locations with a high aircraft PCA score shows a much higher emission of 10−20 nm particles than locations with a low aircraft PCA score. A Wilcoxon rank sum test confirmed statistically significant differences in UFP emissions between the two pollutant features ($p < 2.2 \times 10^{-16}$) with estimated increased UFP emission of the aircraft feature of 2.9×10^{14} [2.5×10^{14} and 3.3×10^{14}] particles/kg fuel.

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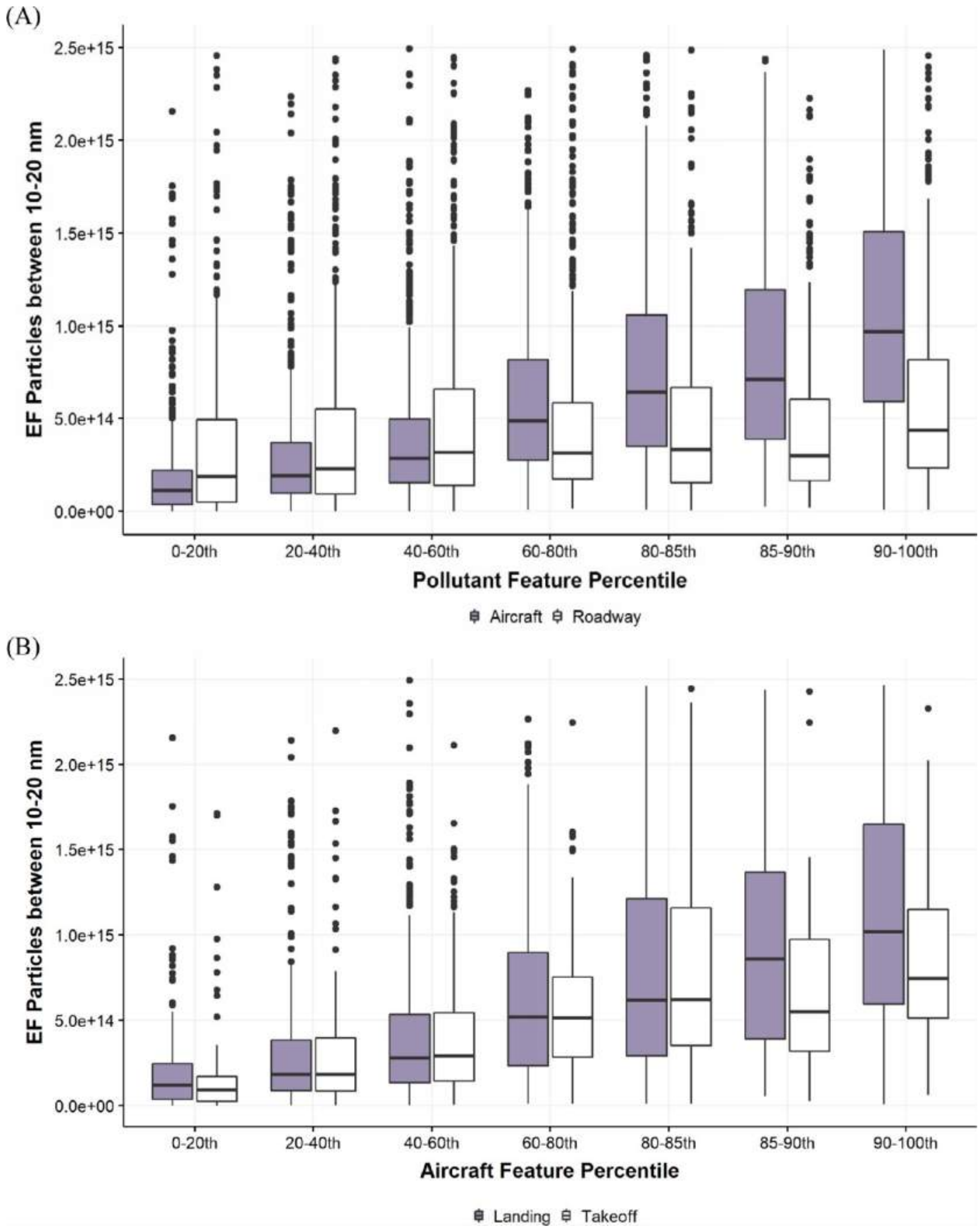

Figure 6. (A) Fuel-based emission factors calculated for quantiles of the PCA scores for the aircraft and roadway features. (B) Fuel-based emission factors calculated only for the aircraft feature for landing and takeoff conditions. Units of the EF are in #particles/kg fuel burned.

Figure 6B further examines the impact of the landing direction on the calculated EF of the aircraft score. A clear difference in emissions is identified for samples under the landing path. The difference between the EF of landing and takeoff conditions is highly significant ($p < 0.01$) and estimated to be 1.4×10^{14} [3.62×10^{13} and 2.5×10^{14}] particles/kg fuel burned based on the Wilcoxon sum test.

4. DISCUSSION

This is the first study that distinguishes between roadway versus aircraft sources of UFP upwind and downwind of a major international airport by exploiting multivariate source features derived from measurements taken on a moving platform. Using multiple pollutant measures taken with this platform throughout the year, we were able to distinguish aircraft-related UFPs from roadway-related UFPs. While UFPs are emitted from both roadway traffic and aircraft and the total number concentration of UFPs (ranging from 10 to 1000 nm) do not distinguish roadway traffic from aircraft, we could separate the pollution from the two sources using measurements of particle size and BC concentrations.

From a multipollutant PCA analysis of mobile monitoring data, we observed two features that explained the majority (61%) of the variance in the pollutant measurements. One of these features is related to roadway traffic, which consisted of relatively larger UFP sizes and high BC concentrations. The other feature, which we termed Ultra-UF, consisted of relatively smaller UFP sizes and lower BC concentrations. By mapping the locations of the relative contributions of each feature, we observed that the roadway feature was located on and very near the major roadways in the study area, such as I-5 and SR-99. In contrast, we observed the Ultra-UF feature below the landing paths of the aircraft. The PCA did not identify other potential sources of BC and UFPs in our region, namely, seasonal residential wood smoke. This is likely because sampling was distributed throughout the year and designed to be in proximity to roadway and aircraft sources.

Finally, after computing fuel-based emission factors based on the mobile monitoring data, we observed that measurements that were most consistent with the Ultra-UF feature and landing aircraft tended to have a higher emission rate of small 10−20 nm-sized particles per kg of fuel burned compared to measurements that were characterized as roadway feature particles. We computed significantly higher Ultra-UF particle emission per kg fuel burned under landing conditions as compared to takeoff conditions.

Our findings are consistent with previous literature on the roadway and aircraft-related UFP pollution. Monitoring campaigns conducted in airport communities near Los Angeles,[31−33] Atlanta,[34] Boston,[35,36] New York,[37] and Amsterdam[38] have all identified elevated levels of UFPs that the aircrafts have caused. The Los Angeles studies, in particular, found elevated concentrations of UFPs underneath the aircraft landing paths of the LAX airport and that concentrations of UFPs at the ground level near the airport runway tend to consist of smaller 10−20 nm size fractions.[35]

Moreover, our estimates of the emission factor of particles from the aircraft-related Ultra-UF feature are consistent with previous studies that range in magnitude from 10^{14} to 10^{17} particles/kg fuel.[39] Also consistent with previous literature, we estimate a larger UFP impact related to aircraft landings as compared to aircraft takeoffs. This is consistent with previous studies directly testing the emission factors from jet engines at different load conditions and reporting higher emissions of smaller particles under low load conditions.[50] Although this question of the community level impact of landings versus takeoffs is not yet fully established, we believe that our results demonstrate substantial enrichment of Ultra-UF particles, on the order of 10^{14} Ultra-UF/kg_{fuel}, during landing conditions. We recognize that our results do not reflect observations made in previously reported studies[40,43] and hypothesize that some of these differences are related to the instrument cut point (capturing the 10−20 nm range is critical) and sampling design (our study was designed to capture community impacts, not near-runway impacts).

The spatial patterns we observed for the roadway feature UFPs are also consistent with previous studies. Most studies have observed elevated concentrations immediately adjacent to and downwind of major freeways.[51] From these previous studies, UFP concentrations have been found to follow a "rapid decay" spatial pattern with a decrease in concentration by at least 50% over a distance of 150 m away from the major roadway, with a gradual decay to the background thereafter over a distance of 500 m. We observed similar spatial patterns for the roadway PCA feature, which was most associated with measurements on and immediately next to the major roadways in our study area, I-5 and SR-99.

There is a relatively rapid downward transport of these aircraft-emitted UFPs and relatively little time for their physical aging due to coagulation with larger particles. This downward transport is due to a combination of large-scale daytime, convective velocities of up to 1 m/s, and local-scale wingtip vortices that can extend vertically downward for several hundred meters at similar, superimposed velocities.[52] This results in plumes from the descending aircraft during the daytime reaching the ground level in approximately a few minutes near the airport and up to 15 to 20 min at 15 km downwind from the airport.

At these plume transport times, 10−20 nm UFPs emitted by jet engines have a characteristic coagulation half-life of about an hour, assuming that they are emitted into a background aerosol with a number concentration of 1×10^4 particles per cubic centimeter and a count mean diameter of 0.2 μm.[53] It is not surprising that the typical size of these UFPs in the downwind footprint is typically between 10 and 30 nm, indicating minimal coagulation losses.

The differences in the spatial extent of the aircraft versus roadway traffic UFPs are important to consider from a population impact perspective. We observed concentrations of total UFPs (10−1000 nm sized particles) to be higher near roadway compared to our near-airport transects. However, most people spend a relatively small proportion of their time on a major roadway (e.g., during commuting), and because of the relatively short distances over which the roadway UFP decays downwind of major roadways, the roadway UFP would affect only a narrow swath of near-roadway residences and other buildings.

In contrast, the affected areas experiencing elevated aircraft UFPs tend to be more diffuse with consistently elevated concentrations occurring in locations below the decent path of the aircraft. Therefore, considering the map shown in Figure 4, there is the potential for more people to be affected by UFPs from the aircraft than from roadway sources, albeit at lower concentrations. Moreover, those living within the area affected by landing aircraft emissions may be exposed to relatively higher concentrations of smaller sized Ultra-UFPs. There is an urgent need to address this problem because it disproportionately affects communities of color. We overlaid US Census ACS data with Sea-Tac flight paths and the I-5 freeway corridor and observed that approximately 22% of the population of King County lives in proximity to potentially elevated concentrations of UFPs (Table 1). Moreover, the proportion of People of Color is greater in areas of UFP exposure, indicating that this is an alarming new Environmental and Racial Justice issue.

Few epidemiologic studies assess the associations between aircraft UFP exposure and health. One study of two specific locations in Los Angeles observed that short-term exposure to

Table 1[a]

Demographic Characteristics	Population	White	Nonwhite
King county	2,163,257 (100%)	1,404,974 (65%)	728,283 (35%)
within 1 km of the flight paths	188,922 (100%)	84,150 (45%)	104,722 (55%)
within 0.5 km of I-5 freeway	370,964 (100%)	205,278 (55%)	165,686 (45%)
within either 1 km of flight paths or 0.5 km of I-5	468,808 (100%)	254,419 (54%)	214,389 (46%)

[a]5 year US Census American Community Survey (ACS) 2014−2018 tract data.

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aircraft-related UFPs is associated with elevated systemic inflammation (IL-6), whereas roadway traffic is more associated with impaired respiratory health (lower FEV_1) and inflammation (elevated sTNFrII).[54] A recent population-based cohort study of all mothers who gave birth from 2008 through 2016 while living within 15 km of LAX found that in utero exposure to aircraft-origin UFPs was positively associated with preterm birth independent of the effects of traffic-related exposures.[55] This suggests that the health effects of aircraft-related UFP exposure may be distinct from roadway traffic UFP exposure, again highlighting the importance of being able to distinguish between sources of UFPs in community settings.

Some of the findings of this study are subject to limitations and uncertainties inherent to a scientific study, as in the following cases. Although both PCA analysis and the ratio of small (e.g., 10−20 nm) to total UFPs indicate a spatial pattern with aircraft activity, there is no chemical or compositional indicator that these particles are directly related to aircraft activity.

We did not observe any features associated with other potentially important urban sources of UFP, including residential wood-smoke burning, industrial emissions, and atmospheric transformation of gaseous pollutants. The PCA methodology does not a priori exclude any pollutant features.

Important future research directions emerged from this study. Although many studies have identified health effects associated with roadway traffic UFPs, the potential health effects from aircraft-related UFP exposure still need major research. Our study highlights the need to fill this knowledge gap because we observed that the particle size distribution of traffic UFPs is different from aircraft UFPs. Our study suggests that the population in some neighborhoods may have more exposure to UFPs than others due to proximity to roadway traffic or overlap with the plumes from aircraft emissions. Additionally, roadway and aircraft traffic has changed in volume, travel patterns, and per unit emissions over time. It will likely continue to change, creating uncertainties in the impacts of future UFP exposures.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.est.0c05933.

> Summary of each mobile monitoring transect; summary of instruments used in the MOV-UP study; summary of colocation calibration results for PNC and BC monitors; summary of drive days across the four seasons of the MOV-UP study; summary measures from the mobile monitoring campaign by monitoring the location and transect; MOV-UP study setup; wind rose plots; spatial distribution of traffic-related pollutant concentration percentiles; and principal component factor loadings for each feature of the secondary PCA analyses (PDF)

■ AUTHOR INFORMATION

Corresponding Author

Elena Austin − *Department of Environmental & Occupational Health Sciences, University of Washington, Seattle, Washington 98195, United States;* orcid.org/0000-0002-4724-1042; Phone: 206-221-6301; Email: elaustin@uw.edu

Authors

Jianbang Xiang − *Department of Environmental & Occupational Health Sciences, University of Washington, Seattle, Washington 98195, United States;* orcid.org/0000-0001-5196-2574

Timothy R. Gould − *Department of Civil & Environmental Engineering, University of Washington, Seattle, Washington 98195, United States*

Jeffry H. Shirai − *Department of Environmental & Occupational Health Sciences, University of Washington, Seattle, Washington 98195, United States;* orcid.org/0000-0002-9864-532X

Sukyong Yun − *Department of Civil & Environmental Engineering, University of Washington, Seattle, Washington 98195, United States*

Michael G. Yost − *Department of Environmental & Occupational Health Sciences, University of Washington, Seattle, Washington 98195, United States*

Timothy V. Larson − *Department of Environmental & Occupational Health Sciences, University of Washington, Seattle, Washington 98195, United States*

Edmund Seto − *Department of Environmental & Occupational Health Sciences, University of Washington, Seattle, Washington 98195, United States*

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.est.0c05933

Notes

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GUIDANCE FOR QUANTIFYING SPECIATED ORGANIC GAS EMISSIONS FROM AIRPORT SOURCES

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ACRONYMS AND ABBREVIATIONS

A/C	Air conditioning
ACRP	Airport Cooperation Research Program
AEE	FAA Office of Environment and Energy
APP	FAA Office of Planning and Programming
APU	Auxiliary power unit
ARFF	Airport rescue and firefighting facilities
Avgas	Aviation gasoline, also known as 100 low lead or 100LL
CAA	Clean Air Act
CARB	California Air Resources Board
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CO	Carbon monoxide
EA	Environmental Assessment
EDMS	Emissions and Dispersion Modeling System
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
FAA	Federal Aviation Administration
FID	Flame ionization detector
GA	General aviation
GAV	Ground access vehicles
GPU	Ground power unit
GSE	Ground service equipment
HAP	Hazardous air pollutant
HHRA	Human health risk assessment
ICAO	International Civil Aviation Organization
IRIS	Integrated Risk Information System
LTO	Landing and takeoff
MOBILE	U.S. EPA motor vehicle emission rate program
MOVES	U.S. EPA Mobile Vehicle Emission Simulator
MSAT	Mobile Source Air Toxic
MEK	Methyl ethyl ketone
NAAQS	National Ambient Air Quality Standards
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NMOG	Non methane organic gas
NOx	Nitrogen oxides
OG	Organic gas
PM	Particulate matter
SCC	Source classification code
SPECIATE	U.S. EPA data system of speciation profiles
SO_2	Sulfur dioxide, an EPA criteria pollutant
THC	Total hydrocarbons
TIM	Time in mode
TOC	Total organic compounds
TOG	Total organic gas
VMT	Vehicle miles traveled
VOC	Volatile organic compound, a precursor to ozone

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1 INTRODUCTION

Inventories of airport-related speciated organic gases (OGs) which include the OGs identified by the United States Environmental Protection Agency (U.S. EPA) to be hazardous air pollutants (HAPs) and the OGs listed in the EPA's Integrated Risk Information System (IRIS)[1] are not required by current EPA regulations. [2] However, per Federal Aviation Administration (FAA) Order 1050.1E Change 1, *Environmental Impacts: Policies and Procedures*,[3] FAA policy is that "If air toxics analysis is performed, [the Emissions and Dispersion Modeling System] EDMS should be used or supplemented with other air toxic methodology and models in consultation with the appropriate FAA program office and [FAA's Office of Environment and Energy] AEE." This guidance provides the means to comply with FAA's policy by presenting a methodology to prepare airport-related emissions inventories of speciated OG/HAP emissions. In cases where it is necessary to prepare such an airport-related inventory, the inventory must be prepared following the approach described in this document to ensure consistency. Inventories must also be prepared utilizing EDMS.

This document provides an approach to, and technical guidance for, preparing speciated OG/HAP emission inventories in support of environmental documents prepared by, or on behalf of, the FAA under the National Environmental Policy Act (NEPA)--it does not address requirements of the California Environmental Quality Act (CEQA). Besides an emissions inventory, NEPA reports (i.e., Federal Environmental Assessments (EAs) and Environmental Impact Statements (EISs)) must not include any other type of OG/HAP assessment including, but not limited to, dispersion, toxicity weighting, exposure, or health risk quantifications. When assessments involving dispersion, toxicity weighting, exposure, or health risk quantifications are required by CEQA, proper analysis methodology should be employed. These types of assessments require a complete understanding of both the reaction of OGs/HAPs in the atmosphere and downstream plume evolution. Because the science of these atmospheric reactions with respect to airport-related OGs/HAPs is still evolving, the related level of understanding is currently limited.

The approach to preparing a speciated OG emission inventory is based on what is currently known about airport-related emissions. Both the FAA and EPA recognize that even though the amount of aircraft engine emission test data is growing, the amount is still limited and there are research gaps that need to be addressed. Through measurement campaigns and studies, the FAA, in partnership with other Federal agencies and the scientific community, is currently collecting additional emissions data and performing analysis with respect to the ultimate fate of these emissions in the atmosphere.

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[1] http://www.epa.gov/iris/

[2] In this guidance, air toxics and toxic air contaminants are referred to as hazardous air pollutants (HAPs). When organic gases are speciated, two groups of gases result, those that are HAPs and those that are not. The collective "group" of gases discussed in this guidance are referred to as "speciated organic gases" and methodologies are presented to estimate airport-related emissions of both. For a detailed discussion of the relationship of HAPs and OG, along with other "groups" of OG, please see Section 1.5.1 of this guidance.

[3] Appendix A, Section 2.4

1.1 Background

In 2003, the FAA's AEE undertook an assessment to determine what was already known about speciated OGs at airports, in general, and aircraft-related OGs, in particular [FAA, 2003]. This initial body of work (referred to as the *FAA Resource Document for HAPs*) focused on those OGs specifically identified by the EPA to be HAPs and was prepared in response to the rising interest by various federal, state and local governmental agencies and the general public in connection with the emerging topic of these pollutants. The need for a more unified approach and technical guidelines for evaluating speciated OG/HAP emissions for airport-related sources (the approach and guidelines presented in this document) was one of the FAA's recommendations from this initial work.

Summary of Findings, Observations and Outcomes from the FAA's Initial Work

1. According to the U.S. General Accounting Office, most U.S. commercial airports represent a small percentage (approximately 0.5 percent) of the total overall air pollution emissions generated in an urban area [GAO, 2003].

2. Air monitoring studies in the vicinities of several large airports have thus far not detected HAP levels considered above those that normally occur in urban areas. Additionally, the samples from these studies have not segregated any OG associated with airport sources from the OG released from motor vehicles or any other mobile or stationary source.

3. The emission levels of OGs from new aircraft engines are predicted to decline over current and historic levels as turbine and internal combustion engines become progressively more fuel efficient and less polluting.

1.2 Relevant Regulations

Under the Clean Air Act (CAA) and its amendments, the EPA is charged with developing standards and guidelines for the control of air pollutant emissions, including HAPs. Of particular relevance to airports, Section 231 of the CAA directs the EPA to "issue proposed emission standards applicable to the emission of any air pollutant from any class or classes of aircraft or aircraft engines which in its judgment causes, or contributes to, air pollution which may reasonably be anticipated to endanger public health or welfare". Presently, the emission standards developed by EPA as a result of the Section 231 directive apply only to aircraft engine smoke and engine exhaust products such as carbon monoxide (CO), nitrogen oxides (NOx) and unburned OGs--the aircraft engine standards do not apply directly to emissions of OGs or any OG designated by the EPA to be a HAP.

This guidance focuses on the airport-related OGs designated by the EPA to be HAPs and/or listed in the EPA's IRIS. It is important to note that the EPA has not established National Ambient Air Quality Standards (NAAQS) for any OG. With respect to OGs, the EPA's focus is primarily on a subset species referred to as volatile organic compounds (VOCs)[4] because VOCs are highly reactive with NOx in the presence of sunlight and form ozone--a pollutant for which the EPA has NAAQS and for which numerous areas within the U.S. are designated non-attainment. Therefore, while the HAPs emitted from aircraft engines, and most other airport sources, are not specifically regulated by the CAA or other (e.g., International Civil Aviation Organization (ICAO)) emission standards, the pollutants are controlled indirectly through the control of the other primary pollutants (e.g., through the control of ozone which, in certain regulated areas, results in a reduction in emissions of VOCs).

Currently, the EPA controls the emission levels of 187 OGs that the agency has designated as HAPs. The sources for which the amounts of these OGs are regulated are major individual and grouped stationary sources, as well as lesser emitting area sources.[5] While some airports may have stationary sources that are subject to EPA's HAP-related controls, airport-related emission sources--sources that primarily consist of aircraft, non-road vehicles such as ground support equipment (GSE), and on-road vehicles such as cars, trucks, vans, and buses--are not subject to these major individual/grouped stationary source or area source regulations.

Airport studies should only report the OGs designated by the EPA to be HAPs and those included in the EPA's IRIS database. Therefore, the primary focus of this documents discussion is this subset of OGs (although comprehensive OG information is presented and discussed).

OGs That Should be Reported in Airport Studies

Airport studies should only report the airport-related OGs designated by the EPA to be HAPs and the OGs included in the EPA's IRIS database.

It should be emphasized that preparation of an emissions inventory of airport-related speciated OG/HAP emissions is neither required nor recommended for all NEPA documents because, under NEPA, air quality assessment are not always required in support of an EA or EIS. Rather, these guidelines apply only when preparing an emissions inventory is called for (i.e., on a "case-by-case" basis).

1.3 Purpose of this Guidance

As stated in the Introduction, the purpose of this document is to provide a uniform approach to, and technical guidance for, preparing an inventory of airport-related speciated OG emissions which include HAPs. This information is intended to serve as a template for the FAA, airport sponsors, and others in preparing an emission inventory of airport-related speciated OGs while taking into consideration the inherent limitations associated with the assessment of these pollutants. The primary aim of an emissions inventory, if conducted, is to fulfill disclosure

[4] The "group" of OGs referred to as VOCs excludes certain organic compounds because they have negligible photochemical reactivity (see Section 1.5.1 of this guidance for additional information).

[5] The EPA published an initial list of 188 HAPs. However, on December 19, 2005, methyl ethyl ketone (MEK) (2-butanone) was removed from the list because there was "adequate data on the health and environmental effects [of MEK] to determine that emissions, ambient concentrations, bioaccumulation, or deposition of the substance may not reasonably be anticipated to cause adverse effects to human health or adverse environmental effects."

requirements for airport improvement projects (or actions) evaluated under the NEPA [NEPA, 1970].

Guideline Purpose

The purpose of this guideline is to provide a uniform approach to, and technical guidance for, preparing an inventory of airport-related speciated OGs (including known HAPs) in support of environmental documents prepared by, or on behalf of, the FAA under NEPA.

1.3.1 Developmental Approach to this Guidance

The principles below were considered when developing this guidance. These principles take into account the current limitations and potentially significant uncertainties associated with these specialized pollutants.

Framework Principles for This Guidance

- Consistency with other methods of evaluating airport-related air pollutants. - Because both criteria pollutants and the speciated OGs associated with airports originate from the same sources (e.g., aircraft, ground support equipment (GSE), and motor vehicles), it is important that the evaluation of these two categories of air emissions is aligned and interconnected to the fullest extent possible. This approach facilitates the use of consistent (or comparable) input data and other important assumptions that are viewed as central to obtaining consistent and reliable results.
- Support the current state-of-the-science. - The FAA is establishing a nationally consistent approach to preparing inventories of airport-related speciated OG, including known HAPs. However, it must be recognized that the topic of airport-related speciated OG is new and dynamic and these guidelines will be updated as scientific and other advancements are made in connection with these pollutants.
- Reflective of the limitations of available databases, procedures and other means of estimating airport-related emissions. - The estimation of airport-related speciated OG involves a wide and varied array of information, data and other supporting materials. These data include aircraft-specific OG speciation profiles; airport-specific operational data; and applicable computer models or other computational techniques. Unfortunately, not all of these assessment parameters and requirements are easily obtainable, readily adaptable or tested for reliability for this highly specialized application.
- Responsive to the immediate need for consistent and practical guidelines. – Despite the existing gaps in information and tools, the potential air quality impacts associated with these emissions are of utmost interest, and this interest will continue into the future as the nation's airport infrastructure and airspace are expanded and improved.

Based upon these provisions and considerations, it is evident that guidelines for preparing an emissions inventory for airport-related speciated OGs/HAPs will help to address certain short-term needs of both the aviation and regulatory communities, while other facets of the evaluation processes are continually advanced. These needs include the ability to quantify the effects (if any) that airport improvement projects or actions may have on the types, sources and amounts of speciated OG/HAPs.

1.4 Additional FAA Guidelines and Other Resources

Other documents, guidelines and resources developed or sponsored by the FAA that provide further support for the assessment of airport air quality issues and that may be applicable to evaluations of airport-related speciated OGs are listed below. Notably, the *Recommended Best Practice For Quantifying Speciated Organic Gas Emissions From Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines* was recently published by the FAA as a companion to this document. This document details joint efforts between the FAA and the EPA to update OG/HAP speciation profile data from these types of aircraft. An abstract of the aircraft-engine related document and abstracts of the other documents, guidelines, and resources are provided below.

FAA Guidelines and Other Resources

- *FAA Environmental Desk Reference for Airport Actions* [FAA, 2007]. This document is a compendium of regulations and requirements that guides a user in evaluating environmental impacts of airport actions under NEPA and other special-purpose regulations.
- *FAA Resource Document for HAPs.* Provides a compilation of what was known about airport- and aircraft-related HAPs in publicly available materials in the year 2003. Presented both as a narrative summary and assembled in an annotated bibliography, these materials cover a broad range of information related to this subject. Topics include HAP emission types and sources, agency regulations, air monitoring data and other supporting information.
- *NEPA Implementing Instructions for Airport Actions (FAA Order 5050.4B)* and *Environmental Impacts: Policies and Procedures (FAA Order 1050.1E, Change 1)* [FAA, 2006a, FAA 2006b]. These two documents provide guidelines for the preparation of EAs, EISs and other similar reviews for airport projects or actions required under NEPA. Under the topic of air quality, these guidelines address the criteria air pollutants and the federal CAA General Conformity Rule. The topic of HAPs is briefly addressed in Order 1050.1E (and 5050.4B).
- *Air Quality Procedures for Civilian Airports and Air Force Bases* and its *Addendum* [FAA, 1997 and 2004]. Referred to as the "*Air Quality Handbook*", this document provides guidance on conducting air quality impact assessments for airport projects and actions required under NEPA and the federal CAA. Contains comprehensive/detailed methodologies on preparing emission inventories and conducting dispersion modeling of airport-related criteria pollutants. The technical guidance and procedures provided are applicable to the assessment of OGs and particulate matter (PM): the two primary classes of HAPs.
- *Emissions and Dispersion Modeling System (EDMS-Version 5.1),* [FAA, 2008]. This software was specifically designed for the assessment of airport-related air quality impacts. Developed by the FAA and updated on a regular basis, EDMS is designated by the FAA as the "required" model for the assessment of aviation-related sources of the EPA criteria air pollutants and their precursors. The *EDMS User's and Technical Manuals* provide comprehensive information on the proper application of this model.
- *Aircraft and Airport-Related Hazardous Air Pollutants: Research Needs and Analysis*, [Transportation Research Board, 2008]. Provides guidance on the most important projects to the airport community for ACRP consideration in the area of HAPs. This report examines the state of the latest research on aviation-related HAP emissions and identified knowledge gaps that existing research has not yet bridged.
- *Recommended Best Practice For Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*, [FAA and EPA, Peer Review Draft, February 28, 2009]. This Recommended Best Practice was produced through an inter-agency partnership and provides an approach to, and technical support for, the quantification of organic gases from this source.

1.5 Important Considerations and Limitations

To address current data gaps, information and evaluation methods will require ongoing and additional research involving the aviation, scientific, and regulatory communities. This may take considerable time and may dictate changes to this guidance document. In the meantime, the topic of speciated OGs/HAPs associated with airports is subject to public disclosure. Therefore, these guidelines are prepared with the recognition that not all of the necessary components are fully developed or in place but with the expectation that scientific advancements will be continually made and incorporated into this "living" guidance document.

Considerations and Limitations Associated With the Evaluation of Airport-Related Speciated OG/HAPs

- <u>There are no Federal regulatory guidelines that specifically address any individual OG from airport sources</u> - By definition, neither airports, in general (nor aircraft) are subject to the regulations of Section 112 (*Hazardous Air Pollutants*) of the CAA insofar as it relates to the development of HAPs inventories of an individual OG/HAP.[a] Moreover, there are no regulatory guidelines on either the federal or state levels that identify when, or under what conditions, the evaluation of speciated OG (an in particular HAPs) from these sources is required nor do they define the type and extent of the analysis.
- <u>Emission inventory results are estimates and are not directly comparable to regulatory standards or other acceptable criteria</u>. – For disclosure and/or alternative comparative purposes, an emission inventory provides a useful estimate of the quantity of a specific OG. However, by itself, the results of an emission inventory are not comparable to any enforceable measures of acceptability. It should be noted that the methodology presented in this document will provide the best estimate of airport-related OG/HAP emissions currently available but the use of the inventories for regulatory purposes is not recommended due to the current lack of quality data available in this area.

[a] It should be noted however, that some sections of Section 112 could potentially implicate airports by other means (i.e., Maximum Achievable Control Technology (MACT) standards can be applicable to airport stationary sources, but only relative to required control technologies. Additionally, it should be noted that state/local air pollution control agencies can exercise discretion in determining acceptability and enforcement.

In complying with NEPA, the FAA's environmental documentation provides full discussion and disclosure of significant environmental impacts. NEPA requires this to inform decision makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment. Section 1502.22 of the Council on Environmental Quality (CEQ) Regulations state: "…when an agency is evaluating reasonably foreseeable significant adverse effects on the human environment in an environmental impact statement [EIS] and there is incomplete or unavailable information, the agency shall always make clear that such information is lacking" [CEQ, 1986]. The purpose of this section is to document the "information that is lacking" (uncertainties and limitations) with respect to the methodologies discussed in this guidance document. The following specific factors are discussed--OG (and HAP) speciation profiles and health risk assessments.

1.5.1 OG Speciation Profiles

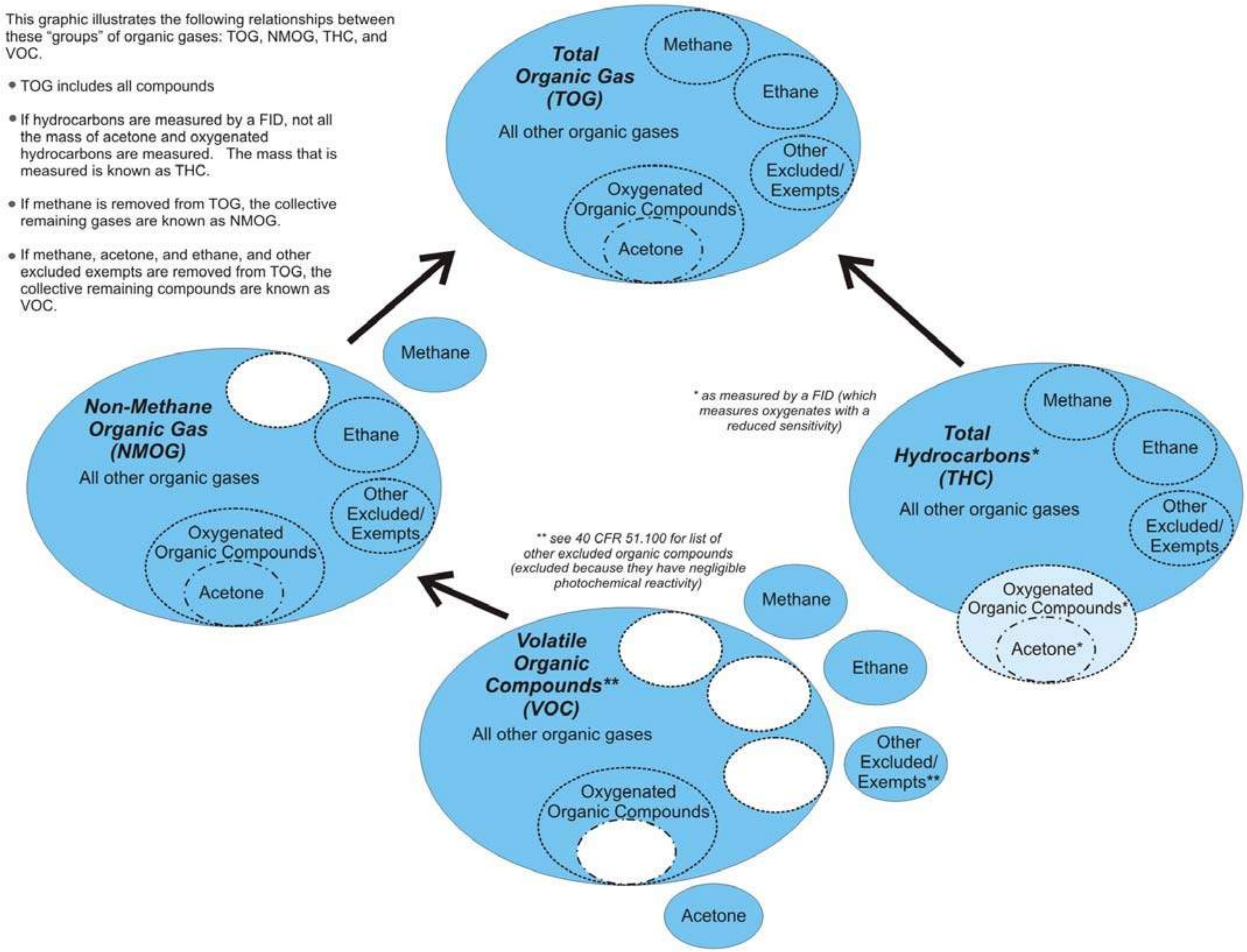
Speciation profiles, in the form of mass fractions, can be used to estimate quantities of individual OGs. A mass fraction is the fraction portion of one substance (xA) relative to the total mixture mass (mtotal). Groups of OG emissions are defined a variety of ways depending on the reason for the assessment/analysis (e.g., preparation of an emissions inventory or photochemical analysis), the modeling need, and/or the regulatory context. Typical groups of OG emissions are total OG (TOG)[6], non-methane OG (NMOG), total hydrocarbon (THC), and volatile organic compounds (VOC). The individual, and groups, of OGs included in each "group" of these gases are described in the following and illustrated on **Figure 1**:

- TOG – TOG is defined by the California Air Resources Board (CARB) as compounds of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate. TOG includes all organic gas compounds emitted to the atmosphere, including the low reactivity compounds (e.g., methane, ethane, various chlorinated fluorocarbons, acetone, perchloroethylene, volatile methyl siloxanes, and oxygenated OG).
- NMOG - As implied, NMOGs include all organic compounds except methane which is the most common OG and a greenhouse gas that is sometimes excluded from the assessment/analysis of organic compounds.
- THC – Organic compounds in exhaust, as measured by a flame ionization detector (FID) per ICAO's Annex 16.[7] Notably, a FID does not accurately measure all of the mass of oxygenated OG, which influences the abundances of specific chemical compounds relative to the total in the measured exhaust. This is important because these abundances dictate the amounts of each speciated compound in the exhaust plume
- VOC – VOC is defined by EPA as any compound of carbon that participates in atmospheric photochemical reactions. For aircraft, this is further defined as exhaust TOG corrected to exclude the mass of methane, ethane, and acetone and to fully account for the mass of formaldehyde and acetaldehyde [U.S. EPA 2007].[8] Notably, additional compounds are excluded/exempt from this group of OG when sources other than aircraft engines are being considered. VOC also excludes carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate.

The HAP speciation profiles adopted by regulatory agencies, and used in this guidance, are intended for use in developing gross estimates of speciated HAP (and OG) emissions on a state- or region-wide basis. These profiles are **not** intended for evaluations of site-specific impacts at the project level. As such, although the speciation profiles discussed in this document are based on the best data, information, and techniques currently available, the factors are subject to a high degree of imprecision and uncertainty.

[6] Also referred to as total organic compounds (TOC) when discussed in an air quality context.
[7] ICAO's Annex 16 addresses protection of the environment from the effect of aircraft noise and aircraft engine emissions.
[8] Per the EPA definition of VOC at http://www.epa.gov/ttn/naaqs/ozone/ozonetech/def_voc.htm

Figure 1
Groups of OGs



1.5.1.1 Conversion Factors

As stated above, depending on the technique used to prepare an estimate, an estimate of mass OG emissions could be representative of TOG, NMOG, THC, or VOC. If an estimate of OG emissions is prepared and the mass OG emissions are not classified as TOG, analysts must first apply a conversion factor to the mass OG emissions prior to using the TOG-specific speciation profiles discussed in this document. Again, *the speciation profiles discussed in this document are TOG specific profiles* of known individual OG species. Therefore, prior to applying a profile to an estimate of mass OG, it will be necessary to convert the mass OG to TOG. The NMOG, THC, and VOC to TOG conversion factors are provided in **Table 1** (THC conversion factors are provided in the Table 1 footnotes).

1.5.2 OG Toxicity and Health Risk Assessments

This guidance does not address the dispersion modeling of, nor the preparation of human health risk assessments (HHRA) for, individual airport-related HAPs as scientific knowledge of these analyses with respect to airports is still very limited. Notably, the FAA is conducting and fostering research to advance knowledge of human health impacts associated with airport sources.

The human health and environmental effects of airport-related OGs/HAPs combined with OGs/HAPs from other sources are not well documented. Further, it is difficult to accurately predict the incidence of human disease or the types of effects that such a chemical exposure has on humans. For example, the unit risk values and the reference concentrations that provide toxicity weighting values for HAPs and the OGs in IRIS are based on toxicological data that are typically obtained and, indeed most often only available, from animal studies. Any adverse effects at high doses for short exposure durations in animals are extrapolated to estimate the effects on humans at low doses for long exposure durations. The affected organs, the types of adverse effects, and the severity of the effects may all differ between study animals and humans (inter-species differences), or between humans and humans (intraspecies differences). These differences are often associated with variations in the particular toxic kinetics, or movement, of a chemical through the exposed organism, such as the absorption, distribution, metabolism, and excretion of the chemical.

There is also considerable uncertainty in the quantitative analysis of airport-related OG emissions, toxicity determinations, and the relative evaluation of human health risks associated with exposure to HAPs. The models that are used to prepare such assessments are subject to error due to the variability of air patterns, atmospheric flow, and the myriad factors that can alter the final concentration of a contaminant in the air. These factors contribute to several dispersion modeling limitations, including:

1) dispersion models are more reliable for predicting long-term concentrations than for estimating short-term concentrations at specific locations; and

2) dispersion models are reasonably reliable in predicting the magnitude of the highest concentrations likely to occur, but without respect to a specific time or location.

Table 1
Conversion Factors

EDMS Source		SPECIATE Profile Number	SPECIATE Profile Name	Profile Quality Rating[c]	Conversion Factors VOC-to-TOG[a]	TOG-to-VOC[a]	NMOG-to-TOG[a]	TOG-to-NMOG[a]
Aircraft	Piston	1099	Aircraft Landing/Takeoff (LTO) - General Aviation	3 - C	1.17	0.93	1.12	0.89
	Turbofan, Turbojet, and Turboprop and Auxiliary Power Units (APUs)[b, d]	5565[e]	[unknown at this writing]	5 - A	1.01	0.99	1.00	1.00
GSE	Diesel	1201	Light-Duty Diesel Vehicles	3 - C	1.00	1.00	1.18	0.85
	Gasoline, Liquid Petroleum Gas, Natural Gas	1186	Heavy Duty Gasoline Trucks	3 - C	1.03	0.97	1.03	0.98
Boilers/ Space Heaters	Coal Fired Boilers	1178	Coal-Fired Boiler - Electric Generation	1 - E	1.02	0.98	1.00	1.00
		1185	Coal-Fired Boiler - Industrial	2 - D	1.22	0.82	1.00	1.00
	Liquid Petroleum Gas, Natural Gas	0003	External Combustion Boiler - Natural Gas	4 - B	2.27	0.44	2.78	0.36
	Residual Fuel Oil	0001	External Combustion Boiler - Residual Oil	4 - B	1.64	0.61	5.26	0.19
Distillate Fuel Oil Boilers/Space Heaters		0002	External Combustion Boiler - Distillate Oil	4 - B	1.00	1.00	1.95	0.51
Emergency Generators	Distillate Oil (Diesel)	0009	Reciprocating Distillate Oil Engine	2 - D	1.17	0.86	1.13	0.88
	Gasoline Fuel	1101	Light Duty Gasoline Vehicles - 46 Car Study	4 - B	1.13	0.89	1.13	0.89
	Kerosene/Naptha (Jet Fuel)	0007	Natural Gas Turbine	3 - C	3.33	0.30	N/A	N/A
	Natural Gas	1001	Internal Combustion Engine - Natural Gas	3 - C	10.74	0.09	4.45	0.22
Incinerators -- Single and Multiple Chamber; Fire Training -- JP-4, JP-5, JP-8 Propane and Tekflame		0122	Bar Screen Waste Incinerator	2 - D	5.92	0.17	5.10	0.20
Fuel Storage	Gasoline	1190	Gasoline Marketed - Summer Blend - 1984	4 - B	1.00	1.00	1.01	0.99
	Jet Kerosene, Distillate Oil, Residual Oil	0297	Fixed Roof Tank - Crude Oil Refinery	3 - C	1.13	0.89	1.10	0.91
	Jet Naphtha (JP-4)	0100	Fixed Roof Tank - Commercial Jet Fuel (Jet A)	3 - C	1.00	1.00	1.00	1.00
Surface Coating/ Painting	Adhesive	1088	Surface Coating Operations - Adhesive Application	3 - C	1.17	0.86	1.76	0.57
	Enamel	1018	Surface Coating Operations - Coating Application - Enamel	4 - B	1.06	0.94	2.15	0.47
	Lacquer	1017	Surface Coating Operations - Coating Application - Lacquer	4 - B	1.00	1.00	1.18	0.85
	Primer	1019	Surface Coating Operations - Coating Application - Primer	4 - B	1.00	1.00	1.23	0.81
	Solvent Base	1003	Surface Coating Operations - Coating Application -Solvent-Base Paint	4 - B	1.01	0.99	1.35	0.74
	Thinner	1016	Surface Coating Operations - Thinning Solvents - Composite	4 - B	1.01	0.99	1.30	0.77
	Varnish/Shellac	0127	Surface Coating - Varnish/Shellac	2 - D	1.63	0.61	1.00	1.00
	Water Base	1013	Surface Coating Operations - Coating Application - Water-Base Paint	4 - B	1.06	0.94	8.92	0.11
Deicing, all processes -- Ethylene and Propylene Glycol		2419	Aerosols, Special Purpose	4 - B	1.12	0.89	3.64	0.27
Solvent Degreasers		1195	Degreasing - Composite	4 - B	1.65	0.61	1.04	0.96

[a] Compounds are referenced as follows: VOC as VOC, TOG as TOG, NMOG as NMOG.
[b] Source: FAA/EPA Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines, February 2009 (Final Review Draft)
[c] With the exception of turbofan, turbojet, and turboprop aircraft engines, all profile quality ratings obtained from EPA's SPECIATE database. A rating of "A" or" 5" equates to "highest quality rating". A rating of "E" or "1" equates to a "lowest quality rating".
[d] To convert THC to TOG or THC to NMOG, the conversion factor is 1.16. To convert THC to VOC, the conversion factor is 1.15.
[e] EPA has assigned Profile No. 5565 to the speciation profile for aircraft equipped with turbofan, turbojet, and turboprop engines and APU's. The profile will be included in EPA's SPECIATE Version 5.0 (to be released by the EPA in 2009).

Model estimates of concentrations that occur at a specific time and site are poorly correlated with actual observed concentrations and are much less reliable. Therefore, it is difficult to correlate monitoring results to modeled air concentrations, and it is correspondingly difficult to make predictions about potential human exposures at specific locations. Also, Gaussian plume models use hourly meteorological data which, while allowing for variation in data with changes in altitude, are assumed to be uniform at those altitudes. Consequently, the accuracy of the modeling results degrades as distance from the source increases.

Another source of error in human health risk assessments is the typically employed assumption that an individual is constantly exposed to a particular chemical over a 70-year lifetime. This assumption does not account for changes in a person's age, size, health, geographical residence, or location (indoors versus outdoors, home versus work, etc.) over time.

Health Risk Assessments

Due to the limitations discussed in this section, the FAA believes that at this time it is not appropriate to analyze the health related effects of HAPs associated with proposed airport development projects.

While the methodology discussed in this guidance document may show that emissions of HAPs would increase with a project's build alternative when compared to a no-action alternative, it is not possible to meaningfully identify whether these emission levels would adversely impact human health. Further, given all the limitations and uncertainties, the FAA believes that health risk assessments would not assist NEPA decision makers or public understanding of whether exposure to some level of emissions resulting from a project (or action) would be harmful.

2 APPROACH and PROCESS

Under NEPA, all federal agencies, including the FAA, are required to identify and describe potential impacts to the human and natural environments that would result from their action(s); including those related to air quality. The analyses and environmental review that identifies/describes these potential impacts are typically documented in EAs and EISs. One of the main goals of this guidance is to make explicit the uniform methodology to be used for identifying/reporting potential impacts to the types and levels of airport-related OGs--with emphasis on preparing/reporting emission inventories of airport-related HAPs and those OG species identified in EPA's IRIS.

As part of FAA's policy, any airport HAPs emission inventories must be prepared using the most current version of the EDMS. Notably, the output of EDMS currently provides fully speciated OG values (394 compounds), but only the compounds considered/identified by EDMS to be HAPs or being included in the IRIS database should be reported in NEPA documentation.[9]

HAPs Emission Inventories

Although EDMS provides fully speciated OG values, only those compounds identified in EDMS as being a HAP and those identified as being included in the IRIS database should be reported in NEPA documentation.

NEPA reports (i.e., EAs and EISs) must not include any other type of HAP assessment including, but not limited to, dispersion, toxicity weighting, exposure, or health risk quantifications (except when required by CEQA and even in that case, proper analysis methodology should be employed). These types of assessments require a more complete understanding of both HAPs reactions in the atmosphere and downstream plume evolution. Because the science of these factors with respect to airport-related HAPs is still evolving, the understanding of the factors is currently limited.

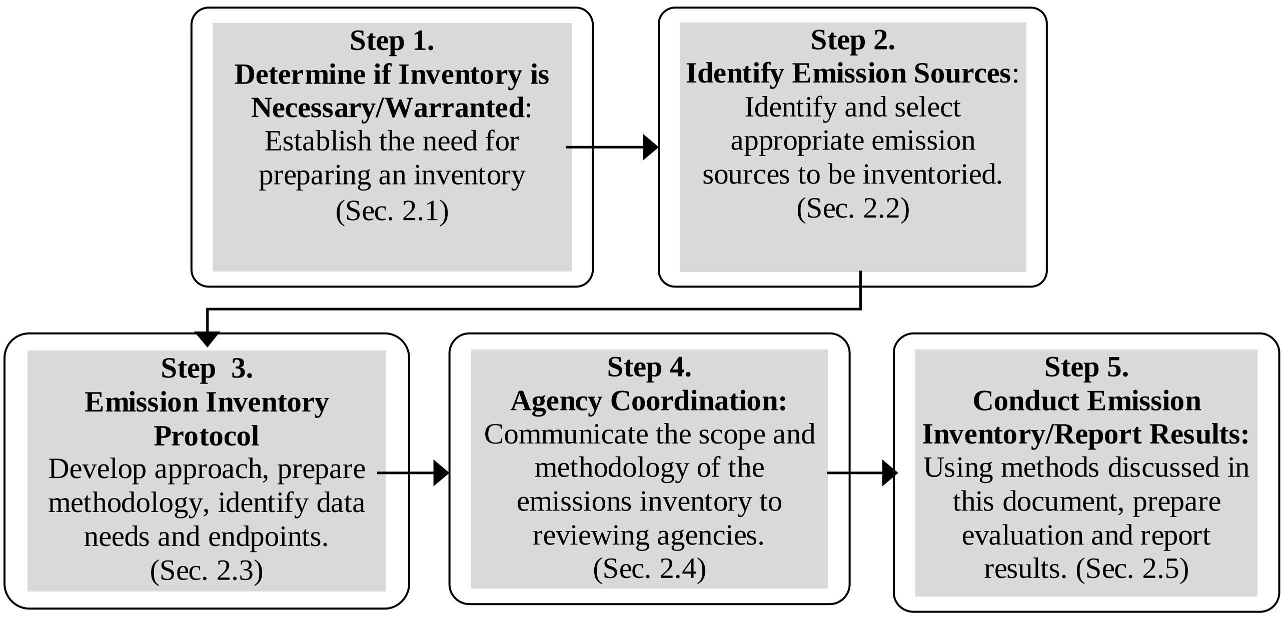
When preparing an emissions inventory, it is important to identify all of the sources of OGs/HAPs at an airport that would be affected by a proposed project/action and, to include these sources in the HAPs emissions inventory. The inventory should not include sources that are not related to an airport's proposed project/action (e.g., non-airport related motor vehicle traffic on a road adjacent to an airport that is not used for airport access and/or egress and is not part of a proposed action/project).

It is also important not to compare an OG inventory prepared for one airport to the inventory of another airport because doing so would not provide any meaningful conclusions (i.e., reporting that one airport emits more or less OGs than another airport is not an indication that one airport is "better" or "worse" than another airport). It is also important to consider that the evaluation of speciated OGs emitted from airport-related sources is an evolving field of study. Therefore, future data sets may result in necessary modifications to this guidance.

[9] http://www.epa.gov/iris

The FAA recognizes that the need to prepare an emissions inventory of speciated OGs/HAPS is not widely instituted nor uniformly applied on Federal, state or local levels. Several estimations of airport-related speciated OGs/HAPs have already been prepared under NEPA. From these existing works, alternative approaches and techniques have been developed that now provide varying and dissimilar results**.** To address this discrepancy, the overall approach to this section is to provide a clear and consistent process for determining when an airport-related emissions inventory of speciated OGs/HAPs may be warranted and how it must be accomplished. **Figure 2** illustrates the recommended approach to undertaking an airport-related OG/HAP emissions inventory.

Figure 2
Recommended Approach to Undertaking an Airport-Related OG/HAP Emission Inventory

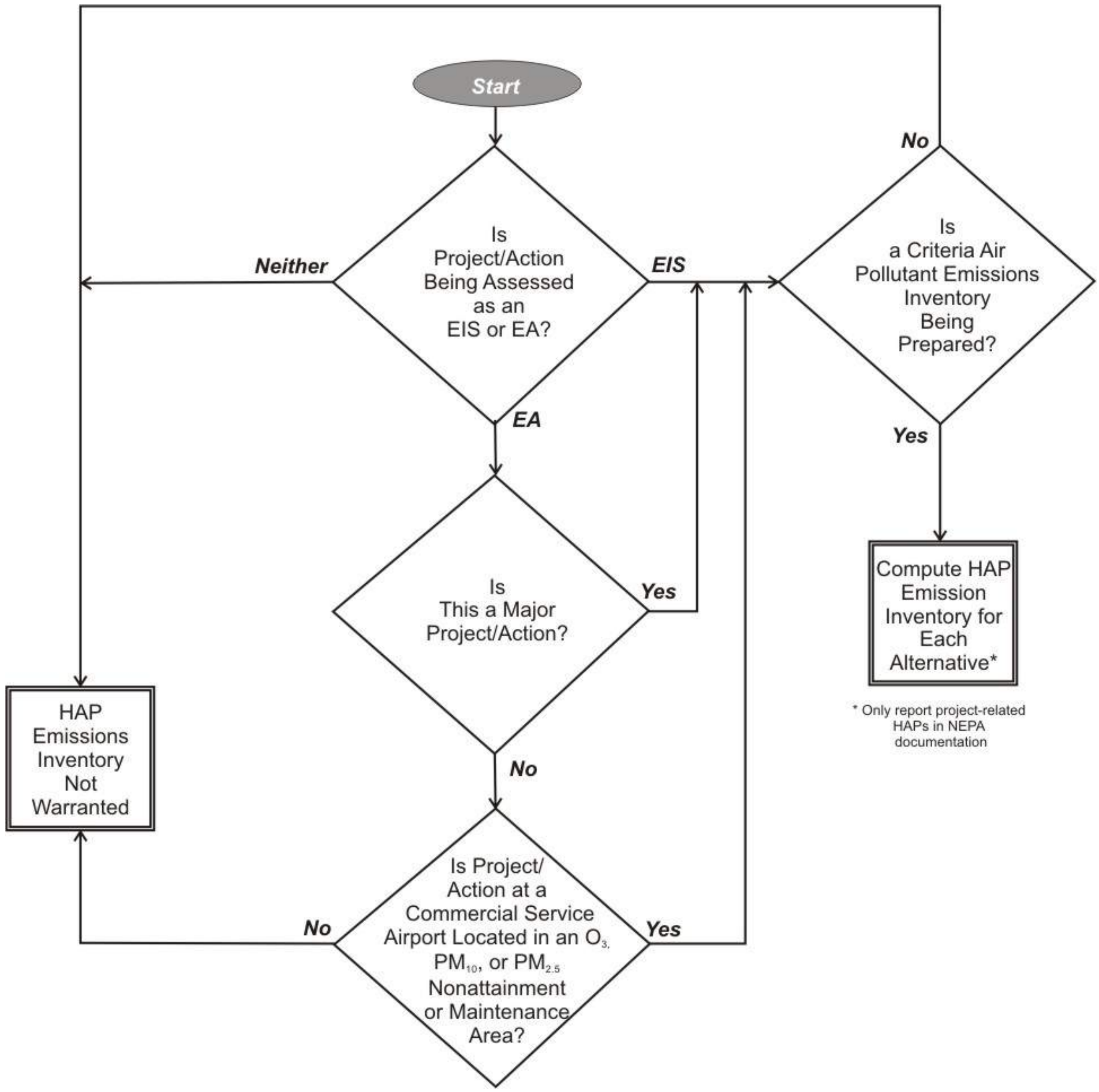


2.1 Determining If an Emissions Inventory is Warranted (Step 1)

The decision to prepare an OG/HAP inventory should be made early in the NEPA process. **Figure 3** provides a flow chart that an analyst can use to determine when airport-related emission inventories of OGs/HAPs must be prepared. As shown, if an EA or EIS is not required to assess a proposed project/action, then preparation of an OG/HAPs inventory is not warranted. In other words only proposed projects/actions evaluated through an EA or EIS should even consider including an OG/HAP inventory. Notably, if a proposed project/action is evaluated through an EIS, an emission inventory must be prepared (for each alternative under consideration) if an inventory of the criteria air pollutants and/or precursors to the criteria air pollutants must be prepared.

When an EIS is being Prepared, When is an OG/HAP Emission Inventory Warranted?
When and EIS is prepared, OG/HAP emission inventories are only warranted when an inventory of the criteria air pollutants and/or precursors to the criteria air pollutants is being prepared.

Figure 3
Determining if an Emissions Inventory is Warranted



The following conditions must be evaluated to determine if an estimate of airport-related OGs/HAPs is warranted for EA projects:

1.) Is the proposed project/action major (e.g., new airport or heliport, new runway or major runway extension, new terminal or major terminal expansion, major construction activity) or is the project at a commercial service airport that is located in a designated nonattainment or maintenance area for ozone, particulate matter 10 microns or less in diameter, or particulate matter 2.5 microns or less in diameter[10]?

and

2.) Is an inventory of the criteria pollutants and/or precursors to the criteria air pollutants being prepared?[11]

If an analyst answers "yes" to both of the conditions above, an OG/HAP emission inventory (an inventory for each of the same alternatives as the criteria pollutant inventory) must be computed and reported in the EA. Notably, where the magnitude of a project/action cannot be determined (i.e., it is questionable whether the project/action is major), an OG/HAPs inventory should be prepared and reported in an EA only when a HAP inventory/evaluation is specifically requested by a regulatory agency.

2.2 Preparing an Emissions Inventory

If it is determined that an emissions inventory of airport-related OG/HAPs is warranted, there are four more steps in the approach to preparing/reporting the results of the inventory. Notably, in connection with EISs and EA's, three of the four steps--identifying the sources to be inventoried, preparing a protocol that defines the evaluation process, and agency coordination--are typically performed for the assessment of the criteria air pollutants. These steps, and the fourth step --preparing the emission inventory and reporting the results--are discussed below.

2.2.1 Airport-Related Sources to be Inventoried (Step 2)

With the exception of construction equipment and construction-related activities, this guidance provides data to support the preparation of a speciated OG/HAP emission inventory for the vast majority of airport-related sources.[12] The following discusses each source.

[10] An area's attainment status is relevant only in terms of O_3 and particulate matter because the O_3 precursor VOC and particulate matter are contributors to concentrations of OGs/HAPs. Attainment statuses for other criteria pollutants such as CO are not as relevant because levels of these pollutants do not significantly alter the level of HAPs being emitted due to airport actions or operations.,

[11] See Section 2.3.4 of the FAA's Air Quality Procedures for Civilian Airports and Air Force Bases, April 1997.

[12] Although it is recognized that construction activities emit OG, it is not currently possible to accurately speciate the emissions for construction equipment due to lack of data.

2.2.1.1 Sources of OG/HAP Emissions

According to the FAA *Air Quality Handbook*, the primary airport-related sources of air pollutant emissions are: aircraft engines; auxiliary power units (APUs); ground support equipment (GSE); and ground access vehicles (GAV)--including passenger, employee and cargo-related motor vehicles [FAA, 1997]. Stationary sources and fuel storage/transfer facilities are generally less significant sources, by comparison, and construction equipment/activity emissions are considered to be short-term and temporary.

Table 2 summarizes the sources of airport-related OG/HAP emissions, their general characteristics and the types of projects/actions that could affect HAP emission levels.

Aircraft

Aircraft generally represent the largest source of total emissions of the criteria air pollutants (or their precursors) at commercial service or public use airports. For air quality assessment purposes, aircraft are generally classified by aircraft type: commercial (including cargo and charter), commuter (air taxi), GA and military. However, the actual or forecast aircraft fleet mix that makes up these categories is unique to each airport.

Aircraft activity levels are measured as operations (landings and takeoffs) or as LTO cycles (one landing plus one takeoff equals one LTO cycle). Furthermore, a LTO cycle is subdivided into four "operational modes" based on engine power settings: takeoff, climbout, approach and taxi/idle (including taxi-in, taxi-out and queue/delay). A method of estimating OG emissions resulting from aircraft engine "startup" will be developed and provided by the FAA at a later date.

Times-in-mode (TIM) are the periods that an aircraft spends in each of the four operational modes. TIMs are based on aircraft type, an airport's operational characteristics (e.g., taxi distances and queue delays) and, for approach, takeoff, and climbout, TIMs are based on the atmospheric mixing height.

At airports, aircraft engines are considered to be one of the dominant sources of ground-based OG. It is important to note that the majority of aircraft-related OG is emitted during the low-power engine mode of an LTO cycle (i.e., taxi/idle).

AEE has published a document that could be considered a companion to this document--*Recommended Best Practice For Quantifying Speciated Organic Gas Emissions From Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines.* The document details the joint efforts between the FAA and the EPA to update OG speciation profile data for this source.

Table 2
Sources of Airport-Related OG/HAP Emissions

Source Category	General Characteristics	Projects/Actions Which May Affect HAP Emissions
Aircraft	Classified by aircraft type: commercial, commuter, military and GA.	Projects/actions which increase the number of operations, result in a change in aircraft fleet mix and/or increases taxi/idle times.
	Primary source of OG in low power mode (i.e., taxi/idle).	
	Engine emission standards established by ICAO and promulgated by the EPA.	
Auxiliary Power Units	OG/HAP emissions from APU use are minimized with use of 400 Hz gate power and pre-conditioned air.	Projects/actions which increase the number of aircraft operations and/or category of operations (e.g., commercial, cargo).
Ground Support Equipment	Classified by two broad categories: on-road or non-road; aircraft function (e.g., service truck, baggage tug, pushback tractor, etc.); and fuel type (e.g., gasoline or diesel). Includes ground power units (GPUs).	Projects/actions which increase the number of aircraft operations and/or category of operations (e.g., commercial, cargo).
	Emissions regulated by EPA.	
	Zero-emission and low-emitting GSE are replacing conventionally-fueled equipment.	
Ground Access Vehicles	Includes private and commercial motor vehicles used by airport patrons, employees and cargo carriers.	Projects/actions which increase the number of aircraft operations and/or result in an increase in vehicle-miles-traveled
	Classified by type, weight and fuel use: light duty gas vehicles, heavy-duty diesel trucks, etc.	
	Emissions regulated by EPA.	
Stationary Sources	Include power plants, boilers, generators, fuel storage facilities, fire training facilities and other aviation maintenance and support facilities.	Projects/actions that increase terminal/concourse/cargo facilities. New/changes to/additional fire training facilities.
	Stack emissions are effectively managed with process design and control equipment. Fuel storage facility emissions of OG from storage/handling of jet and diesel fuel are considered minimal due to low vapor pressure (emissions from storage/handling of gasoline and/or Avgas are higher). Newer fire training facilities use low-emitting propane.	
	Emissions from smoke stacks and vapor vents are individually permitted by state and local agencies.	
Construction Activities[a]	Generally classified as on-road and/or non-road equipment and fuel type (gasoline or diesel).	Any project/action that requires demolition and/or construction.
	Emissions regulated by EPA.	

[a] Although it is recognized that construction activities emit OG, it is not currently possible to accurately speciate the emissions due to lack of data.

GSE/APUs

GSE provide service to aircraft while at an airport terminal and consist of (but are not limited to) the following types of equipment: baggage tugs, tow tractors, belt and cargo loaders and a variety of fuel, food and lavatory service trucks. The fleet of GSE utilized at an airport, their operating times and fuel types (gasoline or diesel) varies by aircraft type (commercial, commuter, GA, military), by airline, and by airport.

For air quality assessment purposes, GSE are generally classified as either "on-road" vehicles or trucks (e.g., an airline employee shuttle bus) and other similar vehicles or "non-road" vehicles/equipment such as tugs, tractors, loaders, etc. At many large metropolitan airports, portions of both the on- and non-road GSE fleets are being converted to engines powered with alternative fuels (propane or natural gas) or electricity.

For large commercial and cargo aircraft, APUs generate on-board electricity and air conditioning (A/C) while an airplane is taxiing or parked at the gate. In some cases, GPUs are used. APUs and GPUs are traditionally powered with jet fuel and diesel fuel, respectively. At many modern airports, gate furnished electricity and air conditioning are used to supplement and/or replace usage of APUs/GPUs.

Despite the continuing conversion of fossil-fueled GSE and APUs to low- or zero-emission fleets, these vehicles and equipment are still considered primary sources of HAPs at airports.

GAV

On-site GAV are the various fleets of public and privately-owned motor vehicles traveling on airport roadways, and in parking lots and parking garages by passengers, employees, commercial vehicles and cargo carriers. These fleets typically include cars, vans, taxis, shuttles, buses and trucks. GAV emissions vary by vehicle and fuel type (gasoline or diesel), travel distance, operating speed, and ambient temperature.

Within an airport's property, emissions of OG from GAV are secondary to aircraft and GSE as sources of HAPs. Outside airport property, GAVs operate on the local and regional roadway networks while traveling to and from an airport. As such, they are difficult to distinguish from background (non-airport) traffic. Emission inventories should not include sources not related to an airport's proposed project/action which may include, but not limited to, the non-airport related motor vehicle traffic the local/regional roadway networks.

Stationary Sources

Stationary sources typically include facilities that discharge emissions from a smokestack (i.e., power generators, steam boilers, space heaters, waste incinerators, etc.). However, this term can also include fire training facilities, engine test facilities and a variety of other aviation-related industrial sources (i.e., solvent degreasing, surface coating, etc.). In nearly all cases, these sources are regulated with individual operating permits or regulated collectively under Title V of the CAA (Permits).

Fuel storage/transfer facilities (tank farms and fuel hydrant systems) are also considered stationary source categories. OG emissions from these sources vary by fuel type and vapor pressure; containment vessel, emission control device, fuel throughput volumes, and local meteorological conditions. Jet fuel is stored in the greatest quantities at most major airports with aviation gas (Avgas[13] or 100-octane low lead (100LL)), gasoline and diesel fuel occurring in comparatively smaller amounts. Because jet fuel and diesel fuel have such a low vapor pressure (i.e., low evaporation rate), OG vapors generally remain well confined in the storage vessel without additional controls. In many cases, this negates the need for a regulatory permit (e.g. individual operating or Title V permit). Vapor pressures for Avgas and gasoline lead more readily to OG vapors.

Airport Rescue and Firefighting Facilities (ARFFs) are used to train personnel for fuel fire suppression. The types of fires simulated include engine fires; exterior pool fires involving the fuselage, the left wing, or the right wing; interior fires on the flight deck, cargo, or passenger areas; and other miscellaneous fires.

Construction Activities

Construction activities at airports generally represent a temporary source of air emissions associated with the site preparation, construction and/or demolition. Depending on the project requirements, the work can involve an assortment of both on-road vehicles (i.e., pick-up trucks, dump trucks, etc.) and non-road (i.e., scrapers, dozers, loaders, etc.) equipment. The exhaust from these vehicles and equipment contains OGs (including HAPs).

While it is recognized that construction equipment and some construction activities (e.g., equipment fueling) result in emissions of HAPs, it is not currently possible to accurately speciate the OG/HAP emissions of construction activities due to lack of data.

2.2.2 Emissions Inventory Protocol (Step 3)

The assembly of an airport-related HAPs emissions inventory is a multifaceted process and can become a complex undertaking potentially involving:

1) extensive data collection;
2) development of assumptions; and
3) a range of outcomes and endpoints.

For these reasons, when it is appropriate to provide such data under NEPA, it is recommended that the proposed approach and methodology be documented for review and, then once approved, included in the appendix of NEPA documents (it is suggested that approach/methodology be entitled *Air Quality Analysis Protocol.* Prior to distributing protocols

[13] Avgas is a portmanteau (a blend of two or more words) for aviation gasoline—a fuel that is used in piston and rotary engines.

to reviewers of the OG/HAPs inventories, the documents should be reviewed by FAA's AEE and/or Office of Airport Planning and Programming (APP). In this way, the means and objectives for accomplishing the work are clearly stated and understood before the work is begun and completed. Written approval of protocols by the reviewing office(s) is also required.

Any supporting materials (i.e., references, computer printouts, etc.) considered necessary to help explain and clarify the work should also be identified the appendix. The supporting materials should also reference this guidance document and the EDMS version used to prepare the OG/HAP inventories.

2.2.3 Agency Coordination (Step 4)

As discussed previously, other than California's CEQA, there are no current or former guidelines, regulations or directives on either the federal or state levels that address the preparation of an emissions inventory of airport-related speciated HAPs. Therefore, it is recommended that the project sponsor coordinate early with the appropriate FAA airports regional or district office. The FAA will aid the sponsor or its consultant in developing a process to contact federal, state and local governmental agencies involved in the review of the OG/HAP inventories. These agencies should include the FAA (e.g. AEE, APP, and regional offices) and may include the EPA, as well as the state and local agencies responsible for air quality management in the area where an airport project(s) are proposed.

Coordination with EPA and/or State Air Quality Agencies

Agency coordination should focus on defining the scope of the inventory and acceptability criteria. Any uncertainty about the approach or methodology should be resolved at this early stage so the inventory adequately addresses all concerns.

2.2.4 Prepare the Emission Inventory and Report the Results (Step 5)

After it is determined that an emission inventory of airport-related speciated OGs/HAPs is warranted (Step 1), the emission sources and OGs/HAPs to be evaluated are identified (Step 2), the methodology developed (Step 3) and coordination with reviewing agencies completed (Step 4), the final step involves preparing the inventories and reporting the results.

2.2.4.1 Conducting the Emission Inventory

As discussed in Section 1, these guidelines focus on the preparation of an emission inventory: a common and universally-accepted method of quantifying the amounts (or mass) of OG/HAP emissions. This method comprises a multifaceted process involving airport operational data or activity levels, appropriate emission indices, and other source-specific OG/HAP emission characteristics. This procedure is the emphasis of this document. As such, detailed guidance for preparing an emission inventory of airport-related speciated HAPs is provided in Section 4 of this document.

2.2.4.2 Reporting the Results

Typically, the results of an OG/HAP emission inventory are expressed in units of tons/year for each individual OG/HAP evaluated (i.e., formaldehyde, benzene, etc.). For comparative purposes, the results may also be segregated by emissions source (i.e., aircraft, GSE, motor vehicles) and/or project/action, or alternative (i.e., build/action, no-build/no-action). Recommendations (including table templates) for presenting these data are also presented in Section 4.

Because the topic of speciated OGs/HAPs is not included among the categories of environmental impacts called for under FAA Orders 1050.1E or 5050.4B [FAA, 2006a; FAA, 2006b], it is recommended that the results be reported separately or in an appendix for a NEPA document.

2.3 Other Agency Guidelines and Requirements for Airport-related OG/HAP Emissions

Although it is recognized that other federal, state and local agencies may have their own procedures and requirements for quantifying airport-related speciated OGs/HAPs, it is not the intent of these guidelines to address or supersede them. As stated above, these guidelines are specifically developed in support of NEPA documents prepared by, or on behalf of, the FAA and airport sponsors.

If additional, or alternative, analyses are conducted for airport-related speciated OGs/HAPs for other purposes, the objectives, methods and results should likewise be treated and published separately from the NEPA analysis. In this way, the outcomes from the different analyses also remain independent and unconfused.

3 SPECIATION PROFILES

Speciation profiles provide estimates of the chemical composition of plume emissions. A profile, or set of profiles, may be used to prepare an emission inventory and/or determine the contributive amount of a particular pollutant for air quality assessment purposes. This guidance recommends the use of profiles to prepare emission estimates (inventories) of individual (speciated) OGs, which include HAPs.

The FAA recommends that estimates of plume emissions of OGs be speciated to individual HAPs using the profiles (mass fractions) provided in the EDMS. Because it is the intent of the FAA/EPA to update the profiles for turbofan, turbojet, and turboprop engines as additional data becomes available, and the profiles for other sources may also be modified/change, air quality practitioners should verify that they have the most recent version of EDMS before beginning an evaluation.

With the exception of the speciation data recommended for aircraft equipped with turbofan, turbojet, or turboprop engines, APU's and the profiles for on-road motor vehicles, the OG speciation profiles for airport sources in EDMS were obtained from the EPA's SPECIATE database (http://www.epa.gov/ttn/chief/software/speciate/index.html). Each airport-source/profile combination was selected using the EPA's Source Classification Codes (SCCs). The applicability of these judgment-based profile assignments was confirmed by assessing SPECIATE's data quality ratings, surrogate data sources, and documentation for each chosen profile, which are directly available in the SPECIATE database. SPECIATE's data quality ratings for the airport-related profiles are provided in Table 1**.** The speciation profile data for aircraft equipped with turbofan, turbojet, or turboprop engines and APU's was recently updated in a joint coordination effort between the FAA and EPA. This data will be included in EPA's intended update to SPECIATE as Profile No. 5565. Speciation profile data for on-road motor vehicles can be obtained from EPA's MOBILE motor vehicle emission rate model.

3.1 Airport-Related/EPA-Identified HAPs and Toxic Compounds

Under Section 112 (*Hazardous Air Pollutants*) of the federal CAA, the EPA classified 188 air pollutants as HAPs. In 2005, the EPA modified the list to classify only 187 air pollutants to be HAPs (methyl ethyl ketone (MEK, also known as 2-butanone) was removed from the list). The EPA also maintains a database of substances found in the environment and their potential to cause human health effects. This database is known as IRIS. Additionally, pursuant to their continuing National Emissions Inventory (NEI) program, the EPA developed a program to address OG emissions with potential human health effects emitted by mobile (motor vehicle) sources. The compounds that the EPA identified as being emitted from motor vehicles are referred to as the "Mobile Source Air Toxics" (MSATs).

A list of the airport-related OGs that are EPA-designated HAPs and/or are identified in IRIS is provided in **Table 3**. There are 45 individual airport-related OGs. Thirty of the OGs are EPA-designated HAPs and/or identified in the IRIS database. Fifteen of the OGs are listed in IRIS (but not designated by the EPA to be HAPs). As shown, the number and type of OGs varies by airport source (e.g., piston engine aircraft emit 16 of the 45 OGs and gas-powered ground support equipment emit 8 of the 45 OGs).

For the purpose of preparing NEPA documents, the FAA recommends that, when warranted, EISs and EAs only report project-related OGs/HAPs in NEPA documentation unless the EPA or a State or local air quality agency requests in writing that the FAA or airport sponsor publishes the full EDMS output report of 394 OGs (including HAPs).

Each substance is readily identified in the current version of EDMS as being a HAP or IRIS-identified substance. It is important to note that these OGs do not have NAAQS (i.e., the EPA has not established standards for concentrations of these pollutants in the ambient (outdoor) air).

Table 3 - Airport-Related OGs Identified in Section 112 of the Clean Air Act and/or IRIS

								Stationary Source																							
		Identified in:		Aircraft		GSE		Boilers/Space Heaters				Fuel Storage Tanks			Surface Coatings									Emergency Generators							
CAS	Species Name	CAA ?	IRIS ?	Pis- ton	Turbo/ APU	Gas, Natural Gas and LPG	Diesel	Coal	Re- sidual Fuel	Dis- tillate Fuel	Natural Gas and LPG	JP- 4	Jet Kerosene, Distillate and Residual Oil	Gas	Sol- vent Base	Water Base	Ena- mel	Lac- quer	Primer	Varnish / Shellac	Ad- hesives	Thinner	Solvent De- greasers	Gas	Diesel	Kero- sene / Naphtha	Natural Gas and LPG	In- cinerators	De- icing	Fire Training	On-Road Motor Vehicles[a]
71556	1,1,1-trichloroethane	Yes	Yes																				x						x		
106990	1,3-butadiene	Yes	Yes	x	x																			x	x						x
540841	2,2,4-trimethylpentane	Yes	Yes			x																		x							
110805	2-ethoxyethanol (cellosolve) (egee)		Yes																										x		
91576	2-methylnaphthalene		Yes		x																										
75070	acetaldehyde	Yes	Yes	x	x		x																	x			x				x
67641	acetone		Yes	x	x				x						x		x			x	x		x						x		
107028	acrolein (2-propenal)	Yes	Yes	x	x																			x							x
100527	benzaldehyde		Yes	x	x		x															x		x							
71432	benzene	Yes	Yes	x	x	x		x			x		x	x		x							x	x	x		x	x		x	x
111762	butyl cellosolve (2-butoxyethanol) (egbe)		Yes												x				x										x		
108907	chlorobenzene		Yes											x																	
110827	cyclohexane		Yes								x				x		x						x	x			x				
75092	dichloromethane (methylene chloride)	Yes	Yes													x						x	x								
141786	ethyl acetate		Yes												x		x				x								x		
75003	ethyl chloride	Yes	Yes													x															
60297	ethyl ether		Yes																				x								
100414	ethylbenzene	Yes	Yes	x	x	x		x						x	x		x					x		x			x				
106934	ethylene dibromide	Yes	Yes																			x									
107211	ethylene glycol	Yes	Yes													x													x		
50000	formaldehyde	Yes	Yes	x	x		x		x	x	x													x		x	x				x
1330207	isomers of xylene	Yes	Yes												x		x	x	x				x				x		x		
98828	Isopropylbenzene (cumene)	Yes	Yes		x									x									x								
108383; 106423	m & p-xylene	Yes	Yes	x	x			x						x																	
67561	methyl alcohol	Yes	Yes		x																										
74873	methyl chloride	Yes	Yes													x															
78933	methyl ethyl ketone (2-butanone)		Yes												x		x			x	x	x	x						x		
108101	methyl isobutyl ketone	Yes	Yes												x		x			x	x								x		
1634044	methyl tert butyl ether (MTBE)	Yes	Yes																												x
108383	m-xylene	Yes	Yes			x																x					x				
91203	naphthalene	Yes	Yes	x	x									x									x								
71363	n-butyl alcohol		Yes													x															
142825	n-heptane		Yes	x	x	x		x		x		x	x	x	x		x	x	x		x	x	x	x			x				
110543	n-hexane	Yes	Yes			x		x	x	x			x	x									x	x			x				
95476	o-xylene	Yes	Yes	x	x	x		x						x	x		x	x	x				x	x			x				
127184	perchloroethylene		Yes																				x								
108952	phenol (carbolic acid)	Yes	Yes	x	x																										
85449	phthalic anhydride		Yes																			x									
123386	propionaldehyde	Yes		x	x		x																	x							
106423	p-xylene	Yes	Yes																			x	x	x							
100425	styrene	Yes	Yes	x	x									x																	
108883	toluene	Yes	Yes	x	x	x		x			x		x	x	x		x	x	x		x	x	x	x			x		x		
79016	trichloroethylene	Yes	Yes																				x								
76131	trichlorotrifluoroethane-F113		Yes																				x								
108054	vinyl acetate	Yes	Yes													x															

[a] Only the HAPs for which the MOBILE6 emissions rate model has programmed emissions factors are included in this listing.

4 EMISSION INVENTORIES

This section describes the recommended procedures to prepare emission inventories of airport-related OGs, including those compounds identified as either HAPs in the CAA and/or potentially toxic compounds in the IRIS database. Emission inventories provide estimates of the total amounts (or masses) of pollutants or pollutant precursors associated with an airport, a proposed project or action, or an individual emission source. In this section, procedures for speciating OGs are provided for the following airport-related sources:

- Aircraft engines,
- APUs,
- GSE,
- GAV, and
- Stationary sources (i.e., boilers, emergency generators, incinerators, training fires, aircraft engine testing, etc.).

A previously stated, the FAA is not currently recommending procedures to estimate speciated OGs (including HAPs) from non-road construction equipment and/or construction-related activities due to a lack of data for this source and activity. Additionally, speciated OG/HAP data for on-road (motor) vehicles should be obtained from the FAA's EDMS.

Because the primary topic of this document is speciated OG, the discussion and methodologies for obtaining/calculating the total mass of OG to be speciated is limited. If additional detail/information is required to develop this mass OG emission estimate for a particular source, analysts should refer to support documentation for the EDMS and/or the FAA's Air Quality Handbook (both can be obtained from FAA's website (www.FAA.gov)).

Airport operational functions can be conveniently divided between the airside (the restricted area of the airfield including runways, taxiways and aprons) and the landside (the public area of the airport including the terminal buildings, airport access/egress roadways and parking facilities).

On the airside, the airfield operational characteristics of primary significance to an air pollutant inventory are the number of aircraft operations (i.e., landings and takeoffs), the fleet makeup (i.e., commercial, GA, military), the aircraft engine types and the TIMs (i.e., approach, taxi/idle, takeoff, etc.). Some of these airfield data are available from airport planning and design documents. Other operational data for aircraft can be acquired from aircraft performance manuals or the EDMS. The GSE fleet, the types of APUs, their fuel types and operating times are also important to know when preparing an estimate of air pollutants. These data are often obtained from on-airport surveys and supplemented with information contained in the EDMS database.

On the landside, the volume of GAV, the fleet mix, engine type (i.e., gasoline or diesel), operating speed, and distances traveled play key roles in an air pollutant inventory. For fuel storage facilities, live-fire training equipment and other stationary sources, the fuel types (i.e., jet fuel, avgas, gasoline, etc.) and throughput volumes are important. Again, this information can be obtained from airport planning documents, on-site surveys, and be augmented with EDMS data.

Input Data, Assumptions and Limitations

The sources of the data and information, important limitations to the materials and any other elements of the airport or its environs that could have an effect on the outcome of the analysis should be recorded and discussed in the *Air Quality Analysis Protocol* (see Section 2.2.2).

The overall approach to preparing an emissions inventory of speciated OG should attempt to make use of airport-specific data/information wherever possible and utilize suitable substitutes, surrogates, and assumptions only to bridge gaps in the data/information. For these reasons, the documentation for any OG/HAPs inventory should include a thorough explanation of how the data were obtained or derived, why they are appropriate for the application, and what the potential limitations may be.

EDMS computes emission inventories of airport-related carbon monoxide, nitrogen oxides, sulfur oxides, OG and PM emissions. The current version (Version 5.1), also provides estimates of speciated OG**.** The following discusses the process used in the EDMS to speciate estimated OG for each of the airport-related sources. A case study, which demonstrates the procedures described in this guidance and used in the EDMS, is provided in **Appendix A**.

4.1 Aircraft Engines

Regardless of the type of aircraft engine (e.g., turbofan, turboprop, turbojet, piston), estimates of OG and speciated OGs for aircraft engines are derived using estimates of:

1) the fuel consumed in each aircraft operating modes (i.e., approach, takeoff, climbout, and taxi) which is a function of the fuel flow rate and the TIM, derived using a high-fidelity model within the EDMS (i.e., BADA, BFFM2) for each operating mode;
2) an OG emission index;
3) a factor that converts the estimated level of OG to TOG[14]; and
4) a speciation profile.

4.1.1 Fuel Consumption

To compute speciated OG for aircraft engines, the quantity of fuel consumed by aircraft type (e.g., Boeing 777-200) and operational mode (e.g., takeoff, climbout, etc.) are first calculated. The calculation to derive fuel consumption for an individual operational mode is provided in **Equation No. 1**.[15]

[14] The speciation profiles discussed in this document and provided in the companion spreadsheet to this guidance are representative of TOG emissions.
[15] Notably, THC emissions are greatest during the taxi and idle aircraft operational modes and emissions attributable to the approach and climbout modes will vary depending on the scenario specific atmospheric mixing height.

Equation No. 1:

Fuel Consumption By Aircraft Operational Mode

$$A_i \times B_i \times D = C_i$$

Where:
A = Fuel flow rate for operational mode per engine (kg/sec)
B = Time in operational mode (sec)
C = Total fuel consumed for operational mode (kg)
D =Number of engines
i = Operational mode of interest (approach, takeoff, climbout, taxi, etc.)

4.1.2 OG Emission Indices

Aircraft OG emission indices are specific to aircraft engine types and operational modes and are typically expressed in units of grams/1,000 kilograms of fuel consumed.[16] At the time of this writing, the FAA is finalizing a Recommended Best Practice for quantifying speciated OGs from aircraft equipped with turbofan, turbojet, and turboprop engines.[17] Analysts should refer to the final documentation for additional detail on the development of the OG speciation profile for these types of engines.

Using an OG emission index specific to the operational mode of interest and the results from **Equation No. 1** for the mode of interest, estimates of the mass of OG are derived as shown in **Equation No. 2**:

Equation No. 2:

Estimated Mass of OG

$$C_i \times D_i \times 1/453.6 = E_i$$

Where:
C = Total fuel consumed for operational mode (kg)
D = THC emission index obtained from EDMS (g/1000 kg of fuel consumed)
E = Mass of OG (lbs)
i = Operational mode of interest (approach, takeoff, climbout, and taxi)
1/453.6 = g to lbs conversion factor

Equations No. 1 and 2 should be used to calculate the estimated mass of OG for each of the aircraft operational modes (i.e., approach, takeoff, etc.) and the results summed to derive the total mass of OG attributable to an entire aircraft landing-takeoff cycle.

[16] Emission indices can be obtained from the EDMS and/or ICAO database.
[17] *Recommended Best Practice for Quantifying Speciated Gas-Phase Hydrocarbon Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*, FAA, EPA August 5, 2008 (Draft)

4.1.3 Conversion Factors

The speciation profiles included in the EDMS database for the purpose of preparing airport-related inventories of speciated OGs/HAPs are representative of TOG. Therefore, before applying the speciation profile data to a mass estimates of OG, the OG must first be converted to TOG. This application is detailed in **Equation No. 3**.

Equation No. 3:

Conversion to TOG

$$E \times F = G$$

Where:
E = Mass of OG emissions (lbs)
F = TOG conversion factor (unitless)
G = Mass of TOG (lbs)

4.1.4 Applying Speciation Profile Data

To speciate the mass of TOG emissions, air quality practitioners obtain the latest speciation profile data and derive the levels of individual OGs by multiplying the profile values by the total amount of TOG (these values are also included in the EDMS). Notably, with respect to aircraft engines, the FAA intends to collaborate with EPA to update the profiles in EDMS as subsequent validated and verified aircraft engine test data becomes available.

Using a speciation profile specific to the type of engine being considered, the calculation for obtaining the estimated level of an individual OG/HAP is provided in **Equation No. 4**.

Equation No. 4:

Speciated OG Emissions - Aircraft

$$G \times H = I$$

Where:
G = Mass of TOG (lbs)
H= Speciation profile for individual OG of interest (mass fraction)
I= Mass of OG of interest (lbs)

4.2 APUs

With one exception, the procedure for calculating speciated OG for an APU is the same as the procedure used to calculate the amount of speciated OG for an aircraft engine. For APUs, the amount of fuel consumed is not based on the amount of time in each of the aircraft operational modes. Rather, the amount of fuel consumed is based on the run time of an APU prior to engine start up on departure and the run time after an aircraft engine is shut down on arrival and, if available, connected to ground power at an airport. Notably, if ground power is not available, an APU may be used the entire time an aircraft is at an airport's gate (if passenger comfort is a concern).

The required data input to obtain an estimate of a speciated OG for an APU is:

1) the APU run time (for a complete landing-takeoff cycle);
2) an OG emission index specific to the APU model;
3) a factor that converts the estimated level of OG to TOG; and
4) a speciation profile.

Equation No. 5 demonstrates how to derive a speciated OG emission for an APU.

Equation No. 5:

Speciated OG Emissions - APU

$$A \times B \times D \times F \times H \times 1/453.6 = I$$

Where:
A = Number of LTO cycles performed by assigned aircraft
B = Time in operation (sec)
D = OG emission index (g/kg fuel consumed)
F = TOG conversion factor (unitless)
H= Speciation profile for individual OG of interest (mass fraction)
I= Mass of OG of interest (lbs)
1/453.6 = g to lbs conversion factor

4.3 GSE

For conventional and alternatively fueled GSE, the factors that determine the amount of speciated OG are:

1) the brake horsepower of the equipment;
2) the load factor;
3) equipment usage (equipment operating time);
4) OG emission indices;
5) a TOG conversion factor specific to the equipment fuel type; and
6) a speciation profile that is also specific to the fuel type.

Equation No. 6 can be used to calculate the pollutant emissions from an individual piece (or type) of equipment.

Equation No. 6:

Speciated OG Emissions - GSE

$$L \times M \times B \times D \times F \times H \times 1/453.6 \times 1/60 = I$$

Where:
L = Average rated brake horsepower
M = Load factor (percentage)
B = Time in operation (min)
D = OG emissions index (g/hp-hr)
F = TOG conversion factor (unitless)
H= Speciation profile for individual OG of interest (mass fraction)
I = Mass of OG of interest (lbs)
1/453.6 = g to lbs conversion factor
1/60 = min to hr conversion factor

4.4 GAVs

EPA's MOBILE6.2 emission rate model provides both exhaust and evaporative emission indices for six OGs that the EPA considers the most common HAPs associated with highway motor vehicles[18] [EPA, 2002b,c]. The MOBILE6.2 output is expressed in units of grams/vehicle-mile and can be segregated by vehicle type (e.g., light duty gas, heavy duty diesel, etc.) or combined into a composite value representative of the entire ground access vehicle fleet. MOBILE6.2 also allows the user to enter ratios for other substances that are not among the six pollutants pre-coded into the model.[19] For OGs, these ratios are expressed as fractions of VOC or TOG.

MOBILE6.2 reports highway motor vehicle emission rates in grams or milligrams of pollutant per vehicle mile traveled. These emission rates, when considered with estimates of travel activity (vehicle-miles-traveled or VMT), provide estimates of the mass of OG. The mass of OG is then converted to TOG and speciated as shown in **Equation No. 7.**

Equation No. 7:

Speciated OG Emissions - Ground Access Vehicles

$$D \times N \times F \times H \times 1/453.6 = I$$

Where:
D = OG emission index (g/mi)
N = Vehicle-miles-traveled (mi)
F = TOG conversion factor (unitless)
H= Speciation profile for individual OG of interest (mass fraction)
I = Mass of OG of interest (lbs)
1/453.6 = g to lbs conversion factor

[18] The six HAPs are: 1,3-butadiene, acetaldehyde, acrolein, benzene, formaldehyde and methyl tertiary butyl ether.
[19] The additional HAPs include: naphthalene, styrene, toluene, xylene, and ethylbenzene.

Notably, the EPA is currently developing a new motor vehicle emission rate model, Mobile Vehicle Emission Simulator (MOVES). Like MOBILE, the MOVES model will also provide emission indices for some OGs. When appropriate, the FAA will incorporate MOVES in to the EDMS.

4.5 Stationary Sources

Airport-related stationary sources of HAPs include a variety of sources including power generators, steam boilers, space heaters, engine test facilities, and other aviation-related industrial sources (solvent decreasing, paint booths, etc.). Live-fire training facilities and fuel storage/transfer facilities are also considered to be stationary sources. In nearly all cases, the types and amounts of HAPs emitted by these sources depend on the type and quantity of the fuel used, operating times, and the existence of emission control equipment.

Some stationary sources may be regulated under Section 112 (*Hazardous Air Pollutants*) of the CAA. Depending on the types and amounts of HAPs emitted, they are potentially subject to the permitting and discharge limitations of the National Emissions Standards for Hazardous Air Pollutants (NESHAPS) program. As a result, speciated OG/HAPs emissions data may already exist for some sources (in their operational permits).

The calculation input for stationary sources is generally the same regardless of the type of source (data units may vary). Generally, the required input is:

1) the throughput of the fuel/paint/solvent/deicing fluid used (where applicable, the required input equals the diluted amount of the fluid) ;
2) an OG emission index;
3) a factor that converts the estimated level of OG to TOG; and
4) a speciation profile.

4.5.1 Combustion Sources

Potential airport-related stationary combustion sources are boilers/space heaters, emergency generators, incinerators, fire training facilities, and aircraft engine testing. The data required to prepare an emission inventory of speciated OG for these sources are:

1) the amount of fuel consumed over a given time period;
2) a THC emission index for the type of fuel;
3) a THC-to-TOG conversion factor; and
4) a speciation profile.

Equation No. 8 provides an estimate of speciated OG/HAP emissions for an individual stationary combustion source.

Equation No. 8:

Speciated OG Emissions - Stationary Combustion Sources

$$C \times D \times F \times H = I$$

Where:
C = Total fuel consumed (e.g., gallons, million cubic feet, or tons)
D =THC emission index ((e.g., lbs / gal, lbs/million cubic feet, or lbs /ton)
F = TOG conversion factor (unitless)
H = Speciation Profile for individual OG of interest (mass fraction)
I = Mass of OG of interest (lbs)

4.5.2 Non-Combustion Sources

Airport-related non-combustion stationary sources are fuel storage tanks, coating and painting operations, deicing, and the use of solvent degreasers. While the final steps in preparing an estimate of speciated OG/HAP emissions remains the same for each source (apply a conversion factor and speciation profile data), the methodologies for calculating the amount of THC vary.

4.5.2.1 Fuel Storage Tanks

Fuel storage and the handling of jet and diesel fuel does not produce significant OG/HAP emissions because these fuels have a relatively low vapor pressure and the emissions remain well confined within the containment vessels and the distribution system. However, OG emissions from Avgas and gasoline storage can be more significant as their vapor pressures are higher than that of jet and diesel fuel. To estimate speciated OG emissions from storage tanks, the data required are:

1) an estimate of the standing storage and working OG emissions[20];
2) a conversion factor; and
3) a speciation profile.

Estimates of OG and the resultant levels of speciated OG from this source will vary depending on the type of fuel that is stored (e.g., gasoline, jet kerosene, etc.). The general methodology for calculating storage tank OG emissions (including speciated OG emissions) is expressed in **Equation No. 9**:

[20] Estimates of standing storage and working HC emissions may be obtained from EDMS, the EPA's TANKS program, and/or using methodologies described in Section 7.1 of Volume I of *Compilation of Air Pollutant Emission Factors*. Information specific to the type of tank (i.e., fixed or floating roof) may be obtained from the airport operator, fueling contractor, or by visual inspection.

Equation No. 9:

Speciated OG Emissions - Fuel Storage Tanks

$$(O + P) \times F \times H = I$$

Where:
O = Standing storage emissions (lbs)
P = Working storage emissions (lbs)
F = TOG conversion factor (unitless)
H = Speciation profile for individual OG of interest (mass fraction)
I = Mass of OG of interest (lbs)

4.5.2.2 Coating and Painting Operations

Emissions of OGs/HAPs from coating and painting activities (use of enamel, primer, varnish, adhesive, etc.) vary depending if air pollutant control measures can/are used and, if so, the type of control measure. **Equation No. 10** provides the general method of calculating and then speciating OG emissions from this source.

Equation No. 10:

Speciated OG Emissions - Coating/Painting Operations

$$Q \times R \times S \times F \times H = I$$

Where:
Q = Quantity of Coating/Paint (gallons)
R = VOC content (lb VOC/gallon)
S = Air pollutant control factor (percentage)
F = TOG conversion factor (unitless)
H = Speciation profile for individual OG of interest (mass fraction)
I = Mass of OG of interest (lbs)

4.5.2.3 Deicing Activities

The level of speciated OG emissions from deicing activities varies depending on the specific chemical present in the deicing fluid (i.e., propylene glycol, ethylene glycol, or other organic compounds) and the amount of diluted fluid used. **Equation No. 11** expresses the methodology for deriving and speciating OG emissions from deicing activities (aircraft or runway).

Equation No. 11:

Speciated OG Emissions - Deicing

$$Q \times T \times U \times D \times F \times H = I$$

Where:
Q = Quantity of Deicing Fluid (gallons)
T = Density of Deicing Fluid (lbs/gallon)
U = Concentration of deicing chemical (percent by weight/100)
D = THC emission index (lbs/lb of chemical consumed)
F = TOG conversion factor (unitless)
H = Speciation profile for individual OG of interest (mass fraction)
I = Mass of HC of interest (lbs)

4.5.2.4 Solvent Degreasers

Emissions of OGs/HAPs that result from the use of organic solvents are estimated by calculating the difference between the volume of solvent consumed and the liquid volume disposed, and then multiplying this difference by the density of the solvent. The resultant emissions are then speciated as shown in **Equation No. 12**:

Equation No. 12:

Speciated OG Emissions – Solvent Degreaser

$$(Q - V) \times T \times F \times H = I$$

Where:
Q = Quantity of solvent consumed (gallons)
V = Quantify of solvent disposed of (gallons)
T = Density of solvent (lbs/gallon)
F = TOG conversion factor (unitless)
H = Speciation profile for individual OG of interest (mass fraction)
I = Mass of OG of interest (lbs)

4.6 Presentation of Results

The outcome of the emissions inventory provides an estimation of the amount of OGs/HAPs generated by the airport, the airport project/action or the individual source. For consistency with the criteria air pollutant emissions inventory, the results are expressed in units of tons/year, pounds/day or as equivalent metric system units. However, because the output data can be overly complex and voluminous, they are most conveniently presented in tabular form, arranged according to the individual OG/HAP selected as pertinent to the inventory, and emission source. **Table 4** provides a sample template for presenting the data.

Table 4
Recommended Tabular Format for Reporting
Estimated Airport OG, by Pollutant and Source
(tons/year)

Pollutant	Sources				Totals
	Aircraft	GSE	GAV	Other	
Formaldehyde	39.21	7.51	15.71	0.07	62.50
Acetaldehyde	1.71	3.22	6.22	0.01	11.16
Benzene	6.32	7.42	28.31	0.02	42.07
Toluene	3.22	4.14	23.21	0.01	30.58

Depending on the purpose and scope of the assessment, the results can be further segregated by inventory year, airport operational level or project alternative.

For reviewing purposes, the results should be accompanied by:

1) Summary explanations of how the inventory was conducted (information and data sources, major assumptions, computational methods);
2) How the results are interpreted or compared (between alternatives or any applicable significance criteria); and
3) Any significant limitations to the understanding and application of the outcome.

5 SUMMARY

Inventories of airport-related speciated OGs (which include the OGs identified by the EPA to be HAPs and the OGs listed in the EPA's IRIS) are not required by current EPA regulations. In cases where it is necessary to prepare such an airport-related inventory, the inventory must be prepared following the approach described in this document to ensure consistency. The following summarizes the main points of these guidelines with respect to preparing/reporting an airport-related OG/HAP emission inventory:

- Airport-related OG inventories are to be prepared using the most current version of FAA's EDMS model.
- If conditions warrant that an inventory be prepared, EAs and EISs should only report emission levels for the airport-related OGs identified in Section 112 of the CAA (as amended) as being a HAP and/or included in the EPA's IRIS database.
- EIS documents must include project/action-related OG/HAP emission inventories if an EIS must also include an emissions inventory of criteria air pollutant emissions or the precursors to the criteria air pollutants.
- EA documents must only include OG inventories if one of the following conditions is met:
    - The proposed project/action is "major" (e.g., a new airport or heliport, a new runway) and the level of operations/level of activity at the airport is such that the proposed project/action could result in more than a minimal change in the type/level of OG/HAP emissions, or
    - The airport is in an area that is designated by the EPA to be non-attainment or maintenance for either ozone, particulate matter 10 microns or less in diameter, or particulate matter 2.5 microns or less in diameter, or
- The EA/EIS reporting requirements with respect to OGs/HAPs are limited to emission inventories only. No other assessment methodologies, including methodologies that involve dispersion, toxicity weighting, exposure, and/or health risk quantifications, should be undertaken--except when required by CEQA.

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APPENDIX A

Example Case Study for Preparing an Emission Inventory of Airport-Related Speciated OGs

1. Introduction

This case study is provided as an instructional aid for preparing a speciated OG emission inventory for an airport. For this demonstration, two types of aircraft/engine combinations and one stationary source (a boiler) are inventoried. For the purpose of this case study, the list of speciated OG is limited to only two compounds--benzene and formaldehyde.

Notably, while the intent of this case study is to provide methodologies, formulae, and results that mirror those within or that would be provided by the EDMS, for certain sources (e.g., aircraft), the results presented in this example case study cannot be recreated in EDMS due to the complexity of the calculations that are used in the EDMS to derive emission estimates..

2. Aircraft Data, Calculations, and Emissions

This case study assumes that an analyst is charged with estimating airport-related OG for an Airbus A320-100 aircraft equipped with two CFM56-5A1 (turbofan) engines[21] and a Cessna 150 aircraft equipped with one Continental 0-200 (piston) engine. Over the time period of interest, there will be 20,000 and 5,000 LTO cycles for the A320-100 and Cessna 150, respectively. Additionally, based on the configuration of the airport and in-the-field surveys, each aircraft type has a combined taxi/idle (delay) time of 26 minutes per LTO (EDMS default times-in-mode for approach, takeoff, and climbout are assumed for the other operational modes). **Table A-1** summarizes the aircraft-related data for this case study.

Table A-1
Aircraft: Case Study Data

Aircraft	Aircraft Type	Engine	Number of Engines	Number of LTO's[a]	Time in Mode: Mode	Time in Mode: Time (min)
Airbus A320-100	Turbofan	CFM56-5A1	2	20,000	Taxi/Idle	26.00
					Approach	4.12
					Takeoff	1.51
					Climbout	0.53
Cessna 150	Piston	0-200	1	5,000	Taxi/Idle	26.00
					Approach	4.45
					Takeoff	5.69
					Climbout	3.20

[a] LTO = Landing and takeoff cycle (one LTO is equal to one arrival plus one departure).

[21] It is recognized that A320-100 aircraft typically operate with APUs which also emit OG. However, for the purposes of this case study, emissions from APUs were not calculated.

The first step is to estimate the total mass of OG emitted by the aircraft--a value that is calculated using fuel flow rates and OG emission indices that are specific to the type of engine and operational mode.[22] Using the base data (number of engines, number of LTOs, times-in-mode), and the fuel flow rate, the total fuel consumed is calculated as discussed in Section 4.1 of this document and detailed in **Equation No. 1** (reproduced below for convenience).

Equation No. 1:

Fuel Consumption By Aircraft Operational Mode

$$A_i \ x \ B_i \ x \ D = C_i$$

Where:
A = Fuel flow rate for operational mode per engine (kg/sec)
B = Time in operational mode (sec)
C = Fuel consumed per operational mode (kg)
D = Number of engines
i = Operational mode of interest (approach, takeoff, climbout, taxi, etc.)

The fuel flow rates for the aircraft in this case study and the calculated total fuel consumed by each aircraft in each operational mode is provided in **Table A-2**.

Table A-2
Aircraft: Fuel Usage Rates and Fuel Consumption Summary

Aircraft	Engine Model/ Number of Engines	Fuel Consumption		Time in Mode (min)	Fuel Consumption/ LTO (kg)
		Operational Mode	Rate/ Engine[a] (kg/sec)		
A320-100 (Turbofan)	CFM56-5A1/ 2	Taxi/Idle	0.105319	26.00	328.60
		Approach	0.052100	4.12	25.76
		Takeoff	1.598940	1.51	289.73
		Climbout	1.139159	0.53	72.45
Cessna 150	0-200 / 1	Taxi/Idle	0.001083	26.00	1.69
		Approach	0.003217	4.45	0.86
		Takeoff	0.003217	5.69	1.10
		Climbout	0.003217	3.20	0.62
[a] For illustrative purposes, the fuel flow rates are EDMS “Step 1” rates.					

To obtain the final estimate of the total OG mass, emission indices, specific to each aircraft operational mode, are multiplied times the amount of fuel consumed in each operational mode. This procedure is detailed in **Equation 2** (repeated below). The fuel consumed (repeated from Table B-2), the OG emission indices (obtained from the EDMS), and resultant amounts of mass

[22] The EDMS provides both aircraft fuel flow rates and HC emission indices.

OG emitted by the aircraft in this case study are provided in **Table A-3** (estimates of mass OG are provided for a single LTO and for all LTOs evaluated for a particular aircraft).

Equation No. 2:

Estimated Mass of OG

$$C_i \times D_i \times 1/453.6 = E_i$$

Where:
C = Total fuel consumed for operational mode (kg)
D = OG emission index (g/kg of fuel consumed)
E = Mass of OG (lbs)
i = Operational mode of interest (approach, takeoff, climbout, taxi, etc.)
1/453.6 = g to lbs conversion factor

Table A-3
Aircraft: Fuel Usage Rates and Total Fuel Consumption Summary

Aircraft	Engine Model/ Number of Engines	Fuel Consumption		OG Emission Indices (g/kg) [a]	Mass OG/LTO (lbs)
		Operational Mode	Per LTO (kg)		
A320-100 (Turbofan)	CFM56-5A1 / 2	Taxi/Idle	328.60	1.475004	1.07
		Approach	25.76	1.541144	0.09
		Takeoff	289.73	0.242322	0.15
		Climbout	72.45	0.247953	0.04
Total/LTO					1.35
Total Mass OG: A320-100 - 20,000 LTOs					27,000
Cessna 150 (Piston)	0-200 / 1	Taxi/Idle	1.69	30.553653	0.11
		Approach	0.86	34.489826	0.07
		Takeoff	1.10	33.932279	0.08
		Climbout	0.62	34.077689	0.05
Total OG/LTO					0.31
Total Mass OG: Cessna 150 - 5,000 LTOs					1,550
[a] For illustrative purposes, OG emission indices are EDMS “Step 1” indices.					

The emission indices obtained from EDMS are representative of THC as shown in **Equation 3** using simple multiplication.

Equation No. 3:

Conversion to TOG

$$E \times F = G$$

Where:
E = Mass OG emissions (lbs)
F = TOG conversion factor (unitless)
G = Mass TOG (lbs)

The THC-to-TOG conversion factor for turboprop aircraft is 1.16 and the THC-to-TOG conversion factor for piston aircraft is 0.90 (analysts should always verify that they have the latest speciation profile and conversion factor data before completing any evaluation). These conversion factors and the resultant amount of TOG from each aircraft are provided in **Table A-4.**

Table A-4
Aircraft: Estimated TOG

Aircraft/Engine	Mass OG (lbs)	THC-to-TOG Conversion Factors	Mass TOG (lbs)
A320-100 / CFM56-5A1/2	27,000	1.16	31,320
Cessna 150 / 0-200	1,550	0.90	1,395

The final step in estimating emissions of benzene and formaldehyde is to apply the mass fractions obtained from the appropriate speciation profiles for these particular compounds (**Equation No 4** repeated below). The mass fractions for benzene and formaldehyde from the speciation profiles for turbofan and piston engines are provided in **Table A-5**.

Equation No. 4:

Speciated OG Emissions - Aircraft

$$G \times H = I$$

Where:
G = Mass TOG (lbs)
H= Speciation profile for OG of interest (mass fraction)
I= Mass of OG of interest (lbs)

Table A-5
Aircraft: Mass Fractions and Estimates of Speciated OGs

Aircraft/Engine	Mass TOG (lbs)	Speciation Profile	Speciation Profile (mass fraction)		Estimated Speciated OG (lbs)	
			Benzene	Formaldehyde	Benzene	Formaldehyde
A320-100 / CFM56-5A1/2	31,320	Turbofan, turbojet, and turboprop aircraft	0.01681	0.12308	526	3855
Cessna 150 / 0-200	1,395	Piston aircraft	0.0179	0.1414	25	197
Total					551	4,052

3. Boiler Data, Calculations, and Emissions

This case study assumes that an analyst is charged with estimating airport-related OG for a boiler fueled by natural gas. To estimate speciated OG emissions for the boiler, a stationary combustion source, the required data (repeated from Section 3.5.1 of this guidance) is 1) the amount of fuel consumed over the time period of interest, 2) an OG emission index, 3) a conversion factor (if applicable), and 4) a speciation profile.

During the evaluated year, 20,000 cubic meters of natural gas are used to fuel the boiler. The OG emission index for a natural gas boiler is 0.18 kilograms per 1,000 cubic meters of natural gas burned. This OG emission index is representative of THC. As such, a factor (2.27) is required to convert the VOC to TOG prior to applying the speciation profile mass fractions for benzene (0.04) and formaldehyde (0.08) to the mass OG estimate. The required operational and other data is summarized in **Table A-6**.

Table A-6
Boiler: Case Study Data

Item		Factor
Natural Gas Burned		20,000 cubic meters
Emission Index		0.18 kilograms of THC/1,000 cubic meters of natural gas burned
Speciation Profile (mass fractions)	Benzene	0.04
	Formaldehyde	0.08

Equation No. 8 (repeated below) provides an estimate of speciated OG emissions from the natural gas boiler. Using this calculation, the estimated amounts of benzene and formaldehyde emitted by the boiler are 0.072 lbs and 1.44 lbs, respectively (e.g., benzene = 20,000 cubic meters x 0.18 kilograms/1000 cubic meters x 2.27 x 0.04 x 2.2046 (conversion from kilograms to lbs) = 0.72 lbs).

Equation No. 8:

Speciated OG Emissions - Stationary Combustion Sources

$$C \times D \times F \times H = I$$

Where:
C = Total fuel consumed (e.g., gallons, million cubic feet, or tons)
D = OG emission index ((e.g., lbs / gal, lbs/million cubic feet, or lbs /ton)
F = TOG conversion factor (unitless)
H = Speciation profile for OG of interest (mass fraction)
I = Mass of OG of interest (lbs)

4. Reporting the Results

Depending on the magnitude of the emissions, estimate levels of individual OG could be reported as lbs/year or tons/year (or a metric equivalent). For the purpose of this case study, **Table A-7** presents the estimate levels of the speciated OG for the evaluated aircraft and the boiler in tons/year. As stated in the main body of this guidance, depending on the purpose and scope of the project, the results can be further segregated by inventory year, airport operational level, or individual project.

Table A-7
Case Study Estimated OG, by Pollutant and Source
(tons/year)

Pollutant	Sources		Total
	Aircraft	Stationary	
Benzene	<1	<1	<1
Formaldehyde	2	<1	2

APPENDIX B

DEFINITIONS

Term	Definition
Aircraft engine standards	Requirements controlling the fuel efficiency and emissions characteristics of aircraft engines.
Aircraft fleet mix	Represents the types of airframes and assigned engines in use at an airport or aviation facility.
Airport-related emissions inventories	A listing, by source, of the amount of air pollutants discharged into the atmosphere of a community; used to establish emission standards.
Airside	The area of an airport property within which aircraft operations occur, including gates, services areas, cargo facilities, etc.
Atmospheric photochemical reactions	Reactions that occur in the atmosphere that convert compounds to different forms in the presence of sunlight. For example, NOx reacts with VOC in the presence of sunlight to form Ozone.
Auxiliary power units	Small on-board engines on an aircraft used to power the craft when normal engines are powered down, such as when the aircraft is at the terminal gate or queued for take-off
Conversion factor	A number used to convert one series of units to another.
Build alternative	One of a series of implementation options of a proposed project.
Emission standards	The maximum amount of air polluting discharge legally allowed from a single source, mobile or stationary.
Environmental assessment	An environmental analysis prepared pursuant to the National Environmental Policy Act to determine whether a federal action would significantly affect the environment and thus require a more detailed environmental impact statement.
Environmental impacts	The results of a proposed action that alter the quality or nature of the environment surrounding the area.
Environmental impact statement	A document required of federal agencies by the National Environmental Policy Act for major projects or legislative proposals significantly affecting the environment. A tool for decision making, it describes the positive and negative effects of the undertaking and cites alternative actions.
Flame ionization detector	A device that measures the number of atoms in a specific chemical species to determine its mass. The precision by which this device measures oxygenated species is low, resulting in the reporting of inaccurate masses.
Greenhouse gas	A gas, such as carbon dioxide or methane, which contributes to potential climate change.
Ground access vehicles	Public and private on-road motor vehicles traversing the airport property and surrounding roadways.
Ground support equipment	Non-road motor vehicles, such as baggage tractors and aircraft tugs, used to service and move aircraft at the gate and on the airside.
Hazardous Air Pollutants	Air pollutants which are not covered by ambient air quality standards but which, as defined in the Clean Air Act, may present a threat of adverse human health effects or adverse environmental effects. Such pollutants include asbestos, beryllium, mercury, benzene, coke oven emissions, radionuclides, and vinyl chloride.
Health risk quantifications	The results of a human health risk assessment by which air emissions have been prioritized, using toxicity weighting, in terms of potential detriment to human health.
Human health risk	The likelihood that a given exposure or series of exposures may have damaged or will damage the health of individuals.
Landside	The area of an airport property intended for public use, through which airport patrons are allowed to travel.

Term	Definition
Low reactivity compounds	Compounds that do not readily react with other chemicals under standard atmospheric and environmental conditions.
National Ambient Air Quality Standards	Standards established by EPA that apply for outdoor air throughout the country.
No-action alternative	The alternative when evaluating a proposed project, that represents the conditions if the project were not to occur.
Non-attainment	Area that does not meet one or more of the National Ambient Air Quality Standards for the criteria pollutants designated in the Clean Air Act.
Operational modes	The divisions within a cycle of operation. For example, the modes of operation within an aircraft LTO cycle include landing, take-off, climb-out, approach, etc.
Organic compounds	Naturally occurring (animal or plant-produced or synthetic) substances containing mainly carbon, hydrogen, nitrogen, and oxygen.
Plume emissions	The cloud of pollutants emitted from the exit plane of an emissions source (i.e. exhaust from a tail pipe)
Plume evolution	The process by which a cloud, or plume, of emissions travels from its source and disperses vertically and laterally in the ambient air.
SPECIATE data quality ratings	A rating scheme developed to assess the completeness, accuracy, validity and utility of data in the SPECIATE database.
Speciated Organic Gas	A single chemical species in an emissions plume whose mass has been derived based on the total mass of the plume.
Speciation profiles	A representation of the mass contribution of a single pollutant relative to the total mass of pollutants in an emissions plume.
Stationary source	A fixed-site producer of pollution, mainly power plants and other facilities using industrial combustion processes.
Surrogate data sources	Data that is used as a proxy for one or more parameters when the parameter(s) are otherwise missing.
Toxicity weighting	The process by which factors are applied to air emissions during health risk assessments, to prioritize those compounds that have documented negative impacts on human health.
Unit risk values and reference concentrations	Factors evaluated when performing toxicity weighting in human health risk assessments
Volatile organic compounds	Any organic compound that participates in atmospheric photochemical reactions except those designated by EPA as having negligible photochemical reactivity.

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Between-airport heterogeneity in air toxics emissions associated with individual cancer risk thresholds and population risks

Ying Zhou*[1] and Jonathan I Levy[2]

Address: [1]Department of Environmental and Occupational Health, Rollins School of Public Health, Emory University, 1518 Clifton Road NE, Atlanta, Georgia 30322, USA and [2]Department of Environmental Health, Harvard School of Public Health, Landmark Center 4th Floor West, PO Box 15677, Boston, Massachusetts, 02215, USA

Email: Ying Zhou* - ying.zhou@emory.edu; Jonathan I Levy - jilevy@hsph.harvard.edu

* Corresponding author

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Abstract

Background: Airports represent a complex source type of increasing importance contributing to air toxics risks. Comprehensive atmospheric dispersion models are beyond the scope of many applications, so it would be valuable to rapidly but accurately characterize the risk-relevant exposure implications of emissions at an airport.

Methods: In this study, we apply a high resolution atmospheric dispersion model (AERMOD) to 32 airports across the United States, focusing on benzene, 1,3-butadiene, and benzo [a]pyrene. We estimate the emission rates required at these airports to exceed a 10^{-6} lifetime cancer risk for the maximally exposed individual (emission thresholds) and estimate the total population risk at these emission rates.

Results: The emission thresholds vary by two orders of magnitude across airports, with variability predicted by proximity of populations to the airport and mixing height (R^2 = 0.74–0.75 across pollutants). At these emission thresholds, the population risk within 50 km of the airport varies by two orders of magnitude across airports, driven by substantial heterogeneity in total population exposure per unit emissions that is related to population density and uncorrelated with emission thresholds.

Conclusion: Our findings indicate that site characteristics can be used to accurately predict maximum individual risk and total population risk at a given level of emissions, but that optimizing on one endpoint will be non-optimal for the other.

Background

For hazardous air pollutants (HAPs), even after implementation of the maximum available control technology (MACT) standards for major stationary sources of air pollution, the residual cancer risks associated with air toxics in the United States (US) generally exceed the 10^{-6} lifetime risk level often considered as a de minimis cancer risk [1,2]. Therefore increasing attention has been paid to various mobile and area sources and other efforts to control residual risks. While a variety of efforts have been implemented and have contributed to risk reductions [3], some source categories which may contribute to air toxics risks in some settings have not been extensively characterized or formally addressed.

Airports represent a complex source type of increasing importance in many areas. Airports do not meet the definition of a major or area source under Section 112 of the Clean Air Act [4], yet include a combination of sources that contribute to air toxics risks. For example, a study of air toxics risks from O'Hare International Airport in Chicago, Illinois (ORD) [5], estimated that cancer risks associated with the airport exceeded 10^{-6} for a 1000 square mile area surrounding the airport, with a maximum individual risk (MIR) of 10^{-4}. Aircrafts, which contributed 87 percent of these risks, are considered mobile sources but are not subject to the requirements of Section 112 [6].

However, modeling risks from airports or from proposed airport expansions can be complex and somewhat uncertain, given the need for accurate emissions inventories and atmospheric dispersion models that address the intricacies of airport emissions (i.e. aircraft emissions that vary over time and space, including vertically). For this reason, some have concluded that currently available data are inadequate to conduct air toxics risk assessments for airports [6]. For airports, even screening analyses can therefore be time consuming and computationally intensive.

In spite of these data and analytical limitations, there is increasing interest among community groups and other stakeholders in including air toxics risks when considering the marginal contribution of airports or proposed airport expansions to health risks [7]. Given this, it would be desirable to be able to quickly but reasonably estimate the emission rate required for a specific airport to reach a given MIR threshold (which we henceforth define as the de minimis individual risk emission threshold, or DMIRET). In principle, the DMIRET would depend on the proximity of populations to runways and taxiways, meteorological conditions, and the proportion of ground-level versus elevated emissions. It would also depend on the characteristics of the pollutant itself, including its potency, chemical reactivity, and whether it is found in the gas or particle phase.

If the DMIRET could be predicted by these and other covariates for a given toxic air pollutant, the likelihood of MIR thresholds being exceeded could be quickly evaluated. This would allow national regulatory agencies to quickly determine which airports would require greater attention and more extensive modeling efforts to address air toxics. In addition, it would allow interested community groups to quickly ascertain whether an airport or airport expansion would likely contribute to air toxics health risks.

However, focusing exclusively on MIR thresholds in making prioritization decisions could be non-optimal. Although many screening-level cancer risk characterizations are driven initially by an individual risk perspective [3], cost-benefit or related analyses would require population risk estimates, i.e. the sum of individual risks. For example, in the evaluation of residual risks for HAPs, if a source/pollutant combination exceeds the MIR threshold, then the number of people at various risk levels and other considerations are utilized in formulating risk management decisions [3]. It would therefore be important to determine whether population risk measures are correlated with the MIR measures. It is possible that a source would have a lower MIR but a greater total population risk, based on the spatial gradient of concentrations, downwind population density, and other factors.

In this study, we determine for 32 airports distributed across the US the minimum aircraft emission rates of three HAPs with differing potencies and chemical characteristics (benzene, 1,3-butadiene, and benzo [a]pyrene) that would lead to a MIR of 10^{-6}. We determine whether significant variability exists in these minimum emission rates and develop models to explain any observed variability based on publicly available covariates. We also calculate the total population risk within 50 km of the airport at these minimum emission rates, and we determine which covariates predict these various measures and whether they are correlated with one another. These analyses allow us to consider the likelihood that an emphasis on avoiding MIR thresholds would be an optimal strategy from a population risk perspective.

Methods

Airport sample selection

As applying detailed atmospheric dispersion models to characterize the marginal effects of all individual airports in the US was infeasible, we instead selected a subset of airports that were representative of the US and adequate to characterize variability in the DMIRET. We began with a set of 325 airports that had been previously characterized using the Emissions and Dispersion Modeling System (EDMS) [8], a combined emissions and dispersion model for assessing air quality at civilian airports and military air bases [9]. These airports represent 95% of commercial jet aircraft operations. We stratified the data set into four census regions – Northeast, Midwest, South and West, as defined by the US Census Bureau [10]. We then randomly selected 10 percent of airports in each region, yielding 5 airports in the Northeast, 8 in the Midwest, 12 in the South, and 7 in the West (Figure 1). Therefore, we obtained a sample of 32 airports for this study, which balanced the need for a large enough sample size for regression analysis with the limitation on computational capacity for air dispersion modeling.

Atmospheric modeling

We modeled the incremental concentration due to aircraft emissions from airports in the study sample using AERMOD. AERMOD's concentration estimates are based on a

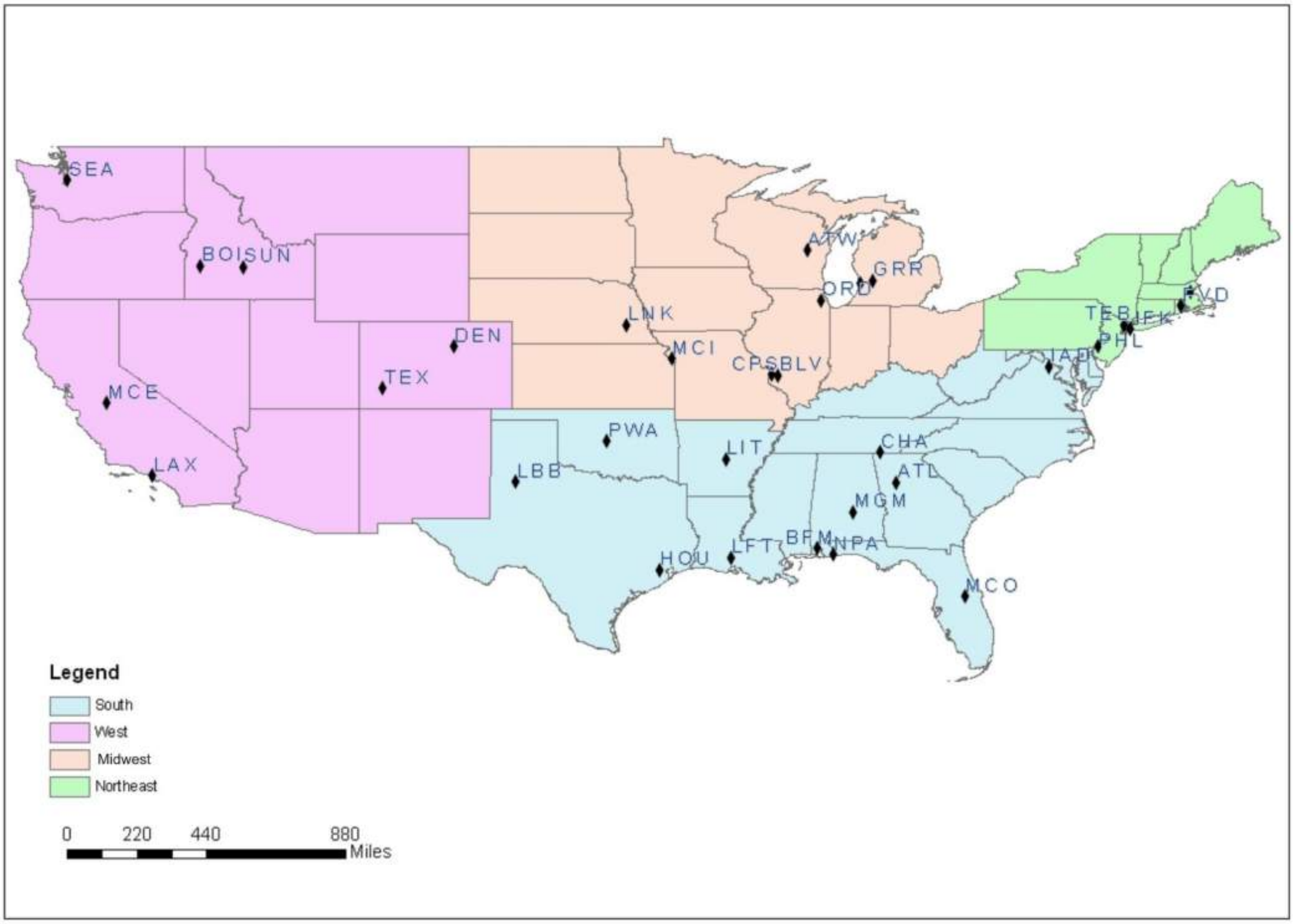

Figure 1
Location of 32 airports chosen for the analysis.

steady-state plume approach with significant improvements over previous commonly applied regulatory dispersion models [11,12]. The concentration distribution predicted by AERMOD has been compared with 16 field studies and one laboratory wind tunnel study. With few exceptions, AERMOD's performance is superior to that of the other applied models tested [12]. Breeze AERMOD 6 Graphical User Interface [13] was used to enter input parameters to AERMOD while the executable AERMOD version 07026 by US Environmental Protection Agency (EPA) [14,15] was used to calculate the incremental concentrations.

Several preprocessors are used to generate input data for AERMOD. AERMET is a meteorological data preprocessor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts. AERMAP is a terrain data preprocessor that incorporates complex terrain using US Geological Survey (USGS) Digital Elevation data. AERSURFACE is a tool that processes land cover data to determine the surface characteristics for use in AERMET.

Surface meteorology and upper air data were obtained from the National Oceanic and Atmospheric Administration (NOAA) [16] for the year 2006. The 1992 National Land Cover Dataset was obtained from USGS from the National Map Seamless Server and was used as input to AERSURFACE. 1 degree terrain elevation data as input to AERMAP were obtained from Trinity Consultants [17].

Emissions distribution approach

Vertical structure

As done previously [9], we modeled the vertical profile of aircraft emissions within seven vertical layers, with data provided by CSSI Inc. The midpoints of these seven layers are at 3, 58, 121, 232, 390, 591 and 837 m. Emissions from engine startup, Auxiliary Power Units (APUs) and aircraft taxi in and out are in layer 1. Aircraft takeoff with initial climb, the climbout and the approach mode are divided among layers 1 to 7. For total hydrocarbon (THC) and volatile organic carbon (VOC) emissions, layer 1 contributes the majority of emissions. For the 32 chosen airports, 87 to 97 percent of THC and VOC emissions are from layer 1 with an average of 94 percent. As a comparison, for carbon monoxide and particulate matter, an average of 74 and 50 percent respectively are from layer 1. Because the contribution by layer did not vary substantially across airports, for the air toxics under study in this analysis, we modeled the contribution of each layer following the average percentage contribution for THC and VOC. This corresponded to 93.7%, 0.3%, 0.5%, 1.1%, 1.1%, 1.6%, and 1.6% from the first layer to the seventh layer respectively.

We treat the emissions within each layer as an area source, with the first layer modeled as a polygon area source approximating the shape of the airport and the rest of the layers modeled as circular area sources. The radius of the top layer is assumed to be 20 km – the horizontal threshold in EDMS. We approximate the radius of the bottom layer as 5 km, although it is modeled as a polygon area source with variable configurations across airports, and the radii of the layers in between were calculated by projecting the bottom layer to the top layer and assuming a cone-like shape. In the end, the top two layers are combined into one due to limitations within AERMOD for modeling area sources above 700 m. Therefore, we have a total of six layers with the highest layer at 591 m with a radius of 15.6 km.

Temporal emission distribution

Modeling detailed hourly emissions for each individual airport was infeasible, so we used the approach from EDMS [18], which modeled the temporal emission profiles of three airports – Providence/T.F. Green International Airport in Warwick, RI (PVD), Hartsfield-Jackson Atlanta International Airport (ATL), and Chicago O'Hare International Airport (ORD) – and developed rules for mapping other airports to these three airports [19]. For example, if the airport has less than or equal to the number of commercial operations that PVD has, then it was mapped to PVD, with the same relative emissions patterns. If the airport has more crossing runways than parallel runways, it was mapped to ORD. Otherwise, it was mapped to ATL. For the airports in the study sample, there are 7 with ATL type, 5 with ORD type and 20 with PVD type emission profiles (See Figure S1 in Additional File 1).

Receptor selection

We modeled pollutant dispersion within 50 km of each airport of interest, using the discrete receptor setting in AERMOD. This radius would be expected to capture the MIR, as the MIR would likely occur near the airport, but would not go beyond the recommended modeling distance for AERMOD. Although not all total population exposure would occur within this radius, a significant enough portion would generally be found to evaluate our core hypotheses. Within 5 km of the airport, a higher receptor density is used with receptor locations being the centroids of census block groups. Between 5 and 50 km of the airport, the receptors are the centroids of census tracts. Population data are based on year 2000 US Census data [20]. For the airports in the study sample, the number of receptors within 50 km of the airport ranges from less than 20 (for SUN in Idaho and TEX in Colorado) to nearly 4,000 (for JFK in New York and TEB in New Jersey) with an average of about 700.

Pollutants modeled

We focus on three air toxics with different chemical characteristics – benzene, 1,3-butadiene, and benzo [a]pyrene (BaP). We use benzene to represent conservative air toxics (i.e. non-reactive), 1,3-butadiene to represent reactive air toxics, and BaP to represent particulate air toxics (as a particle-bound polycyclic aromatic hydrocarbon). For 1,3-butadiene, modeling complex chemical reactions is beyond the scope of AERMOD. Instead, we assumed a half life of 2 hours, its half life reported in sunlight [21], to determine whether this leads to qualitatively different conclusions than seen for conservative air toxics. Both dry and wet deposition of BaP are modeled. For dry deposition, a mass median diameter of 0.1 μm with a fine mass fraction of 0.93 is used, based on the recommended values for polycyclic organic compounds from Appendix B of the report on Deposition Parameterizations for the Industrial Source Complex (ISC3) Model [22].

Cancer potency factors

For the three selected pollutants, we relied on standard inhalation unit risks to estimate health risks. Benzene is a known human carcinogen which has been associated with leukemia and other neoplastic conditions. Within the EPA's Integrated Risk Information System (IRIS) database, the inhalation unit risk of benzene was reported as a range, with values between 2.2×10^{-6} and 7.8×10^{-6} for lifetime exposure to 1 μg/m^3 benzene in air [23]. Given the nature of our analysis, for which the core variability calculations and models are not dependent on the chosen cancer potency factor (as risks scale linearly with potency), we selected the average of this range of values (5×10^{-6}) for our potency estimate and do not formally address uncertainties within our primary analyses.

1,3-butadiene is also considered by the EPA to be a known human carcinogen, with an inhalation unit risk based on epidemiological evidence. The most recent value reported in IRIS is 3×10^{-5} for lifetime exposure to 1 μg/m^3 in air [23]. Finally, BaP does not have an inhalation unit risk in the IRIS database, so we relied on an assessment conducted by the California Office of Environmental Health Hazard Assessment (OEHHA). OEHHA considered BaP to be genotoxic, and developed an inhalation unit risk of 1.1 × 10^{-3} for lifetime exposure to 1 μg/m^3 in air based on a study of respiratory tract tumors in hamsters [24]. We recognize that BaP's risks may be influenced significantly by non-inhalation pathways, but focus herein on inhalation, given that BaP is being used as a representative of particle-bound compounds rather than because of specific interest in BaP.

Analytical framework

For each of the pollutants and airports, we estimate the DMIRET, the total population risk at that level of emissions, and the population intake fraction (defined below). To estimate the DMIRET, we first identify the receptor location (i.e. census block group) in the modeling domain with the highest incremental concentration from aircraft emissions. This concentration is then combined with the corresponding cancer potency factor to estimate the increase in maximum individual cancer risk. Since AERMOD does not include non-linear atmospheric chemistry, we can then back-calculate the emission rate corresponding to the maximum individual risk threshold of 10^{-6}, which is defined as the DMIRET.

We can then adjust the incremental concentration outputs at all receptors within 50 km of the airport to correspond with the DMIRET, and can directly estimate population cancer risk as the sum across receptors of population multiplied by incremental concentration, multiplied by the cancer potency factor. A component of this calculation is the total population exposure within 50 km of the airport per unit emissions, which we summarize using the metric of intake fraction (iF) – the fraction of a material released from a source that is inhaled or ingested [25]. We calculate iF by combining marginal concentration (C_i) and population count (P_i) at corresponding receptors within 50 km from the airport times a nominal breathing rate (BR) of 20 m^3 per day divided by emission rate (Q), which can be represented as $iF = (\Sigma C_i \times P_i) \times BR/Q$. As none of the three pollutants studied have meaningful in-situ formation, this will capture population exposure per unit emissions for these pollutants. Once iF has been calculated, population risks at the DMIRET can be easily obtained by combining the emission rate (i.e. the DMIRET), iF, cancer potency factor, and nominal breathing rate. In our regression analyses, we consider predictors of variability in iF as well as the DMIRET, so that both individual risk and population risk findings from this study can be extrapolated to other airports not included in this study sample.

Regression analysis independent variables

To help explain variability in the DMIRET and iF, we summarized several independent variables to represent local meteorology, population near the airport, and distance from the airport to the nearest receptor. Meteorological variables include mixing height and wind speed. Three different ways of incorporating mixing heights are tested – annual average mixing height, the annual average of the maximum daily mixing height, and the harmonic mean mixing height (which theoretically captures the inverse relationship between mixing height and concentrations). For the population variable in the iF regression, we use total population within 50 km of the airport. For the DMIRET regression, we consider two different ways of calculating the distance between the airport and the nearest receptor: the distance from the airport centroid to the nearest receptor, and the distance from the airport fenceline to the nearest receptor. We note that the nearest receptor may not be the receptor with the maximum individual risk, but this represents a variable available for an airport prior to conducting any dispersion modeling. Table S1 (see Additional file 2) summarizes the values of these independent variables.

Results and discussion

Summary statistics

Table 1 lists the emission thresholds (DMIRET) corresponding to 1 × 10^{-6} cancer risks for benzene, 1,3-butadiene and BaP at the maximally exposed receptor location across the 32 airports as well as the summary statistics such as the mean, standard deviation, minimum and maximum. Intake fractions are also listed in Table 1 for comparison. First considering the DMIRET, there is approximately 100-fold variation across airports for all three pollutants. The mean DMIRET is 10, 2 and 0.05 metric tons per year for benzene, 1,3-butadiene and BaP respectively, but values at individual airports differ from the mean by an order of magnitude in either direction. Of note, the maximum individual risk occurs at the same receptor for all three pollutants at all airports. This receptor is the receptor with the minimum distance to the airport in many cases, or one of the receptors with the closest distances in the rest of the cases.

The mean intake fractions for the three pollutants modeled are on the order of 10^{-5}, meaning that for every metric ton of aircraft pollutants emitted from airports, on average 10 g is inhaled by all residents within 50 km of the airport. Although the 50 km radius somewhat complicates comparisons with studies generally using larger radii, these values are on average slightly greater than previously reported for primary pollutants from power plants [26,27] and similar to those previously reported for mobile sources [28,29]. This would be anticipated given that 94% of VOC emissions from airplanes are at ground level, similar to mobile sources, while power plants usually have tall stack heights. For iF, the variation across airports is even larger than for DMIRET, with an approximate

Table 1: Intake fraction (iF) and de minimis individual risk emission threshold (DMIRET) values for the 32 airports, reported to two significant figures.

	iF			DMIRET		
Airport	Benzene	1,3-butadiene	BaP	Benzene (metric ton/year)	1,3-butadiene (metric ton/year)	BaP (kg/year)
ATL	8.2E-06	4.3E-06	7.8E-06	5.0	0.86	23
ATW	1.6E-06	9.3E-07	1.6E-06	39	7.7	180
BFM	7.1E-06	5.0E-06	6.8E-06	0.82	0.14	3.8
BIV	2.3E-06	1.6E-06	2.2E-06	6.3	1.1	29
BLV	2.0E-06	7.2E-07	1.8E-06	21	6.0	100
BOI	1.1E-05	7.0E-06	1.0E-05	2.7	0.46	12
BOS	1.4E-05	1.0E-05	1.4E-05	3.0	0.51	14
CHA	4.7E-06	3.6E-06	4.5E-06	1.6	0.27	7.3
CPS	1.1E-05	7.0E-06	1.0E-05	1.4	0.24	6.3
DEN	2.1E-06	8.4E-07	1.9E-06	14	2.6	66
GRR	2.5E-06	1.3E-06	2.4E-06	24	4.8	110
HOU	1.9E-05	1.1E-05	1.8E-05	1.9	0.32	8.6
IAD	9.9E-06	4.4E-06	9.1E-06	10	1.9	47
JFK	5.8E-05	3.3E-05	5.5E-05	4.0	0.71	19
LAX	3.4E-05	2.0E-05	3.2E-05	3.9	0.69	18
LBB	4.8E-07	3.0E-07	4.6E-07	17	2.9	76
LFT	5.6E-06	3.5E-06	5.3E-06	5.8	1.1	27
LIT	3.5E-06	2.6E-06	3.4E-06	2.8	0.47	13
LNK	3.2E-06	2.3E-06	3.0E-06	3.1	0.53	14
MCE	4.6E-06	3.6E-06	4.4E-06	2.3	0.40	11
MCI	2.4E-06	1.1E-06	2.2E-06	7.3	1.3	34
MCO	7.4E-06	2.8E-06	6.9E-06	9.6	1.8	45
MGM	3.6E-06	1.8E-06	3.3E-06	4.5	0.88	21
NPA	5.0E-06	3.0E-06	4.7E-06	1.8	0.31	8.2
ORD	2.6E-05	1.4E-05	2.4E-05	5.6	0.99	26
PHL	1.9E-05	1.1E-05	1.8E-05	3.4	0.58	16

Table 1: Intake fraction (iF) and de minimis individual risk emission threshold (DMIRET) values for the 32 airports, reported to two significant figures. *(Continued)*

PVD	1.2E-05	8.3E-06	1.2E-05	1.4	0.24	6.6
PWA	4.8E-06	3.5E-06	4.6E-06	3.0	0.51	14
SEA	1.2E-05	7.1E-06	1.2E-05	1.8	0.31	8.4
SUN	1.7E-07	1.3E-07	1.7E-07	14	2.5	65
TEB	2.9E-05	1.6E-05	2.7E-05	1.9	0.32	8.6
TEX	5.2E-08	2.7E-08	4.9E-08	110	30	520
Mean	1.0E-05	6.0E-06	9.6E-06	10	2.3	49
Min	5.2E-08	2.7E-08	4.9E-08	0.82	0.14	3.8
Max	5.8E-05	3.3E-05	5.5E-05	110	30	520
SD	1.2E-05	6.9E-06	1.2E-05	20	5.4	94

1000-fold difference between the minimum and the maximum. It should be noted that a high iF indicates that a unit change in emissions would have a greater influence on total population risk, given the greater total population exposure, while a low DMIRET indicates that a unit change in emissions would have a greater influence on maximum individual risk.

Among the three pollutants studied, benzene has the highest iF, as it is modeled as a conservative pollutant. BaP is generally similar to benzene, with somewhat lower values for 1,3-butadiene, indicating that the removal rate due to wet and dry deposition for BaP is somewhat less than due to chemical reactions for 1,3-butadiene. Considering the pollutant concentrations at the same emission rates, the average ratio of 1,3-butadiene to benzene across all the different receptor locations in the modeling domain is 0.43, versus 0.92 for the average ratio of BaP to benzene. As expected, the ratios for the receptors closer to the airport are close to 1 (ratios of 0.90 and 0.97 for 1,3-butadiene to benzene and BaP to benzene, respectively), while the same ratios for receptors about 50 km from the airport are 0.22 and 0.87, respectively. This emphasizes that pollutant characteristics will have a smaller effect on maximum individual risk than on population risk.

We can estimate the population cancer risk at the DMIRET for each airport, which addresses the question of whether having the identical maximum individual cancer risk across airports would lead to similar population risks. The population cancer risk at the DMIRET can be calculated as DMIRET × iF × potency factor/BR. The population cancer risk at the DMIRET varies by nearly two orders of magnitude across airports (factor of 99 difference between minimum and maximum population risk for benzene, factor of 71 difference for 1,3-butadiene, and factor of 93 difference for BaP). The airports with the highest population risk at the DMIRET are those that have a high iF, such as JFK, ORD, and LAX, and the population risk is not significantly correlated with the DMIRET itself (correlation coefficient of -0.09 for benzene, p = 0.62).

Another way of considering the difference in prioritization between a population risk and maximum individual risk approach is to consider the implications of a unit change in emissions on both endpoints. For example, at JFK, a one metric ton/year increase in benzene emissions would result in a population risk increase of 0.04 lifetime cancer cases (the highest value across all airports), as the product of an iF of 5.8×10^{-5} and the potency of 5×10^{-6} per μg/m^3, divided by the nominal breathing rate of 20 m^3/day with appropriate unit conversions. As a comparison, the one metric ton/year increase in benzene emissions would result in a maximum individual risk increase of 2.5×10^{-7}, given a DMIRET of 4 metric tons/year (corresponding to a maximum individual risk of 10^{-6}). This is near the median of the maximum individual risk increase across airports. Figure S2 (see Additional file 3) demonstrates the generally weak association between the population risk increase and maximum individual risk increase per unit increase in benzene emissions. This is driven by the relatively weak correlation between the iF and the DMIRET (the correlation coefficient between these two measures for benzene is -0.27, p = 0.13). This is not surprising as different factors influence total population exposure and maximum individual exposure, which we analyze more systematically in the regression analysis.

Regression analysis

In univariate regressions, the most significant predictor of DMIRET is distance to airport, with greater significance for distance from airport centroid to receptors. There is a non-linear relationship between DMIRET and distance, which is anticipated given standard Gaussian dispersion concepts, in which the relationship between pollutant concentration and downwind distance is reflected in the dispersion coefficient(s). We tried different transformations on the distance variable as well as on the DMIRET (dependent variable), of which the log transformation on the DMIRET turns out to work best. Figure S3 (see Additional file 4) shows how the log-transformed benzene DMIRET increases approximately linearly with distance. The plots for 1,3-butadiene and BaP are similar to that for benzene. In multivariate models (Table 2), both the distance variable and a log-transformed annual average mixing height variable are significant ($p < 0.05$). These regressions explain 74–75% of the variability in DMIRET across the three pollutants. The log transformation on mixing height improves the model fit, and there is no significant difference in model fit using the three different mixing height measures.

Turning to intake fractions, given the definition of iF, we construct no-intercept models considering total population and the product of population and mixing height (since intake fraction should be zero if there is no exposed population). As anticipated, total population is a highly significant predictor, and the product of population and average daily mixing height is also significant at the $p < 0.05$ level (Table 3). The final regression equations therefore reinforce that iF will increase linearly with population, but with a slope that is lower in areas with greater mixing heights and therefore lower concentrations per unit emissions. These regressions explain 93–95% of the variability in intake fraction across the three pollutants, although the R^2 should be interpreted with care for no-intercept models.

Figure S4 (See Additional file 5) shows how benzene intake fraction increases approximately linearly with population within 50 km from airports. For 1,3-butadiene and BaP, the plots are similar, but with slightly different slopes. The one outlier from this linear relationship is TEB (Teterboro, New Jersey). This can be explained by the fact that TEB is in a relatively less populated area but is within 50 km of New York City. Thus, it has a similar total population within 50 km as JFK (the other high-population point on Figure S4), but that population is disproportionately found at longer distances from the airport where incremental concentrations from TEB are lower. If we had constructed regressions including population within various radii, our predictive power would have increased further, but we retain the model shown in Table 3 to be parsimonious.

Uncertainty and sensitivity analyses

Although the DMIRET and iF values in Table 1 are presented without uncertainty bounds, numerous factors contribute uncertainty to these values. Meteorological factors, airport emissions characterization, and other atmospheric dispersion model inputs influence both values, and the DMIRET is also affected by the assumed cancer potency value. As the DMIRET will scale linearly with potency, uncertainty bounds could be readily calculated if the uncertainties in potency were fully characterized. This could allow a decision maker to determine, for example, the emission rate that would not exceed a 10^{-6} maximum individual cancer risk with 95% confidence. In addition, in situations where potency ranges are reported (as for benzene), it could be determined whether the emissions from an airport would exceed a 10^{-6} maximum individual cancer risk for any of the values within that range. As the range for benzene does not reflect a formal confidence interval and no such uncertainty characterization is available for the other air toxics, we do not formally incorporate uncertainty in potency, but recognize that the

Table 2: Parameter estimates for de minimis individual risk emission threshold regressions for different pollutants.

Dependent Variable	Independent Variables			
	Distance between nearest census block group centroid and airport centroid (km)	Log annual average mixing height (m)	**Intercept**	**R²**
Log benzene emission threshold (kg/year)	0.683 (<0.0001)	1.43 (0.019)	-1.65 (0.66)	0.74
Log 1,3-butadiene emission threshold (kg/year)	0.751 (<0.0001)	1.40 (0.028)	-3.23 (0.41)	0.75
Log BaP emission threshold (g/year)	0.687 (<0.0001)	1.42 (0.021)	-0.019 (0.995)	0.74

P-values are listed below regression coefficients.

Table 3: Parameter estimates for intake fraction regressions for different pollutants.

Dependent Variable	Independent Variables		R^2
	Population within 50 km of the airport	Product of Population and annual average mixing height (m)	
Benzene iF	8.18×10^{-12} (<0.0001)	-7.05×10^{-15} (<0.0001)	0.95
1,3-butadiene iF	4.78×10^{-12} (<0.0001)	-4.19×10^{-15} (<0.0001)	0.93
BaP iF	7.69×10^{-12} (<0.0001)	-6.59×10^{-15} (<0.0001)	0.95

P-values are listed below regression coefficients.

DMIRET values in Table 1 should be interpreted with caution given these uncertainties.

In addition, to illustrate some of the uncertainties associated with our atmospheric modeling, we conducted sensitivity analyses for concentration estimates from one airport (PVD) using meteorological input from a different year and characterizing airport emissions as a volume source rather than as an area source. Note that a volume source is essentially an area source with a third dimension of height. When meteorological data for 2007 are used, the maximum annual average concentration found in the modeling domain is 44 percent lower than the base case (meteorological data from 2006), possibly due to a combination of faster wind speed but lower mixing height that were observed in year 2007. This means that the MIR is 44 percent lower and the corresponding DMIRET will be 79 percent (1/0.56) higher. The population intake fraction is 46 percent lower than the base case, possibly mainly due to the lower mixing height that was observed in year 2007 and which translates to 46 percent lower population risk for the same emission rate. When a volume source is used instead of an area source, the results are most sensitive to settings in the first layer, where more than 90 percent of the emissions are from. For example, the size of the lateral dimension of the volume source in the first layer can change the maximum concentration in the domain by as much as 68 percent from the base case value. The corresponding intake fraction values are not as sensitive to the volume source parameter settings, which stayed within 10 percent of the base case value. While these quantitative results do not necessarily generalize to all airports, they emphasize that the DMIRET and population risk estimates should not be considered as absolute values, but would vary across years and include uncertainties beyond the potency uncertainties described above.

Limitations

Multiple limitations influence the interpretation of our findings. First, our analyses only characterized the emission rates from aircraft that would lead to 10^{-6} maximum individual risk for individual air toxics, omitting non-aircraft sources at the ground level and the cumulative effect of multiple exposures. However, previous studies [5] have shown that aircraft dominate the air toxics risks from airports, the vertical emissions profile indicates that model outputs for ground-level sources would be similar, and our methods are readily generalizable to a cumulative risk framework. The fact that the DMIRET was highly correlated between pollutants with differing chemical characteristics (correlation coefficient > 0.99 for all three pollutants we studied) indicates that model outputs for one pollutant could be readily extrapolated to other pollutants without complex chemical reactions or extensive in-situ formation. Similarly, given the linearity in the system, the emission threshold associated with other individual risk levels of interest could be quickly ascertained. Treating all aircraft emissions as area sources clearly omits some important spatial heterogeneity, especially given the runway configurations and correlation between flight patterns and wind direction, and modeling the time-varying emissions of individual aircraft at all airports was well beyond the scope of this study. Our methodology is clearly generalizable, but the magnitude and location of the MIR could differ if these complexities were taken into account.

In addition, as we were lacking comprehensive emission inventories for all airports, we could not directly interpret the DMIRET in relation to the actual or anticipated emission rates, which complicates interpretability. In other words, although the DMIRET is lowest for BaP given its potency, the emissions of BaP would be anticipated to be much lower than the emissions of benzene or 1,3-butadiene. Preliminary examination of estimated air toxics emissions for PVD, ORD, and ATL suggest that current emissions from these airports would exceed a 10^{-6} MIR for benzene and 1,3-butadiene but not BaP, but more comprehensive analyses (including formal examination of key sensitivities and uncertainties) would be needed to draw policy-relevant conclusions for these and other airports. If flight activity proved to be a reasonable proxy of emissions, this could provide another indicator that could be combined with estimates of DMIRET and iF to yield rapid yet reasonable interpretations. More generally, useful conclusions could potentially be drawn even for airports lacking comprehensive emissions inventories. For example, if a very small airport would need to have emissions greater than those from a very large airport to exceed a defined MIR threshold, it could be concluded that the MIR threshold would not likely be exceeded.

Conclusion

In spite of these limitations, our analyses corroborate our hypotheses and demonstrate the viability of our approach. Using state-of-the-art four-dimensional emissions characterization and atmospheric dispersion modeling, we demonstrated that both the emission rate contributing to a 10^{-6} maximum individual risk and the total population exposure within 50 km of the airport per unit emissions vary substantially across airports but can be predicted with reasonable precision using easy to obtain variables, such as distance from the airport, total population, and mixing height. These results provide a method to quickly but reasonably determine the likelihood of public health impacts of concern for airport modifications or expansions. In addition, there is low correlation between the emission rate contributing to a 10^{-6} maximum individual risk and the total population risk within 50 km of the airport at that emission rate, emphasizing that decisions based solely on one factor may not be optimal for the other factor. Our methods can be generalized to other source categories and can be expanded to include other pollutants with non-threshold dose-response curves in future assessments.

Abbreviations

ATL: Hartsfield-Jackson Atlanta International Airport; BaP: Benzo [a]pyrene; BR: Breathing rate; DMIRET: de minimis individual risk emission threshold; EDMS: Emissions and Dispersion Modeling System; EPA: Environmental Protection Agency; HAP: Hazardous air pollutants; iF: Intake Fraction; IRIS: Integrated Risk Information System; ISC: Industrial Source Complex model; JFK: John F. Kennedy International Airport in New York City; LAX: Los Angeles International Airport in Los Angeles; MACT: Maximum available control technology; MIR: Maximum individual risk; NOAA: National Oceanic and Atmospheric Administration; OEHHA: Office of Environmental Health Hazard Assessment; ORD: O'Hare International Airport in Chicago; PVD: Providence/T.F. Green International Airport in Warwick, RI; SUN: Friedman Memorial Airport in Hailey, Idaho; TEB: Teterboro Airport in Teterboro, New Jersey; TEX: Telluride Regional Airport in Telluride, Colorado; THC: Total hydrocarbon; USGS - US Geological Survey; VOC: Volatile organic carbon

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

YZ collected input data and carried out the atmospheric modeling, conducted the statistical analysis and drafted the manuscript. JIL conceived of the study, helped refine the analysis and revised the manuscript. All authors read and approved the final manuscript.

Additional material

Additional file 1

***Relative emission profiles by hour of day and day of week for three template airports**. The plots in this file show the relative emission profile by hour of day as well as day of week for ATL, ORD and PVD. Note that all emissions are relative to the maximum value by hour of day or day of week, which is assigned a value of 1.0.*
Click here for file
[http://www.biomedcentral.com/content/supplementary/1476-069X-8-22-S1.doc]

Additional file 2

***Distribution of independent variables and summary statistics at 32 airports**. The data in this table summarize the values of the independent variables at the 32 airports under study.*
Click here for file
[http://www.biomedcentral.com/content/supplementary/1476-069X-8-22-S2.doc]

Additional file 3

***Increase in maximum individual cancer risk and total population cancer risk within 50 km of the airport from benzene for a 1 metric ton/year increase in emissions at each airport**. This figure demonstrates the generally weak association between the population risk increase and maximum individual risk increase per unit increase in benzene emissions.*
Click here for file
[http://www.biomedcentral.com/content/supplementary/1476-069X-8-22-S3.doc]

Additional file 4

***Benzene de minimis individual risk emission threshold with a natural logarithm transformation vs. distance between the nearest census block centroid and the airport centroid**. This figure shows the log-transformed benzene DMIRET increases approximately linearly with distance.*
Click here for file
[http://www.biomedcentral.com/content/supplementary/1476-069X-8-22-S4.doc]

Additional file 5

***Benzene intake fractions vs. population within 50 km of airports**. This figure shows how benzene intake fraction increases approximately linearly with population within 50 km from airports.*
Click here for file
[http://www.biomedcentral.com/content/supplementary/1476-069X-8-22-S5.doc]

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JANIS A. BOBRIN

WATER RESOURCES COMMISSIONER
705 North Zeeb Road
P.O. Box 8645
Ann Arbor, MI 48107-8645

email: drains@ewashtenaw.org
http://drain.ewashtenaw.org

DENNIS M. WOJCIK, P.E.
Chief Deputy Water Resources Commissioner

DANIEL R. MYERS, P.E.
Director of Public Works

Telephone 734.222.6860
Fax 734.222.6803

April 19, 2010

Ms. Molly Lamrouex
Airports Division
MDOT Bureau of Aeronautics and Freight Services
2700 Port Lansing Road
Lansing, Michigan 48906

Re: Ann Arbor Municipal Airport, Environmental Assessment

Dear Ms. Lamrouex:

This office has completed a review of the subject document received by this office on April 07, 2010. This review only took under consideration the sections that were in regard to water resources.

As a result of this review the following comments are offered:

1. The Wood Outlet Drain, a designated county drain, extends approximately 1,000 linear feet further to the north than is shown in Figure 4.8.
2. It is indicated that build alternative 3 is the preferred alternative. This alternative extends the runway 950 linear feet to the west.
3. It is indicated that the preferred alternative does not impact the stream that is existing on the site. Using GIS measurements it appears that the stream is less than 1,000 linear feet from the existing runway. The runway extension would bring this infrastructure within 50 linear feet or less of the stream. In addition to this the grading limits shown in Appendix D-7 clearly extend into and beyond the location of the stream. Based on this information it is not understood how it has been concluded that there are no impacts to the stream.
4. It is indicated that the preferred alternative does not impact the floodplain for the stream that is existing on the site. It is indicated that proposed grading for the expansion would not occur within the designated floodplain boundary. Based on the floodplain boundary shown on FEMA Community-Panel Number: 260623 0010 C these statements are incorrect. Not only do the grading limits indicated for the preferred alternative extend into the floodplain boundary but the runway extension itself will extend into this floodplain

boundary. Based on this information it is not understood how it has been concluded that there are no impacts to the floodplain.

5. It is noted in the report that: "The amount of impervious surface on site would increase slightly due to the extension of the runway and taxiway from the existing 7 percent of the 837 acres to 7.4 percent." This slight increase noted equates to an additional 3.348 acres or 145,839 square feet. This increase in impervious surface is considered by this office to be significant and not slight particularly knowing that the additional runoff from this area will discharge to the Wood Outlet Drain.
6. It is noted in the report that: "Implementation of appropriate best management practices (BMPs) would continue to control the rate of stormwater runoff and maintain water quality standards." It is unknown by this office as to what the control rate of stormwater is currently being implemented or whether this rate meets county standards.   The additional volume created by this increase in imperviousness is not spoken to at all by the report. The type or locations of the appropriate BMPs indicated are not identified.

If you would like to discuss these issues please contact me.

Sincerely,

Dennis M. Wojcik, P.E.
Chief Deputy Water Resources Commissioner

CC: M. Kulhanek, City of Ann Arbor
N. Billetdeaux, JJR

the ann arbor chronicle
it's like being there

Commission OKs FY 2013 Parks Budget

Also: Windemere tennis court problems; drain project at Veterans

BY MARY MORGAN APRIL 27, 2012 at 8 am

Ann Arbor park advisory commission meeting (April 17, 2012): The action items at this month's PAC meeting focused on the upcoming fiscal year, with parks-related budget recommendations for July 1, 2012 through June 30, 2013. Sam Offen, who chairs PAC's budget and finance committee, observed that the FY 2013 budget is in better shape than in recent years.

At left is city councilmember Christopher Taylor (Ward 3), who also serves as an ex officio member of the Ann Arbor park advisory commission. To the right is Sam Offen, chair of PAC's budget and finance committee. (Photos by the writer.)

This is the second year of a two-year budget cycle, and commissioners had recommended approval of budgets for both years at their April 2011 meeting. The recent recommendations for FY 2013 include: (1) increasing the frequency of the mowing cycle from every 19 days to every 14 days; (2) increasing seasonal staffing between April 15–October 15 to maintain active recreation areas better; (3) establishing three seasonal park steward/supervisor positions to improve park maintenance and enforcement; and (4) increasing seasonal staffing at the ice arenas to improve facility cleanliness.

Fee increases at several parks and rec facilities are also part of the budget recommendations, but most have already been implemented in the current fiscal year.

The April 17 meeting included a public hearing on the renewal of the city's park maintenance and capital improvements millage, which will likely be on the November 2012 ballot. No one spoke at the hearing. In general, "there seems to be a great deal of relative silence" about the millage, parks and rec manager Colin Smith told commissioners. Few people have attended the recent public forums held by parks staff. The final forum is set for Thursday, April 26 from 6:30-7:30 p.m. at the Ann Arbor District Library's Traverwood branch, 3333 Traverwood Drive.

Parks staff gave an update on deteriorating conditions at Windemere Park's two tennis courts, and provided an initial estimate on costs to replace one or both courts at that location. No formal recommendation has been made, but options include moving the courts to another park. Commissioners discussed the need to assess the distribution and conditions of all of the city's public courts – including ones in the public school system – as well as their overall usage, to get a better idea of where the greatest needs are.

Another update came from an engineer at the Washtenaw County water resources commissioner's office, who described a drain replacement project that will affect Veterans Memorial Park later this year. Also related to Veterans Memorial, the request for proposals (RFP) for a skatepark there has been issued. [.pdf of skatepark RFP] The goal is to solicit proposals for a consultant to handle design and oversee construction of the skatepark, which will be located on city-owned property.

During public commentary, commissioners were given an update on the nonprofit Project Grow, which has several gardens located in city parks and is celebrating its 40th anniversary this year. Another speaker urged commissioners to take control of the parking lots in city parks, and possibly increase revenues by installing metered parking.

Parks & Rec Budget Recommendation

Park commissioners considered two resolutions related to the city's fiscal year 2013 budget, for the year beginning July 1, 2012 through June 30, 2013. It's the second year of a two-year budget planning cycle. PAC had previously recommended approval of budgets for both years at its April 2011 meeting. The parks budget is part of the city's overall budget, which city administrator Steve Powers proposed at the April 16 meeting of the Ann Arbor city council.

Most of these changes have already been implemented, as part of the current year's budget. Colin Smith, the city's parks and rec manager, reminded commissioners that there will be no increase in budgeted expenses. These changes will be made within the budget plan that was discussed last year for FY 2013, when the FY 2012 budget was formally adopted. [.pdf of budget resolution adopted by council for FY 2012, including parks-related items]

The portion of the city budget relating to parks is separated into two parts: (1) park operations; and (2) parks and recreation.

Sam Offen, who chairs PAC's budget and finance committee, noted that the budget is in better shape than in recent years. He joked that it makes his job much easier.

Parks & Rec Budget Recommendation: Parks Operations Budget

PAC was asked to approve recommendations for the FY 2013 parks operations budget, which includes the following proposed changes: (1) increasing the frequency of the mowing cycle from every 19 days to every 14 days; (2) increasing seasonal staffing between April 15–October 15 to maintain active recreation areas better; (3) establishing three seasonal park steward/supervisor positions to improve park maintenance and enforcement; and (4) increasing seasonal staffing at the ice arenas to improve facility cleanliness. [.pdf of parks operations budget recommendation]

There was considerable discussion about whether to change the wording on the recommendation for the mowing cycle. Tim Doyle initially felt it sounded too much like a dictate rather than an objective, and preferred deferring to staff's judgement on the exact number of days in the cycle. After some wordsmithing on a possible amendment, Christopher Taylor – PAC's ex officio member who also serves on city council – was asked whether his council colleagues would understand the intent. "Contextually, it's plain enough," he said.

Ultimately, PAC reached a consensus not to change wording on the recommendation.

Outcome: Commissioners voted unanimously to recommend approval of the FY 2013 parks operations budget.

Parks & Rec Budget Recommendation: Parks & Rec Budget

In a separate resolution, PAC was asked to recommend approval of the FY 2013 parks and recreation budget. The resolution commended parks staff for its work, and made several general recommendations: (1) reduce energy expenses to reflect the benefit of infrastructure energy improvements at recreational facilities, including Cobblestone Farm and Mack Pool; (2) reduce materials and supplies used to maintain various facilities as a result of recent improvements; (3) reduce water usage expense to reflect actual usage better; (4) eliminate unnecessary software installations where appropriate; (5) increase revenue by initiating additional programming at the Argo Cascades; and (6) increase revenue by increasing fees for admission to swimming pools. [.pdf of parks & rec budget recommendation] [.pdf of fee increases]

Most of these items have been started in the current fiscal year, Offen noted, and will continue into FY 2013.

Outcome: Commissioners unanimously recommended approval of the FY 2013 parks and recreation budget.

Parks Millage Renewal: Public Hearing

No one spoke during a public hearing on the renewal of the city's park maintenance and capital improvements millage, which will likely be on the November ballot.

Park commissioners had been briefed by staff about the millage renewal at PAC's March 20, 2012 meeting.

John Lawter, PAC's vice chair who was presiding over the meeting in the absence of chair Julie Grand, noted that two of the four public informational forums regarding the millage had been held.

[The third forum took place on Monday, April 23. The final one is set for Thursday, April 26 from 6:30-7:30 p.m. at the Ann Arbor District Library's Traverwood branch, 3333 Traverwood Drive.]

From left: Greg McDonald, assistant manager of city operations for Community Television Network (CTN), explains a camera problem to Colin Smith, the city's parks and recreation manager. The controller that allows CTN staff technicians to remotely control cameras in city council chambers wasn't working during the April 17 park advisory commission meeting. CTN staff instead adjusted the cameras manually prior to the meeting, to capture wide angle views of the proceedings.

Colin Smith, parks and rec manager, noted that Grand had wanted to schedule some of the public forums prior to the public hearing at PAC, and prior to a vote by PAC on whether to recommend millage renewal. That way, PAC could respond if any issues arose. However, Smith added, "there seems to be a great deal of relative silence," and nothing has come up to indicate that the city is on the wrong track in seeking renewal. [At an April 11 forum held at Cobblestone Farm, several city parks staff, PAC commissioners, city councilmember Jane Lumm, and two members of the media – from The Chronicle and WEMU – showed up. But only one member of the public came: Eric Meves, a board member at Project Grow who also spoke during public commentary at the April 17 PAC meeting (see below).]

Gwen Nystuen observed that it's hard to get people excited now about a vote that won't happen until November. She said she hadn't heard anything unfavorable about the millage, and that people in Ann Arbor are very supportive of parks. "I'm optimistic," she said.

Sam Offen asked whether there were any significant comments or feedback from the first two forums. Lawter reported that the one person at the forum he attended was supportive. [That person was Meves.] Nystuen praised the staff – she said they had done a good job of answering questions at the first forum about how the budget was prepared.

Informational handouts are being distributed, and Smith pointed out that information about the millage renewal is also available on the city's website.

Windemere Park Tennis Courts

Parks planner Amy Kuras gave a presentation on the tennis courts at Windemere Park, a nearly four-acre parcel on the city's northeast side, north of Glazier Way between Green and Earhart roads. There was no action requested of PAC at this meeting – the staff just wanted to update commissioners on the situation.

The courts were initially built in 1986, then color coated in 2007. Repairs to cracks in the court were attempted in 2009, Kuras said, but failed because of poor soil conditions. The city also attempted to install new net posts in 2009, but that also failed.

In 2010, the city took soil borings in five parts of the park. The borings revealed saturated organic soil and fill, particularly in areas located near the tennis courts in the west part of the park.

Part of the problem is a high water table, Kuras said. In fact, the parks staff have noted higher water tables throughout the city, she added. The only hard data that the city has collected on the water table is at the municipal airport, and there the water table measures between 2-7 feet below the surface now, compared to 15 feet below the surface 50 years ago. Jen Lawson, the city's water quality manager, attributed the change to a variety of factors, Kuras reported, including climate change and more impervious surfaces in the city.

Kuras presented a chart showing cost estimates to replace either one or both courts at the current location. She based her estimates on work done for tennis courts at Veterans Memorial Park and West Park. The total would be $181,377 for two courts at Windemere, or $107,408 for one court. [Link to chart of itemized replacement costs.]

The options to consider, Kuras said, include: (1) replacing both tennis courts at the current location, (2) replacing the courts in another part of Windemere Park, (3) replacing only one court, (4) removing

the courts, or (5) possibly putting the courts in another park.

Matt Warba, the city's acting field operations manager, told commissioners that he's frustrated by the situation. The staff has attempted several repairs, but with water at just two feet below the surface, it's difficult. There's a likelihood that having tennis courts at that location isn't reasonable, he said. But he understands the value to the neighborhood, and the staff is still working on getting some firm numbers and options to consider. There's no easy or quick solution, he said, but they're working on it.

Cracked pavement at the Windemere Park tennis court. (Image provided by city staff in a slide presentation to PAC.)

Windemere Park Tennis Courts: Public Commentary

Jeff Alson told commissioners that he has lived near the park since the late 1970s. He bought his home there in part because of the park. There are a lot of tennis players in the neighborhood, and there are a lot of young children in the area so demand could grow. But because of water issues there's only one court that can be used. Last summer, he hardly played there at all. Alson said he understood that there are problems with water that make maintenance of the courts more expensive. But he emphasized that the courts have held up well for at least the last 10 years, and he would consider it a good investment. It would be disappointing to him if the courts were removed. Alson concluded by thanking commissioners for their service to the city.

Windemere Park Tennis Courts: Commission Discussion

David Barrett asked whether the water table is the same throughout the park. Yes, Kuras said, but the soil composition is different at certain locations in the park – that's a factor, too. She clarified that there are water table issues at other parks, but nothing to the degree they're seeing at Windemere.

Barrett recalled that when the city decided to put in rain gardens at Burns Park, they were slow to let the community know about it. He wondered what kind of outreach was happening for the tennis courts at Windemere. Colin Smith, parks and recreation manager, indicated that outreach would occur when the staff had more information to share. If it makes sense to move the tennis courts, the neighborhood would need to be engaged, he said.

Tim Doyle asked is there's evidence of this same kind of problem at other city tennis courts. He said he's encountered it on a similar project he's working on near Honey Creek, on the west side of town. Warba said that certainly there are areas in the parks that are wetter than they've been in the past. But the Windemere courts are the worst by far.

Sam Offen noted that there are a lot of city tennis courts on the west side of town, but he wondered how many there were on the northeast side. Kuras reported that there are three courts in Leslie Park and two in Sugarbush Park, and it might be possible to accommodate new tennis courts somewhere in Foxfire North Park. All of those parks are in northeast Ann Arbor.

Jeff Alston, a resident who'd spoken during public commentary, pointed out that the courts at Sugarbush are too short for adults to play – they hit the back fence with their rackets, he said.

Gwen Nystuen said she didn't know too much about tennis courts, but that it seemed like the city should assess the distribution and conditions of all of its courts, as well as their overall usage, to get a better idea of where the greatest needs are.

Commissioners and staff also discussed the availability of tennis courts at Ann Arbor public schools, noting that certain times of day and certain days of the week those courts are heavily used by students. Tim Berla noted that Ann Arbor Rec & Ed runs tennis leagues, as does the Ann Arbor Area Community Tennis Association. He pointed out that court conditions aren't just a concern for the city parks – a sinkhole developed at the relatively new tennis courts at Skyline High School, putting one of

the courts out of commission. Berla suggested looking at other materials, such as clay, which he said required more maintenance but wouldn't crack.

Assuming there's need for more tennis courts on the northeast side of town, Berla wondered whether the former Pfizer property – now owned by the University of Michigan – could be a possible location for new courts. He noted that there's a lot of unused land there, as well as available parking.

Drain Project at Veterans Memorial Park

Scott Miller, an engineer with the Washtenaw County water resources commissioner's office, was on hand to give a presentation about a drain project that would affect Veterans Memorial Park. He said the county had been petitioned by the city to do this project. It's referred to as the West Park Fairgrounds project, which is the name of the drain that runs through that section of town – on the west side of town, in the former fairgrounds area. Miller acknowledged that it was a bit confusing, given that a park in a different location is called West Park.

Scott Miller of the Washtenaw County water resources commissioner's office describes an upcoming drain project that will affect Veterans Memorial Park.

The upper end of the drain is located in the Maple Village Shopping Center, where Kmart and Plum Market are located. The drain starts out as a 30-inch pipe and quickly transitions to a 54-inch pipe and then a 66-inch corregated metal pipe as it runs toward town. The pipe runs through Veterans Memorial Park, crosses under Dexter Road and heads east, eventually connecting to a pipe that contains another branch of the Allen Creek.

The city conducted video inspection of the pipe and found several sections that are cracked and corroded, resulting in leaks. Portions of the pipe were clogged with debris. [The city council voted at its Sept. 20, 2010 meeting to petition the county water resources commissioner for this project, estimated to cost roughly $2 million. It will be repaid by the city in annual installments over 15 years.]

Miller said the county staff began work last fall, first clearing the debris and then conducting another video assessment. That revealed two sections of the pipe that have a significant sag, and result in water being held in those sections year-round. One sagging section is in the parking area in the shopping center. Another is in the north side of the park's parking lot that's accessed off of Dexter Road. The preliminary design is to dig up the two sections of sagging pipe and replace them. For the rest of the pipe, the plan calls for putting in a cast lining to reinforce the pipe structurally.

The project would cause minimal disruption, he said, but would include some impact to the parking lot and a small portion of the area west of one of the ballfields. The county is coordinating with the city, which is doing road work and water main replacement along Dexter Road, as well as upcoming work to renovate the ballfields in the park.

The project is in the design phase now, Miller said, with construction expected to begin in the fall.

Drain Project at Veterans Memorial Park: Commission Discussion

Gwen Nystuen asked for more details about how much land would be dug up for the project. Miller reported that in the Maple Village lot, a section about 15 feet wide and 150 feet long would be excavated. In Veterans Memorial Park, the work would be about 15 feet wide and 190 feet long.

Nystuen also commented on the confusing name of the project, and Miller agreed: "It's raised confusion at a lot of levels," he said, but they don't have much latitude to change it.

David Barrett pointed out that there's already disruption to the park – a big pile of dirt has been dumped by the ballfield. He wondered if the county had also coordinated with Ann Arbor Rec & Ed, which runs softball leagues in the park. Miller said the drain work hasn't yet started, so the excavated dirt isn't from their project. Matt Warba, the city's acting field operations manager, clarified that it was likely related to road construction there. Parks and rec manager Colin Smith said the parks staff has been coordinating with Rec & Ed since last year regarding work in the park.

Sam Offen asked about the project's timeframe. It will likely take about two months, Miller replied, but more if there's a lot of rain. In response to another query from Offen, Miller said the county is mindful of the potential flooding impact downstream, but noted that this project isn't intended to increase capacity dramatically. There will be more efficient flow, however.


Ann Arbor park advisory commissioner David Barrett.

Tim Berla clarified that Rec & Ed has cancelled its fall season, which starts in August, because of renovation work on the ballfields at three parks, including Veterans. [PAC had recommended those renovations at their February 2012 meeting.] He asked whether it would be possible to do the park portion of the drain project first, to ensure it would be finished by the spring season. Miller said it probably wouldn't matter – the entire project is expected to be done by the spring of 2013 – but he would look into it.

Berla also asked whether the proposed skatepark – to be located in another part of Veterans Memorial Park – would affect the drain project, in terms of adding runoff. Miller said that although the addition of any impervious surfaces would affect runoff, the pipe is underutilized and has the capacity to handle it.

Smith noted that one of the elements of the skatepark design, as reflected in the request for proposals, will be to include stormwater management that meets or exceeds city standards.

Communications & Commentary

Every meeting includes opportunities for public commentary and communications from commissioners and staff.

Comm/Comm: Public Commentary – Parking in Parks

During public commentary, **George Gaston** told commissioners that he recently visited the University of Michigan's Matthaei Botanical Gardens – it's a lovely place, he said. He had noticed that UM now has metered parking there at $1.20 per hour, between 8 a.m. and 8 p.m. Gaston noted that the city leases its Fuller Park parking lot to UM. It was supposed to be a temporary arrangement, but it's been going on for about 20 years. He wondered if the city has considered taking back control of that lot and and making it a metered lot, too. UM hospital employees use it 24/7, Gaston said, but only pay for part of that time. It could be a great revenue source for the city.

Gaston noted that people park their vehicles all day at Island Park and West Park, as two examples. And with UM planning to build a parking structure on Wall Street that would add another 500 spaces to that area, it might be possible to forego leasing the 18 spaces at Riverside Park to UM and adding metered spaces instead. "You might gain real money out of this," Gaston said. There's precedent in the city for 24-hour metered lots – at the Amtrak station on Depot Street, for example. Right now, it seems the city is undercharging the university for parking. With meters, the lots would be available to anyone if they paid. It might make sense to look into this, he concluded.

Comm/Comm: Project Grow – Public Commentary

Eric Meves, a board member of Project Grow, gave commissioners an overview of the nonprofit. He started by referring to Gaston's comments about parking, noting that Project Grow had to buy parking tags at Matthaei for its gardeners there this year. Meves told commissioners that Project Grow is celebrating its 40th anniversary this year, and he's gardened with the group for 39 of those years.

Several Project Grow gardens are in city parks, so he wanted PAC to become familiar with the organization. It's an educational organization, with assistance for low-income residents. Although the nonprofit has received city funding in the past, it no longer receives public money, he noted.

Project Grow doesn't own any land. About a third of the gardens are located in Washtenaw County parks, and a third on Ann Arbor public school property. The remaining third is evenly divided between

UM land, private property, and city of Ann Arbor parks. About 300-350 families have garden plots each year, Meves said. People do it to grow food, but also for outdoor exercise and to be in a pleasant environment, he said. There's also an element of community – being with your fellow gardeners.

Eric Meves, treasurer of the Project Grow board.

The nonprofit grosses about $40,000 to $50,000 annually, Meves said. About 60% of that comes from plot fees – it costs about $130 for a full plot. About 20% of revenues come from fundraising, primarily through an annual plant sale. The remaining 20% comes from an organic gardening class that Project Grow developed for Washtenaw Community College.

Roughly half of those revenues allow Project Grow to have one half-time employee who works out of his house, Meves said. The group relies on volunteers and a working board. The rest of the funds are used to pay for things like water, utilities, insurance and capital improvements. There are about 40 people on a waiting list for gardens now – demand for gardens is about two to three times what Project Grow can provide, he said.

Meves unfurled a map that he said was made with the help of Merle Johnson and Dan Rainey of the city's information technology department. It showed possible additional locations for gardens within the parks system.

Comm/Comm: Project Grow – Manager's Report

Later in the meeting, Colin Smith reported that parks planner Amy Kuras has been working with the Project Grow managing director [Kirk Jones] to draft an agreement that will outline the formal relationship between the city and the nonprofit. It's been a few years since the city funded Project Grow, he said, but because the group uses city parkland, there's still a relationship. The agreement will stipulate what the procedures are for putting gardens into parks. There have been varied reactions to having gardens in the parks, depending on the neighborhood, he noted. Parks staff will share the agreement with PAC when it's ready, he said.

Tim Berla asked if there's anything PAC or the city can do to help Project Grow identify potential locations for more gardens. Kuras said she works with the organization – sometimes she'll be contacted by someone in a neighborhood who's interested, and she'll in turn contact Project Grow, or sometimes Project Grow comes to her. There are certain requirements, she noted. The land needs to be in a sunny area, and have access to a water source. The city also needs to hold a public meeting if a park is being considered for gardens, and sometimes neighbors don't want it, she said.

From left: Park advisory commissioners Tim Berla and John Lawter. Lawter, who chaired the April 17 meeting in the absence of chair Julie Grand, was reviewing procedural rules with Berla before the meeting. Berla's advice: "No one ever did time" for flubbing Robert's Rules.

Smith noted that the agreement with Project Grow will include details about how PAC can be involved in the process of selecting new locations.

Gwen Nystuen said she appreciated that Eric Meves had spoken to PAC during public commentary. She hadn't realized how many people are involved, and how the city provides relatively little land for

the group. It's useful information, she said, especially given the growing interest in the local food movement.

Tim Doyle clarified with Smith that there is no relationship between Project Grow and the city's greenbelt program.

Comm/Comm: Skatepark RFP

Smith reported that the request for proposals (RFP) for a skatepark at Veterans Memorial Park would be issued the following day. [.pdf of skatepark RFP] The goal is to solicit proposals for a consultant to handle design and oversee construction of the skatepark, which will be located on city-owned property.

Tim Doyle asked how the project would be funded. Smith replied that there are three sources for the roughly $1 million cost of the project: (1) private donations – primarily solicited through the Friends of the Ann Arbor Skatepark; (2) a $300,000 state grant; and (3) up to $400,000 in matching funds from the Washtenaw County parks and recreation commission. The Ann Arbor Area Community Foundation is acting as fiduciary for the project.

The city's contribution will be the land and staff time to manage the process, Smith said, not money. It will be a city-owned asset, he said.

In terms of process, a selection committee – which will include members of the Friends of the Ann Arbor Skatepark, as well as city and county representatives – will be relied on to make a recommendation for the designer. That recommendation will be reviewed by PAC. PAC commissioner David Barrett will serve on the committee. Park planner Amy Kuras is the city's point person on the project.

Construction is expected to start in the spring of 2013.

Gwen Nystuen asked about the relocation of pathways that will be required because of the skatepark location. Kuras noted that some pathways in Veterans Memorial Park are being redone as part of the Dexter Avenue improvement project that's currently underway. Paths that connect to the skatepark will be designed as part of the overall skatepark design, she said.

Comm/Comm: Manager's Report – Market Manager

Smith reported that the field had been narrowed to two candidates to replace Molly Notarianni, who left the job of public market manager earlier this year. He said he hoped to have finalized a hire by PAC's May 15 meeting.

Comm/Comm: Manager's Report – Argo Cascades

The same day as the PAC meeting, the consultant who designed the new canoe/kayak bypass by Argo Dam – Gary Lacy of Boulder, Colo. – was testing the series of drop pools along with city staff. Smith said he had hoped that Lacy would have the time to give an update to PAC about the new Argo Cascades, but the morning had been chilly and Lacy had gotten a late start on the testing, so he wasn't able to attend the meeting.

A grand opening of the Argo Cascades is planned for June, but it will be open to the public before that. May 5 is the date for the first trips from the Argo Pond livery to Gallup Park, Smith said.

Present: David Barrett, Tim Berla, Doug Chapman, Tim Doyle, John Lawter, Karen Levin, Gwen Nystuen, Sam Offen, councilmember Christopher Taylor (ex-officio). Also Colin Smith, city parks and recreation manager.

Absent: Julie Grand, councilmember Mike Anglin (ex-officio).

Next meeting: PAC's meeting on Tuesday, May 15, 2012 begins at 4 p.m. in the city hall second-floor council chambers, 301 E. Huron St., Ann Arbor. [confirm date]

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Section: Center Column, Govt., Meeting Watch

The following terms describe the content of this article. Click on a term to see all articles described with that term: **Ann Arbor Parks & Recreation**, **drains**, **park maintenance and capital improvements millage**, **parks budget**, **Project Grow**, **skatepark**, **tennis courts**

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One Comment

1. BY TRACEY WENTZ & BLACKMER
MAY 1, 2012 at 11:54 am | PERMALINK

We encourage action, soon. This problem has existed for a long time without solution. Just listen to the nearby neighborhoods say the demand is there and fix a community resource. Seems like a sunk cost without adequate maintenance.

Consider a local bond issue or ~ and do something.

FAA
Airports

Grant Assurances
Airport Sponsors

A. General.

1. These assurances shall be complied with in the performance of grant agreements for airport development, airport planning, and noise compatibility program grants for airport sponsors.

2. These assurances are required to be submitted as part of the project application by sponsors requesting funds under the provisions of Title 49, U.S.C., subtitle VII, as amended. As used herein, the term "public agency sponsor" means a public agency with control of a public-use airport; the term "private sponsor" means a private owner of a public-use airport; and the term "sponsor" includes both public agency sponsors and private sponsors.

3. Upon acceptance of this grant offer by the sponsor, these assurances are incorporated in and become part of this grant agreement.

B. Duration and Applicability.

1. **Airport development or Noise Compatibility Program Projects Undertaken by a Public Agency Sponsor**. The terms, conditions and assurances of this grant agreement shall remain in full force and effect throughout the useful life of the facilities developed or equipment acquired for an airport development or noise compatibility program project, or throughout the useful life of the project items installed within a facility under a noise compatibility program project, but in any event not to exceed twenty (20) years from the date of acceptance of a grant offer of Federal funds for the project. However, there shall be no limit on the duration of the assurances regarding Exclusive Rights and Airport Revenue so long as the airport is used as an airport. There shall be no limit on the duration of the terms, conditions, and assurances with respect to real property acquired with federal funds. Furthermore, the duration of the Civil Rights assurance shall be specified in the assurances.

2. **Airport Development or Noise Compatibility Projects Undertaken by a Private Sponsor**. The preceding paragraph 1 also applies to a private sponsor except that the useful life of project items installed within a facility or the useful life of the facilities developed or equipment acquired under an airport development or noise compatibility program project shall be no less than ten (10) years from the date of acceptance of Federal aid for the project.

3. **Airport Planning Undertaken by a Sponsor.** Unless otherwise specified in this grant agreement, only Assurances 1, 2, 3, 5, 6, 13, 18, 30, 32, 33, and 34 in section C apply to planning projects. The terms, conditions, and assurances of this grant agreement shall remain in full force and effect during the life of the project.

C. **Sponsor Certification.** The sponsor hereby assures and certifies, with respect to this grant that:

1. **General Federal Requirements.** It will comply with all applicable Federal laws, regulations, executive orders, policies, guidelines, and requirements as they relate to the application, acceptance and use of Federal funds for this project including but not limited to the following:

Federal Legislation

a. Title 49, U.S.C., subtitle VII, as amended.
b. Davis-Bacon Act - 40 U.S.C. 276(a), et seq.[1]
c. Federal Fair Labor Standards Act - 29 U.S.C. 201, et seq.
d. Hatch Act – 5 U.S.C. 1501, et seq.[2]
e. Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 Title 42 U.S.C. 4601, et seq.[1 2]
f. National Historic Preservation Act of 1966 - Section 106 - 16 U.S.C. 470(f).[1]
g. Archeological and Historic Preservation Act of 1974 - 16 U.S.C. 469 through 469c.[1]
h. Native Americans Grave Repatriation Act - 25 U.S.C. Section 3001, et seq.
i. Clean Air Act, P.L. 90-148, as amended.
j. Coastal Zone Management Act, P.L. 93-205, as amended.
k. Flood Disaster Protection Act of 1973 - Section 102(a) - 42 U.S.C. 4012a.[1]
l. Title 49, U.S.C., Section 303, (formerly known as Section 4(f))
m. Rehabilitation Act of 1973 - 29 U.S.C. 794.
n. Civil Rights Act of 1964 - Title VI - 42 U.S.C. 2000d through d-4.
o. Age Discrimination Act of 1975 - 42 U.S.C. 6101, et seq.
p. American Indian Religious Freedom Act, P.L. 95-341, as amended.
q. Architectural Barriers Act of 1968 -42 U.S.C. 4151, et seq.[1]
r. Power plant and Industrial Fuel Use Act of 1978 - Section 403- 2 U.S.C. 8373.[1]
s. Contract Work Hours and Safety Standards Act - 40 U.S.C. 327, et seq.[1]
t. Copeland Anti kickback Act - 18 U.S.C. 874.1
u. National Environmental Policy Act of 1969 - 42 U.S.C. 4321, et seq.[1]
v. Wild and Scenic Rivers Act, P.L. 90-542, as amended.
w. Single Audit Act of 1984 - 31 U.S.C. 7501, et seq.[2]
x. Drug-Free Workplace Act of 1988 - 41 U.S.C. 702 through 706.

Executive Orders

Executive Order 11246 - Equal Employment Opportunity[1]
Executive Order 11990 - Protection of Wetlands
Executive Order 11998 – Flood Plain Management
Executive Order 12372 - Intergovernmental Review of Federal Programs
Executive Order 12699 - Seismic Safety of Federal and Federally Assisted New Building Construction[1]
Executive Order 12898 - Environmental Justice

Federal Regulations

a. 14 CFR Part 13 - Investigative and Enforcement Procedures.
b. 14 CFR Part 16 - Rules of Practice For Federally Assisted Airport Enforcement Proceedings.
c. 14 CFR Part 150 - Airport noise compatibility planning.
d. 29 CFR Part 1 - Procedures for predetermination of wage rates.[1]
e. 29 CFR Part 3 - Contractors and subcontractors on public building or public work financed in whole or part by loans or grants from the United States.[1]
f. 29 CFR Part 5 - Labor standards provisions applicable to contracts covering federally financed and assisted construction (also labor standards provisions applicable to non-construction contracts subject to the Contract Work Hours and Safety Standards Act).[1]
g. 41 CFR Part 60 - Office of Federal Contract Compliance Programs, Equal Employment Opportunity, Department of Labor (Federal and federally assisted contracting requirements).[1]
h. 49 CFR Part 18 - Uniform administrative requirements for grants and cooperative agreements to state and local governments.[3]
i. 49 CFR Part 20 - New restrictions on lobbying.
j. 49 CFR Part 21 - Nondiscrimination in federally-assisted programs of the Department of Transportation - effectuation of Title VI of the Civil Rights Act of 1964.
k. 49 CFR Part 23 - Participation by Disadvantage Business Enterprise in Airport Concessions.
l. 49 CFR Part 24 - Uniform relocation assistance and real property acquisition for Federal and federally assisted programs.[1 2]
m. 49 CFR Part 26 – Participation By Disadvantaged Business Enterprises in Department of Transportation Programs.
n. 49 CFR Part 27 - Nondiscrimination on the basis of handicap in programs and activities receiving or benefiting from Federal financial assistance.[1]
o. 49 CFR Part 29 – Government wide debarment and suspension (nonprocurement) and government wide requirements for drug-free workplace (grants).
p. 49 CFR Part 30 - Denial of public works contracts to suppliers of goods and services of countries that deny procurement market access to U.S. contractors.

q. 49 CFR Part 41 - Seismic safety of Federal and federally assisted or regulated new building construction.[1]

Office of Management and Budget Circulars

a. A-87 - Cost Principles Applicable to Grants and Contracts with State and Local Governments.

b. A-133 - Audits of States, Local Governments, and Non-Profit Organizations

[1] These laws do not apply to airport planning sponsors.

[2] These laws do not apply to private sponsors.

[3] 49 CFR Part 18 and OMB Circular A-87 contain requirements for State and Local Governments receiving Federal assistance. Any requirement levied upon State and Local Governments by this regulation and circular shall also be applicable to private sponsors receiving Federal assistance under Title 49, United States Code.

Specific assurances required to be included in grant agreements by any of the above laws, regulations or circulars are incorporated by reference in this grant agreement.

2. Responsibility and Authority of the Sponsor.

a. **Public Agency Sponsor:** It has legal authority to apply for this grant, and to finance and carry out the proposed project; that a resolution, motion or similar action has been duly adopted or passed as an official act of the applicant's governing body authorizing the filing of the application, including all understandings and assurances contained therein, and directing and authorizing the person identified as the official representative of the applicant to act in connection with the application and to provide such additional information as may be required.

b. **Private Sponsor:** It has legal authority to apply for this grant and to finance and carry out the proposed project and comply with all terms, conditions, and assurances of this grant agreement. It shall designate an official representative and shall in writing direct and authorize that person to file this application, including all understandings and assurances contained therein; to act in connection with this application; and to provide such additional information as may be required.

3. Sponsor Fund Availability. It has sufficient funds available for that portion of the project costs which are not to be paid by the United States. It has sufficient funds available to assure operation and maintenance of items funded under this grant agreement which it will own or control.

4. Good Title.

a. It, a public agency or the Federal government, holds good title, satisfactory to the Secretary, to the landing area of the airport or site thereof, or will give assurance satisfactory to the Secretary that good title will be acquired.

b. For noise compatibility program projects to be carried out on the property of the sponsor, it holds good title satisfactory to the Secretary to that portion of the property upon which Federal funds will be expended or will give assurance to the Secretary that good title will be obtained.

5. **Preserving Rights and Powers**.

a. It will not take or permit any action which would operate to deprive it of any of the rights and powers necessary to perform any or all of the terms, conditions, and assurances in this grant agreement without the written approval of the Secretary, and will act promptly to acquire, extinguish or modify any outstanding rights or claims of right of others which would interfere with such performance by the sponsor. This shall be done in a manner acceptable to the Secretary.

b. It will not sell, lease, encumber, or otherwise transfer or dispose of any part of its title or other interests in the property shown on Exhibit A to this application or, for a noise compatibility program project, that portion of the property upon which Federal funds have been expended, for the duration of the terms, conditions, and assurances in this grant agreement without approval by the Secretary. If the transferee is found by the Secretary to be eligible under Title 49, United States Code, to assume the obligations of this grant agreement and to have the power, authority, and financial resources to carry out all such obligations, the sponsor shall insert in the contract or document transferring or disposing of the sponsor's interest, and make binding upon the transferee all of the terms, conditions, and assurances contained in this grant agreement.

c. For all noise compatibility program projects which are to be carried out by another unit of local government or are on property owned by a unit of local government other than the sponsor, it will enter into an agreement with that government. Except as otherwise specified by the Secretary, that agreement shall obligate that government to the same terms, conditions, and assurances that would be applicable to it if it applied directly to the FAA for a grant to undertake the noise compatibility program project. That agreement and changes thereto must be satisfactory to the Secretary. It will take steps to enforce this agreement against the local government if there is substantial non-compliance with the terms of the agreement.

d. For noise compatibility program projects to be carried out on privately owned property, it will enter into an agreement with the owner of that property which includes provisions specified by the Secretary. It will take steps to enforce this agreement against the property owner whenever there is substantial non-compliance with the terms of the agreement.

e. If the sponsor is a private sponsor, it will take steps satisfactory to the Secretary to ensure that the airport will continue to function as a public-use airport in accordance with these assurances for the duration of these assurances.

f. If an arrangement is made for management and operation of the airport by any agency or person other than the sponsor or an employee of the sponsor, the sponsor will reserve sufficient rights and authority to insure that the airport will be operated and maintained in accordance Title 49, United States Code, the regulations and the terms, conditions and assurances in this grant agreement and shall insure that such arrangement also requires compliance therewith.

g. Sponsors of commercial service airports will not permit or enter into any arrangement that results in permission for the owner or tenant of a property used as a residence, or zoned for residential use, to taxi an aircraft between that property and any location on airport. Sponsors of general aviation airports entering into any arrangement that results in permission for the owner of residential real property adjacent to or near the airport must comply with the requirements of Sec. 136 of Public Law 112-95 and the sponsor assurances.

6. Consistency with Local Plans. The project is reasonably consistent with plans (existing at the time of submission of this application) of public agencies that are authorized by the State in which the project is located to plan for the development of the area surrounding the airport.

7. Consideration of Local Interest. It has given fair consideration to the interest of communities in or near where the project may be located.

8. Consultation with Users. In making a decision to undertake any airport development project under Title 49, United States Code, it has undertaken reasonable consultations with affected parties using the airport at which project is proposed.

9. Public Hearings. In projects involving the location of an airport, an airport runway, or a major runway extension, it has afforded the opportunity for public hearings for the purpose of considering the economic, social, and environmental effects of the airport or runway location and its consistency with goals and objectives of such planning as has been carried out by the community and it shall, when requested by the Secretary, submit a copy of the transcript of such hearings to the Secretary. Further, for such projects, it has on its management board either voting representation from the communities where the project is located or has advised the communities that they have the right to petition the Secretary concerning a proposed project.

10. Air and Water Quality Standards. In projects involving airport location, a major runway extension, or runway location it will provide for the Governor of the state in which the project is located to certify in writing to the Secretary that the project will be located, designed, constructed, and operated so as to comply with applicable air and water quality standards. In any case where such standards have not been approved and where applicable air and water quality standards have been promulgated by the Administrator of the Environmental Protection Agency, certification shall be obtained from such Administrator. Notice of certification or refusal to certify shall be provided within sixty days after the project application has been received by the Secretary.

11. Pavement Preventive Maintenance. With respect to a project approved after January 1, 1995, for the replacement or reconstruction of pavement at the airport, it assures or certifies that it has implemented an effective airport pavement maintenance-management program and it assures that it will use such program for the useful life of any pavement constructed, reconstructed or repaired with Federal financial assistance at the airport. It will provide such reports on pavement condition and pavement management programs as the Secretary determines may be useful.

12. **Terminal Development Prerequisites.** For projects which include terminal development at a public use airport, as defined in Title 49, it has, on the date of submittal of the project grant application, all the safety equipment required for certification of such airport under section 44706 of Title 49, United States Code, and all the security equipment required by rule or regulation, and has provided for access to the passenger enplaning and deplaning area of such airport to passengers enplaning and deplaning from aircraft other than air carrier aircraft.

13. **Accounting System, Audit, and Record Keeping Requirements**.

    a. It shall keep all project accounts and records which fully disclose the amount and disposition by the recipient of the proceeds of this grant, the total cost of the project in connection with which this grant is given or used, and the amount or nature of that portion of the cost of the project supplied by other sources, and such other financial records pertinent to the project. The accounts and records shall be kept in accordance with an accounting system that will facilitate an effective audit in accordance with the Single Audit Act of 1984.

    b. It shall make available to the Secretary and the Comptroller General of the United States, or any of their duly authorized representatives, for the purpose of audit and examination, any books, documents, papers, and records of the recipient that are pertinent to this grant. The Secretary may require that an appropriate audit be conducted by a recipient. In any case in which an independent audit is made of the accounts of a sponsor relating to the disposition of the proceeds of a grant or relating to the project in connection with which this grant was given or used, it shall file a certified copy of such audit with the Comptroller General of the United States not later than six (6) months following the close of the fiscal year for which the audit was made.

14. **Minimum Wage Rates.** It shall include, in all contracts in excess of $2,000 for work on any projects funded under this grant agreement which involve labor, provisions establishing minimum rates of wages, to be predetermined by the Secretary of Labor, in accordance with the Davis-Bacon Act, as amended (40 U.S.C. 276a-276a-5), which contractors shall pay to skilled and unskilled labor, and such minimum rates shall be stated in the invitation for bids and shall be included in proposals or bids for the work.

15. **Veteran's Preference.** It shall include in all contracts for work on any project funded under this grant agreement which involve labor, such provisions as are necessary to insure that, in the employment of labor (except in executive, administrative, and supervisory positions), preference shall be given to Vietnam

era veterans, Persian Gulf veterans, Afghanistan-Iraq war veterans, disabled veterans, and small business concerns owned and controlled by disabled veterans as defined in Section 47112 of Title 49, United States Code. However, this preference shall apply only where the individuals are available and qualified to perform the work to which the employment relates.

16. **Conformity to Plans and Specifications.** It will execute the project subject to plans, specifications, and schedules approved by the Secretary. Such plans, specifications, and schedules shall be submitted to the Secretary prior to commencement of site preparation, construction, or other performance under this grant agreement, and, upon approval of the Secretary, shall be incorporated into this grant agreement. Any modification to the approved plans, specifications, and schedules shall also be subject to approval of the Secretary, and incorporated into this grant agreement.

17. **Construction Inspection and Approval.** It will provide and maintain competent technical supervision at the construction site throughout the project to assure that the work conforms to the plans, specifications, and schedules approved by the Secretary for the project. It shall subject the construction work on any project contained in an approved project application to inspection and approval by the Secretary and such work shall be in accordance with regulations and procedures prescribed by the Secretary. Such regulations and procedures shall require such cost and progress reporting by the sponsor or sponsors of such project as the Secretary shall deem necessary.

18. **Planning Projects.** In carrying out planning projects:

    a. It will execute the project in accordance with the approved program narrative contained in the project application or with the modifications similarly approved.
    b. It will furnish the Secretary with such periodic reports as required pertaining to the planning project and planning work activities.
    c. It will include in all published material prepared in connection with the planning project a notice that the material was prepared under a grant provided by the United States.
    d. It will make such material available for examination by the public, and agrees that no material prepared with funds under this project shall be subject to copyright in the United States or any other country.
    e. It will give the Secretary unrestricted authority to publish, disclose, distribute, and otherwise use any of the material prepared in connection with this grant.
    f. It will grant the Secretary the right to disapprove the sponsor's employment of specific consultants and their subcontractors to do all or any part of this project as well as the right to disapprove the proposed scope and cost of professional services.
    g. It will grant the Secretary the right to disapprove the use of the sponsor's employees to do all or any part of the project.
    h. It understands and agrees that the Secretary's approval of this project grant or the Secretary's approval of any planning material developed as part of

this grant does not constitute or imply any assurance or commitment on the part of the Secretary to approve any pending or future application for a Federal airport grant.

19. Operation and Maintenance.

a. The airport and all facilities which are necessary to serve the aeronautical users of the airport, other than facilities owned or controlled by the United States, shall be operated at all times in a safe and serviceable condition and in accordance with the minimum standards as may be required or prescribed by applicable Federal, state and local agencies for maintenance and operation. It will not cause or permit any activity or action thereon which would interfere with its use for airport purposes. It will suitably operate and maintain the airport and all facilities thereon or connected therewith, with due regard to climatic and flood conditions. Any proposal to temporarily close the airport for non-aeronautical purposes must first be approved by the Secretary. In furtherance of this assurance, the sponsor will have in effect arrangements for-

1) Operating the airport's aeronautical facilities whenever required;
2) Promptly marking and lighting hazards resulting from airport conditions, including temporary conditions; and
3) Promptly notifying airmen of any condition affecting aeronautical use of the airport. Nothing contained herein shall be construed to require that the airport be operated for aeronautical use during temporary periods when snow, flood or other climatic conditions interfere with such operation and maintenance. Further, nothing herein shall be construed as requiring the maintenance, repair, restoration, or replacement of any structure or facility which is substantially damaged or destroyed due to an act of God or other condition or circumstance beyond the control of the sponsor.

b. It will suitably operate and maintain noise compatibility program items that it owns or controls upon which Federal funds have been expended.

20. Hazard Removal and Mitigation. It will take appropriate action to assure that such terminal airspace as is required to protect instrument and visual operations to the airport (including established minimum flight altitudes) will be adequately cleared and protected by removing, lowering, relocating, marking, or lighting or otherwise mitigating existing airport hazards and by preventing the establishment or creation of future airport hazards.

21. Compatible Land Use. It will take appropriate action, to the extent reasonable, including the adoption of zoning laws, to restrict the use of land adjacent to or in the immediate vicinity of the airport to activities and purposes compatible with normal airport operations, including landing and takeoff of aircraft. In addition, if the project is for noise compatibility program implementation, it will not cause or permit any change in land use, within its jurisdiction, that will reduce its compatibility, with respect to the airport, of the noise compatibility program measures upon which Federal funds have been expended.

22. Economic Nondiscrimination.

a. It will make the airport available as an airport for public use on reasonable terms and without unjust discrimination to all types, kinds and classes of aeronautical activities, including commercial aeronautical activities offering services to the public at the airport.

b. In any agreement, contract, lease, or other arrangement under which a right or privilege at the airport is granted to any person, firm, or corporation to conduct or to engage in any aeronautical activity for furnishing services to the public at the airport, the sponsor will insert and enforce provisions requiring the contractor to-

   1) furnish said services on a reasonable, and not unjustly discriminatory, basis to all users thereof, and

   2) charge reasonable, and not unjustly discriminatory, prices for each unit or service, provided that the contractor may be allowed to make reasonable and nondiscriminatory discounts, rebates, or other similar types of price reductions to volume purchasers.

c. Each fixed-based operator at the airport shall be subject to the same rates, fees, rentals, and other charges as are uniformly applicable to all other fixed-based operators making the same or similar uses of such airport and utilizing the same or similar facilities.

d. Each air carrier using such airport shall have the right to service itself or to use any fixed-based operator that is authorized or permitted by the airport to serve any air carrier at such airport.

e. Each air carrier using such airport (whether as a tenant, non tenant, or subtenant of another air carrier tenant) shall be subject to such nondiscriminatory and substantially comparable rules, regulations, conditions, rates, fees, rentals, and other charges with respect to facilities directly and substantially related to providing air transportation as are applicable to all such air carriers which make similar use of such airport and utilize similar facilities, subject to reasonable classifications such as tenants or non tenants and signatory carriers and non signatory carriers. Classification or status as tenant or signatory shall not be unreasonably withheld by any airport provided an air carrier assumes obligations substantially similar to those already imposed on air carriers in such classification or status.

f. It will not exercise or grant any right or privilege which operates to prevent any person, firm, or corporation operating aircraft on the airport from performing any services on its own aircraft with its own employees [including, but not limited to maintenance, repair, and fueling] that it may choose to perform.

g. In the event the sponsor itself exercises any of the rights and privileges referred to in this assurance, the services involved will be provided on the same conditions as would apply to the furnishing of such services by commercial aeronautical service providers authorized by the sponsor under these provisions.

h. The sponsor may establish such reasonable, and not unjustly discriminatory, conditions to be met by all users of the airport as may be necessary for the safe and efficient operation of the airport.

i. The sponsor may prohibit or limit any given type, kind or class of aeronautical use of the airport if such action is necessary for the safe operation of the airport or necessary to serve the civil aviation needs of the public.

23. Exclusive Rights. It will permit no exclusive right for the use of the airport by any person providing, or intending to provide, aeronautical services to the public. For purposes of this paragraph, the providing of the services at an airport by a single fixed-based operator shall not be construed as an exclusive right if both of the following apply:

a. It would be unreasonably costly, burdensome, or impractical for more than one fixed-based operator to provide such services, and

b. If allowing more than one fixed-based operator to provide such services would require the reduction of space leased pursuant to an existing agreement between such single fixed-based operator and such airport. It further agrees that it will not, either directly or indirectly, grant or permit any person, firm, or corporation, the exclusive right at the airport to conduct any aeronautical activities, including, but not limited to charter flights, pilot training, aircraft rental and sightseeing, aerial photography, crop dusting, aerial advertising and surveying, air carrier operations, aircraft sales and services, sale of aviation petroleum products whether or not conducted in conjunction with other aeronautical activity, repair and maintenance of aircraft, sale of aircraft parts, and any other activities which because of their direct relationship to the operation of aircraft can be regarded as an aeronautical activity, and that it will terminate any exclusive right to conduct an aeronautical activity now existing at such an airport before the grant of any assistance under Title 49, United States Code.

24. Fee and Rental Structure. It will maintain a fee and rental structure for the facilities and services at the airport which will make the airport as self-sustaining as possible under the circumstances existing at the particular airport, taking into account such factors as the volume of traffic and economy of collection. No part of the Federal share of an airport development, airport planning or noise compatibility project for which a grant is made under Title 49, United States Code, the Airport and Airway Improvement Act of 1982, the Federal Airport Act or the Airport and Airway Development Act of 1970 shall be included in the rate basis in establishing fees, rates, and charges for users of that airport.

25. Airport Revenues.

a. All revenues generated by the airport and any local taxes on aviation fuel established after December 30, 1987, will be expended by it for the capital or operating costs of the airport; the local airport system; or other local facilities which are owned or operated by the owner or operator of the airport and which are directly and substantially related to the actual air transportation of passengers or property; or for noise mitigation purposes on or off the airport. The following exceptions apply to this paragraph:

1) If covenants or assurances in debt obligations issued before September 3, 1982, by the owner or operator of the airport, or provisions enacted before September 3, 1982, in governing statutes controlling the owner or operator's financing, provide for the use of the revenues from any of the airport owner or operator's facilities, including the airport, to support not only the airport but also the airport owner or operator's general debt obligations or other facilities, then this limitation on the use of all revenues generated by the airport (and, in the case of a public airport, local taxes on aviation fuel) shall not apply.

2) If the Secretary approves the sale of a privately owned airport to a public sponsor and provides funding for any portion of the public sponsor's acquisition of land, this limitation on the use of all revenues generated by the sale shall not apply to certain proceeds from the sale. This is conditioned on repayment to the Secretary by the private owner of an amount equal to the remaining unamortized portion (amortized over a 20-year period) of any airport improvement grant made to the private owner for any purpose other than land acquisition on or after October 1, 1996, plus an amount equal to the federal share of the current fair market value of any land acquired with an airport improvement grant made to that airport on or after October 1, 1996.

3) Certain revenue derived from or generated by mineral extraction, production, lease, or other means at a general aviation airport (as defined at Section 47102 of title 49 United States Code), if the FAA determines the airport sponsor meets the requirements set forth in Sec. 813 of Public Law 112-95.

b. As part of the annual audit required under the Single Audit Act of 1984, the sponsor will direct that the audit will review, and the resulting audit report will provide an opinion concerning, the use of airport revenue and taxes in paragraph (a), and indicating whether funds paid or transferred to the owner or operator are paid or transferred in a manner consistent with Title 49, United States Code and any other applicable provision of law, including any regulation promulgated by the Secretary or Administrator.

c. Any civil penalties or other sanctions will be imposed for violation of this assurance in accordance with the provisions of Section 47107 of Title 49, United States Code.

26. Reports and Inspections. It will:

a. submit to the Secretary such annual or special financial and operations reports as the Secretary may reasonably request and make such reports available to the public; make available to the public at reasonable times and places a report of the airport budget in a format prescribed by the Secretary;

b. for airport development projects, make the airport and all airport records and documents affecting the airport, including deeds, leases, operation and use agreements, regulations and other instruments, available for inspection by any duly authorized agent of the Secretary upon reasonable request;

c. for noise compatibility program projects, make records and documents relating to the project and continued compliance with the terms, conditions, and assurances of this grant agreement including deeds, leases, agreements, regulations, and other instruments, available for inspection by any duly authorized agent of the Secretary upon reasonable request; and

d. in a format and time prescribed by the Secretary, provide to the Secretary and make available to the public following each of its fiscal years, an annual report listing in detail:

    1) all amounts paid by the airport to any other unit of government and the purposes for which each such payment was made; and

    2) all services and property provided by the airport to other units of government and the amount of compensation received for provision of each such service and property.

27. **Use by Government Aircraft.** It will make available all of the facilities of the airport developed with Federal financial assistance and all those usable for landing and takeoff of aircraft to the United States for use by Government aircraft in common with other aircraft at all times without charge, except, if the use by Government aircraft is substantial, charge may be made for a reasonable share, proportional to such use, for the cost of operating and maintaining the facilities used. Unless otherwise determined by the Secretary, or otherwise agreed to by the sponsor and the using agency, substantial use of an airport by Government aircraft will be considered to exist when operations of such aircraft are in excess of those which, in the opinion of the Secretary, would unduly interfere with use of the landing areas by other authorized aircraft, or during any calendar month that –

a. Five (5) or more Government aircraft are regularly based at the airport or on land adjacent thereto; or

b. The total number of movements (counting each landing as a movement) of Government aircraft is 300 or more, or the gross accumulative weight of Government aircraft using the airport (the total movement of Government aircraft multiplied by gross weights of such aircraft) is in excess of five million pounds.

28. **Land for Federal Facilities.** It will furnish without cost to the Federal Government for use in connection with any air traffic control or air navigation activities, or weather-reporting and communication activities related to air traffic control, any areas of land or water, or estate therein, or rights in buildings of the sponsor as the Secretary considers necessary or desirable for construction, operation, and maintenance at Federal expense of space or facilities for such

purposes. Such areas or any portion thereof will be made available as provided herein within four months after receipt of a written request from the Secretary.

29. Airport Layout Plan.

a. It will keep up to date at all times an airport layout plan of the airport showing (1) boundaries of the airport and all proposed additions thereto, together with the boundaries of all offsite areas owned or controlled by the sponsor for airport purposes and proposed additions thereto; (2) the location and nature of all existing and proposed airport facilities and structures (such as runways, taxiways, aprons, terminal buildings, hangars and roads), including all proposed extensions and reductions of existing airport facilities; (3) the location of all existing and proposed nonaviation areas and of all existing improvements thereon; and (4) all proposed and existing access points used to taxi aircraft across the airport's property boundary. Such airport layout plans and each amendment, revision, or modification thereof, shall be subject to the approval of the Secretary which approval shall be evidenced by the signature of a duly authorized representative of the Secretary on the face of the airport layout plan. The sponsor will not make or permit any changes or alterations in the airport or any of its facilities which are not in conformity with the airport layout plan as approved by the Secretary and which might, in the opinion of the Secretary, adversely affect the safety, utility or efficiency of the airport.

b. If a change or alteration in the airport or the facilities is made which the Secretary determines adversely affects the safety, utility, or efficiency of any federally owned, leased, or funded property on or off the airport and which is not in conformity with the airport layout plan as approved by the Secretary, the owner or operator will, if requested, by the Secretary (1) eliminate such adverse effect in a manner approved by the Secretary; or (2) bear all costs of relocating such property (or replacement thereof) to a site acceptable to the Secretary and all costs of restoring such property (or replacement thereof) to the level of safety, utility, efficiency, and cost of operation existing before the unapproved change in the airport or its facilities except in the case of a relocation or replacement of an existing airport facility due to a change in the Secretary's design standards beyond the control of the airport sponsor.

30. Civil Rights. It will comply with such rules as are promulgated to assure that no person shall, on the grounds of race, creed, color, national origin, sex, age, or handicap be excluded from participating in any activity conducted with or benefiting from funds received from this grant. This assurance obligates the sponsor for the period during which Federal financial assistance is extended to the program, except where Federal financial assistance is to provide, or is in the form of personal property or real property or interest therein or structures or improvements thereon in which case the assurance obligates the sponsor or any transferee for the longer of the following periods: (a) the period during which the property is used for a purpose for which Federal financial assistance is extended, or for another purpose involving the provision of similar services or benefits, or

(b) the period during which the sponsor retains ownership or possession of the property.

31. Disposal of Land.

a. For land purchased under a grant for airport noise compatibility purposes, including land serving as a noise buffer, it will dispose of the land, when the land is no longer needed for such purposes, at fair market value, at the earliest practicable time. That portion of the proceeds of such disposition which is proportionate to the United States' share of acquisition of such land will be, at the discretion of the Secretary, (1) reinvested in another project at the airport, or (2) transferred to another eligible airport as prescribed by the Secretary. The Secretary shall give preference to the following, in descending order, (1) reinvestment in an approved noise compatibility project, (2) reinvestment in an approved project that is eligible for grant funding under Section 47117(e) of title 49 United States Code, (3) reinvestment in an approved airport development project that is eligible for grant funding under Sections 47114, 47115, or 47117 of title 49 United States Code, (4) transferred to an eligible sponsor of another public airport to be reinvested in an approved noise compatibility project at that airport, and (5) paid to the Secretary for deposit in the Airport and Airway Trust Fund. If land acquired under a grant for noise compatibility purposes is leased at fair market value and consistent with noise buffering purposes, the lease will not be considered a disposal of the land. Revenues derived from such a lease may be used for an approved airport development project that would otherwise be eligible for grant funding or any permitted use of airport revenue.

b. For land purchased under a grant for airport development purposes (other than noise compatibility), it will, when the land is no longer needed for airport purposes, dispose of such land at fair market value or make available to the Secretary an amount equal to the United States' proportionate share of the fair market value of the land. That portion of the proceeds of such disposition which is proportionate to the United States' share of the cost of acquisition of such land will, (1) upon application to the Secretary, be reinvested or transferred to another eligible airport as prescribed by the Secretary. The Secretary shall give preference to the following, in descending order: (1) reinvestment in an approved noise compatibility project, (2) reinvestment in an approved project that is eligible for grant funding under Section 47117(e) of title 49 United States Code, (3) reinvestment in an approved airport development project that is eligible for grant funding under Sections 47114, 47115, or 47117 of title 49 United States Code, (4) transferred to an eligible sponsor of another public airport to be reinvested in an approved noise compatibility project at that airport, and (5) paid to the Secretary for deposit in the Airport and Airway Trust Fund.

c. Land shall be considered to be needed for airport purposes under this assurance if (1) it may be needed for aeronautical purposes (including runway protection zones) or serve as noise buffer land, and (2) the revenue from interim uses of such land contributes to the financial self-sufficiency of the airport. Further, land purchased with a grant received by an airport operator or owner before December 31, 1987, will be considered to be needed for airport purposes if the Secretary or Federal agency making such grant before December 31, 1987, was notified by the operator or owner of the uses of such land, did not object to such use, and the land continues to be used for that purpose, such use having commenced no later than December 15, 1989.

d. Disposition of such land under (a) (b) or (c) will be subject to the retention or reservation of any interest or right therein necessary to ensure that such land will only be used for purposes which are compatible with noise levels associated with operation of the airport.

32. **Engineering and Design Services.** It will award each contract, or sub-contract for program management, construction management, planning studies, feasibility studies, architectural services, preliminary engineering, design, engineering, surveying, mapping or related services with respect to the project in the same manner as a contract for architectural and engineering services is negotiated under Title IX of the Federal Property and Administrative Services Act of 1949 or an equivalent qualifications-based requirement **prescribed** for or by the sponsor of the airport.

33. **Foreign Market Restrictions.** It will not allow funds provided under this grant to be used to fund any project which uses any product or service of a foreign country during the period in which such foreign country is listed by the United States Trade Representative as denying fair and equitable market opportunities for products and suppliers of the United States in procurement and construction.

34. **Policies, Standards, and Specifications.** It will carry out the project in accordance with policies, standards, and specifications approved by the Secretary including but not limited to the advisory circulars listed in the Current FAA Advisory Circulars for AIP projects, dated ____________________ (the latest approved version as of this grant offer) and included in this grant, and in accordance with applicable state policies, standards, and specifications approved by the Secretary.

35. **Relocation and Real Property Acquisition.** (1) It will be guided in acquiring real property, to the greatest extent practicable under State law, by the land acquisition policies in Subpart B of 49 CFR Part 24 and will pay or reimburse property owners for necessary expenses as specified in Subpart B. (2) It will provide a relocation assistance program offering the services described in Subpart C and fair and reasonable relocation payments and assistance to displaced persons as required in Subpart D and E of 49 CFR Part 24. (3) It will make available within a reasonable period of time prior to displacement, comparable replacement dwellings to displaced persons in accordance with Subpart E of 49 CFR Part 24.

36. **Access By Intercity Buses**. The airport owner or operator will permit, to the maximum extent practicable, intercity buses or other modes of transportation to have access to the airport; however, it has no obligation to fund special facilities for intercity buses or for other modes of transportation.

37. **Disadvantaged Business Enterprises.** The recipient shall not discriminate on the basis of race, color, national origin or sex in the award and performance of any DOT-assisted contract or in the administration of its DBE program or the requirements of 49 CFR Part 26. The Recipient shall take all necessary and reasonable steps under 49 CFR Part 26 to ensure non discrimination in the award and administration of DOT-assisted contracts. The recipient's DBE program, as required by 49 CFR Part 26, and as approved by DOT, is incorporated by reference in this agreement. Implementation of this program is a legal obligation and failure to carry out its terms shall be treated as a violation of this agreement. Upon notification to the recipient of its failure to carry out its approved program, the Department may impose sanctions as provided for under Part 26 and may, in appropriate cases, refer the matter for enforcement under 18 U.S.C. 1001 and/or the Program Fraud Civil Remedies Act of 1986 (31 U.S.C. 3801).

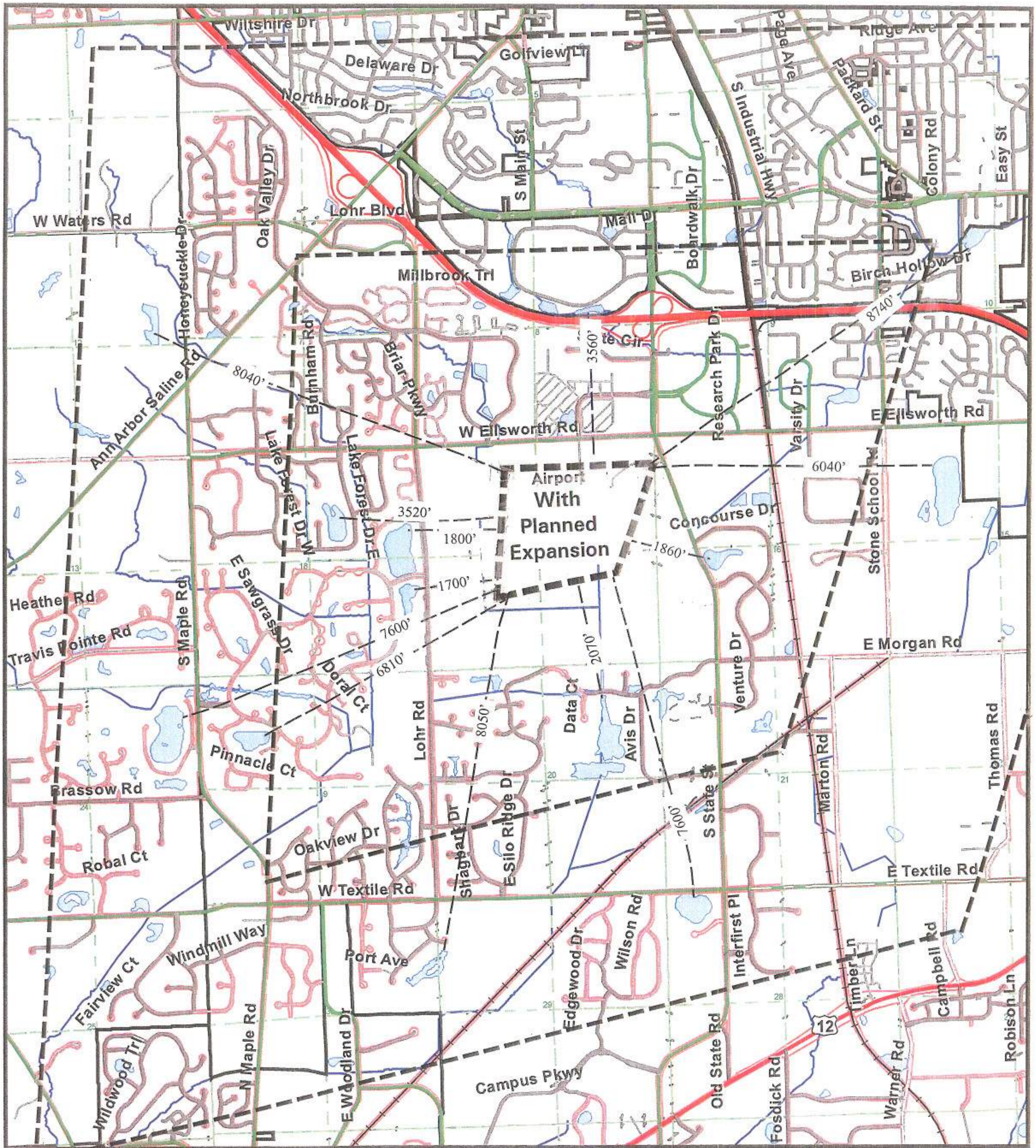
38. **Hangar Construction.** If the airport owner or operator and a person who owns an aircraft agree that a hangar is to be constructed at the airport for the aircraft at the aircraft owner's expense, the airport owner or operator will grant to the aircraft owner for the hangar a long term lease that is subject to such terms and conditions on the hangar as the airport owner or operator may impose.

39. **Competitive Access.**

a. If the airport owner or operator of a medium or large hub airport (as defined in section 47102 of title 49, U.S.C.) has been unable to accommodate one or more requests by an air carrier for access to gates or other facilities at that airport in order to allow the air carrier to provide service to the airport or to expand service at the airport, the airport owner or operator shall transmit a report to the Secretary that-

    1) Describes the requests;
    2) Provides an explanation as to why the requests could not be accommodated; and
    3) Provides a time frame within which, if any, the airport will be able to accommodate the requests.

b. Such report shall be due on either February 1 or August 1 of each year if the airport has been unable to accommodate the request(s) in the six month period prior to the applicable due date.



April 2010

GIS Map Print

Location Map

N

0 2,400 4,800

Feet

1 inch = 3,000 feet

Washtenaw County Michigan 1826

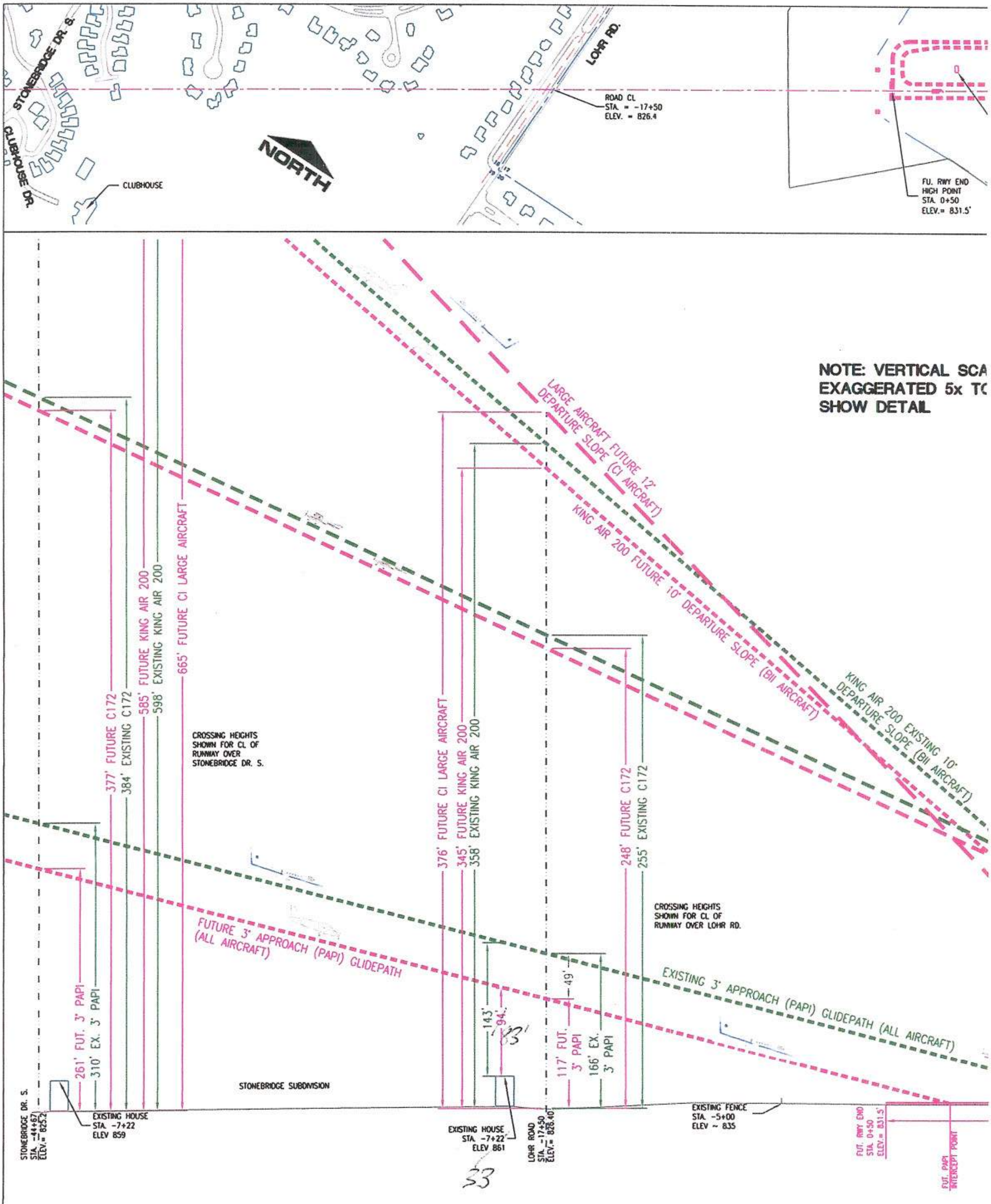
Geographic Information System

The information contained in this cadastral map is used to locate, identify and inventory parcels of land in Washtenaw County for appraisal and taxing purposes only and is not to be construed as a "survey description". The information is provided with the understanding that the conclusions drawn from such information are solely the responsibility of the user. Any assumption of legal status of this data is hereby disclaimed.

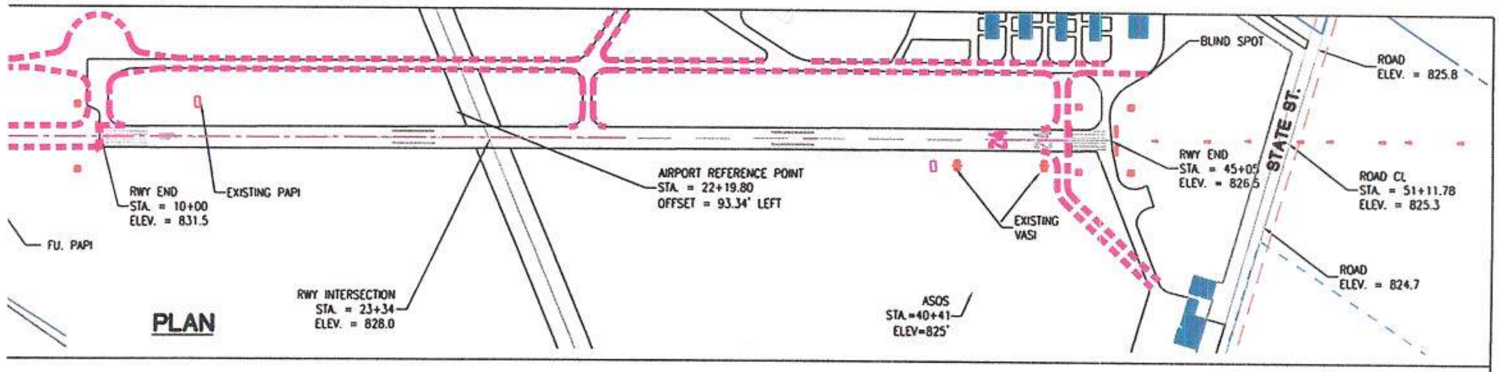
NOTE: PARCELS MAY NOT BE TO SCALE

Date Printed: 04/01/2010

Committee for Preserving Community Quality



APPROACH AND DEPARTURE



PLAN

APPROACHES

APPROACH SLOPE FOR ALL AIRCRAFT WOULD BE AT 3° ALONG THE PRECISION APPROACH PATH INDICATOR (PAPI).

APPROACH CLEARANCE (LOHR RD.)
166' EXISTING
117' PROPOSED EXTENSION

DEPARTURES

DEPARTURE SLOPES ARE SHOWN FOR 3 AIRCRAFT TYPES FOR THE 839' AIRPORT ELEVATION AT 83°F. CROSSING HEIGHTS SHOWN FOR CL OF RUNWAY OVER LOHR RD.

CESSNA 172 – AI SMALL AIRCRAFT
MAX. GROSS LOAD: 2,300 LBS
CLIMB RATE: 700 FT. PER MINUTE
CLIMB AIRSPEED: 73 KNOTS
CLIMB ANGLE: 5.4°
GROUND ROLL: 850 FT.
DEPARTURE CLEARANCE (LOHR RD.)
255' EXISTING
248' PROPOSED EXTENSION

KING AIR 200 – BII SMALL AIRCRAFT
MAX. GROSS LOAD: 12,5000 LBS
CLIMB RATE: 2,400 FT. PER MINUTE
CLIMB AIRSPEED: 125 KNOTS
CLIMB ANGLE: 10°
GROUND ROLL: 2200 FT.
DEPARTURE CLEARANCE (LOHR RD.)
358' EXISTING
345' PROPOSED EXTENSION

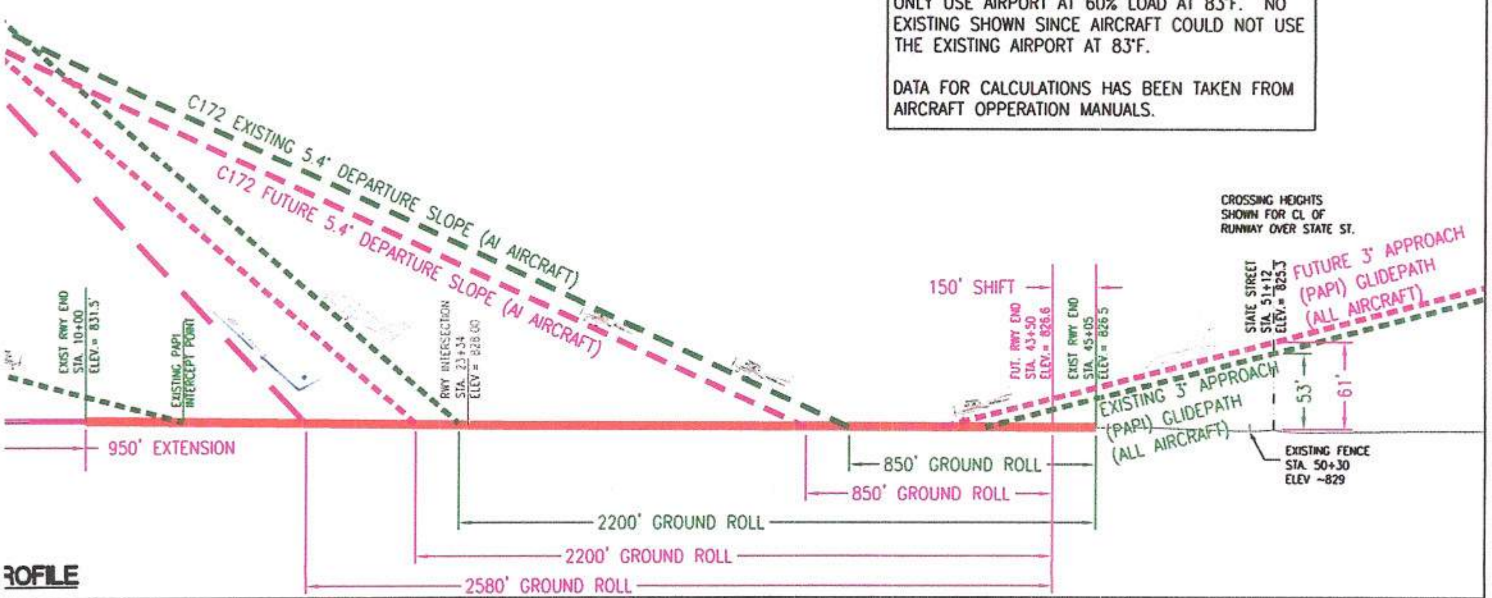
HAWKER 700A – CI LARGE AIRCRAFT
MAX. GROSS LOAD: 24,800 LBS*
CLIMB RATE: 3,000 FT. PER MINUTE
CLIMB AIRSPEED: 135 KNOTS
CLIMB ANGLE: 12°
GROUND ROLL: 2850 FT.
DEPARTURE CLEARANCE (LOHR RD.)
376' PROPOSED EXTENSION

* FOR FUTURE RUNWAY LENGTH AIRCRAFT COULD ONLY USE AIRPORT AT 60% LOAD AT 83°F. NO EXISTING SHOWN SINCE AIRCRAFT COULD NOT USE THE EXISTING AIRPORT AT 83°F.

DATA FOR CALCULATIONS HAS BEEN TAKEN FROM AIRCRAFT OPPERATION MANUALS.

TYPICAL CLIMB PERFORMANCE BY AIRCRAFT TYPE

AIRCRAFT TYPE	TYPICAL CLIMB ANGLE	TYPICAL CLIMB RATES
SINGLE ENGINE PISTON	4°–7°	500–1,000 FT/MIN
TWIN ENGINE PISTON	7°–9°	1,00–1,500 FT/MIN
TWIN ENGINE TURBOPROP	10°–11°	2,000–2,500 FT/MIN
JET	12°–16°	3,000–4,000 FT/MIN



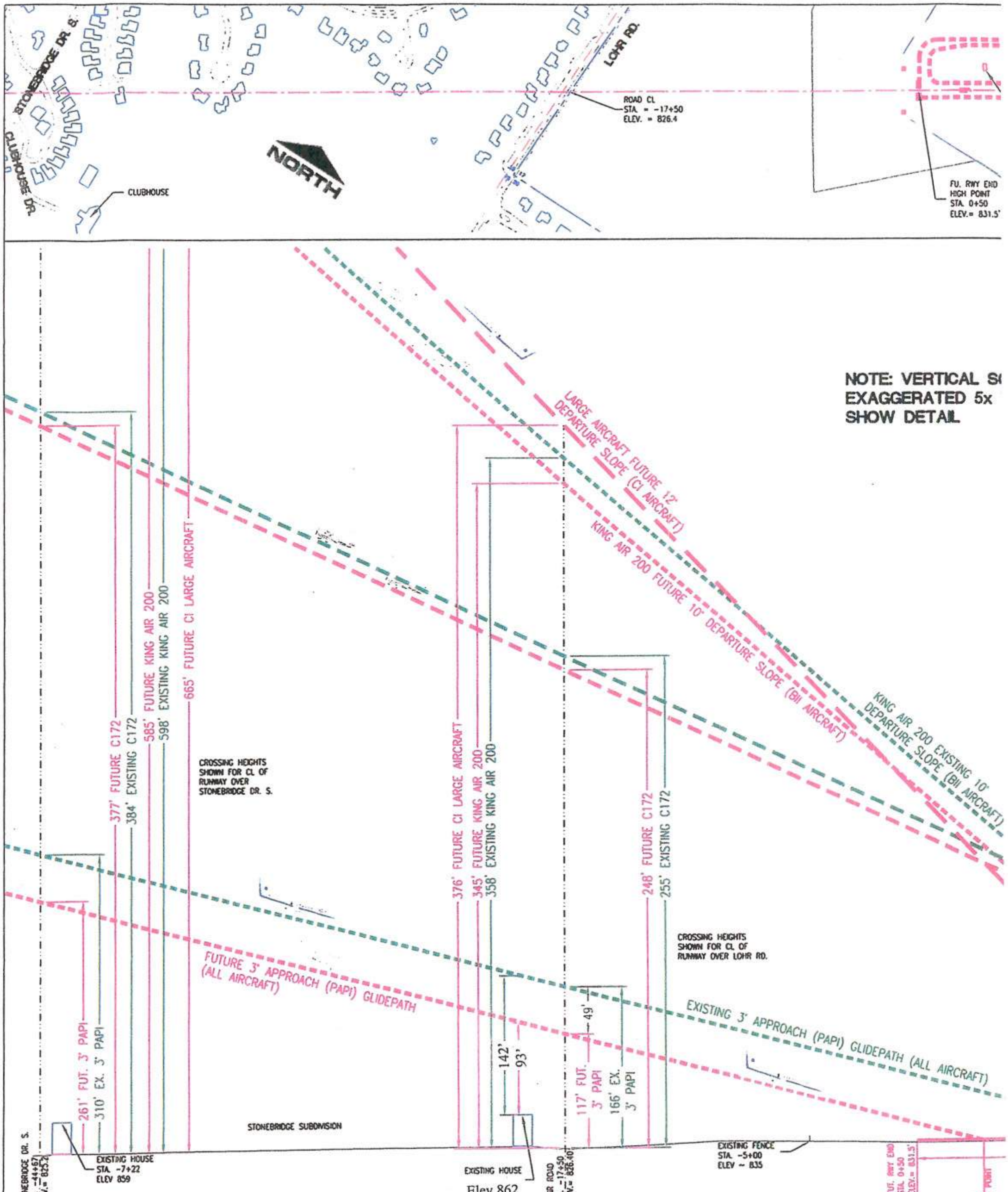
ROFILE

CLEARANCES

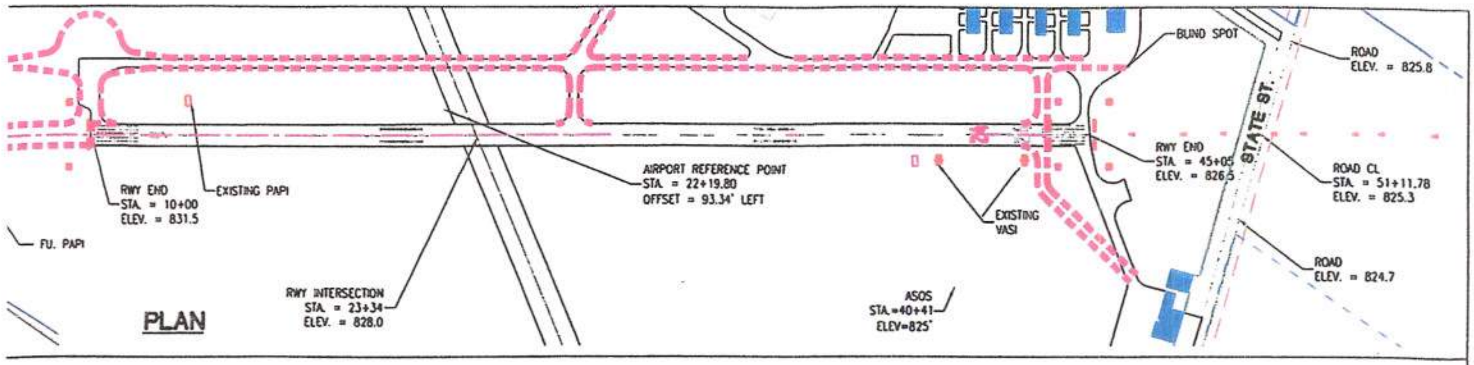
URS GRAND RAPIDS, MI., 3950 SPARKS DR. S.E. 616 574-8500

PROJECT NO. 12940723

ANN ARBOR MUNICIPAL AIRPORT



Corrected APPROACH AND DEPARTURE



APPROACHES

APPROACH SLOPE FOR ALL AIRCRAFT WOULD BE AT 3° ALONG THE PRECISION APPROACH PATH INDICATOR (PAPI).

APPROACH CLEARANCE (LOHR RD.)
166' EXISTING
117' PROPOSED EXTENSION

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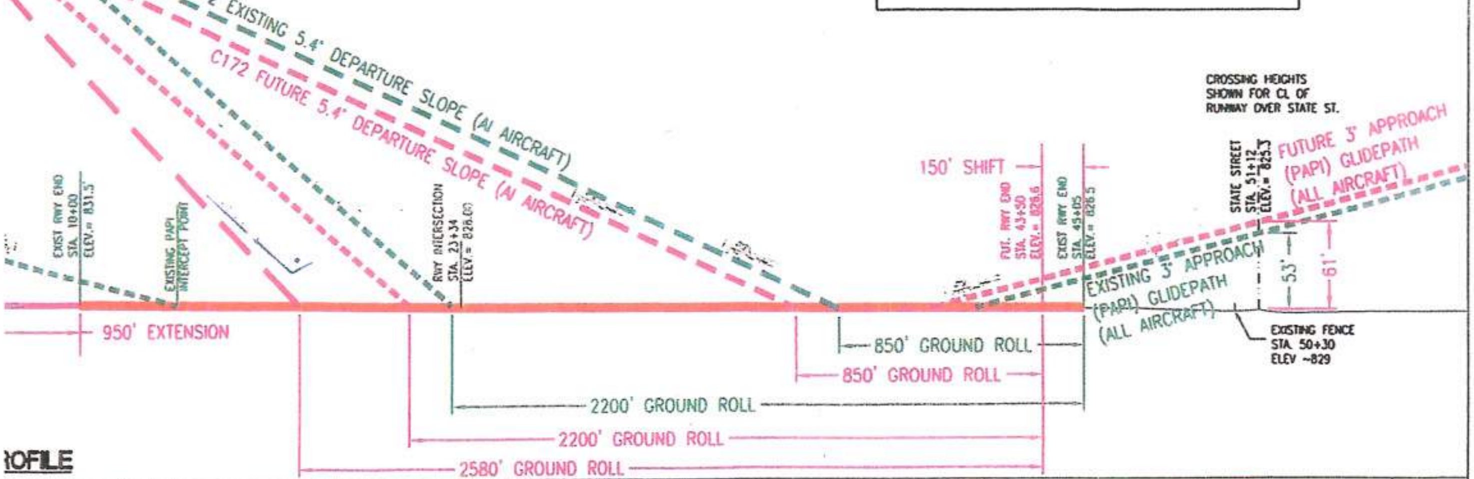

CLEARANCES

Base Map by:

URS GRAND RAPIDS, MI.

ANN ARBOR MUNICIPAL AIRPORT

Committee for Preserving Community Quality April 2010

Aircraft Emergency Landing: Stonebridge Golf Course – June 2009

National Transportation Safety Board FACTUAL REPORT AVIATION	NTSB ID: CHI01LA181	Aircraft Registration Number: N24898
	Occurrence Date: 06/21/2001	Most Critical Injury: Fatal
	Occurrence Type: Accident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone
Ann Arbor	MI	48103	1405	EDT

Airport Proximity: On Airport/Airstrip	Distance From Landing Facility:

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
Masko	Mustang MII	Airplane

Revenue Sightseeing Flight: No **Air Medical Transport Flight:** No

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

*** Note: NTSB investigators may have traveled in support of this investigation and used data provided by various sources to prepare this aircraft accident report. ***

On June 21, 2001, at 1405 eastern daylight time, an amateur-built Masko Mustang MII, N24898, piloted by a commercial pilot, was destroyed when it impacted terrain following a loss of control while maneuvering in the traffic pattern at the Ann Arbor Municipal Airport (ARB), Ann Arbor, Michigan. The aircraft had just completed a touch and go and was turning from the upwind to the crosswind leg of the traffic pattern for runway 06 (3,500 feet by 75 feet, concrete). The local flight was being operated under the provisions of 14 CFR Part 91 and was not on a flight plan. Visual meteorological conditions prevailed at the time of the accident. The pilot and the pilot rated passenger received fatal injuries. The flight originated from ARB at 1353.

Witnesses to the accident saw the airplane make a steep right turn prior to spiraling to the ground.

A postaccident examination of the airplane revealed no anomalies that could be associated with a pre-impact condition.

The pilot held commercial and certified flight instructor certificates with airplane single engine land and instrument airplane ratings. The pilot also held a ground instructor certificate with advanced and instrument ratings. According to Federal Aviation Administration records, the pilot reported having 398 hours of flight time as of March 15, 2001. The pilot's logbook was not recovered.

The pilot rated passenger held a commercial pilot certificate with airplane single engine land and instrument airplane ratings. He held a certified flight instructor certificate with an airplane single engine land rating. The pilot rated passenger also held a ground instructor certificate with an advanced rating. According to Federal Aviation Administration records, the pilot rated passenger reported having 307 hours of flight time as of May 10, 2001. The pilot rated passenger's logbook was not recovered.

Toxicology tests performed on the pilot and pilot rated passenger were negative for all tests performed. Autopsies were performed on the pilot and pilot rated passenger by Washtenaw County on June 22, 2001.

It was reported that the airplane was purchased on June 16, 2001. The pilot was the flight instructor of the new owner. The owner was not aboard the airplane when the accident occurred.

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI01LA181
Occurrence Date: 06/21/2001
Occurrence Type: Accident

Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
ANN ARBOR MUNI	ARB	839 Ft. MSL	06	3500	75

Runway Surface Type: Concrete

Runway Surface Condition: Dry

Approach/Arrival Flown: NONE

VFR Approach/Landing: Touch and Go

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
Masko	Mustang MII	8

Airworthiness Certificate(s): Experimental (Special)

Landing Gear Type: Tailwheel

Amateur Built Acft?	Number of Seats:	Certified Max Gross Wt.	Number of Engines:
Yes	2	1500 LBS	1

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Reciprocating	Lycoming	O-320	150 HP

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
		Hours	Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?/Type	ELT Operated?	ELT Aided in Locating Accident Site?
Yes /	No	No

Owner/Operator Information

Registered Aircraft Owner	Street Address		
Craig W. Peterson	1841 Hiller Rd.		
	City	State	Zip Code
	West Bloomfield	MI	48324

Operator of Aircraft	Street Address		
Craig W. Peterson	1841 Hiller Rd.		
	City	State	Zip Code
	West Bloomfield	MI	48324

Operator Does Business As:

Operator Designator Code:

- Type of U.S. Certificate(s) Held: None

Air Carrier Operating Certificate(s):

Operating Certificate:

Operator Certificate:

Regulation Flight Conducted Under: Part 91: General Aviation

Type of Flight Operation Conducted: Personal

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI01LA181
Occurrence Date: 06/21/2001
Occurrence Type: Accident

First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File		25

Sex: M | Seat Occupied: Left | Occupational Pilot? Civilian Pilot | Certificate Number:

Certificate(s): Flight Instructor; Commercial

Airplane Rating(s): Single-engine Land

Rotorcraft/Glider/LTA: None

Instrument Rating(s): Airplane

Instructor Rating(s): Airplane Single-engine; Instrument Airplane

Current Biennial Flight Review?

Medical Cert.: Class 2 | Medical Cert. Status: Valid Medical--no waivers/lim. | Date of Last Medical Exam: 10/2000

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	398									
Pilot In Command(PIC)										
Instructor										
Instruction Received										
Last 90 Days										
Last 30 Days										
Last 24 Hours										

Seatbelt Used? Yes | Shoulder Harness Used? Yes | Toxicology Performed? Yes | Second Pilot? Yes

Flight Plan/Itinerary

Type of Flight Plan Filed: None

Departure Point	State	Airport Identifier	Departure Time	Time Zone
Same as Accident/Incident Location		ARB	1353	EDT

Destination	State	Airport Identifier
Local Flight	MI	ARB

Type of Clearance: VFR

Type of Airspace: Class D

Weather Information

Source of Wx Information:

No record of briefing

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI01LA181
Occurrence Date: 06/21/2001
Occurrence Type: Accident

Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
ARB	1353	EDT	839 Ft. MSL	0 NM	0 Deg. Mag.

Sky/Lowest Cloud Condition: Clear Ft. AGL | Condition of Light: Day

Lowest Ceiling: Broken 8500 Ft. AGL | Visibility: 10 SM | Altimeter: 30.03 "Hg

Temperature: 19 °C | Dew Point: 15 °C | Weather Conditions at Accident Site: Visual Conditions

Wind Direction: 60 | Wind Speed: 5 | Wind Gusts:

Visibility (RVR): Ft. | Visibility (RVV) SM

Precip and/or Obscuration:

Accident Information

Aircraft Damage: Destroyed | Aircraft Fire: None | Aircraft Explosion None

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot	1				1
Second Pilot					
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants					
Other Crew					
Passengers	1				1
- TOTAL ABOARD -	2				2
Other Ground					
- GRAND TOTAL -	2				2

National Transportation Safety Board FACTUAL REPORT AVIATION	NTSB ID: CHI01LA181 Occurrence Date: 06/21/2001 Occurrence Type: Accident	

Administrative Information

Investigator-In-Charge (IIC)

John M. Brannen

Additional Persons Participating in This Accident/Incident Investigation:

Lorenzo Rodney
FAA-Detroit, Michigan - FSDO
Belleville, MI

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI95FA050	Aircraft Registration Number: N1QF
Occurrence Date: 12/01/1994	Most Critical Injury: Fatal
Occurrence Type: Accident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone
ANN ARBOR	MI	48105	1007	CST

Airport Proximity: Off Airport/Airstrip	Distance From Landing Facility:

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
Agusta	A109A II /A109A II	Helicopter

Revenue Sightseeing Flight: No **Air Medical Transport Flight:**

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

*** Note: NTSB investigators either traveled in support of this investigation or conducted a significant amount of investigative work without any travel, and used data obtained from various sources to prepare this aircraft accident report. ***

HISTORY OF FLIGHT

On December 1, 1994, about 1007 central standard time, an Agusta SPA A109A II, N1QF, operated by Metro Aviation, Inc., was destroyed when it collided with the terrain near Ann Arbor, Michigan. The commercial pilot and two passengers (medical evacuation crew members) were fatally injured. The 14 CFR Part 91 positioning flight departed the St. Joseph Hospital in visual meteorological conditions about 1003, en route to Howell, Michigan. The purpose of the flight was to pick up a patient at Howell, and return to St. Joseph's Hospital.

Prior to the morning of the accident N1QF was designated as the standby helicopter; however, the primary helicopter was scheduled for maintenance on the day of the accident, therefore essential equipment had to be moved from the primary craft to N1QF. Before the transfer could be accomplished, N1QF was required to prepare for dispatch on the accident flight. What was later described by a witness as a "hasty dispatch," necessitated a hurried departure to accomplish the transfer of equipment, complete a preflight,and other items necessary for a medical evacuation flight. The witness to the departure stated that a complete preflight was accomplished by the crew; although this witness did not actually have an opportunity to watch the entire preparation. The witness indicated that the start of the engines was "normal," with no delay in the engine start up. The flight departed at 1003.

At 1005 N1QF contacted the Ann Arbor, Federal Aviation Administration (FAA) Control Tower (ATCT), giving its position as one and one half miles east of St. Joseph's Hospital and requesting landing permission stating, in part, "I'd like to proceed inbound.. single engine landing, please." Six seconds later the flight was cleared into the class D surface area. Seven seconds later, N1QF responded stating, "Ah, disregard, I'm going down at this time." No additional information was transmitted, nor was the reason for the single engine landing stated. The pilot did not declare an emergency nor did he request assistance.

The pilot then contacted the dispatcher, at St. Joseph's Hospital and stated that he was going to land, "north of the university." The dispatcher requested the information be repeated and the pilot did so. There was no indication of any need for assistance, the nature of any emergency situation, nor was there any discussion of difficulties being experienced by the flight. Twenty-six seconds after the pilot's repeating the location to the dispatcher, he made a final transmission, indicating a crash was imminent.

Eyewitnesses observed the accident helicopter during the final few seconds of the flight. Two

Narrative (Continued)

witnesses stated that the helicopter was trailing smoke from the area of the engines. One witness indicted that the helicopter was maneuvering just prior to the impact and that during the final descent which he described as "dropped like a stone," it appeared the rotor blades were "not turning hardly at all." Witnesses reported that the helicopter was nearly silent just prior to ground impact and that there was no engine noise at all after impact.

OTHER DAMAGE

One small tree was damaged during the impact with the terrain.

PERSONAL INFORMATION

The pilot was born May 27, 1952, and was the holder of a commercial helicopter certificate number 2157108, with instrument helicopter privileges. At the time of the accident he had 5,000 hours flight time, with 3,500 hours of pilot in command time and 300 hours in the make and model of helicopter involved in the accident. He held a second class medical certificate issued June 9, 1994. His most recent biennial flight review was accomplished in an Agusta A109 on October 23, 1994.

AIRCRAFT INFORMATION

The helicopter was an Agusta SPA A109A II, serial number 7311, N1QF. The helicopter was maintained on an Approved Inspection Program. The most recent inspection occurred on June 13, 1994, with a total time in service of 1,870 hours. The helicopter had accumulated 57 hours since the inspection, at the time of the accident. The helicopter was last fueled on November 22, 1994.

WRECKAGE AND IMPACT INFORMATION

The helicopter impacted flat terrain in a commercial area, on a northeast heading. Ground scars and eyewitness reports indicated that the helicopter impacted in a near vertical direction with little forward motion. The landing gear was found in the extended (gear down) position. The helicopter was lying on its left side. The fuselage was crushed to about one-half the original height. The tail boom was partially separated from the fuselage from ground impact and impact with a small tree. Three of the main rotor blades were intact with little bending. The tail rotor assembly had impact damage only with no rotational damage evident. The main rotor head exhibited marks and damage consistent with blade coning impact.

The rotor system was inspected during the on scene phase of the investigation including the main and tail rotors, transmission and gearbox. No discrepancies were noted.

Both engines and the transmission exhibited little impact damage and were removed for further study. During the on-scene investigation both engines rotated and there was continuity throughout the gear train. No damage was visible in the output drive shafts on either engine. The fuel control pointer on the number 1 engine was at 30 degrees with the throttle handle at idle. The fuel control pointer on the number 2 engine was at 85 degrees with the throttle handle about mid-range. Fuel vacuum checks were done with engine number 1 having no leaks and engine number 2 having a leak traced to the fuel pump assembly.

MEDICAL AND PATHOLOGICAL INFORMATION

A post mortem examination of the pilot was conducted by the Washtenaw County (Michigan) Medical Examiner, on December 2, 1994. No contributing pre-existing pathology was found.

A toxicological examination of specimens from the pilot proved negative for those drugs screen.

Narrative (Continued)

TESTS AND RESEARCH

Fuel samples from the fueling source were found to be free of water and within limits for Jet-A1.

Fuel and oil samples from the helicopter were tested at the Allison lab and were found to be within limits for Jet-A1 fuel and MIL-L-23699E oil.

An examination of light bulb filaments revealed stretched filaments in the "Master Warning," "Master Caution," "Engine #1 Low RPM," "Engine #2 Low RPM." and "Low Rotor RPM" panels.

Both engines were test run at Allison on a production test stand on January 11, 1995. Number 1 engine was found to be within limits. Number 2 engine experienced excessive compressor vibration, therefore, the control components from that engine were tested on the number 1 engine which had been successfully run. The engine operation did not reach the limits falling about 2% below top limits.

The compressor for engine number 2 was disassembled and inspected. A visual inspection revealed unusual balance marks. The rotor was check balanced and it measured at 0.006 oz-in of unbalance. The limit should have been 0.001 oz-in. Although the exact mode of unbalance was not determined, experienced sources indicated that the unusual marks could not be associated with normal operation of the engine; however could be associated with impact artifact.

The individual components (originally) from engine number 2 were tested on October 11, 1995, and the fuel control was found to fall about 2% below the top limit. There was nothing found that would have prevented the engine from operating normally at the cruise setting.

Throughout the on-scene investigation and during the testing of components, nothing was found to indicate any reason that an engine should stop running inflight. Nothing was found in either engine to indicate an indication necessitating a need to manually shut down an engine inflight.

ADDITIONAL DATA/INFORMATION

Parties to the investigation were the FAA Flight Standards District Office, Belleville, Michigan; Agusta Aerospace Corporation, Philadelphia, Pennsylvania; Allison, Indianapolis, Indiana; Allied Signal Aerospace, South Bend, Indiana; and Metro Aviation Inc., Shreveport, Louisiana.

The helicopter wreckage was released to representatives of the owner on December 16, and December 22, 1994 and January 9, 1996.
Updated on Feb 2 2009 2:42PM

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI95FA050
Occurrence Date: 12/01/1994
Occurrence Type: Accident

Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
		Ft. MSL	0		

Runway Surface Type:

Runway Surface Condition:

Approach/Arrival Flown:

VFR Approach/Landing: Forced Landing

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
Agusta	A109A II /A109A II	7311

Airworthiness Certificate(s): Normal

Landing Gear Type: Retractable - Tricycle

Amateur Built Acft?	Number of Seats:	Certified Max Gross Wt.	Number of Engines:
No	4	5730 LBS	2

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Turbo Shaft	ALLISON	250-C20B	420 HP

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
AAIP	06/1994	57 Hours	1890 Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?/Type	ELT Operated?	ELT Aided in Locating Accident Site?
No		

Owner/Operator Information

Registered Aircraft Owner	Street Address		
AGUSTA AEROSPACE CORP.	3050 RED LION RD.		
	City	State	Zip Code
	PHILADELPHIA	PA	19114

Operator of Aircraft	Street Address		
METRO AVIATION, INC.	P. O. BOX 7008		
	City	State	Zip Code
	SHREVEPORT	LA	71137

Operator Does Business As: MIDWEST MED FLIGHT

Operator Designator Code: HDNA

- Type of U.S. Certificate(s) Held:

Air Carrier Operating Certificate(s): On-demand Air Taxi

Operating Certificate:

Operator Certificate:

Regulation Flight Conducted Under: Part 91: General Aviation

Type of Flight Operation Conducted: Positioning

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI95FA050
Occurrence Date: 12/01/1994
Occurrence Type: Accident

First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File	On File	42

Sex: M | Seat Occupied: Right | Occupational Pilot? Yes | Certificate Number: On File

Certificate(s): Commercial

Airplane Rating(s): None

Rotorcraft/Glider/LTA: Helicopter

Instrument Rating(s): Helicopter

Instructor Rating(s): None

Current Biennial Flight Review?

Medical Cert.: Class 2 | Medical Cert. Status: Valid Medical--no waivers/lim. | Date of Last Medical Exam: 06/1994

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	5000	300			500	150	160	5000		
Pilot In Command(PIC)	3500	300						3500		
Instructor										
Instruction Received										
Last 90 Days	32	32			11		3	32		
Last 30 Days	10	10			4		1	10		
Last 24 Hours	1	1					1	1		

Seatbelt Used? Yes | Shoulder Harness Used? Yes | Toxicology Performed? Yes | Second Pilot? No

Flight Plan/Itinerary

Type of Flight Plan Filed: Company VFR

Departure Point	State	Airport Identifier	Departure Time	Time Zone
Same as Accident/Incident Location		NONE	1003	EST

Destination	State	Airport Identifier
HOWELL	MI	NONE

Type of Clearance: None

Type of Airspace: Class D

Weather Information

Source of Wx Information:

No record of briefing

This space for binding

National Transportation Safety Board

FACTUAL REPORT

AVIATION

NTSB ID: CHI95FA050

Occurrence Date: 12/01/1994

Occurrence Type: Accident

Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
	0000		0 Ft. MSL	0 NM	0 Deg. Mag.

Sky/Lowest Cloud Condition: Unknown 0 Ft. AGL

Condition of Light: Day

Lowest Ceiling: Broken 12000 Ft. AGL

Visibility: 10 SM

Altimeter: "Hg

Temperature: -1 °C

Dew Point: °C

Weather Conditions at Accident Site: Visual Conditions

Wind Direction: 180

Wind Speed: 12

Wind Gusts: 16

Visibility (RVR): 0 Ft.

Visibility (RVV) 0 SM

Precip and/or Obscuration:

No Obscuration; No Precipitation

Accident Information

Aircraft Damage: Destroyed

Aircraft Fire: None

Aircraft Explosion None

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot	1				1
Second Pilot					
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants					
Other Crew					
Passengers	2				2
- TOTAL ABOARD -	3				3
Other Ground	0	0	0		0
- GRAND TOTAL -	3	0	0		3

NTSB ID:	CHI95FA050
Occurrence Date:	12/01/1994
Occurrence Type:	Accident

Administrative Information

Investigator-In-Charge (IIC)

STEPHEN A. WILSON

Additional Persons Participating in This Accident/Incident Investigation:

RICHARD G GASTRICH
BELLEVILLE, MI

PAOLO FERRERI
PHILADELPHIA, PA

SCOTT S SCHEURICH
INDIANAPOLIS, IN

MILTON K GELTZ
SHREVEPORT, LA

National Transportation Safety Board FACTUAL REPORT AVIATION	NTSB ID: CHI90FA003	Aircraft Registration Number: N9704J
	Occurrence Date: 10/07/1989	Most Critical Injury: Fatal
	Occurrence Type: Accident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone
ANN ARBOR	MI	48108	1201	EDT

Airport Proximity: On Airport/Airstrip | Distance From Landing Facility: 0

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
PIPER	PA-28-180 /PA-28-180	Airplane

Revenue Sightseeing Flight: No Air Medical Transport Flight: No

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

*** Note: NTSB investigators either traveled in support of this investigation or conducted a significant amount of investigative work without any travel, and used data obtained from various sources to prepare this aircraft accident report. ***

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI90FA003
Occurrence Date: 10/07/1989
Occurrence Type: Accident

Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
ANN ARBOR	ARB	839 Ft. MSL	24	3500	75

Runway Surface Type: Asphalt

Runway Surface Condition: Dry

Approach/Arrival Flown: NONE

VFR Approach/Landing: Full Stop; Traffic Pattern

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
PIPER	PA-28-180 /PA-28-180	28-3894

Airworthiness Certificate(s):

Landing Gear Type: Tricycle

Amateur Built Acft? No | Number of Seats: 4 | Certified Max Gross Wt. 2400 LBS | Number of Engines: 1

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Reciprocating	LYCOMING	O-360-A4A	180 HP

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
Unknown		0 Hours	Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?/Type Yes / | ELT Operated? Yes | ELT Aided in Locating Accident Site?

Owner/Operator Information

Registered Aircraft Owner	Street Address		
DAVID B. ESTEP	952 E. 163RD PLACE		
	City	State	Zip Code
	SOUTH HOLLAND	IL	60473

Operator of Aircraft	Street Address		
DAVID B. ESTEP	952 E. 163RD PLACE		
	City	State	Zip Code
	SOUTH HOLLAND	IL	60473

Operator Does Business As: | Operator Designator Code:

- Type of U.S. Certificate(s) Held: None

Air Carrier Operating Certificate(s):

Operating Certificate: | Operator Certificate:

Regulation Flight Conducted Under: Part 91: General Aviation

Type of Flight Operation Conducted: Personal

This space for binding

National Transportation Safety Board

FACTUAL REPORT AVIATION

NTSB ID: CHI90FA003

Occurrence Date: 10/07/1989

Occurrence Type: Accident

First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File		34

Sex: M | Seat Occupied: Unknown | Occupational Pilot? Unknown | Certificate Number: On File

Certificate(s): Private

Airplane Rating(s): Single-engine Land

Rotorcraft/Glider/LTA: None

Instrument Rating(s): None

Instructor Rating(s):

Current Biennial Flight Review?

Medical Cert.: Class 3 | Medical Cert. Status: Valid Medical--no waivers/lim. | Date of Last Medical Exam: 05/1989

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	72	7								
Pilot In Command(PIC)										
Instructor										
Instruction Received										
Last 90 Days										
Last 30 Days										
Last 24 Hours										

Seatbelt Used? Yes | Shoulder Harness Used? No | Toxicology Performed? Yes | Second Pilot? No

Flight Plan/Itinerary

Type of Flight Plan Filed: None

Departure Point	State	Airport Identifier	Departure Time	Time Zone
CHICAGO	IL	3HA	0900	CDT

Destination	State	Airport Identifier
Same as Accident/Incident Location		ARB

Type of Clearance: None

Type of Airspace:

Weather Information

Source of Wx Information:

Flight Service Station

National Transportation Safety Board
FACTUAL REPORT
AVIATION

NTSB ID: CHI90FA003
Occurrence Date: 10/07/1989
Occurrence Type: Accident

Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
ARB	1204	EDT	839 Ft. MSL	0 NM	0 Deg. Mag.

Sky/Lowest Cloud Condition: Unknown 0 Ft. AGL | Condition of Light: Day

Lowest Ceiling: Overcast 3000 Ft. AGL | Visibility: 20 SM | Altimeter: 30.00 "Hg

Temperature: -18 °C | Dew Point: -18 °C | Weather Conditions at Accident Site: Visual Conditions

Wind Direction: 300 | Wind Speed: 8 | Wind Gusts:

Visibility (RVR): 0 Ft. | Visibility (RVV) 0 SM

Precip and/or Obscuration:

Accident Information

Aircraft Damage: Destroyed | Aircraft Fire: None | Aircraft Explosion None

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot	1				1
Second Pilot					
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants					
Other Crew					
Passengers	2				2
- TOTAL ABOARD -	3				3
Other Ground	0	0	0		0
- GRAND TOTAL -	3	0	0		3

National Transportation Safety Board

FACTUAL REPORT

AVIATION

NTSB ID: CHI90FA003

Occurrence Date: 10/07/1989

Occurrence Type: Accident

Administrative Information

Investigator-In-Charge (IIC)

WILLIAM C. BRUCE

Additional Persons Participating in This Accident/Incident Investigation:

G. ERIKSON
WILLIAMSPORT, PA

J. CHADWELL
VERO BEACH, FL

R. JOHNSON

The Announcement Effect of an Airport Expansion on House Prices

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2 authors:

G. Donald Jud
University of North Carolina at Greensboro

Daniel T. Winkler
University of North Carolina at Greensboro

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The Announcement Effect of an Airport Expansion on Housing Prices

G. Donald Jud & Daniel T. Winkler

Abstract The purpose of this study is to examine the influence of the announcement of a new airport hub on housing prices near the airport. While numerous studies of airport noise have found that high noise levels reduce property values, few have been able to measure the announcement effect on values. The results indicate that after controlling to extraneous influences, housing property prices in a 2.5 mile band from the Greensboro/High Point/Winston Salem metropolitan airport declined approximately 9.2% in the post-announcement period. In the next 1.5-mile band, house prices declined approximately 5.7% in the post-announcement period.

Keywords Airport noise · Aircraft noise · Property values · Housing prices · Residential property

Introduction

Local economic development groups often look to improved air service as a way to quicken the pace of economic growth in their communities. This is especially true in areas where the pace of growth is perceived to be lagging. The Greensboro/High Point/Winston-Salem MSA (the Triad) is an eight-county area of central North Carolina that includes the cities of Greensboro, High Point, and Winston-Salem. The economy of the region has long been concentrated in apparel, furniture, textile, and tobacco manufacture. But by the mid-1990s, regional growth had begun to lag

G. D. Jud (✉) · D. T. Winkler
Bryan School of Business & Economics, University of North Carolina—Greensboro,
P.O. Box 26165(Greensboro, NC 27402-6165, USA
e-mail: juddon@uncg.edu

D. T. Winkler
e-mail: dt_winkler@uncg.edu

both state and national averages as the region's major industries faced stiffening international competition.

Local economic development groups sought a FedEx hub as a way to stimulate the region's economic growth. The new hub offered significant economic development benefits to the region. It was anticipated to initially employ 750 people, 250 full-time with an average salary of $34,000, and a longer-term goal of employing 1,500 people. In addition, the hub would bring state tax incentives for infrastructure improvements, and also attract additional businesses related to FedEx.

In April 1998, it was announced that Federal Express had decided to locate a regional air-cargo hub at the Piedmont-Triad International Airport (PTI). The hub would require an expansion of the current airport infrastructure by adding a third runway to the current airport. Newspaper reports at the time anticipated that the hub would begin operation in May 2004, with about 20 flights a night scheduled for landing and takeoff between 10 P.M. and 4:00 A.M. The number of flights was expected to expand to 126 per night by 2009.

Following the initial announcement, a widely reported public debate erupted between proponents who stressed the anticipated economic benefits on area employment and income and opponents who warned of the effects on noise, pollution, and congestion. A search using the *InfoTrac* database revealed a total of 508 news stories and 582 opinion and editorial pieces in the Greensboro *News & Record* relating to the FedEx hub between January 1998 and June 2004.[1] This paper examines the effect of the FedEx announcement on surrounding property values.[2] The first section reviews the literature on airport noise and property values. The second and third sections present the methodology and empirical model, respectively. The fourth section lays out the data and empirical results, and the final section reviews relevant findings.

[1] For the first several months, the news stories in the *News & Record* reported that six metropolitan airports were being considered for the FedEx hub. The final announcement that FedEx had chosen PTI occurred on April 13, 1998. In July 1998, the governor signed into law a multi-million dollar incentive package that included millions of dollars of tax breaks for FedEx. The first draft of the FAA environmental impact statement was released on April 6, 2000, which supported the FedEx proposal. In June 2000, the Environmental Protection Agency expressed a concern that the noise level estimates were underestimated, and state environmental regulators were concerned about damage to wetlands and wildlife habitats. During the months leading to the elections, opponents of the FedEx hub openly campaigned against politicians who supported FedEx; some politicians changed their position and some others lost the election because of their support for the hub. In November 2001, the FAA released its final impact study selecting the PTI hub as the preferred alternative of six options, and formally approved the project. However, delays in the approval process resulted in the target date for an operational hub being postponed until 2009; clearing and leveling of land began in 2004 with the expectation this phase being completed in early 2007.

[2] It is important to note that what we refer to as an announcement effect is actually a series of announcements that extends over multiple years (but well before the operation of the airport expansion). These announcements provide information to housing market participants who act on this information, resulting in adjustments to housing prices.

Literature Review

The relationship between airport noise and property prices has been examined for a number of cities in North America and Europe.[3] The results of many of the early studies have been summarized by Nelson (1980). All of the studies estimate hedonic price equations for residential property in which the level of noise is included among the attributes of the properties examined.

In order to compare the results of the studies, Nelson develops a Noise Depreciation Index (NDI), which measures the percentage decline in the price of housing for each unit increase in noise exposure. Nelson finds that the NDI averages 0.58 for the 18 airport studies he examines, that is, residential property values fall 0.58% for every decibel increase in airport noise.

More recent studies by Pennington, Topham, and Ward (1990) and Collins and Evans (1994) examine the relationship between noise and property values in Manchester, England. Pennington, Topham, Ward report no relationship between housing values and noise in Manchester during 1985–1986. Collins and Evans (1994) reexamine the Manchester data employed by Pennington, Topham, and Ward using a neural networks approach. They report that noise indeed does exert a strong, independent effect on residential values, which is negative. The effect of airport noise in the Manchester area has further been examined by Tomkins, Topham, Twomey, and Ward (1998) using 1992–1993 data. They estimate the noise discount at 0.84% per decibel.

Uyeno, Hamilton, and Briggs (1993) report a NDI of 0.68 using data for the Vancouver area in 1987. A unique feature of the Uyenro, Hamilton, and Briggs paper is the results reported for vacant land. They find the NDI is significantly higher for vacant land than for detached housing. Levesque (1994) explores the impact of noise in the area surrounding the Winnipeg airport during 1985–1986. He decomposes the effects of noise into two separate aspects: intensity and frequency. He reports that frequency is less important than loudness and the variability of the loudness during a single occurrence.

Other studies by Espey and Lopez (2000), Feitelson, Hurd, and Mudge (1996), and O'Byrne, Nelson, and Seneca (1985) explore the impact of airport noise in other metro areas, including Atlanta and the Reno-Tahoe area. While the studies employ different measures of airport noise, each reports significant noise discounts. However, Lipscomb (2003) finds that the change in noise level causes a negative but statistically insignificant change in the housing sales price for a small city located near Atlanta GA; the relatively small sample size might partially explain the insignificant noise effect.

McMillen (2004) estimates the noise discount applying to properties around Chicago's O'Hare airport. He measures noise using the annual energy mean sound level (L_{dn}), which has become the most common measure of noise for North

[3] Although our study does not directly measure the impact of a change in airport noise, noise is the primary reason cited in prior research that explains a negative impact on housing values. Therefore, we review the airport noise literature.

American airports. The L_{dn} statistic measures average sound levels over the course of a year, including a 10 dB penalty for nighttime. The FAA and HUD define areas exposed to L_{dn} levels of 65 or over as incompatible with residential housing. McMillen reports a 9.2% discount on homes selling in severe noise areas where L_{dn} levels are 65 or above.

Nelson (2004) conducts a meta-analysis of airport noise and property values. The study consists of 33 estimates of noise discount for 23 airports in Canada and the U.S., combining the findings of various prior studies. His results indicate that the noise discount is between 0.50 and 0.60 per decibel (dB). Properties would sell at about 10–12% less if located at 75 dB instead of 55 dB.[4]

Salvi (2003) applies a hedonic regression specified as a spatial error component model for single family housing data in the Zurich Switzerland airport area. He finds that airport noise decreases housing values by up to 4% for noise levels of 55 dB and under, and up to 27% for noise level of about 68 dB. Although spatial autocorrelation is found to exists, its effect on the estimated coefficients and their standard errors is minimal.

An Ex-ante versus Ex-post Housing Price Methodology

Our study differs from most prior research because if focuses on the *announcement* effect on property values of an airport expansion to accommodate an air cargo hub. We measure the change in the property values pre- and post-announcement of the airport expansion, but before the actual construction or operational use of the new airport facility.[5]

A potential problem with almost all airport noise studies is that they examine the effects of noise in an ex post dimension, that is, after the noise level has increased and property markets have had time to adjust. The problem with this approach is that after the fact, noise is very highly correlated with other aspects of the property market: air pollution, traffic congestion, and other neighborhood/location amenities. This is the point made by Pennington, Topham, and Ward in explanation of their insignificant findings for the Manchester area. They suggest that noise is inextricably bound up with other, more important neighborhood/location variables so that its effect cannot be reliably untangled using property data collected after the noise level has changed.

[4] The impact of noise on property values is non-linear; the audible irritation to humans from noise, as measured per decibel (dB),) is greater per dB increase at higher levels of noise than per dB increase at lower levels of noise. Theebe (2004) analyzed 160,000 transactions in the Western part of The Netherlands, and found very little impact of noise below 65 dB from trains, vehicular traffic, and airplanes on property values. However, the estimates were relatively large between 66 and 75 dB, especially for more expensive properties.

[5] During the period of study, the airport expansion was announced and studies of the environmental impact were conducted during the approval process. However, the actual airport expansion had not begun.

To overcome this problem, we propose an event study methodology.[6] Using this approach, we are able ex ante to study effects of the noise announcement. Because the announcement of a change in noise (both frequency and intensity) does not change the actual noise level, we are unable to directly examine the effect of a change in noise. Instead, we assume that the expectation of future noise brought about by the announcement is related to distance from the airport.[7] Thus, the announcement of a significant change in airport traffic (and noise) will affect the shape of value-distance gradient for properties surrounding the airport.[8]

Empirical Model

To examine the effect of the FedEx announcement on the value of surrounding residential property, we posit the following hedonic price model for property *i* at time *t*:

$$\ln P_{i,t} = a_0 + a_1 T_{i,t} + a_2 D_{i,t} + a_3 A_{i,t} + a_4 C_{i,t} + u_{i,t} \qquad (1)$$

where

$\ln P_{i,t}$	log of the real sales price (sales price adjusted by the consumer price index CPI-U),
$T_{i,t}$	time of sale,
$D_{i,t}$	a vector of distance bands,
$A_{i,t}$	a vector of housing property characteristics,
$C_{i,t}$	vector of city location variables,
$u_{i,t}$	a stochastic error term.

[6] The concept of event study methodology was coined in the finance literature as a method used to study the impact of new information (usually from an announcement) on stock prices. The methodology developed by Fama, Fisher, Jensen, and Roll (1969) used the market model in a pre-announcement period to estimate the regression parameters. In the subsequent announcement period, these parameters were used to provide regression residuals. A cumulative change in residuals indicated a significant announcement effect. Work by Brown and Warner (1980, 1985) tested variations of event study methodology. Karafiath (1988) demonstrates that the use of dummy variables for the days of the announcement period provides identical results to the use of the regression residuals. Burnett, Carroll, and Thistle (1995) offer a general methodology to correct for changes in market parameters.

[7] The final Record of Decision by the FAA was issued on 12-31-01. The noise impact estimates were provided in the report. A total of 178 people and 75 homes would be within the DNL 65 dBA noise contour without the expansion. With the expansion, 698 people and 262 homes would be within the contour. Of these, 126 people and 53 homes would be inside the 70dBA contour. Also, 549 people and 231 homes (of the 628 people and 262 homes) would experience an increase of DNL 1.5 dBA within the DNL 65 dBA (BThreshold of Significance'' for noise impacts). This information does not necessarily coincide with the distance bands used in this study, so it is not possible to meaningfully equate the dBA information to the findings our study. In addition, there have been revisions to the dBA impact and the contours since the report was issued.

[8] Because it does not use a measure of noise level, but instead, includes structural variables measuring distance bands (pre- and post-event) from the airport, this study measures the anticipated Bnet'' effect of the airport expansion. Although the principal concern of most communities that are considering an airport expansion is increased noise, other negative effects would include expected construction and traffic congestion, while anticipated longer-term advantages include more employment and shopping, as well as enhancement of roads and other infrastructure. Nonetheless, the literature on airport expansion points generally points to noise as the primary negative effect.

The coefficients of the variables are denoted by a_0, $a_1, ... a_4$. The distance variables include distance bands (in miles) from the airport (d) for $0 < d \leq 2.5$ and $2.5 < d \leq 4.0$. The distance bands capture the additional impact on property values of proximity to the airport.

The effect of the announcement on values is revealed by estimating Eq. 1 using data in the period prior to the FedEx announcement (1997–1998) and again with data following the announcement (1999:1–2004:2).[9] The effect of the announcement on property values is revealed by comparing the estimated coefficients on the distance variable. If $!_1$ is the coefficient on the distance variable estimated in the pre-announcement period and $+_1$ is the coefficient estimated for the post-announcement period, the effect of the FedEx announcement is $(+_1 - !_1)$. The test statistic for statistical significance is a Wald statistic for structural change with unequal subsample variances:

$$t = \left[(+_1 - !_1)^2 \Big/ \left(s_\lambda^2 + s_!^2 \right) \right]^{0.5} \qquad (2)$$

where s_λ and s_α are the standard errors of $+_1$ and $!_1$, respectively [Greene (1990), p. 189].[10]

Sample Data and Empirical Results

The Piedmont-Triad International Airport is located adjacent to I-40 about midway between the town limits of Greensboro and Kernersville, NC. Our sample is drawn from properties sold in Guilford and Forsyth Counties from January 1997 through June 2004 (see Fig. 1). The Forsyth County portion of the sample includes only the eastern portion of the county defined by zip code 27284, which subsumes the town of Kernersville. The sample includes 29,614 properties. Of the total sample, 8,957 were sold during 1997–1998, while 20,657 were sold from 1999:1–2004:2.

Table 1 shows the means and standard deviations for all variables in the sample. The sample sizes are 8,957 and 20,657 for the pre-announcement and post-announce-

[9] Although the announcement that FedEx chose the PTI Airport for its hub occurred in April 1998, we decided to separate the sample into the 1997:1–98:4 and 1999:1–2004:2 time frames for four reasons. First, several months of vociferous debates occurred, and there was sentiment suggesting that FedEx could have reversed its decision. It was clear that the FedEx hub had organized opposition who would be challenging a FedEx hub in court. Second, the sample used in this study consists of closing prices which can occur up to several months after making an offer on a property. Such new homebuyers could have made offers before the final announcement, or at least, without the knowledge of subsequent information. Third, while it would be possible to exclude altogether a portion of the latter observations occurring in the pre-event sample; a large sample is needed, and we wanted to minimize the influence of changes to area that were unrelated to FedEx hub announcement (which might occur by extending the pre-event sample using observations prior to 1997). Fourth, the inclusion of data in the Bpre-event'' period would work in favor of the null hypothesis that the FedEx announcement had no effect because some of the negative impact would be captured in the pre-event dummy distance band coefficients, making the difference in the pre- and post-event distance bands smaller.

[10] Although a dummy variable pre- and post-event could be introduced into Eq. 1, this specification would assume that the other coefficients would not change pre- and post-event. We find that this assumption is not true. Also, the use of Eq. 2 allows for variances of the pre- and post-sample to be statistically different.

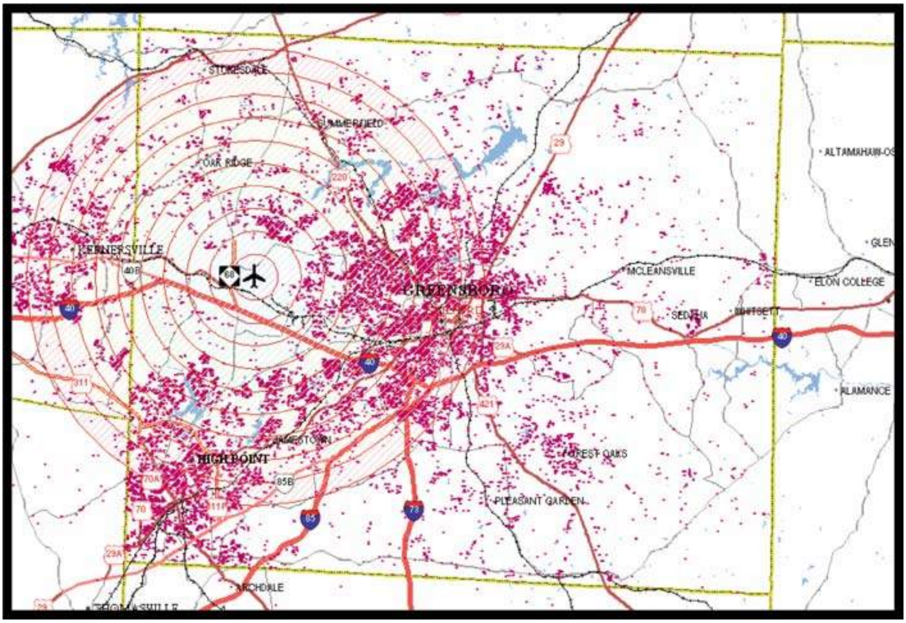

Fig. 1 Sales of single-family homes surrounding the Piedmont-Triad Airport, 1997.01–2004.06. The circular lines are placed one mile apart

Table 1 Means and standard deviations

Variable	Pre-announcement		Post-announcement		Total sample	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Event	–	–	–	–	0.6975	0.45933
Time	1.9983	0.5698	5.4949	1.5796	4.4373	2.1020
LE 2.5 miles	0.0255	0.1575	0.0292	0.1684	0.0281	0.1651
GT 2.5 & LE 4.0 miles	0.0568	0.2315	0.0555	0.2289	0.0559	0.2297
Ave. house value	124,266	29,592	125,279	28,870	124,972	29,094
Large lot	0.1384	0.3454	0.1927	0.3944	0.1763	0.3811
Fireplace	0.9221	0.5785	0.9427	0.5519	0.9365	0.5602
Bedrooms	3.3132	0.6976	3.3576	0.6862	3.3441	0.6899
Full baths	2.1345	0.9384	2.0157	0.7233	2.0517	0.7964
Half baths	0.5077	0.6413	0.5554	0.5462	0.5409	0.5770
Garage	1.2127	0.9407	1.304	0.9713	1.2764	0.9631
Stories	0.7951	1.0382	1.0305	1.0461	0.9593	1.0493
Age	20.3055	20.8458	20.0939	21.0518	20.1579	20.9896
New	0.1159	0.3201	0.0939	0.2917	0.1006	0.3008
Greensboro	0.5723	0.4948	0.5494	0.4976	0.5563	0.4968
High point	0.188	0.3907	0.1871	0.39	0.1873	0.3902
Kernersville	0.1074	0.3096	0.1269	0.3329	0.1210	0.3262
Log of sales price	11.2906	0.5889	11.359	0.5724	11.3383	0.5783
n	8,957		20,657		29,614	

ment periods.[11] Approximately 2.8% of the sample is within a 2.5-mile distance band of the airport, and 5.6% within the next 1.5 miles of the airport. For the pre-announcement sample, 228 properties are within 2.5 miles of the airport and 509 within the next 1.5 mile band. For the post-announcement sample, the numbers are 603 and 1,146 properties, respectively.

A least-squares estimation of Eq. 1 is shown in the Appendix. This model has adjusted R-squares of 0.62 for the pre-announcement period and 0.71 for the post-announcement period; the F-values are highly statistically significant. These results, however, have econometric problems including heteroscedasticity and spatial correlation.

Inferences based on least squares are biased in the presence of heteroscedasticity (Greene, 1990). White's (1980) general test indicates that the least squares estimator is not consistent, and therefore, heteroscedasticity is a problem.[12] An examination of the residuals indicates that the heteroscedastic disturbance is directly related to time of sale (*Time*). When error variances vary directly with an independent variable, Pindyck and Rubinfeld (1981) suggest a data transformation using weighted least squares.[13]

Spatial autocorrelation is a frequent problem associated with housing price data. Accordingly, it is important to identify the presence of spatial correlation and correct for it if necessary.[14] The simultaneous autoregressive (SAR) model is commonly used to correct for spatial correlation in hedonic pricing models.[15] In the SAR model, house prices are assumed to be dependent on surrounding house prices. In addition, however, the independent variables (property characteristics) are assumed to be correlated with housing characteristics of surrounding houses (Griffith, 1993).

---

[11] Testing for the difference in the pre- and post-event means, assuming they have unequal variances, all variables are statistically different at the 0.05 level except the means for the distance bands, age of the house, and dummy variable houses located in the city of High Point. This finding is not surprising given the very large sample size.

[12] The White statistic is 458.38 for the pre-announcement sample and 1,049.81 for the post-announcement sample. These statistics are $\#^2$ distributed, and are significant at the 0.0001 level.

[13] The weighted least squares procedure is based on the *Time* variable. Using this procedure, the original intercept becomes a variable term and the slope parameter associated with the of the *Time* variable becomes the new intercept term. For more details, see pp 145–146 of Pindyck and Rubinfeld (1981).

[14] Spatial autocorrelation occurs when similar values cluster in a geographical area. Similar to time series autocorrelation, positive spatial autocorrelation can be measured on a continuum from 0 to 1, with the latter associated with perfect positive spatial autocorrelation. A large positive spatial autocorrelation means that neighboring properties have similar values that are not independent of each other. The coefficients and standard errors are affected by spatial autocorrelation, and therefore, corrections are necessary to correct for it.

[15] The SAR model is appropriate in situations involving higher order spatial dependency (a stronger effect), whereas the conditional autoregressive model (CAR) assumes only a first-order dependency (Griffith, 1993). When compared to the simpler autoregressive response (AR) model, the SAR model does not assume the error terms to be independent of the dependent variable, leading to a complicated error term covariance matrix.

Table 2 Pre- and post-announcement spatial autoregressive model results

Variable	Pre-announcement		Post-announcement	
	Coefficient	*t*-value	Coefficient	*t*-value
Intercept	10.2762	149.95	10.4763	260.43
Time	0.0118	1.44	−0.0084	−5.81
LE 2.5 miles	−0.0024	−0.07	−0.0992	−5.84
GT 2.5 & LE 4.0 miles	−0.0272	−1.05	−0.0875	−6.78
Large lot	0.0392	4.89	0.0143	12.83
Fireplace	0.1860	23.00	0.1447	37.47
Bedrooms	0.1960	25.99	0.1281	36.60
Full baths	0.0524	11.58	0.1404	42.90
Half baths	0.0369	5.41	0.0862	21.59
Garage	0.1389	24.71	0.1136	45.79
Stories	0.0318	6.25	0.0366	15.43
Age	−0.0047	−16.53	−0.0047	−35.04
New	0.0239	1.54	0.0346	5.43
Greensboro	−0.0356	−1.86	−0.0031	−0.37
High point	−0.2108	−9.50	−0.1995	−19.68
Kernersville	−0.1377	−5.70	−0.1670	−15.26
n	8,957			20,657
SAR spatial parameter	0.4640	30.35	0.6530	75.32

The empirical findings for the SAR model using the transformed heterscedasticity-consistent variables are reported in Table 2.[16] The SAR estimates are based upon five nearest neighbors and a geometrically declining weight of 0.85 for the next nearest neighbor.[17] The findings suggest that spatial autocorrelation is relatively large and statistically significant in the pre- and post-event samples, increasing from 0.46 in the pre-announcement sample to 0.65 post announcement.

As shown in Table 2, the coefficients of the independent variables have the anticipated signs and magnitudes. The *Time* trend variable shows that the real value of houses increased 1.2% per year in the pre-announcement time period and decreased 0.84% per year in the post-announcement period. The negative price trend in the post-announcement period reflects the effects of the 2001 recession and the severe loss of textile, apparel, and furniture jobs on the economy of the Greensboro NC MSA.

In the pre-event time period, properties located near the airport (within 4.0 miles) sold for slightly lower prices, on average, than other more-distant properties. The coefficients of −0.24 and −2.72%, however, are not statistically significant. Properties within the city limits of High Point and Kernersville had lower prices compared to those outside the city limits of the towns.

[16] The SAR model was estimated using Statistics Toolbox 2.0 software (written by Kelley Pace and Ronald Barry) and Matlab 6.5.

[17] SAR models were tested with many variations including changes to the number of nearest neighbors as well as different geometrically declining weights. The findings are robust to the particular specification used. In addition, a Delaunay triangle spatial weight matrix was tested; the results reported here for five nearest neighbors indicate a slightly higher spatial correlation than using the Delaunay triangle spatial weight matrix.

Table 3 Test of pre- and post announcement distance variables.

Distance variable	SAR coefficient difference	SAR Wald *t*-test
LE 2.5 miles	−0.0968	2.4445
GT 2.5 & LE 4.0 miles	−0.0603	2.0764

While many of the amenity coefficients changed somewhat in the pre- and post-event equations, the number of bedrooms and bathrooms were the most notable. Bedrooms became significantly less important, while the number of full- and half-bathrooms became much more important, measured by the impact on selling price. As expected, the effect age on house price was negative. The age coefficients suggest that property values fall 0.5% per year.

Of particular interest in this study are the magnitudes of the coefficients on the distance bands in the pre- to the post-announcement periods.[18] Prior to the announcement, properties within 2.5 miles were subject to a 0.2% discount.[19] Following the announcement, these properties sold at a 9.4% discount, an increase of 9.2%. Properties that were more than 2.5 miles from the airport but no more than 4.0 miles from the airport had a 2.7% discount before the event and an 8.4% after the event; this difference is 5.7%.

The Wald *t*-tests in Table 3 provide a formal test for comparing the distance coefficients before and after the announcement period. The results of the Wald tests provide evidence that the FedEx announcement was associated with a significant negative impact on properties located within 2.5 miles of the airport. The difference in the regression coefficients denoting properties less than or equal to 2.5 miles from the airport is −0.0968, and this difference has a *t*-value of 2.45 which is statistically significant at the 0.01 level. The distance coefficient for $2.5 < d \leq 4.0$ indicates a difference of −0.0603 with a *t*-value of 2.08; this difference is statistically significant at the 0.05 level. These findings suggest a strong localized effect on housing values for properties located close to the airport.

Conclusion

This study examines the announcement effect on housing values of building an air-cargo hub in the Greensboro/High Point/Winston-Salem metropolitan area. The study differs from other studies of airport noise by focusing on the change in pre- versus post-announcement housing prices, prior to the actual construction and operation of the proposed airport hub. The methodology employed in this study is useful for city planners, real estate professionals and others who desire to measure the net effect on housing values of an airport expansion prior to actual construction.

[18] In addition to these distance bands, other bands were tested. The next 1.5 mile distance band (where $4.0 < d \leq 5.5$), for example, have relatively small but positive pre-and post-announcement coefficients, but the difference in the two coefficients was not statistically significant. Therefore, price declines beyond the 4-mile radius are relatively small and not statistically significant.

[19] The percentage impacts of a one-unit change in the distance dummy variables on sales price are given by $e^x - 1$, where x is the estimated coefficient on the particular dummy variable.

It has the advantage of measuring the change in housing prices *ex ante* instead of *ex post*. This is important because neighborhood and locational attributes often change substantially after an airport expansion is operational. Although noise level measurement is possible *ex post*, the net effect is very difficult to determine years later.

The results of the study indicate that even after controlling for housing, neighborhood, and locational characteristics, there is a 9.2% decrease in housing prices for properties located within 2.5 miles from the Greensboro Airport. A 5.7% decrease occurs for properties in the next 1.5-mile band surrounding the airport. With an average house price of $154,182 in the 2.5 mile band during the post-announcement period and a 9.2% discount, the average loss per house seller is $15,622 or about $9.42 million for the post-event sample. In the next 1.5-mile band (between 2.5 and 4 miles), the average house sold for $151,070, and an average loss of $9,131 per house seller was incurred or about $10.46 million in total during the post-event sample.

Although the event methodology used in this study differs from the NDI approach employed by Nelson (1980) and others, the discounts from the pre-announcement to the post-announcement period provide information about the estimated change in the level of noise. Nelson's (2004) finding of a 10–12% discount for properties located at 75 dB instead of 55 dB suggests that residents in the 2.5 mile radius at PTI International Airport are expecting an increase in noise levels of perhaps 15 dB or more. Using NDI measures from various studies ranging from 0.50 to 0.84% per decibel, a 9.2% decrease in housing prices suggests an increase in the noise level of 11 to 18 dB. For the next 1.5-mile band, the 5.7% decrease indicates a noise level increase of 7 to 11 dB.[20]

As with any event study methodology, even after resolving measurement problems, the announcement impact of the event is likely to differ from the actual. Therefore, one should not necessarily assume that the estimated discount for properties in the 2.5-mile band around the airport will continue to prevail once the air-cargo hub is operational. Changes to the infrastructure and unanticipated employment clusters, for example, together with lower or higher than expected noise levels and flight frequencies might propel properties prices in the 2.5-mile zone to sell at larger or smaller discounts than estimated here. Additional study of the actual impact of the air-cargo hub following construction and operation would be necessary to measure this change.

However, in the short-run, the findings of this study indicate that homeowners nearest an airport may have reason to be concerned that the announcement of an airport expansion will have a noticeable negative effect on housing prices. While the magnitude of the housing price decrease might change depending on the particular airport expansion plans and community in question, there is evidence that an announcement can have a detrimental impact on housing prices for properties nearest an airport, as property markets anticipate negative consequences to follow.

[20] Caution should be exercised when converting the distance band housing price changes to anticipated changes in the noise level because (1) the NDI measures are estimated using data from other airports with unique environmental characteristics, (2) the effect of a given increase in NDI changes depending on the initial level of noise, and (3) the band represents a radius around the airport which might not be uniform because of the projected landing patterns.

Appendix

Pre- and Post-Announcement OLS Regression Model Results

Variable	Pre-Announcement		Post-Announcement	
	Coefficient	*t*-value	Coefficient	*t*-value
Intercept	9.9502	343.99	10.0619	649.53
Time	0.0229	3.37	−0.0105	−7.58
LE 2.5 miles	−0.0108	−0.43	−0.1085	−8.36
GT 2.5 & LE 4.0 miles	−0.0532	−3.10	−0.0618	−6.42
Large lot	0.0862	6.94	0.0866	14.38
Fireplace	0.2351	31.12	0.2006	44.31
Bedrooms	0.2318	32.73	0.1461	34.68
Full baths	0.0708	15.23	0.2304	56.68
Half baths	0.0429	6.19	0.1300	25.27
Garage	0.1570	29.96	0.1413	49.42
Stories	0.0518	10.60	0.0325	11.13
Age	−0.0033	−14.04	−0.0028	−21.59
New	0.0450	3.42	0.0580	7.45
Greensboro	0.0061	0.46	0.0203	2.84
High point	−0.1736	−11.37	−0.1678	−20.44
Kernersville	−0.1239	−7.56	−0.1500	−17.78
n	8,957			20,657
Adjusted R^2	0.6165			0.7092
F-Value (Model)	960.91			3358.69

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PITTSFIELD CHARTER TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RES #09-23
RESOLUTION OPPOSING PROPOSED EXPANSION OF THE ANN ARBOR MUNICIPAL AIRPORT RUNWAY

MARCH 24, 2009

Minutes of a Regular Meeting of the Township Board of Pittsfield Charter Township, Washtenaw County, Michigan, held at the Township Administration Building located at 6201 W. Michigan Avenue, in said Township, on the 24th day of March, at 6:30 p.m.

Members Present: Grewal, Israel, Scribner, Ferguson, Hunt, Krone, Yi.
Members Absent: None.

The following preamble and resolution were offered by Member Scribner and supported by Member Ferguson.

WHEREAS, the Ann Arbor airport is under the jurisdiction of the City of Ann Arbor and operated by an independent Authority and the land is located within Pittsfield Charter Township immediately adjacent to a residential area; and

WHEREAS, the existing width and length has not posed any substantial safety concerns in the past with only five incidents of landing mishaps out of a total of 600,000 landings in the past eight years; and

WHEREAS, the proposed changes and expansion would shift the runway dangerously close to a busy township roadway (Lohr Road) and closer to dense residential subdivisions; and

WHEREAS, such a runway expansion will significantly increase air traffic volumes and noise pollution experienced by residential subdivisions in the vicinity of the Ann Arbor airport, thereby resulting in a decline of residential home property values; and

WHEREAS, the City of Ann Arbor has not fully demonstrated the economic and safety justifications for undertaking the proposed runway expansion; and

WHEREAS, the City of Ann Arbor appears to have not taken into consideration the negative safety implications such a runway expansion may impose on the surrounding residential subdivisions by expanding a runway closer to residential subdivisions

NOW THEREFORE BE IT RESOLVED, the Pittsfield Charter Township Board of Trustees urges the City of Ann Arbor to reconsider the merits of expanding the Ann Arbor Airport runway in light of the negative implications such an expansion would impose on the residents of Pittsfield Charter Township.

AYES: Grewal, Israel, Scribner, Ferguson, Hunt, Krone, Yi.
NAYS: None.
ABSENT: None.
ABSTAIN: None.

RESOLUTION DECLARED ADOPTED.

Alan Israel

Alan Israel, Clerk
Pittsfield Charter Township

DATED: March 24, 2009.

CERTIFICATE

I, Alan Israel hereby certify that the foregoing is a true and complete copy of a resolution adopted by the Township Board of Pittsfield Charter Township, County of Washtenaw, State of Michigan, at a Regular Meeting held on March 24, 2009, and that said meeting was conducted and public notice of said meeting was given pursuant to and in full compliance with the Open Meetings Act, being Act 267, Public Acts of Michigan, 1976, and that the minutes of said meeting were kept and will be or have been made available as required by said Act.

Alan Israel

Alan Israel, Clerk
Pittsfield Charter Township

DATED: March 24, 2009.

PITTSFIELD CHARTER TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RES #17-21
RESOLUTION OPPOSING PROPOSED EXTENSION OF THE ANN ARBOR MUNICIPAL AIRPORT RUNWAY

April 12, 2017

At a Regular Meeting of the Township Board of Pittsfield Charter Township, Washtenaw County, Michigan, held at the Township Administration Building located at 6201 W. Michigan Avenue, in said Township, on the 12th day of April, 2017 at 6:30 p.m.

Present: Grewal, Anzaldi, Scribner, Edwards-Brown, Jaffer, Krone, Ralph.
Absent: None.

The following preamble and resolution were offered by Treasurer Scribner, and supported by Trustee Ralph.

WHEREAS, the Pittsfield Township Board of Trustees first adopted a resolution opposing the proposed runway expansion/extension on March 24, 2009 that expressed concerns centered around safety and decline in property values (Resolution #09-23); and

WHEREAS, in the eight (8) years since the adoption of Resolution No. 09-23, Pittsfield Township has not only steadfastly opposed the runway extension, it has fostered a strong partnership with the Committee for Preserving Community Quality, established by Pittsfield Township residents also opposed to the runway extension at the Ann Arbor Municipal Airport; and

WHEREAS, it is readily apparent that any runway extension will increase the viability of passenger and commercial jet aircraft usage at the Ann Arbor Municipal Airport thereby not only significantly compromising public safety and property values but also increasing air pollution and potential groundwater contaminants and, furthermore, this extension will detract from the considerable monetary and community investments made in the last few years by Washtenaw County, Ann Arbor SPARK and others toward the revitalization of the east side of Washtenaw County, specifically in and around the Willow Run airport; and

WHEREAS, Pittsfield Township and the Committee for Preserving Community Quality have extensively and specifically documented (officially by way of responses to the Environment Assessments and otherwise) our reasons for opposing the runway extension, which include, but are not limited to: (1) planes landing to the East on an expanded runway just 93 feet over Pittsfield homes, posing danger to residents; (2) Ann Arbor has not justified a proper Purpose and Need for the expansion, and the minimum required operations for expansion have not been met; (3) the Environmental Assessments do not acknowledge the potential dangers resulting from the presence of large numbers of Canada geese surrounding the airport through much of the year; (4) the expansion would attract larger and heavier aircraft closer to the population center, likely in violation of the Pittsfield Noise Ordinance; (5) any pilot could land any type of plane – no matter how large -- at any time because it is a municipal airport funded with federal tax dollars; (6) and that these risks could pose dangers to the safety of water in wells located on airport property, for which the airport property was originally acquired almost a century ago for water rights, wells which provide drinking water to Ann Arbor and an aquifer that flows throughout Pittsfield Township; and

WHEREAS, the City of Ann Arbor has, despite the very significant safety and environmental concerns noted above, included the proposed runway extension in their capital improvement plan; and

WHEREAS, the second Environmental Assessment (conducted because of egregious flaws of the first one), that includes over 200 public comments with only seven (7) in support of the proposed extension, is currently in the review process by the Federal Aviation Administration; and

WHEREAS, the Pittsfield Township Board of Trustees wants to not only reiterate our continued and steadfast opposition to the runway expansion/extension, we want to expressly and officially request a test by the United States Environmental Protection Agency) (EPA) of the aquifer located at the Ann Arbor Municipal Airport, since the 2016 Ann Arbor Municipal Airport Draft Environmental does not report any water testing data; and

WHEREAS, the City of Ann Arbor has worked with the EPA to retroactively address water quality issues as related to the Dixoane Plume, Pittsfield Township would like to request the EPA to proactively address negative impacts to water quality (that is consumed by City of Ann Arbor and Pittsfield Township residents) that may result from the proposed extension of the runway at the Airport;

NOW THEREFORE BE IT RESOLVED, the Pittsfield Charter Township requests Congresswoman Debbie Dingell, State Senator Rebekah Warren, State Representative Adam Zemke and County Commissioner Felicia Brabec to advocate on this matter with the EPA and request that EPA conduct a test of the aquifer located at the Ann Arbor Municipal Airport; and

BE IT FURTHER RESOLVED that copies of this resolution shall be provided to Congresswoman Debbie Dingell, State Senator Rebekah Warren, State Representative Adam Zemke and County Commissioner Felicia Brabec, and City of Ann Arbor councilmembers.

ROLL CALL VOTE:

AYES: Grewal, Anzaldi, Scribner, Edwards-Brown, Jaffer, Krone, Ralph.
NAYS: None.
ABSENT: None.
ABSTAIN: None.

RESOLUTION DECLARED ADOPTED.

Mandy Grewal, Supervisor
Pittsfield Charter Township

DATED: April 13, 2017

CERTIFICATE

I, Michelle L. Anzaldi hereby certify that the foregoing is a true and complete copy of a resolution adopted by the Township Board of Pittsfield Charter Township, County of Washtenaw, State of Michigan, at a Regular Meeting held on April 12, 2017, and that said meeting was conducted and public notice of said meeting was given pursuant to and in full compliance with the Open Meetings Act, being Act 267, Public Acts of Michigan, 1976, and that the minutes of said meeting were kept and will be or have been made available as required by said Act.

Michelle L. Anzaldi

Michelle L. Anzaldi, Clerk
Pittsfield Charter Township

DATED: April 13, 2017

LODI TOWNSHIP
WASHTENAW COUNTY, MICHIGAN
RESOLUTION # 2009-009
A RESOLUTION OPPOSING PROPOSED RUNWAY EXPANSION OF THE ANN ARBOR MUNICIPAL AIRPORT

WHEREAS, the Ann Arbor airport is under the jurisdiction of the City of Ann Arbor and operated by an independent Authority and the land is located within Pittsfield Charter Township immediately adjacent to residential areas, including Lodi Township;

WHEREAS, the existing width and length of Runway 6-24 has not be posed any substantial safety concerns in the past with only five incidents of landing mishaps out of a total of 600,000 landings in the past eight years; and

WHEREAS, the proposed changes and expansion would shift the runway so that it ends a mere 700 yards from a busy roadway (Lohr Road) and closer to dense residential subdivisions; and

WHEREAS, such a runway will significantly accommodate larger and heavier aircraft, increase air traffic volumes, and increase noise pollution experienced by residential subdivisions in the vicinity of the Ann Arbor airport, thereby resulting in a decline in residential home property values; and

WHEREAS, the City of Ann Arbor has not fully demonstrated the economic and safety justifications for undertaking the proposed runway expansion; and

WHEREAS, the City of Ann Arbor appears to have not taken into consideration the negative safety implications such a runway expansion may impose on the surrounding residential subdivisions by expanding a runway closer to residential subdivisions;

NOW, THEREFORE BE IT RESOLVED, the Lodi Township Board of Trustees urge the City of Ann Arbor to reconsider the merits of expanding the Ann Arbor Airport runway in light of the negative implications such an expansion would impose on the residents of Lodi Township.

ROLL CALL VOTE:
Ayes: Masters, Staebler, Lindemann, Canham, Foley, and Godek.
Nays: Rentschler.
Absent: None.
Abstain: None.

RESOLUTION DECLARED ADOPTED

____
Elaine Masters, Clerk, Lodi Township
DATED: May 12, 2009

DOT/FAA/TC-21/4

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Analysis of the Neighborhood Environmental Survey

February 2021

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

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7. Author(s)
[1]Miller, Nicholas P.; Czech, Joseph J.; Hellauer, Kurt M.; Nicholas, Bradley L.;

[2]Lohr, Sharon; Jodts, Eric; Broene, Pam; Morganstein, David; Kali, Jennifer; Zhu, Xiaoshu; Cantor, David; Hudnall, Jeannie; Melia, Karen

8. Performing Organization Report No.
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9. Performing Organization Name and Address
[1]Harris Miller Miller & Hanson Inc.
d/b/a HMMH Inc.
700 District Avenue, Suite 800
Burlington, MA 01803

[2]Westat Inc.
1600 Research Blvd.
Rockville, MD 20850

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15. Supplementary Notes
Please Contact FAA-APL-AEE-100 Noise Division Manager, Donald Scata for further information on this study.

16. Abstract
The Federal Aviation Administration (FAA) has undertaken a multi-year research effort to quantify the impacts of aircraft noise exposure on communities around commercial service airports in the United States (US). The goal of this research effort was to develop an updated and nationally representative civil aircraft dose-response curve, quantifying the relationship between aircraft noise exposure and community annoyance. To characterize this relationship, the research team designed and conducted the Neighborhood Environmental Survey (NES), which collected information from a statistically representative number of adult residents living around a balanced sample of 20 US. Airports — objectively chosen to reflect the nation as a whole. From the survey data, a national dose-response curve was derived that describes the relationship between aircraft noise exposure [in terms of Day-Night Average Sound Level (DNL)] and the percentage of individuals reported as being highly annoyed by aircraft noise.

Aircraft noise exposure levels were modeled using the FAA Integrated Noise Model (INM), version 7.0d; based on 12-month sets of aircraft flight tracking data collected between 2012 and 2014 for each NES airport. Community response data was collected through a mail survey questionnaire, designed to follow the recommendations of the International Commission on the Biological Effects of Noise (ICBEN) (Fields et al. 2001), requesting respondents to rank on a scale from 1 to 5 (with 5 being most): "*Thinking about the last 12 months or so, when you are here at home, how much does [noise from aircraft] bother, disturb or annoy you?*" Responses of either 4 or 5 where then considered as "highly annoyed."

Just over 10,000 people completed and returned the mail questionnaire (resulting in a response rate of 40 percent); administered in six separate "waves" over a 12-month period beginning in October 2015. Logistic regression analysis of the "highly-annoyed" responses from the mail questionnaire and their associated aircraft noise exposure levels were used to generate the national dose-response curve. The percentage of those surveyed who were highly annoyed by aircraft noise increased monotonically with increasing noise exposure. In comparison to prior studies on this topic, the NES's national curve shows substantially more people highly annoyed for a given DNL aircraft noise exposure level.

17. Key Words	18. Distribution Statement
Aircraft noise, Annoyance, Dose-Response, Schultz Curve, National Curve, Day-Night Level, DNL, Logistic regression	This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
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Errata

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Analysis of the Neighborhood Environmental Survey

January 2021
Final Report

Page replaced	Change made
23	Table 6-1, footnote superscripts made visible/corrected.
E-16 (Appendix E)	Figure E-1 replaced.
E-17 (Appendix E)	Figure E-2 replaced.

Released February 23, 2021

Analysis of the Neighborhood Environmental Survey

Volume 1 of 4

Contracts DTFACT-15-D-00008 and DTFACT-15-D-00007

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Prepared for:

Federal Aviation Administration
William J. Hughes Technical Center
4th Floor, M26
Atlantic City International Airport
Atlantic City, NJ 08405

Prepared by:

Nicholas P. Miller
Joseph J. Czech
Kurt M. Hellauer
Bradley L. Nicholas

HMMH
700 District Avenue, Suite 800
Burlington, MA 01803
(781) 229-0707

Sharon Lohr
Eric Jodts
Pam Broene
David Morganstein
Jennifer Kali
Xiaoshu Zhu
David Cantor
Jeannie Hudnall
Karen Melia

Westat
1600 Research Boulevard
Rockville, Maryland 20850
(301) 251-1500

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List of Acronyms and Abbreviations

Acronym*	Definition
AAPOR	American Association for Public Opinion Research
ACE	Central Region
ACRP	Airport Cooperative Research Program
ACS	American Community Survey
AEA	Eastern Region
AEDT	Aviation Environmental Design Tool
AEE	FAA's Office of Environment and Energy
AFE	Above Field Elevation
AGL	Above Ground Level (altitude) or Great Lakes Region
ANE	New England Region
ANM	Northwest Mountain Region
ARTCC	Air Route Traffic Control Center
ASNA	Aviation Safety and Noise Abatement Act
ASO	Southern Region
ASW	Southwest Region
ATADS	Air Traffic Activity Data System
ATCT	Air Traffic Control Tower
AWP	Western Pacific Region
BTS	Bureau of Transportation Statistics
CART	Categorization and Regression Tree
CATI	Computer-Assisted Telephone Interviewing
CDD	Cooling Degree Days
CDSF	Computerized Delivery Sequence File
CFR	Code of Federal Regulations
CI	Confidence Interval
CSV	Comma-separated Value
CTL	Community Tolerance Level
dB	Decibel, A-weighted
DM	Data Management
DNL	Day-Night Average Sound Level
EO	Executive Order
EFA	Exploratory Factor Analysis
EPA	Environmental Protection Agency
ETMS	Enhanced Traffic Management System
F or °F	Fahrenheit
FAA	Federal Aviation Administration
FAQ	Frequently Asked Question
FICAN	Federal Interagency Committee on Aviation Noise
FICON	Federal Interagency Committee on Noise
FWA	Federalwide Assurance
GPS	Global Positioning System

Acronym*	Definition
GSSD	Global System for Sustainable Development
HA	Highly Annoyed
HDD	Heating Degree Days
HMMH	Harris Miller Miller & Hanson Inc.
ICR	Information Collection Request
Intl	International
ICBEN	International Commission on Biological Effects of Noise
IFR	Instrument Flight Rules
INM	Integrated Noise Model
IRB	Institutional Review Board
ISO	International Organization for Standardization
L_{max}	Maximum A-weighted Sound Level
LMS	Learning Management System
MSL	Mean Sea Level
NA	Number of Events (at or) Above a Specified (single-event) Sound Level
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NEPA	National Environmental Policy Act
NES	Neighborhood Environmental Survey
NM or nm	Nautical Miles
NOAA	National Oceanic and Atmospheric Administration
NOP	National Offload Program
OHRP	Office for Human Research Protection
OMB	Office of Management and Budget
PAF	Principle Axis Factoring
Percent HA	Percent Highly Annoyed
PDARS	Performance Data Analysis and Reporting System
PII	Personally Identifiable Information
PND	Postal Non-Deliverable
PO	Post Office
PRA	Paperwork Reduction Act
PUF	Public Use File
QC	Quality Control
RNAV	Area Navigation
RNP	Required Navigation Performance
RR1	Response Rate 1
RR2	Response Rate 2
RSS	Residual Sum of Squares
RUF	Restricted Use File
SEL	Sound Exposure Level
SID	Standard Instrument Departure
SQL	Structured Query Language
STAR	Standard Terminal Arrival Route

Acronym*	Definition
TCH	Arrival Threshold Crossing Height
TFMS	Traffic Flow Management System
TFMSC	Traffic Flow Management System Counts
TNO	Netherlands Organisation for Applied Scientific Research
TOW	Takeoff Weight
TRACON	Terminal Radar Approach Control Facility
TRC	Telephone Research Center
VFR	Visual Flight Rules
US	United States
USGS	United States Geological Survey
USPS	United States Postal Service
UTC	Coordinated Universal Time
WBAN	Weather Bureau Army Navy

*See Table 3-1 for airport abbreviations.

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Executive Summary

The Federal Aviation Administration (FAA) has undertaken a multi-year research effort to quantify the impacts of aircraft noise exposure on communities around commercial service airports in the United States (US). Community annoyance is the impact of interest covered by this report. Researchers typically determine an individual's annoyance to noise through sociological surveys that measure subjective reactions to cumulative noise exposure. To be a scientifically valid evaluation of aircraft noise, the survey and resulting analysis should query respondents experiencing a wide range of noise exposure from airports with variations in aircraft operations using an identical methodology (i.e., survey timeframe, survey instruments, and survey focus). Such efforts typically provide a dose-response curve that pairs the surveyed annoyance of many individuals to their noise exposure.

The Federal Interagency Committee on Noise (FICON) performed the most recent in-depth US Government agency review of human annoyance to noise in 1992. The dose-response curve that FICON developed in 1992 confirmed the appropriateness of Federal policy at that time. The FICON curve suggests that 12.3 percent of persons are "highly annoyed" by a Day-Night Average Sound Level (DNL) of 65 dB (FICON 1992). Research published in the two decades since the release of the FICON report suggests the FICON curve might under-estimate annoyance due to aircraft noise exposure. More recent dose-response curves from data collected outside the US have shown increased levels of annoyance at a given noise exposure level; further, the FICON curve included multiple modes of transportation, not just aircraft.

The overall goal of this research effort was to produce an updated and nationally representative civil aircraft dose-response curve for the US. To meet this goal, the research team designed and conducted a national survey, known as the Neighborhood Environmental Survey,[1] with an appropriate number of residents around an objectively selected sample of airports in the US. This report provides details on the Neighborhood Environmental Survey as well as an analysis of the mail questionnaire administered as a part of the Neighborhood Environmental Survey. The result of this effort is an update to the scientific evidence on the relationship between aircraft noise exposure and the annoyance of individuals living in airport communities.

The number of airports, and the mail survey sample size for each airport, were selected to provide an accurate estimation of the dose-response curve describing the relationship between annoyance (in terms of percent highly annoyed) and aircraft noise exposure. With criteria specified by the FAA, a multi-stage and statistically rigorous process was used to select a representative sample of US airports. Eligibility criteria were established to define a sampling frame consisting of airports in the contiguous US with at least 100 annual average daily jet operations, at least 100 people exposed to DNL greater than or equal to 65 dB, and at least 100 people exposed to DNL between 60 dB and 65 dB. Applying the eligibility criteria to all airports in the contiguous US resulted in a sampling frame of 95 airports. A subset of 20 airports was selected from the 95-airport set using a balanced sampling approach on a set of FAA-chosen factors. The Federal Interagency Committee on Aviation Noise (FICAN) reviewed the methods used to select the 20 surveyed airports and stated, "the balanced sampling methodology that was employed is the correct choice given the purpose of the study and the number and range of airports available for selection" (FICAN 2013).

The national survey utilized multiple independent reviews of the employed methods as well as a pilot study. Airport Cooperative Research Program (ACRP) Project 02-35 (Miller et al. 2014a) was a pilot study that enabled real-world testing of the methods used in the national survey. In addition to the FICAN review of the national survey's methodology, external review groups examined the methods underlying the data collection and analysis process and the resulting data. These reviews took place at three separate points during the ACRP study and during this research effort. Further, the statistical analysis methodologies were approved by the Bureau of

[1] Although the survey issued to respondents was titled the "Neighborhood Environment Survey", the official title as recorded by the Federal Office of Management and Budget (OMB) is the "Neighborhood Environmental Survey", i.e., "environmental" instead of 'environment'. The official OMB record of the survey can be found under OMB Control Number: 2120-0762 at: https://www.reginfo.gov/public/do/PRAViewICR?ref_nbr=201409-2120-002.

Transportation Statistics (BTS) and data collection was approved the Office of Management and Budget (OMB). Finally, an Institutional Review Board also reviewed all the methodologies used in conducting the national survey.

The research team used the FAA Integrated Noise Model (INM), version 7.0d, to compute the aircraft noise exposure for the 20 airports selected for the national survey.[2] The computations used a twelve-month sample of radar flight tracks and associated flight specific information, (e.g., aircraft type, time of operation, distance flown). DNL contours were computed for each airport based on operational data spanning June 2012 to May 2013 [November 2013 to October 2014 for Chicago O'Hare International Airport (ORD)]. The noise contours were used by the research team to stratify residential locations around each airport into groups based on DNL ranges. Five DNL strata were developed based on contour lines of DNL 50, 55, 60, 65 and 70 dB. The DNL values ultimately paired with the survey responses to create the dose response curve were computed for each respondent location by adjusting for the calendar year 2015 operations counts from the FAA's Air Traffic Activity Data System (ATADS). The radar flight tracking data analysis for the 2012-2013 period (the 2013-2014 period for ORD) was applied to the modeling for 2015.

Two survey instruments were administered to adult residents within the Neighborhood Environmental Survey: a mail questionnaire and a follow-up telephone interview for the mail respondents. A previous test survey of populations around three US airports, conducted by the research team through the ACRP Project 02-35, was used to inform the survey methods used here. The ACRP Project 02-35 results indicated that the response rate for the mail survey was greater and the cost was less than a phone survey. While the ACRP 02-35 results were inconclusive in determining if the mail survey data was significantly different from the telephone survey data, the mail survey was chosen to maximize the number of responses that could be attained for the funding available for the overall effort. The Neighborhood Environmental Survey's resultant national dose-response curve was based solely on the annoyance responses from the mail survey. The mail survey was administered to the individuals in the selected airport communities in six separate "waves" over a 12-month period starting in October 2015. The use of a 12-month period ensured seasonal effects did not influence the resulting dose-response curve.

All mail survey respondents were invited to complete a follow-up telephone interview, which asked detailed questions on several areas including respondents' opinions on noise, exposure to aircraft noise, relationship to the airport, concerns about aircraft operations, views on airport community relations, among others. The telephone survey data could aide in understanding why some people are highly annoyed by aircraft noise at a particular noise exposure while others at the same noise exposure are not; further, the information may help explain differences in annoyance responses among airports. The detailed questions used for the phone questionnaire were not appropriate for the mail questionnaire because the subject matter would have disclosed the purpose of the survey and potentially biased responses to the aircraft annoyance question. The phone survey data was not used to calculate the national dose-response curve as all responding households were already represented in the mail survey.

The mail questionnaire followed the recommendations of the International Commission on the Biological Effects of Noise (ICBEN) (Fields et al. 2001) and used a single question that read: "Thinking about the last 12 months or so, when you are here at home, how much does [noise from aircraft] bother, disturb or annoy you?" This primary question was embedded among 13 other questions on various sources of noise and other aspects of the respondent's community to mask the purpose of the survey and minimize potential response bias. Consistent with ICBEN recommendations, the respondent was given choices of "not at all," "slightly," "moderately," "very," or "extremely." A respondent was identified to be 'highly annoyed' if they answered either of the latter two choices. Over 10,000 people responded and completed the mail questionnaire – a response rate of 40 percent. Bias checks were conducted during and after the data collection and none was detected.

[2] Although INM was superseded in 2015 by the FAA's Aviation Environmental Design Tool (AEDT), the initial phases of this project had started prior to 2015. Further, INM had been used to select the respondents. The use of INM was maintained for consistency throughout the project.

Analysis of the 'highly annoyed' responses and the associated DNL was used to generate dose-response curves for each individual airport and a national dose-response curve. The analysis used the same form of the logistic regression model used by FICON in 1992, not only for historic consistency but because it was found to require the fewest assumptions, offer the greatest flexibility, and provide a good fit[3] to the observed data. The research team deemed the choice of logistic regression the most appropriate, compared to other curve fitting techniques. The national curve is applicable in the range of DNL 50 dB to DNL 75 dB; however, caution should be exercised in predicting annoyance for DNL greater than 70 dB, due to the relative lack of respondents at these exposure levels.

The dose-response curve created from the mail questionnaire shows considerably more people are highly annoyed by aircraft noise at a given noise exposure level compared to historical FICON data. In general, between 9 and 22 percent of those surveyed for the Neighborhood Environmental Survey were highly annoyed by the various items listed in the mail questionnaire. However, 42 percent of the respondents were highly annoyed by aviation noise (at any DNL). The percentage of those surveyed who were highly annoyed by aircraft noise increased monotonically with increasing noise exposure. The national dose-response curve shows that nearly two-thirds of people are highly annoyed at DNL 65 dB. The national dose-response curve also has a greater percent highly annoyed for a given noise exposure than recent European standards from the Netherlands Organization for Applied Scientific Research (TNO, see Janssen and Voss, 2011) and the International Organization for Standardization (ISO) (2016). While the national dose-response curve shows more people being highly annoyed at a given noise exposure level than the historical FICON data or more recent international standards, it is similar to results obtained in Europe since 2000. Caution should be exercised when comparing the national dose-response curve to the TNO and ISO standards, as the national curve provides the community response for a recent time frame whereas the TNO and ISO standards incorporate survey data taken over the last 50 years. As previously mentioned, the FICON data, which is included in the newer European standards, shows a lower level of percent highly annoyed for a given noise exposure. Differences between the national curve and the dose-response curves taken previously could be due to changes in people's attitudes toward noise; changes in the nature of the noise exposure; differences in the cultures of those being surveyed; differences in study design, implementation, or measurement; or a combination of these factors.

This report also presents several additional analyses to explore the heterogeneity of the individual airport relationships. The six factors analyzed were climate, three flight event characteristics, race/ethnicity, and income.[4] The 'Noticeable' flight event characteristic, (i.e., the number of events having a maximum sound level at or above 50 dB, $NA50L_{max}$), demonstrated marginal significance and should be investigated further because of the high correlation of $NA50L_{max}$ with DNL. None of the other five factors showed a statistically significant relationship with percent highly annoyed after accounting for the noise exposure as measured by DNL.

Overall, this research effort accomplished its goal, as it provides an updated and nationally representative dose-response curve of civil aircraft noise exposure and community annoyance for the US.

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[3] "Fitting" or "fit" refers to the process whereby statistical techniques are used to produce a curve that best represents or "fits" the underlying data.

[4] Climate was characterized in terms of "degree days." The three flight event characteristics were (1) whether the aircraft was 'visible' at its point of closest approach to the respondent, (2) whether an event was 'noticeable' (related to the event's maximum sound level), and (3) the aircraft noise event's 'relative importance' (whether the event's DNL was part of the hierarchical list of events which contributed all but 1 dB of the respondent's total DNL). Income was characterized by percentage of population below the poverty level. For race/ethnicity, each respondent was characterized as minority (Hispanic, black or African American, American Indian, or Alaska Native, Asian, or Native Hawaiian or Other Pacific Islander) or nonminority (white non-Hispanic).

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1 Introduction

Research published by Schultz (1978) informs several aspects of aviation noise policy in the United States (US). This includes land-use compatibility guidelines around airports and the factors that determine noise mitigation funding. Schultz developed a correlation between transportation noise exposure levels in terms of a relatively large range of Day-Night Average Sound Levels (DNL) and the percent of the population highly annoyed (the so-called "Schultz curve") using social surveys on noise annoyance conducted in the 1960s and 1970s from a variety of countries. Not only is Schultz's work 40 years old, but the research also included multi-modal transportation (air, rail, and road) and was conducted at a time when aircraft operations were louder and less frequent.

Through the Aviation Safety and Noise Abatement Act (ASNA) of 1979, Congress directed the Federal Aviation Administration (FAA) to establish a single metric for assessing land use compatibility with respect to noise from aircraft operations, and to establish standards and methods for assessing the noise environment associated with ongoing aircraft operations near airports. In 1981, the FAA implemented the ASNA provisions; these are published at 14 Code of Federal Regulations (CFR), Part 150 ("Part 150")[5]. This regulation adopted the DNL metric, established land use compatibility guidelines for aircraft noise, specifying 65 A-weighted decibels (dB) of DNL as a threshold of noncompatibility for certain land uses, including residential, and established standardized methods for assessing the noise environment (FAA 2007). Currently, the FAA uses DNL 65 dB to support a variety of policy objectives, including assessment, identification, and mitigation of noncompatible land uses in the vicinity of civil airports, and evaluation of environmental consequences, (i.e., changes to the noise setting), that would occur if changes to aircraft operations or airfield infrastructure near an airport were implemented.

In 1992, the Federal Interagency Committee on Noise (FICON) compared Schultz's polynomial curve fit[6] with a logistic regression curve fit of 400 points, consisting of Schultz's 161 points plus 239 additional points. FICON arrived at a curve with very similar shape within the range of commonly encountered aviation noise (FICON 1992). Equation (1.1) is the general expression for the logistic regression model used by FICON relating DNL to percentage "highly annoyed" (percent HA). FICON's curve, Equation (1.2), has β_0=-11.13 and β_1=0.141 and DNL is expressed in dB.

$$\text{Percent HA} = \frac{100\ \exp(\beta_0 + \beta_1 DNL)}{1 + \exp(\beta_0 + \beta_1 DNL)}. \tag{1.1}$$

$$\text{Percent HA}_{\text{FICON 1992}} = \frac{100\ \exp(-11.13 + 0.141\ DNL)}{1 + \exp(-11.13 + 0.141\ DNL)}. \tag{1.2}$$

From the FICON curve, a DNL of 65 dB corresponds to 12.3 percent of people being highly annoyed. FICON also re-evaluated the use of DNL as the primary descriptor for long-term noise exposure of civil and military aircraft operations, and the particular level of DNL 65 dB, and recommended its continued use for the purpose outlined in the ASNA. Note that several researchers, including Schultz, suggested that DNL 65 dB was the practical, feasible threshold for acceptable noise exposure in residential areas (EPA 1974). The FICON effort was the last in-depth government agency review on the metric and measure. FICON re-affirmed Schultz's work, yet stated, "This work is continuing and may provide a basis for an improved understanding of community response to noise."

[5] 14 CFR Part 150 was first promulgated as an Interim Rule at 46 Federal Register (FR) 8316 on January 19, 1981. The Final Rule was published at 49 FR 49260. Subsequent clerical and substantive amendments have occurred in the intervening years, the most recent of which was published at 72 FR 68475 in 2007.

[6] "Fitting" or "fit" refers to the process whereby statistical techniques are used to produce a curve that best represents or "fits" the underlying data.

Before this research effort, the largest systematic scientific study of multiple airports in the US was conducted between 1967 and 1971 at nine airports, the so-called "Tracor" study in 1973 (Connor and Patterson 1973); which found substantial differences among human responses. More recent surveys of airport communities have been conducted largely on a case-by-case basis; survey results published through 2008 are cataloged (Fields 1991; Bassarab, Sharp, and Robinette 2009). A number of these surveys were performed to evaluate the effects of specific events such as runway repairs or noise abatement procedures (Fidell et al. 1985). Other surveys of airport communities were summarized in 2011 (Fidell et al. 2011). Recent studies in the US and in Europe suggest that the attitude towards noise may have changed with time (Janssen et al. 2011; Groothius-Oudshoorn and Miedema 2006; Miedema and Vos 1998; Fidell and Silvati 2004). In addition, continued negative public reactions to aircraft noise at exposures less than DNL 65 dB suggest that a re-examination of the dose-response relationship is appropriate.

Noise is often the most immediately objectionable community effect of aviation and one that the FAA continues to investigate ways to address. Therefore, it is crucial to the FAA to collect updated community annoyance data for US airports. An updated dose-response curve would also provide FAA the scientific background to make informed decisions regarding aviation noise.

The overall goal of this research effort was to produce an updated and nationally representative dose-response curve that quantifies the relationship of peoples' surveyed annoyance response to aircraft produced noise exposure in the US. The study surveyed people living near 20 airports in the contiguous US regarding their annoyance with aircraft noise – the Neighborhood Environmental[7] Survey (NES). By combining survey results with modeled aircraft noise exposures in terms of DNL at each respondent's location, the outcome of the NES permits derivation of a nationally applicable dose-response relationship between aircraft noise and annoyance. This relationship is conceptually similar to the "Schultz Curve." Additional information collected through the surveys may also provide information about underlying causes of annoyance, such as climate or attitudes toward the airport.

Historical surveys on aircraft annoyance (e.g., Schultz and others) were primarily administered by telephone. Technological and respondent behavior changes in recent years has become a concern as survey response rates for telephone surveys have dropped considerably, increasing the potential for bias. Concurrently, address-based sampling with high coverage of the US population has become viable through the commercial availability of US Postal Service data, such that mail survey response rates today are substantially higher than telephone survey response rates. In order to determine the best mode for this research, a test survey of populations around three US airports in Airport Cooperative Research Program (ACRP) Project 02-35 (Miller et al. 2014a) was conducted. ACRP Project 02-35 is hereafter referred to as "ACRP 02-35" or "the ACRP 02-35 study". ARCP 02-35 indicated that the response rate for the mail survey was three times greater than the telephone survey and at lower cost. Due to the study's small sample size, it was not possible to be fully conclusive, but the ACRP study did not indicate that there were statistically different annoyance responses between the mail and telephone surveys. Additionally, web and in-person methodologies were considered but ruled out due to viability and cost concerns, respectively. Therefore, the NES's resultant national dose-response curve was based solely on a mail survey.

This report documents the major technical components of the survey:

- Development of the survey instruments (Section 2),
- The statistical process of selecting the 20 airports from the relevant population (sampling frame) of US airports (Section 3),

[7] Although the survey materials issued to respondents were titled the "Neighborhood Environment Survey", the official title as recorded by the Federal Office of Management and Budget (OMB) is the "Neighborhood Environmental Survey", i.e., "environmental" instead of 'environment'. The official OMB record of the survey can be found under OMB Control Number: 2120-0762 at: https://www.reginfo.gov/public/do/PRAViewICR?ref_nbr=201409-2120-002.

- The sample design within airports wherein individual households were selected from the 20 airport communities (Section 4),
- Submission of survey method to the Office of Management and Budget (OMB) and Westat Institutional Review Board (IRB) (Section 5),
- The process used to sample residents, administer the questionnaires, and calculate response rates (Section 6),
- The process used to produce the aircraft noise exposure contours and respondent-specific noise levels (Section 7),
- The resultant national dose-response relationships (Section 8),
- Results of additional analyses attempting to explain differences among airports (Section 9), and
- Data files available for further analyses (Section 10).

A bibliography of the references cited herein and Appendices A through J containing supportive detailed information follows Section 10.

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2 Development of Survey Instruments

Carefully designed survey instruments were used to collect people's annoyance reactions to the aircraft noise they experience. The two instruments used in this 20-airport research effort – a mail questionnaire and a telephone questionnaire – were first developed and tested in ACRP 02-35. The selection of those two survey modes was based on considerations of cost, data quality, and complexity of the instrument and comparability of results with earlier annoyance surveys. The comparison assessed in-person, telephone, mail, and web survey formats. The in-person survey ranked highest in all considerations, including cost. The FAA judged the cost for the in-person mode too high for the current effort while mail and phone were rated acceptable in all categories.

Research of the success of web-based surveys concluded that a web survey, rather than a mail survey, would not permit adequate coverage of potential respondents that do not have access to the web. In addition, mail surveys yield significantly higher response rates than web surveys. Some consideration was given to providing the respondents a choice between a mail questionnaire and a web questionnaire. This was rejected because a number of studies have found that giving respondents a choice depresses response rates (Dillman, Smyth and Christian 2008; Messer and Dillman 2011; Manfreda et al. 2008; Millar and Dillman 2011).

A thorough review of the literature was conducted to support the selection and design of the instruments. The main annoyance questions used in the questionnaire were based on recommendations by the International Commission on Biological Effects of Noise (ICBEN) (Fields et al. 2001). The intent was to identify which factors are most likely to affect annoyance reactions to aircraft noise, and address these in the design of the instruments. Some broad conclusions about 30 hypotheses were reached. In general, demographic characteristics of residents (gender, age, education, socio-economic status, etc.) have no important impact on noise annoyance (Fields 1993; Miedema and Vos 1999). As a result, demographic characteristics do not explain differences between annoyance reactions in different geographical areas. Selected attitudes, on the other hand, have a consistently strong effect: fear of danger from the noise source, perception that authorities could better control the noise, and self-reported general sensitivity to noise. A change in noise exposure affects reactions for road traffic and railway noise, but the effect on aircraft noise annoyance is uncertain. Ambient noise levels and time spent at home do not have an important effect on annoyance (Miller et al. 2014b).

Two survey modes were developed and tested during ACRP 02-35: (1) a mail survey using a brief questionnaire, and (2) a telephone survey with an interview of approximately 20 minutes in duration. The mail questionnaire was shorter due to the exclusion of detailed questions on aircraft that would have been visible to respondents from the outset. Thus, their inclusion would have given away the nature of the survey and could have biased responses to the aircraft annoyance question. In the telephone survey, the annoyance questions were asked first, and thus not subject to bias from later questions about aircraft.

The ACRP 02-35 study proposed that a mail questionnaire should form the basis for an updated dose-response relationship because of the following reasons:

- The ACRP project's telephone survey had a response rate of only 12 percent compared to the mail survey's 35 percent;
- Mail surveys have fewer coverage issues compared to telephone;
- The majority of mail survey households adhered to the respondent selection protocol, providing evidence against the concern that those most annoyed would self-select into the survey;
- The mail survey respondents were closer to Census figures on demographic variables collected; and

- While acknowledging small sample sizes, there is no evidence that there was a difference in annoyance between respondents to the mail survey and respondents to the telephone survey. Further, in light of the above reasons, if any differences in annoyance existed, it could indicate improved data on the mail survey due to a more robust representation of the population.

The ACRP project also provided insight to the desired sample sizes. The number of addresses selected at each airport should be sufficient to determine a statistically significant difference (if there is one) between the revised relationship and the Schultz/FICON curve (Schultz 1978; FICON 1992). The derived dose-response relationship will certainly vary from airport to airport; consequently, the number of addresses selected must be sufficient to explore any heterogeneity across airports. A detailed analysis showed that 500 completed mail questionnaires are required for each of the 20 airports. Similar methods were used to determine the precision of responses to 100 completed telephone interviews for each of the 20 airports.[8]

All mail survey respondents were invited to complete a follow-up telephone interview, which asked detailed questions on a number of areas including respondents' opinions on noise, exposure to aircraft noise, relationship to the airport, concerns about aircraft operations, views on airport community relations, among others. The telephone survey data could aide in understanding why some people are highly annoyed at a particular noise exposure while others at the same noise exposure are not; further, the information may help explain differences in annoyance responses among airports. The detailed questions used for the phone questionnaire were not appropriate for the mail questionnaire because the subject matter would have disclosed the purpose of the survey and potentially biased responses to the aircraft annoyance question. The mail and Computer Assisted Telephone Interviewing (CATI) survey instruments used for this research effort are provided in Appendix A and Appendix B, respectively. The mail questionnaire contained 11 questions. The telephone questionnaire contained up to 51 questions.

Both the mail and telephone survey instruments are very similar to those used in the ACRP 02-35 study, though both have some changes and additions relative to the ones used during ACRP 02-35 work:

- The instruments used in this research effort have material describing the Paperwork Reduction Act that requires approval of all federal government surveys by the OMB. Race categories were revised to conform to OMB guidelines.
- ACRP 02-35's survey name was the "Community Attitude Survey" whereas the survey in this project is called the "Neighborhood Environmental Survey".
- The NES was conducted for and funded by the US Department of Transportation whereas the Community Attitude Survey was conducted for and funded by the National Academies of Sciences, Engineering and Medicine.
- The telephone instrument has several clarification changes of wordings and some question deletions.

Once the mail and telephone survey instruments were finalized, they and all other materials were translated into Spanish to allow the survey to be administered in Spanish, as was needed.

[8] For a complete discussion of the sample size determination see Supporting Statement for a New Collection RE: Neighborhood Environmental Survey, Part B, Section B.1, https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201409-2120-002

3 Airport Selection

A statistical process was used to select a representative sample of 20 airports from a sampling frame of 95 US airports. Section 3.1 describes the four criteria applied to construct the sampling frame of 95 airports. Balanced sampling was used to select a representative sample of 20 airports from the sampling frame using a set of balancing factors, as described in Section 3.2. The selections of individual addresses, based on DNL strata, is the subject of Section 4.

3.1 Sampling Frame

The sampling frame, from which the 20 airports for this research effort were selected, was based on four criteria. An eligible airport needed to:

1. Be located within the contiguous US,
2. Have at least 100 average daily jet operations as shown by FAA's Traffic Flow Management System Counts (TFMSC) for 2011,
3. Have at least 100 people exposed to DNL greater than or equal to 65 dB, and
4. Have at least 100 people exposed to DNL between 60 dB and 65 dB.

Criterion 1 reflects the fact that only airports in the 48 contiguous States were included.[9] Criterion 2 helped ensure there were sufficient operations to provide a minimum of noise exposure to the surrounding communities. Criteria 3 and 4 were to ensure the surveyed airports would have a sufficient number of people at all exposure levels of interest.

These criteria yielded the 95 airports listed in Table 3-1 and mapped in Figure 3-1. Of these, three airports had been previously sampled in the ACRP 02-35 study, (San Diego International Airport (SAN), Portland International Airport (PDX), and General Edward Lawrence Logan International Airport (BOS)), and were excluded from the sample.[10] Including any of these three airports in the NES sample would have meant re-sampling the same addresses.

The FAA designated three international airports for inclusion in the sample because of their large number of operations: Hartsfield-Jackson Atlanta International Airport (ATL), Chicago O'Hare International Airport (ORD), and Los Angeles International Airport (LAX). The remaining 17 airports in the sample were selected from the 89 airports that remained after excluding the directed airports (ATL, ORD, and LAX), and after excluding the three ACRP 02-35 airports (SAN, PDX, and BOS), from the list of 95 airports. The FAA further specified that one of the remaining 17 airports in the sample be chosen from the three major New York City-area airports (LaGuardia Airport (LGA), John F. Kennedy International Airport (JFK), or Newark Liberty International Airport (EWR)), and the sampling procedure ensure that any possible sample contained exactly one of these three airports.

[9] This criterion led to the exclusion of Honolulu International Airport as it met criteria 2-4. No other airports in Alaska or Hawaii met these criteria.

[10] However, the FAA may make the data available from ACRP 02-35 for further analysis.

Table 3-1. List of Airports Eligible for the Survey

Airport Identifier	Airport Name	Airport Identifier	Airport Name
ABQ	Albuquerque Intl Sunport	LIT	Bill and Hillary Clinton National Airport / Adams Field
ALB	Albany Intl	MCO	Orlando Intl
APA	Centennial	MDW	Chicago Midway Intl
ATL	Hartsfield-Jackson Atlanta Intl	MEM	Memphis Intl
AUS	Austin-Bergstrom Intl	MHT	Manchester
BDL	Bradley Intl	MIA	Miami Intl
BED	Laurence G Hanscom Field	MKE	General Mitchell Intl
BFI	Boeing Field / King County Intl	MSN	Dane County Regional
BHM	Birmingham Intl	MSP	Minneapolis-St. Paul Intl
BIL	Billings Logan Intl	MSY	Louis Armstrong New Orleans Intl
BNA	Nashville Intl	OAK	Metropolitan Oakland Intl
BOI	Boise Air Terminal / Gowen Field	OKC	Will Rogers World
BOS	General Edward Lawrence Logan Intl	OMA	Eppley Airfield
BTR	Baton Rouge Metropolitan, Ryan Field	ONT	Ontario Intl
BTV	Burlington Intl	ORD	Chicago O'Hare Intl
BUF	Buffalo Niagara Intl	ORF	Norfolk Intl
BUR	Bob Hope	PBI	Palm Beach Intl
BWI	Baltimore/Washington Intl Thurgood Marshall	PDK	Dekalb-Peachtree
CAE	Columbia Metropolitan	PDX	Portland Intl
CAK	Akron-Canton Regional	PHL	Philadelphia Intl
CHS	Charleston Air Force Base/Intl	PHX	Phoenix Sky Harbor Intl
CLE	Cleveland-Hopkins Intl	PIT	Pittsburgh Intl
CLT	Charlotte/Douglas Intl	PNS	Pensacola Gulf Coast Regional
CMH	Port Columbus Intl	PSP	Palm Springs Intl
CVG	Cincinnati/Northern Kentucky Intl	PVD	Theodore Francis Green State
DAL	Dallas Love Field	PWM	Portland Intl Jetport
DCA	Ronald Reagan Washington National	RDU	Raleigh-Durham Intl
DFW	Dallas/Fort Worth Intl	RIC	Richmond Intl
DSM	Des Moines Intl	RNO	Reno/Tahoe Intl
DTW	Detroit Metropolitan Wayne County	ROC	Greater Rochester Intl
ELP	El Paso Intl	SAN	San Diego Intl
EWR	Newark Liberty Intl	SAT	San Antonio Intl
FAT	Fresno Yosemite Intl	SAV	Savannah / Hilton Head Intl
FLL	Fort Lauderdale/Hollywood Intl	SBA	Santa Barbara Municipal
FSD	Joe Foss Field	SDF	Louisville Intl-Standiford Field
FXE	Fort Lauderdale Executive	SEA	Seattle-Tacoma Intl
GEG	Spokane Intl	SFO	San Francisco Intl
HOU	William P. Hobby	SJC	Norman Y. Mineta San Jose Intl
HPN	Westchester County	SNA	John Wayne Airport-Orange County
IAD	Washington Dulles Intl	STL	Lambert-St. Louis Intl
IAH	George Bush Intercontinental/Houston	SYR	Syracuse Hancock Intl
IND	Indianapolis Intl	TEB	Teterboro
JAX	Jacksonville Intl	TPA	Tampa Intl
JFK	John F. Kennedy Intl	TUL	Tulsa Intl
LAS	McCarran Intl	TUS	Tucson Intl
LAX	Los Angeles Intl	TYS	McGhee Tyson
LGA	LaGuardia	VNY	Van Nuys
LGB	Long Beach / Daugherty Field		

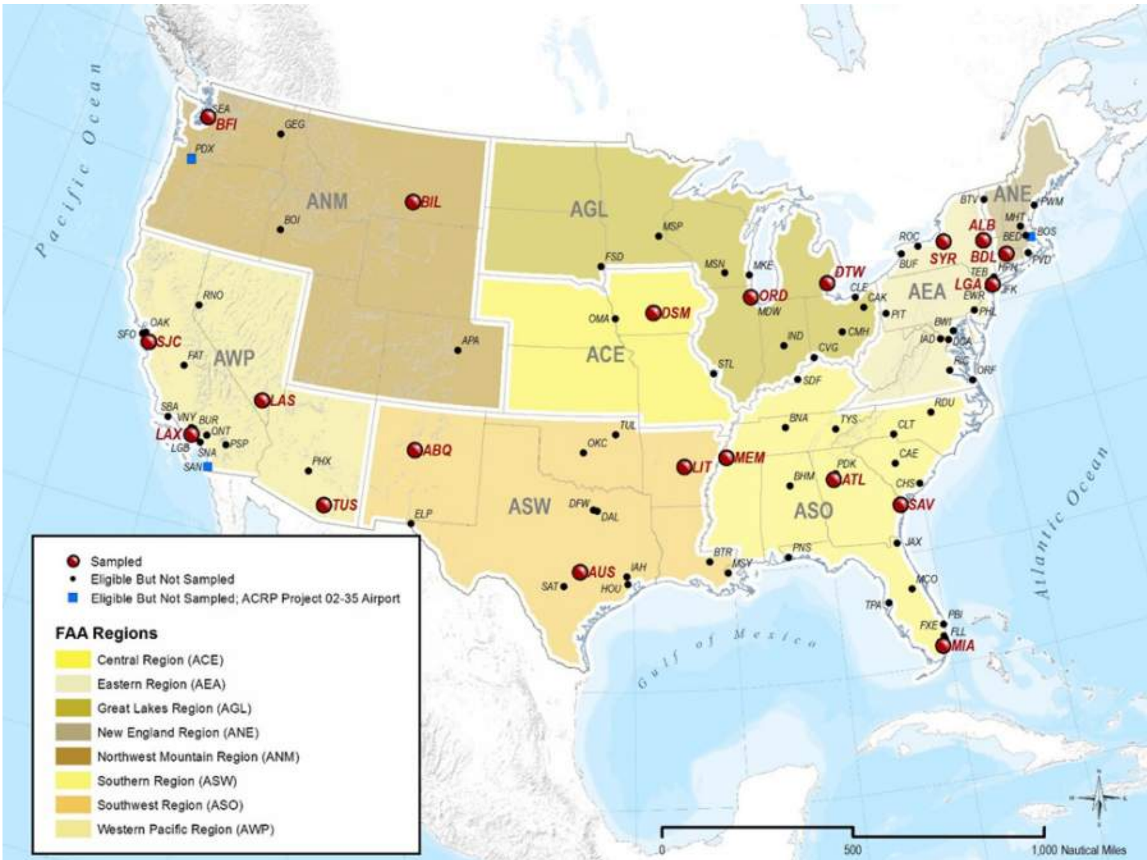

Figure 3-1. Map of Airports Eligible for the Survey and Sampled Airports

3.2 Balanced Sampling of 20 Airports

Balanced sampling was used to select the 20 airports for the NES, with the goal of obtaining a representative sample of airports. An "ideal" sample of airports would be a small-scale version of the population that mirrors the population for every characteristic of interest; however, because most characteristics are unknown before sampling, no sample selection procedure can provide an absolute guarantee that every characteristic in the sample has the same distribution as in the population. Balanced sampling ensures that the sample matches the population on a predetermined subset of characteristics called the balancing factors. The values of the balancing factors are known for the population units before sampling, and the balanced sample is selected so that the sample mean of each balancing factor approximately equals the population mean for that factor.[11] The method of balanced sampling dates back to Yates (1946), was advocated as an alternative to probability sampling by Royall (1976), and is described and explored in detail in Valliant et al. (2000) and Tillé (2011).

The airport sample for the NES has approximately the same proportion of airports as the population with respect to each of the balancing factors shown in Table 3-2. The set of 20 airports, taken as a whole, represents the population of 95 airports with respect to these balancing factors. The FAA, in collaboration with the research team, selected these factors for the reasons outlined below.

[11] A balanced sample is also a goal of random sample selection (Brewer, 2002, p. 82). A large randomly selected sample is expected to be approximately balanced on different factors because of the law of large numbers. But in a sample of size 20, a particular randomly chosen sample can be badly unbalanced on some factors. The balanced sample selection guarantees that the sample is representative on the balancing factors. Variables that are highly correlated with the balancing factors are expected to be approximately balanced as well.

Table 3-2. Balancing Factors for Selection of Airports

Balancing Factor	Description of Selection Variables
FAA Region	Proportion of airports in each of eight FAA regions in the contiguous US(1)
Average Daily Temperature	Proportion of airports with average daily temperature above 70 degrees F
	Proportion of airports with average daily temperature below 55 degrees F
Percent of DNL Nighttime Flight Operations	Proportion of airports with 20 percent DNL nighttime operations(2)
Average Daily Flight Operations	Proportion of airports with more than 300 average daily flight operations(3)
Aircraft Fleet Mix Ratio	Proportion of airports with a fleet mix ratio of commuter to large jet aircraft flight operations exceeding 1(4)
Population within 5 Miles	Proportion of airports with at least 230,000 people living within 5 miles of the airport(5)

Notes:

(1) The FAA has nine regions but only eight in the contiguous US.

(2) DNL nighttime is 10:00 p.m. to 6:59 a.m.; 20 percent was the originally calculated median percentages of nighttime operations, discovered later to have been in error, see text below and Appendix C for further detail .

(3) Three hundred flight operations was a rounding of the median number of daily flight operations across the 95 airports, 270.

(4) Large jet aircraft defined as jet-engine aircraft weighing more than 41,000 pounds, such as the B737, A320, B757, B747; Commuter aircraft are all non-jet aircraft, such as the ATR-42, SF-340 and general aviation aircraft, along with regional and business jet aircraft, such as the Canadair Regional Jet and Learjet.

(5) The mean population within 5 miles of the airport, 230,000, was selected as the dividing point (instead of the median) because it ensured that the airports with the largest population affected were represented in the sample proportionately to their representation in the population of 95 airports.

The region factor ensured that the proportion of sampled airports within each region would be approximately equal to the proportion of the 95 airports within that region. This forced the sample to be spread out among the eight regions; without this balancing, it would have been theoretically possible for all of the airports except for ATL, ORD, LAX, and the New York City-area airport to have been located in one area of the country with no sampled airports in the rest of the country.

The temperature factor was chosen to ensure that the sample contained airports with a range of temperatures. Previous research has indicated that temperatures affect annoyance, with higher annoyance being observed at higher temperatures (Miedema, Fields and Vos 2005). Together, the two temperature factor divisions guarantee that the sample percentage of airports in each of the three average daily temperature ranges—below 55 degrees F, between 55 and 70 degrees F, and above 70 degrees F—matches the population percentage in that category.

For DNL nighttime operations, the sample was selected to match the population percentage of airports with more than 20 percent nighttime operations, according to initial calculations of those percentages. After the survey data were collected, an error was discovered in the calculations of the percentage of nighttime operations. This error does not affect the representativeness of the sample, however — balanced sampling guarantees that the sample is representative on any factors used in the design — and, in fact, the sample closely matches the population distribution for the corrected values of percentage nighttime operations. The population distribution of corrected percentage nighttime operations has 25th, 50th, and 75th percentiles of 9.8 percent, 12.8 percent, and 15.8 percent, respectively; the corresponding percentiles for the sample are 9.9 percent, 12.6 percent, and 17.0 percent.

The operations and fleet mix factors ensured that the sampled airports have variations in the number of daily operations and fleet mix. The population factor was included so that airports with varied population settings, (i.e., airports in rural, suburban and urban settings), would be included.

The target sample size for each category of each factor was set equal to the integer closest to the product of 20 and the proportion of the 95 airports in the sampling frame in that category. A sample met the balancing constraints if it achieved the target sample size for each of the factors in Table 3-2. In this way, the proportion of airports in the sample with average daily temperature above 70 degrees Fahrenheit (F) approximately[12] equalled the proportion of airports in the sampling frame with average daily temperature above 70 degrees F; the proportion of airports in the sample with more than 20 percent nighttime operations approximately equalled the proportion of airports in the sampling frame with more than 20 percent nighttime operations; and so on, for each of the balancing factors.

Restricted random sampling (Valliant, Dorfman, and Royall 2000) with a modification to include the airports ATL, ORD, and LAX, was used to select a sample that provides balance on the factors given in Table 3-2. In restricted random sampling, a large number[13] of random samples is generated from the population of airports. Each of those samples is checked to see whether it meets the balancing constraints; any samples that do not meet the constraints are rejected. Finally, one sample is selected at random from the non-rejected samples (all of which meet the balancing constraints). This procedure results in a sample that is randomly selected from the set of possible samples that are balanced with respect to the factors in Table 3-2. The procedure for generating candidate balanced samples, and the random selection at the last stage, ensure that the sample used for the NES, after accounting for the inclusion of LAX, ATL, and ORD, was selected using objective procedures and not subjective judgments. The details of the procedure used to select the sample of 20 airports are given in Appendix C along with a description of the development of each of the balancing factors. Appendix C also presents the distribution of the balancing factors for the sample of 20 airports, relative to the distribution for the 95 airports listed in Table 3-1.

Table 3-3 and Figure 3-1 show the 20 airports in the sample. As described in Chapter 7, noise modeling also included SEA due to the influence of its aircraft operations on BFI.

Table 3-3. The 20 Airports in the Sample

Identifier	Airport Name	Identifier	Airport Name
ABQ	Albuquerque International Sunport	LAX	Los Angeles International
ALB	Albany International	LGA	LaGuardia
ATL	Hartsfield-Jackson Atlanta International	LIT	Bill and Hillary Clinton National Airport / Adams Field
AUS	Austin-Bergstrom International	MEM	Memphis International
BDL	Bradley International	MIA	Miami International
BFI	Boeing Field / King County International	ORD	Chicago O'Hare International
BIL	Billings Logan International	SAV	Savannah / Hilton Head International
DSM	Des Moines International	SJC	Norman Y. Mineta San Jose International
DTW	Detroit Metropolitan Wayne County	SYR	Syracuse Hancock International
LAS	McCarran International	TUS	Tucson International

[12] The equality was approximate because the number of airports in the sample meeting each criterion had to be an integer.

[13] The balanced sampling procedure guarantees that the sample as a whole is representative with respect to the balancing factors; the additional step of random selection from the set of possible samples that meet the balancing constraints provides an additional layer of protection for the sample being representative on other characteristics.

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4 Address Selection and Data Collection Protocols

This section describes the process whereby individual addresses were selected, based on DNL strata, near each of the 20 airports; and the protocols that were used for the mail and telephone surveys. Section 4.1 describes how the sample size for each aircraft was determined for each of the noise strata. Section 4.2 describes the procedures used to select the sampled addresses from each noise stratum, and to divide the sample into release groups so that addresses from each noise stratum and airport would be sampled throughout the yearlong period of data collection. Sections 4.3 and 4.4 describe the data collection protocols for the mail and telephone surveys, respectively.

4.1 Sample Size Selection of Addresses

With the objective of this research effort to determine a regression-based curve describing the national relationship between annoyance (in terms of percent HA) and DNL, the sample design for addresses to be selected from each airport community was tailored for estimating a regression relationship (Lohr 2014). The target population for each airport was defined to be addresses with aircraft DNL of 50 dB or greater. FAA primarily considered the following factors in choosing DNL 50 dB as the NES's lower bound for a contour interval:

- In addition to the primary DNL threshold of 65 dB, the FAA also considers changes in DNL at noise exposures as low as DNL 45 dB, for purposes of identifying reportable changes for air traffic actions under the National Environmental Policy Act (NEPA).
- The US Environmental Protection Agency (EPA) has identified DNL 55 dB as adequate to protect public health and welfare with an adequate margin of safety (EPA 1974).
- While the FAA's Integrated Noise Model (INM) can accurately compute aircraft noise exposure over the full extent of conditions required by regulation, the accuracy of the calculation depends on a number of assumptions about thrust, altitude, and airspeed. As aircraft distance from the airport increases, the importance of these parameters to the noise on the ground also increases. As a result, greater care must be taken in the preparation of modeling inputs for lower DNL values and increased modeling uncertainty is possible.
- The 1992 FICON curve had relatively few (annoyance) data points below DNL 55 dB compared to greater DNL values.
- The cost of the NES would increase with decreasing DNL because greater numbers of population/respondents would need to be included.

The number of airports and sample size for each airport were selected to allow accurate estimation of the national dose-response curve and dose-response curves for each airport. There are two components to the variance of the estimated national curve: the first is the variability among respondents within an airport community, and the second is the differences from one airport to another. Increasing the number of respondents for one particular airport community only addresses the first source of variability; increasing the number of airports reduces both sources of variability. Having 20 airports allows the relationship to be estimated precisely using a smaller sample size within each airport community. The research team used results of previous studies (FICON 1992; Fidell and Silvati 2004; Fidell et al. 2011) to calculate estimated precisions for varied numbers of respondents. This effort demonstrated that the numbers of respondents in Table 4-1 should achieve the aforementioned goal. Increasing the number of addresses per airport beyond 500 was not expected to increase precision appreciably.

Table 4-1. Target Number of Respondents for each Airport, and for the NES as a Whole

Survey	Each Airport or All Airports	Noise Exposure Range, dB DNL					Total
		50-55	55-60	60-65	65-70	70+	
Mail	Each airport	100	100	100	100	100	500
Mail	Total, all airports	2,000	2,000	2,000	2,000	2,000	10,000
Telephone	Each airport	19.5	19.5	19.5	19.5	19.5	97
Telephone	Total, all airports	389	389	389	389	389	1,945

Each mail respondent was invited to participate in an additional telephone interview, and the anticipated number of telephone respondents was calculated assuming that 19.5 percent of mail respondents could be reached by telephone and would agree to participate in the telephone interview. Tables 4-2 and 4-3 show the assumptions made about response rates and vacancies used when planning the survey. Based on the ACRP 02-35 study and on the rates of other recent studies, the research team anticipated an overall mail response rate of 40.0 percent and a telephone response rate of 7.8 percent, as shown in Table 4-3. These response rates include assumptions about postal non-deliverables, resident locations with no matching phone number or with invalid phone numbers.

Table 4-2. Anticipated Sample Sizes and Completes

Item	Number
A. Mail Survey	
A1. Initial sample	26,700
A2. 6.3% PND (Postal nondeliverables) (see Note 1)	1,682
A3. Eligible sample (A1 minus A2)	25,018
A4. 40% of A3 complete mail questionnaires	10,007
B. Telephone Survey (see Note 2)	
B1. 40% of A4 match to telephone number	4,003
B2. 85.1% of B1 are valid matches	3,407
B3. 30% of B2 complete phone interview	1,022
B4. 60% of A4 do not match to telephone number	6,004
B5. 14.9% of B1 are invalid matches	596
B6. Total phone number requests (B4 + B5)	6,600
B7. 35% of B6 provide phone number	2,310
B8. 40% of B7 complete phone interview	924
B9. Total telephone completes (B3 + B8)	1,946

Notes:
(1) Postal nondeliverables are mailed questionnaires returned as nondeliverable by the US Postal Service.
(2) The numbers here vary from the table in the OMB submission due to a corrected error.

Table 4-3. Anticipated Response Rates

Response Rate	Percent
Anticipated mail survey response rate (A4/A3)	40%
Anticipated telephone survey response rate (B9/A3)	7.8%

In order to achieve high precision for the estimated dose-response relationships, a stratified random sampling design was used to select addresses across a range of noise exposures. The sample allocation in Table 4-1 also makes the sample design robust to planning assumptions about the shape of the curve (Abdelbasit and Plackett 1983, Chaloner and Larntz 1989) and allows for evaluating possible deviations from the assumed logistic model.

Stratified random sampling provided a sample that was relatively evenly distributed across noise levels by allowing the sample to have greater sampling fractions for addresses at greater noise exposures than would have been possible with simple random sampling within airports. A simple random sample of 500 households, taken from the set of an airport's households with DNL greater than or equal to 50 dB, would give low precision for estimating the logistic regression function. Most of the addresses in a simple random sample would have low DNL, and few, if any, households in the simple random sample would have high DNL. Such a sample would result in fitting a logistic regression curve to a data set with almost all of the DNL values at the low end of the range, and thus would have little information for fitting a curve to the upper end of the DNL range (approximately DNL 70 dB in this case).

Five DNL strata were defined by contour lines of DNL 50, 55, 60, 65 and 70 dB. The strata were defined as 50-55 dB, 55-60 dB, 60-65 dB, 65-70 dB and "70+" dB, where addresses exactly on the boundaries were assigned to the higher noise stratum. Addresses were randomly selected within each of the noise strata at each airport, with an initial target sample size of 100 respondents per stratum. To achieve 100 respondents in each stratum, approximately 250 addresses would be needed under the assumed response rate (40 percent) to receive 100 completed questionnaires.

As stated in Section 5, any Federally-funded project that solicits information from US citizens requires review and approval by the US OMB.[14] After the sampling plan, which included the associated survey instruments, was approved by the OMB, the DNL contours were used to ascertain the number of addresses in each DNL stratum at each of the 20 airports in the sample. When addresses were counted in September 2015,[15] it was found that only three of the airports had at least 250 addresses in the highest DNL stratum of 70 dB or more, and only seven airports had at least 250 addresses with DNL greater than or equal to 65 dB. Table 4-4 gives the number of airports, out of the sample of 20 airports, with sufficient addresses (250 at expected 40 percent response rate) to obtain at least 100 completed questionnaires in each of the five noise strata and number of airports with any addresses at each noise strata.

Table 4-4. Airports Having Sufficient Addresses to Complete 100 Questionnaires within Each Noise Exposure Range

Number of Airports Statistic	Numbers of Airports Having Addresses in DNL Range				
	50-55 dB	55-60 dB	60-65 dB	65-70 dB	70 dB or Greater
Having adequate sample sizes to meet goal of 100 subjects per noise exposure range	20	20	11	7	3
Having any subjects per noise exposure range	20	20	20	17	7

The sample size of 500 for each airport (100 per noise stratum) was re-allocated to the noise strata at airports with insufficient numbers of addresses in high noise strata. The re-allocation was done starting at the highest noise stratum. If there were insufficient addresses to yield 100 respondents in the DNL 70+ dB noise stratum, then all addresses in that stratum were to be sampled. The difference was calculated between the target sample size in that stratum (100) minus the expected number of respondents from that stratum. That difference was then allocated equally to the remaining noise strata at the airport. If there were insufficient addresses in the DNL 65-70 dB stratum, the process was repeated with that stratum, and the difference between the target sample size and the expected number of responses in that stratum was allocated equally to the lower noise strata. For example, for an airport with no addresses having DNL greater than 70 dB, but with sufficient addresses in the other noise strata, the sample was re-allocated so as to yield an expected 125 respondents in each of the four noise strata of DNL 50-55 dB, 55-60 dB, 60-65 dB, and 65-70 dB. Table 4-5

[14] Paperwork Reduction Act, Pub. L. No. 96-511, 94 Stat. 2812, codified at 44 U.S.C. §§ 3501–3521 https://www.gpo.gov/fdsys/pkg/PLAW-104publ13/html/PLAW-104publ13.htm

[15] The FAA furnished to the contractor team the 95 airports from whom survey respondents at 20 airports (selected as previously described) were to be sampled. At the time of this initial selection (circa 2011) each of these 95 airports were believed to contain at least 100 people (not necessarily addresses) exposed to between DNL 60 dB and DNL 65 dB and 100 people exposed to DNL greater than 65 dB based on prior FAA analysis.

shows the updated estimates of completes by strata after this re-allocation. The individual airport sample sizes for each stratum varied and, therefore, are not shown in Table 4-5.

Table 4-5. Revised Planned Number of Respondents for each Airport, and for the NES as a Whole

Survey	Each Airport or All Airports	Number of Planned Respondents in DNL Range					Total
		50-55 dB	55-60 dB	60-65 dB	65-70 dB	70 dB or Greater	
Mail	Each airport	*	*	*	*	*	500
Mail	Total, all airports	3,449	3,441	1,856	913	341	10,000
Telephone	Each airport	*	*	*	*	*	97
Telephone	Total, all airports	671	669	361	178	66	1,945

* Counts for each airport by noise strata are not displayed since the numbers were variable depending on number of addresses available.

4.2 Procedures for Selecting Addresses

The target sample sizes allocated in Section 4.1 were inflated to allow for a reserve sample in the event that response rates were less than expected, or that the rates for vacant and seasonal housing or undeliverable addresses were greater than expected. The initial sample sizes were calculated based on the predicted 40 percent response rate and 6.3 percent postal nondeliverable (PND) rate. Extra reserve sample was included should the response rate be less than 40 percent or the PND rate exceed 6.3 percent at some airports. The size of the reserve sample varied across airports because airports with a greater number of addresses classified as vacant, seasonal, and drop points[16] were allocated additional reserve sample. As mentioned in Section 4.1, all addresses were selected for the sample in noise strata that had insufficient addresses to yield 100 respondents under these assumptions.

The US Postal Service (USPS) Computerized Delivery Sequence File (CDSF)[17] was used as the household sampling frame. For each airport in the sample, contours for DNL 50, 55, 60, 65, and 70 dB were determined using the FAA's INM, as described above. These contours defined the sampling strata for each airport. The contours were provided as GIS shape files to the sampling vendor who identified all households within each stratum using the USPS CDSF.

Addresses identified as businesses, group quarters[18], and post office (PO) boxes (unless this was the only way the household received mail) were excluded from sampling. However, to ensure maximum coverage, addresses identified as vacant and seasonal were included due to the length of the field period and the chance the occupancy status would change by the time of sample release. Additionally, drop points were included since some airports had a very high proportion of such addresses. Addresses that met these criteria were sampled with equal probability within noise strata at each airport, resulting in a total initial sample size of 53,916. The sample was randomly assigned to six waves within each airport and noise stratum, with a wave released every 2 months. The first wave's size was set based upon estimates of sample performance from the ACRP 02-35 study and was released in its entirety at the beginning of data collection. To ensure that the first wave was a representative subsample of the initial sample, it was formed by sorting the initial sample within each airport noise stratum by county, census tract, block group, and block; then selecting an equal probability systematic sample within each airport noise stratum. The Wave 1 sample size within each

[16] Response rates are often less for addresses in these classifications. A drop point is a mail delivery point that serves multiple households (US Postal Service 2016, p. 22).
[17] A product of the United States Postal Service (USPS) available through third-party vendors, the Computerized Delivery Sequence (CDS) program provides a frequently updated list of all addresses in the US.
[18] We followed the US Census Bureau, which classifies all people not living in housing units (house, apartment, mobile home, rented rooms) as living in group quarters. There are two types of group quarters: institutional (e.g., correctional facilities, nursing homes, or mental hospitals) and non-institutional (e.g., college dormitories, military barracks, group homes, or missions).

noise stratum was calculated based on the target number of approximately 10,000 completes for the noise stratum (500 for each airport) divided by the number of waves (six), and a response rate of 40 percent and PND rate of 6.3 percent, i.e., target/(.4 × .937 × 6). Wave 1 consisted of 4,476 addresses. The performance of this and future waves provided actual information on the response and PND rates at each sampled airport's noise strata to inform future sample release sizes within each airport and noise strata to meet the targets.

Waves 2 through 6 were formed by randomly assigning the remaining addresses (53,916 minus 4,476) to five approximately equal-sized waves of about 9,890 each. Waves 2 through 6 were further randomly assigned to release groups of 20 addresses each within each airport and noise stratum where there were sufficient addresses to obtain the overall goal of 100 completed questionnaires. The number of release groups ($n_{relgrps}$) that could be formed in each noise stratum was calculated by dividing the remaining number of addresses in the noise stratum by 20. To ensure that each wave matched as closely as possible the geographical distribution of the initial sample, the waves and release groups were assigned by first sorting the remaining addresses within each airport noise stratum by county, census tract, block group, and block, then numbering the addresses from 1 to $n_{relgrps}$ repeatedly. This was followed by a sort by airport noise stratum, and release group number, then numbering the release groups from 2 to 6 repeatedly to create Waves 2 to 6.

In the higher noise strata where there were insufficient addresses to achieve 100 completed questionnaires at a particular airport, single, equal release groups were assigned to each wave because all sampled cases in these strata were scheduled to be released. In these higher noise strata, Waves 2 to 6 were assigned by sorting the remaining cases (after excluding Wave 1) by county, census tract, block group, and block, then numbering the addresses from two to 6.

Because each wave was a representative subsample of the initial sample, and the same mailout procedures were followed for each wave/release group, this allowed any number of release groups to be sent out each wave without bias. Releasing the sample in this manner allowed the target sample sizes to be obtained because more or fewer release groups could be released in particular airports and noise strata where needed.

4.3 Procedures for Mail Survey

The mailing protocol used for the main data collection followed published procedures (Dillman, Smyth and Christian 2008). All sampled addresses were contacted between two to four times, depending on when the questionnaire was returned. The contacts included:

- An initial survey package,
- A thank-you/reminder postcard approximately 1 week after the initial survey mailing,
- A second survey package mailing 2 weeks after the thank-you/reminder postcard (3 weeks after initial survey mailing), and
- A third survey package mailing 3 weeks after the second survey package mailing.

The contents of each survey package included a cover letter that provided the survey purpose and sponsorship, Frequently Asked Questions (FAQs) and answers, and a paper questionnaire that the respondent was requested to complete and return via an included postage-paid envelope. All materials mailed to the respondent referenced the "Neighborhood Environment Survey." All survey materials were provided in English and Spanish. This followed established procedures for eliciting response from Spanish-speaking households (Brick et al. 2012). A quasi-random selection procedure was used to select an adult to answer the mail questionnaire. The instructions on the inside page asked that the adult with the next birthday complete the questionnaire.

A $2 cash prepaid monetary incentive was included with the initial mail package sent via USPS first-class mail. Pre-paid incentives of this size have been shown to significantly increase response to mail surveys (Church

1993; Dillman, Smyth and Christian 2008; Edwards et al. 2005). For example, in a recent meta-analysis of incentive experiments (Mercer et al. 2015), it was found that incentives of this size increase response rates by approximately 10 percentage points for a mail survey. The initial survey package and the thank-you reminder postcard were mailed to all sampled addresses. Only nonrespondents to the prior mail packages received subsequent survey package mailings. Mailings returned as PND by the USPS were excluded from subsequent mailings.

The second survey package was sent using express delivery. This increased the visibility of the package and maximized response at this stage (Dillman, Smyth and Christian 2008). Mailings undeliverable by express delivery were not excluded from the last mailing since USPS can often deliver to these addresses. The last mailing was sent USPS first class.

4.4 Procedures for Telephone Survey

Households that completed the mail questionnaire were eligible for the telephone interview. First, an attempt was made to obtain a telephone number for each household through a directory. Those that had a successful telephone match were mailed a letter requesting participation in the telephone survey. If no telephone match was available or if the matched phone number was determined to be invalid, the household was mailed a request to provide a telephone number. This survey package included a cover letter explaining the follow-up contact procedure and sponsorship. A short form for providing the household's telephone number was also included. The request for telephone number followed the mail contact procedures outlined by Dillman, Smyth, and Christian (2008), except there were three contacts. All households received a reminder postcard, and nonresponding households received a nonresponse follow-up request. All mailings were done using USPS first-class postage.

For the telephone interview, an adult was selected using the Rizzo method (Rizzo, Brick and Park 2004). If there is just one adult household member, that person was selected, whereas if exactly two, the CATI program randomly selected one of them. If more than two, the CATI program randomly determined if the screener respondent was selected or one of the other adults. If the screener respondent is not selected the adult with the next birthday was selected. If the screener respondent did not know which adult had the next birthday, a roster of adults in the household was collected and one adult was selected at random. This is a probability method of selection and gives each adult in the household an equal chance of being selected. Respondents were able to complete the telephone interview in English or Spanish. Respondents who completed the telephone interview received $10 as a thank-you and were told about the $10 at the beginning of the call and in the advance letters. An incentive was used because additional participation was requested from the household. Promised incentives on telephone surveys have been found to be effective in improving response (Singer et al. 1999). The meta-analysis by Mercer et al. (2015), for example, predicts this amount would increase response rates by approximately 5 percentage points.

Appendix D contains the analysis of the telephone survey results.

5 Reviews of Survey Method

The NES utilized multiple independent reviews of the employed methods as well as a pilot study, ACRP 02-35. The statistical analysis methodologies were approved by the Bureau of Transportation Statistics (BTS) and data collection was approved the OMB. An Institutional Review Board at Westat also reviewed all of the methodologies used in conducting the national survey. Technical bodies also reviewed the work. This included the Federal Interagency Committee on Aviation Noise (FICAN) as well as external review groups that examined the methods underlying the data collection and analysis process and the resulting data. These reviews took place at three separate points during the ACRP study and during the conduct of the NES. Sections 5.1 and 5.2 describe the regulatory and other technical reviews for the NES, respectively.

5.1 Regulatory Reviews

Regulatory reviews consist of those conducted by the OMB and Westat's Institutional Review Board (IRB).

5.1.1 OMB approval

Federally-sponsored data collections involving the public are required to receive an OMB approval under the Paperwork Reduction Act (PRA). Such clearance is required for data collections involving 10 or more respondents within a 12-month period. The approval process entails four main steps:

1. Preparation of an Information Collection Request (ICR) package,
2. A Federal Register notice informing the public of the intent to request clearance for the proposed data collection with a 60-day comment period,
3. A Federal Register notice informing the public that the ICR package is being submitted to OMB with a 30-day comment period, and
4. Submission of the ICR package to OMB with a 60-day review period.

Under Task 2 of the contract, FAA, HMMH, and Westat coordinated to prepare the NES's OMB submission from early 2013 through early 2015.[19] A 60-day Federal Register notice (2014-13686[20]) was posted on June 12, 2014 to solicit public comment on the proposed survey. Seven comments were received from the public and the team prepared responses in August 2014. A 30-day Federal Register notice (2014-21795[21]) was posted on September 12, 2014. No comments were received. FAA submitted the ICR materials to OMB on December 12, 2014. Two teleconferences were held with OMB to discuss the submission in April 2015. OMB approved the submission on April 27, 2015 and the survey was assigned OMB control number 2120-0762 (expiration date: 04/30/2018).

5.1.2 IRB approval

An IRB is a type of committee used in research that is formally designated to review, approve, and monitor behavioral and biomedical research involving humans. Westat's IRB includes a diverse group of nine individuals: researchers across a broad range of substantive areas, a physician, and two unaffiliated community members. The Board meets once a month to review protocols that include sensitive topics or vulnerable populations at the discretion of the IRB Chair. The IRB operates under procedures set forth in the regulations of the US Department of Health and Human Services and in the Federalwide Assurance (FWA)

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[19] https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201409-2120-002

[20] https://www.federalregister.gov/documents/2014/06/12/2014-13686/agency-information-collection-activities-requests-for-comments-clearance-of-renewed-approval-of

[21] https://www.federalregister.gov/documents/2014/09/12/2014-21795/agency-information-collection-activities-requests-for-comments-clearance-of-new-approval-of

granted to Westat by the Office for Human Research Protections (OHRP). IRB approval is required before research may begin, continue, or be changed by the research team.

Westat's IRB requires each study to submit an initial application consisting of background material on the study, including research goals, methods, informed consent process, and materials (e.g., letters, scripts, questionnaires). The IRB then reviews the material to ensure compliance with human subjects' protection research rules and regulations.

Westat submitted the NES initial application to the IRB on August 26, 2015 and received expedited approval on September 1, 2015. Westat's IRB conducted annual continuing reviews for the duration of the contract.

5.2 Other Technical Reviews

As described below, the NES also underwent reviews by other agencies, two reviews by panels of experts and the NES's statistical methods were presented at three professional conferences on statistics and survey methodology.

In 2014, the BTS reviewed the statistical analyses methodologies as part of the DOT review of the OMB PRA package. BTS approved the methodologies within the PRA.

The FICAN consists of representatives from the US Departments of Defense, Interior, Transportation, and Housing and Urban Development, in addition to the US EPA, and the National Aeronautics and Space Administration (NASA); a representative from the National Institute of Health also participates in FICAN meetings, though it is not an official member. In 2013, FICAN reviewed the methods used to select the 20 airports that were surveyed and stated, "the balanced sampling methodology that was employed is the correct choice given the purpose of the research effort and the number and range of airports available for selection" (FICAN 2013).

In 2016 and 2017, the FAA convened a professionally facilitated Expert Review from international professionals in the field of noise dose-response research, to provide an objective third party review of the project's survey design, noise modeling, regression analysis techniques, supplemental analysis, and development of the national dose-response curve. The 2016 Expert Review consisted of five members and the 2017 Expert Review consisted of six members. Members were affiliated with private industry, a scientific/research resource of the US Department of Transportation, and two European scientific organizations. Many of the members had over 30 years of relevant experience. The Expert Panels provided suggestions for additional analyses and insight to the project team that were incorporated into this report. In addition to these reviews, in 2013 an expert review was conducted in association with the ACRP 02-35 project on the questions used in the mail questionnaire and phone interview.

The statistical methods employed in the NES have been presented at three professional conferences on statistics and survey methodology (Jodts and Lohr 2017a; Jodts and Lohr 2017b; Lohr, Broene and Jodts 2017).

6 Survey Administration and Response Rates

This section describes how the survey was administered and data was collected as well as the actual response rates for the mail and phone instruments. Section 6.1 documents how the data collectors were trained. Section 6.2 addresses the flow of data collection for both survey instruments. Section 6.3 describes the management and review of data. Section 6.4 provides the response rate calculation methodology. Section 6.5 details the survey response rates by various metrics.

6.1 Data Collector Training

In November 2015, five data collectors were trained and started work on the project. Due to attrition, in June 2016, three additional data collectors were trained and started production.

Training consisted of three phases: self-paced, WebEx, and role-play. The following sections detail the structure and content of each training session. Trainees had to successfully complete each session to move to the next stage.

6.1.1 Self-Paced

In the self-paced portion of training, data collectors were expected to review specific materials to introduce themselves to the study subject and survey instrument. The materials were placed in Westat's Learning Management System (LMS) and the data collectors could complete them on their own. If they did not complete their self-study within the specified timeframe, they were unable to proceed to the next section of training. Under the self-paced portion, data collectors reviewed sample letters and postcards and practiced going through the instrument. Trainees were required to take and pass a quiz addressing materials in the self-paced tutorial.

6.1.2 WebEx

The WebEx session was led by project staff (trainer) and facilitated by a Westat Telephone Research Center (TRC) team leader. During this time, the trainer provided an opportunity for the data collectors to ask any questions they may have had on the self-paced training materials. For the majority of this training, the trainer and trainees went through the instrument demonstrating different scenarios. In this segment, the trainer would have the interviewing platform open, which was viewable by all trainees on their computer screens via web conference. The trainees took turns reading the questions as if they were the interviewer, and the trainer would answer based on the scenario they were practicing. The trainee would then indicate which answer to select.

6.1.3 Role-Plays

In the final stage of training, the data collectors were paired with each other, and took turns acting as interviewer and respondent. They were expected to complete two role-plays, acting as both the interviewer and as the respondent. These role-plays covered different scenarios the interviewer might encounter during live production. The role-play sessions were monitored by supervisory staff who verified that trainees had mastered the content before proceeding to live interviewing.

6.1.4 Training for Spanish Language Interviewing

All Spanish bilingual data collectors completed the English self-paced, WebEx, and role-play sessions. They also participated in a separate Spanish role-play session where they completed the interview in Spanish with another Spanish-speaking data collector. All requirements for completion were the same as the English role-plays.

6.2 Data Collection Flow

6.2.1 Mail Survey

As noted in Section 2, the sample was released in waves, and the wave sizes varied to adjust for yield rates (number of competed questionnaires/sample released) within each airport's noise strata as data collection progressed in order to meet targets. The sample releases in each wave took into account the average yield for the performance to date but were somewhat conservative (meaning erring on the side of inviting too many households) to account for variation in yield at each wave and to ensure the completed questionnaires hit the overall targets in the end. Wave 2, in particular, was much larger than other waves since the sample was drawn before returns from the final Wave 1 mailing came in. This meant the team had limited data available and, therefore, made conservative assumptions about eligibility and response rates. Later waves were also drawn at a similar time in the preceding wave, but benefited from the cumulative yields to date allowing for more precise sample releases. Variations in response rate and yield at each wave accounted for differences in later waves. Table 6-1 shows the date and quantities mailed for each stage by wave. As discussed in Sections 4.3 and 4.4, the NES provided English and Spanish versions of the questionnaire to all respondents, in order to address lower Hispanic response rates observed in the ACRP study. Seven hundred fifty nine of the 10,328 completed mail questionnaires (7.3 percent) were done in Spanish, and 154 of the 2,328 telephone interviews (6.6 percent) were conducted in Spanish.

6.2.2 Telephone Survey

Telephone interviewing began November 12, 2015, and finished on November 13, 2016. Of the households that completed the mail questionnaire, 6,736 had a matched phone number or provided a phone number in response to a phone request and were called in an attempt to complete the telephone interview.

The telephone survey mail activities occurred on an ongoing basis driven by mail questionnaire receipts, but the sample waves were not a driving factor in the operations. The following indicates the date of initial and final mailing for each type and the schedule throughout operations. Minor adjustments to the weekly mailings were made periodically throughout the year to account for postal holidays.

- On November 4, 2015, the first telephone request mailing was sent to addresses that had completed the mail questionnaire but for whom there was no matching phone number. These requests continued each Wednesday for additional addresses as they completed the mail questionnaire and for those whom were identified as having an incorrect matched number. The last mailing was sent October 26, 2016.
- The first advance letter mailing for addresses that had completed the mail questionnaire and had a matching phone number was sent on November 5, 2015. These letters continued each Thursday for additional addresses as they completed the mail questionnaire. The last mailing was sent November 3, 2016.
- Thank you/reminder postcards were sent to the first batch of addresses receiving the telephone request mailing on November 12, 2015, and continued each Thursday for subsequent mail batches. The last mailing was sent October 27, 2016.
- The first nonresponse follow-up mailing for those who had not returned their phone number were was sent on November 25, 2015, and continued each Thursday. The last mailing was sent October 27, 2016.
- The first thank-you letter mailing, with $10 incentive, for those completing the telephone interview was sent November 19, 2015, and continued each Thursday for additional completes. The last mailing was sent November 17, 2016.

Table 6-1. Mail Quantities by Wave and Stage

Wave	Mailing	Date	Quantity
1	Initial survey invitation	10/13/2015	4,476
1	Thank you/reminder postcard	10/20/2015	4,476
1	2nd survey invitation (Express)	11/3/2015	3,677
1	3rd survey invitation	11/24/2015	2,759
2	Initial survey invitation	12/15/2015	5,509
2	Thank you/reminder postcard	12/22/2015	5,509
2	2nd survey invitation (Express)	1/5/2016	4,665
2	3rd survey invitation	1/26/2016	3,424
3	Initial survey invitation	2/16/2016	4,856
3	Thank you/reminder postcard	2/23/2016	4,856
3	2nd survey invitation (Express)	3/8/2016	3,661
3	3rd survey invitation	3/29/2016	3,749(1)
4	Initial survey invitation	4/12/2016	4,485
4	Thank you/reminder postcard	4/19/2016	4,485
4	2nd survey invitation (Express)	5/3/2016	3,600
4	3rd survey invitation	5/24/2016	2,857
5	Initial survey invitation	6/14/2016	3,907
5	Thank you/reminder postcard	6/21/2016	3,907
5	2nd survey invitation (Express)	7/7/2016	3,091
5	3rd survey invitation	7/28/2016	2,581
6	Initial survey invitation	8/16/2016(2)	4,935
6	Thank you/reminder postcard	8/23/2016	4,935
6	2nd survey invitation (Express)	9/7/2016	3,822
6	3rd survey invitation	9/27/2016	3,086

Notes:
(1) For Wave 3, the third survey invitation mailing was larger than the second invitation mailing because of an error in the parameters used to extract the addresses that led to an inadvertent inclusion of some addresses in the final nonresponse mailing.
(2) During the Wave 6 initial mail out, the postage meter broke down while the survey packages were being metered. Shipped pieces metered on the 8/16/2016 amounted to 3,724, and after the meter was repaired, the remaining 1,661 pieces were shipped on the 8/17/2016.

6.3 Data Management and Review

Returned NES mail questionnaires and Telephone Request Forms with at least one completed question were scanned using TeleForm, a questionnaire design and scanning software that provides automated data capture. Scanning staff reviewed the resulting scanned images for quality, and then passed them into the software's verification and data capture module. Alchemy, an image database and retrieval system, was used to store the questionnaire form images. The hard-copy forms were retained in a secured location until data files were complete.

The data capture module presented for verification any data items that the software could not read with the required level of confidence. The level of confidence is a feature of the TeleForm software that reflects the likelihood that a scanned image is what the software perceives it to be, (e.g., a specific number or letter).

The scanning verification staff compared images against the data recorded by the software and typed corrections into the recorded data as necessary. Once recorded data for a form were accurate, the data were saved to the database. If the scanning staff could not determine the content of the image with certainty, (e.g., if the marks were particularly light), the staff would review the original hard copy questionnaire.

Scanning quality control (QC) staff also reviewed frequencies of the captured data. Verification staff and QC staff also reviewed open-ended items to ensure that all text was captured correctly.

Data Management (DM) staff also reviewed frequencies of the captured data after the scanning verification and QC staff completed their review and resulting data updates. DM staff made additional data updates when necessary, such as reviewing and reconciling multiple responses to a single item on the mail questionnaire or outlier values, (e.g., very large household sizes).

During these receipt, scanning, data capture, and data review processes, the scanned data resided in a series of tables in a Structured Query Language (SQL) server database to preserve the data at each snapshot in time. Additional products, such as SAS®, readily communicate with SQL server to allow for efficient transmission of data from one stage to the next.

6.4 Response Rate Calculation Methodology

Response rates for mail and telephone surveys were calculated per American Association for Public Opinion Research (AAPOR) guidelines (AAPOR 2016). Response Rate 1 (RR1) and Response Rate 2 (RR2) were for the mail and phone surveys, respectively. Equation (6.1) is the formula for RR1. RR1, or the minimum response rate, is the number of complete interviews (mail questionnaires in this research effort) divided by the number of interviews (complete plus partial) plus the number of non-interviews (refusal and break-off plus non-contacts plus others) plus all cases of unknown eligibility (unknown if housing unit, plus unknown, other).

$$RR1 = \frac{I}{[(I+P)+(R+NC+O)+(UH+UO)]} \tag{6.1}$$

where:

- RR = Response rate;
- I = Complete interview;
- P = Partial interview;
- R = Refusal and break-off;
- NC = Non-contact;
- O = Other;
- UH = Unknown if household/occupied HU;
- UO = Unknown, other.

Equation (6.2) shows the formula for RR2. RR2 counts partial interviews as respondents.

$$RR2 = \frac{I+P}{[(I+P)+(R+NC+O)+(UH+UO)]} \tag{6.2}$$

In short, the numerator includes the cases with questionnaire data in the final data file while the denominator includes all samples cases minus the ineligible cases (PNDs).

6.5 Response Rates and Additional Survey Metrics

Tables 6-2 and 6-3 report the observed sample size and pertinent response rates, which overall compare favorably to the anticipated rates reported in Table 6-4 through Table 6-9. The resulting response rate for each was slightly greater than the anticipated rate – 40.3 percent observed vs. 40.0 percent anticipated for the mail survey and 9.1 percent observed vs. 8.6 percent anticipated for the telephone survey.

Table 6-2. Sample Sizes and Completes

Item	Number
A. Mail Survey	
A1. Initial sample	28,168
A2. 9.1% PND (Postal nondeliverables)	2,561
A3. Eligible sample (A1 minus A2)	25,607
A4. Completed mail questionnaires	10,328
B. Telephone Survey (see Note 1)	
B1. 49% of A4 match to telephone number	5,066
B2. 77.8% of B1 are valid matches	3,942
B3. 30% of B2 completed phone interview	*1,179*
B4. 51% of A4 did not match to telephone number	5,262
B5. 22.2% of B1 were invalid matches	1,124
B6. Total phone number requests sent (B4 + B5) (see Note 2)	6,289
B7. 31% of B6 provide phone number	1,967
B8. 58% of B7 completed phone interview	*1,149*
B9. Total telephone completes (B3 + B8)	2,328

Notes: American Association for Public Opinion Research (AAPOR); response rate (RR)
(1) Telephone complete numbers reflect full (n=2,244) and partial (n=84) interviews.
(2) This number is slightly below the sum of the two previous numbers (difference of 97) because 48 of the 5,262 completed the mail questionnaire too close to the end of data collection to receive a phone number request. Additionally, 47 of the 1,124 were identified as invalid numbers too late in the data collection to receive a phone request, and another two mail respondents requested future contacts be stopped before the phone request was sent.

Table 6-3. Response Rates

Response Rates	Percent
Final mail survey response rate (A4/A3) (AAPOR RR1) (see Note 1)	40.3%
Final telephone survey response rate (B9/A3) (AAPOR RR2)	9.1%

(1) AAPOR 2016.

One notable exception is the PND rate, which was greater than anticipated (9.1 percent observed vs. 6.3 percent anticipated). For this research effort, including all vacant addresses ensured complete coverage of the sample area, whereas for the ACRP 02-35 study, only two of three airports included vacant addresses. Other factors that may have led to a higher PND rate are:

- Vacancy rates vary significantly from airport to airport and some of the sampled airports in the NES had high vacancy rates;
- The NES was in the field longer than the ACRP study, therefore, providing more time for the PNDs to be returned; and
- The NES had a third survey mailing 3 weeks later than the second and final mailing in the ACRP study allowing additional PNDs to be identified. However, while the sample was drawn all at once prior to the start of data collection (up to 1 year in advance of Wave 6 release), this should not have affected the observed rates because it is presumed that the vacancy rates remain stable over time, with the exception of households that are demolished (i.e., removed from the sample universe). With the exception of the

first wave, which was closest to the sample draw, evidence that this rate did not increase over time is provided in Table 6-6, which covers the PND rate across waves.

The telephone match rates (see Section 4.4) and accuracy of matched numbers also differed from the anticipated rates. The match rate is largely a reflection of the population with listed landline telephone numbers. This means communities with a greater than average proportion of unlisted phone numbers or cell phone only households will have lower match rates. The three airports in the ACRP 02-35 study averaged a 40 percent match rate. The NES, by contrast, averaged 49 percent and this resulted in more matched phone numbers than anticipated. However, the accuracy of the matched phones was a bit less than in the ACRP study, meaning a lower percentage of matches reached the correct household. This could have been due to the lag between sample selection and release for some cases or other unknown factors.

Lastly, there was a large improvement in the response rate among those who had provided a phone number (58 percent observed vs. 40 percent anticipated). While the design included a thank-you/reminder postcard and a follow-up request to the nonresponders of the phone request for the NES, the rate of provided phone numbers was slightly less than the anticipated rates based upon ACRP 02-35 results (31 percent observed vs. 35 percent anticipated). It is unknown why a higher response rate was experienced among those who provided their number.

Tables 6-4 through 6-9 provide data collection metrics and response rates (AAPOR RR1 for mail surveys and AAPOR RR2 for telephone surveys) for the survey by stratum, wave, and airport, respectively. Tables 6-8 and 6-9 indicate that the airports had varied response rates for both mail and telephone, with mail response rates ranging from 31.8 percent to 54.1 percent, and telephone response rates ranging from 5.5 percent to 10.5 percent. The correlation between the mail response rate and the telephone response rate across airports is 0.90. In Table 6-5, the response rate decreases for successive noise exposure strata. However, this decrease may be related to the variability in airport response rates, since the airports with larger ranges of noise exposure tend to have lower overall response rates. The response propensity analysis in Appendix E (Section E-1) found that for most airports, the value of DNL was not statistically significantly associated with response rate after accounting for the other variables in the model.

Table 6-4. Mail Survey (AAPOR RR1) Sample Sizes, Completes, and Response Rates by Strata

DNL Stratum	Sample size (1)	Completes	Yield (2)	PND	PND rate	Response rate (RR1)
50-55	9,134	3,592	39.3%	817	8.9%	43.2%
55-60	9,261	3,481	37.6%	804	8.7%	41.2%
60-65	5,470	2,016	36.9%	419	7.7%	39.9%
65-70	3,041	914	30.0%	330	10.9%	33.7%
70+	1,262	325	25.8%	191	15.1%	30.3%
Overall	**28,168**	**10,328**	**36.7%**	**2,561**	**9.1%**	**40.3%**

Notes:
(1) Sample size represents the number of addresses to which the mail questionnaire was sent.
(2) Yield is defined as completes divided by sample size.

Table 6-5. Telephone Survey (AAPOR RR2) Sample Sizes, Completes, and Response Rates by Strata

DNL Stratum	Sample size (1)	Completes	Response rate (RR2)
50-55	9,134	831	10.0%
55-60	9,261	801	9.5%
60-65	5,470	453	9.0%
65-70	3,041	186	6.9%
70+	1,262	57	5.3%
Overall	**28,168**	**2,328**	**9.1%**

Notes:
(1) Sample size represents the number of addresses to which the mail questionnaire was sent.

Table 6-6. Mail Survey (AAPOR RR1) Sample Sizes, Completes, and Response Rates by Wave

Wave	Sample size (1)	Completes	Yield (2)	PND	PND rate	Response rate (RR1)
1	4,476	1,704	38.1%	324	7.2%	41.0%
2	5,509	2,009	36.5%	525	9.5%	40.3%
3	4,856	1,861	38.3%	507	10.4%	42.8%
4	4,485	1,601	35.7%	401	8.9%	39.2%
5	3,907	1,402	35.9%	370	9.5%	39.6%
6	4,935	1,751	35.5%	434	8.8%	38.9%
Overall	**28,168**	**10,328**	**36.7%**	**2,561**	**9.1%**	**40.3%**

Notes:
(1) Sample size represents the number of addresses to which the mail questionnaire was sent.
(2) Yield is defined as completes divided by sample size.

Table 6-7. Telephone Survey (AAPOR RR2) Sample Sizes, Completes, and Response Rates by Wave

Wave	Sample size (1)	Completes	Response rate (RR2)
1	4,476	418	10.1%
2	5,509	503	10.1%
3	4,856	452	10.4%
4	4,485	369	9.0%
5	3,907	299	8.5%
6	4,935	287	6.4%
Overall	**28,168**	**2,328**	**9.1%**

Notes:
(1) Sample size represents the number of addresses to which the mail questionnaire was sent.

Table 6-8. Mail Survey (AAPOR RR1) Sample Sizes, Completes, and Response Rates by Airport

Airport Identifier	Sample size (1)	Completes	Yield (2)	PND	PND rate	Response rate (RR1)
ABQ	1,484	513	34.6%	174	11.7%	39.2%
ALB	1,034	504	48.7%	52	5.0%	51.3%
ATL	1,744	503	28.8%	266	15.3%	34.0%
AUS	1,574	510	32.4%	118	7.5%	35.0%
BDL	1,066	519	48.7%	50	4.7%	51.1%
BFI	1,302	516	39.6%	76	5.8%	42.1%
BIL	1,169	508	43.5%	111	9.5%	48.0%
DSM	1,085	527	48.6%	62	5.7%	51.5%
DTW	1,287	508	39.5%	106	8.2%	43.0%
LAS	1,724	527	30.6%	214	12.4%	34.9%
LAX	1,504	521	34.6%	63	4.2%	36.2%
LGA	1,489	528	35.5%	54	3.6%	36.8%
LIT	1,612	535	33.2%	340	21.1%	42.1%
MEM	1,880	511	27.2%	310	16.5%	32.5%
MIA	1,810	534	29.5%	133	7.3%	31.8%
ORD	1,126	500	44.4%	47	4.2%	46.3%
SAV	1,390	528	38.0%	100	7.2%	40.9%
SJC	1,222	501	41.0%	43	3.5%	42.5%
SYR	1,024	515	50.3%	72	7.0%	54.1%
TUS	1,642	520	31.7%	170	10.4%	35.3%
Overall	**28,168**	**10,328**	**36.7%**	**2,561**	**9.1%**	**40.3%**

Notes:
(1) Sample size represents the number of addresses to which the mail questionnaire was sent.
(2) Yield is defined as completes divided by sample size.

Table 6-9. Telephone Survey (AAPOR RR2) Sample Sizes, Completes, and Response Rates by Airport

Airport Identifier	Sample size (1)	Completes	Response rate (RR2)
ABQ	1,484	112	8.5%
ALB	1,034	139	14.2%
ATL	1,744	129	8.7%
AUS	1,574	110	7.6%
BDL	1,066	138	13.6%
BFI	1,302	92	7.5%
BIL	1,169	138	13.0%
DSM	1,085	139	13.6%
DTW	1,287	133	11.3%
LAS	1,724	90	6.0%
LAX	1,504	108	7.5%
LGA	1,489	79	5.5%
LIT	1,612	141	11.1%
MEM	1,880	121	7.7%
MIA	1,810	100	6.0%
ORD	1,126	103	9.5%
SAV	1,390	108	8.4%
SJC	1,222	93	7.9%
SYR	1,024	148	15.5%
TUS	1,642	107	7.3%
Overall	**28,168**	**2,328**	**9.1%**

Notes:
(1) Sample size represents the number of addresses to which the mail questionnaire was sent.

Table 6-10 shows the distribution a plot of completed mail questionnaires and telephone interviews by month. The goal of a yearlong data collection was to capture an average dose response across all seasons.[22] Since each wave's mailings crossed over 2 months and returns continued to come in during the months following, it is not possible to calculate a monthly response rate.

Table 6-10. Completes by Month

Month	Mail	Telephone
January	1,058	253
February	934	232
March	906	210
April	999	174
May	730	235
June	521	195
July	777	171
August	1,024	154
September	855	165
October	833	155
November	877	185
December	814	199
Total	**10,328**	**2,328**

Notes:
(1) October and November include 2015 and 2016.

[22] The yearlong data collection was also consistent with computing a yearly DNL.

7 Computation of DNL for Average Daily Flight Operations

Cumulative aircraft noise exposure is typically presented in terms of DNL that is based on annual average daily operations. Examining a year's worth of data accounts for seasonal or other variability in aircraft operations. For this project, a method was devised to compute noise exposure for every day of a year and the overall annual average day DNL in a consistent, repeatable manner for each airport considered.

It is important to note that for modeling of any kind, a degree of uncertainty in the results should be expected. Modeling accuracy is dependent on a range of factors. The two primary factors are 1) how well the fundamental quantity to be modeled is understood and calculated, and 2) how accurately the inputs needed by the model are provided. The aircraft noise modeling for this research effort used the FAA-approved INM, which provides both detailed noise calculations and a framework to manage the large amount of input data needed to accurately represent actual conditions. In this way, any aircraft noise modeling uncertainty was minimized resulting in accurate results suitable for the analysis described in this report.

Although the focus of the research effort is the national dose-response based on the 20 airports listed in Section 3.2, noise modeling included Seattle-Tacoma International Airport (SEA). Because of its proximity to BFI and the layout of SEA-based flight tracks, SEA's flight operations significantly influence the DNL of BFI's set of potential respondents. Of the 20 selected airports, only BFI had another airport (SEA) in proximity capable of influencing the DNL of the selected airport.

This section documents in detail how DNL for each of the 20 airports was computed. Section 7.1 provides an overview of the method. Section 7.2 address the basic setup parameters used in the INM. Section 7.3 discusses the radar flight track data and its processing. Section 7.4 addresses final data processing and Section 7.5 concludes with consideration of numbers of operations and final DNL calculations.

Appendix F summarizes the basic data used for modeling each of the airports. The intent of Appendix F is to assist in understanding the general nature of the airspace use and the predominant aircraft types that use each airport. It is not intended to provide sufficient information to repeat the noise metric calculations done for this research effort.

7.1 Overview of Method and Introduction

DNL for every potential respondent location at each airport was computed with the FAA's INM version 7.0d (FAA 2013), based on annual average daily flight operations. Although INM was superseded in 2015 by the FAA's Aviation Environmental Design Tool (AEDT)[23], initial phases of this project had started years prior and had used INM for selection of respondents. The use of INM, instead of AEDT, was maintained for consistency throughout the project.

Most of the input data for the INM relied on a year's worth of radar flight tracking data from the FAA for each of the 20 airports. Section 7.3.2 gives specific dates. FAA radar flight tracking data sources consisted of the Performance Data Analysis and Reporting System (PDARS)[24] and National Offload Program (NOP).[25] Operations counts derived from the radar flight tracking data were scaled and balanced to match official

[23] https://aedt.faa.gov/

[24] PDARS gathers information from systems at Air Route Traffic Control Centers (ARTCCs), Terminal Radar and Approach Control (TRACON) facilities and most recently from Air Traffic Control Tower (ATCT) facilities. ARTCCs track and provide service to an aircraft for the duration of its journey. TRACONs track and provide service to aircraft approaching and departing between 5 and 50 miles of an airport. ATCTs track and provide service to aircraft on the airport surface and immediate vicinity. Definition from http://www.atac.com/pdars.html

[25] NOP is operated by the FAA, and collects National Airspace System (NAS) operational data daily. One of the data items collected is flight tracks. Flight tracks contain identifying flight number and flight status (arrival, departure, or overflight) and position reports including (latitude, longitude, altitude, and time-of-report).

National Airspace System air traffic operations data available for public release, (i.e., the FAA's Air Traffic Activity Data System (ATADS) counts), for 2015 for each airport. Using specialized data management software and utilities[26], the radar flight tracking data for each airport was consistently checked and pre-processed into INM-compatible input for each available day. INM was used to generate daily DNL results, which were then energy-averaged to determine the average annual day DNL results.

DNL for each airport was computed twice – once for the generation of DNL contours and the selection of respondents (Section 4) using data from 2012 and 2013/2014 and a second time when the survey was completed with a final set of respondents using updated aircraft operations counts for 2015. See Section 7.3.2 for further detail about the data sources for each run.

No ground run-up modeling was performed.

7.2 Basic Setup Parameters

This section describes the basic physical parameters unique to each airport that are required by the INM – runway lengths and locations (7.2.1), helipads (7.2.2), if any, and local weather conditions (7.2.3) and terrain (7.2.4).

7.2.1 Runway Geometry

The INM includes an internal airport layout database, including runway locations, orientation, start-of-takeoff roll points, runway end elevations, landing thresholds, approach angles, etc. The primary information INM uses concerning runways is:

- Departure thresholds (i.e. where aircraft begin their take-off roll),
- Arrival threshold (a location marked on the runway),
- Arrival threshold crossing height (TCH) (the height that arriving aircraft cross the arrival threshold),
- Displaced threshold (distance from the runway end where an aircraft first touches down),
- Runway gradient (i.e. is the runway slightly uphill or downhill),
- Runway location, and
- Runway direction.

The INM data for each of the selected airports were updated with data downloaded from the "Airport Data & Contact Information" section of FAA's website.[27] These data originate from the FAA Airport Master Record (5010-1) forms.

7.2.2 Helipad Location

The locations of helipads (if present) were determined using a combination of FAA 5010 data, location of the beginning/end of helicopter flight tracks, and visual investigation of satellite imagery. INM requires that helicopter operations originate and end at a helipad. Therefore, a helipad must be identified if helicopter operations are to be modeled at a particular airport. If helicopters operate from runways, then a virtual helipad must be identified at the location on the runway used by helicopters.

[26] HMMH's proprietary programs, InFLIGHT™ and RealContours™ and several HMMH-developed processing utilities, were used to process and check the radar data into an INM-compatible form. These programs and utilities manage the large amount of data involved in running the INM using operations for a year of operations at an airport. These HMMH programs do no noise related computation; they assist in preparing the input needed by the INM.
[27] FAA 5010 data downloaded July 10, 2013 from http://www.faa.gov/airports/airport_safety/airportdata_5010/

7.2.3 Weather

The INM has several settings that account for the effects that meteorological conditions have on aircraft performance profiles and sound propagation. INM's meteorological settings include average temperature, barometric pressure, relative humidity, and wind direction and speed.

For purposes of establishing the sampling frame and consistency with the radar flight tracking data (see Section 7.3 for the latter), weather data was downloaded from the National Climatic Data Center (NCDC) website[28] for the date range June 2012 to May 2013 for all airports.[29] The data range of the weather data was the same as the radar flight tracking data's date range, for all airports except ORD.[30] Annual average daily weather conditions were based on analysis of the hourly NCDC data. Table 7-1 displays the resultant annual average weather conditions for each airport. The computation of each day's DNL for the 2015 case year used the data from Table 7-1[31], including ORD.

Table 7-1. Modeled Average Weather Conditions

Airport Identifier	WBAN Station ID	Temperature (degrees Fahrenheit)	Barometric Pressure (inches of Mercury)	Relative Humidity (Percent RH)
ABQ	23050	59.0	29.96	32.5
ALB	14735	50.0	30.02	67.9
ATL	13874	62.8	30.06	63.9
AUS	13904	68.5	30.00	65.5
BDL	14740	51.8	30.00	65.5
BFI	24234	53.4	30.06	71.3
BIL	24033	49.8	29.98	50.7
DSM	14933	52.2	30.01	62.8
DTW	94847	51.7	30.02	65.0
LAS	23169	71.1	29.88	25.5
LAX	23174	63.2	29.98	69.4
LGA	14732	56.2	30.01	61.8
LIT	13963	62.9	30.05	66.1
MEM	13893	62.9	30.04	63.8
MIA	12839	76.7	30.04	70.8
ORD	94846	51.6	30.00	66.6
SAV	3822	66.1	30.06	71.2
SJC	23293	59.1	30.03	67.9
SYR	14771	50.7	30.00	67.6
TUS	23160	70.9	29.90	33.3
SEA	24233	52.7	30.09	72.0

7.2.4 Terrain

Terrain data describe the elevations of the ground surface surrounding the airport and on airport property. The INM uses terrain data to adjust the ground level under the flight paths at which noise metrics are computed. The terrain data do not affect the aircraft's performance or emitted noise levels, but do affect the

[28] Weather data available at: ftp://ftp3.ncdc.noaa.gov/pub/data/noaa/isd-lite/

[29] Weather data were not adjusted for missing or bad radar dates described in Section 7.3. The entire range was used for weather averaging.

[30] As described in Section 7.3.2, ORD's radar data ranged from November 2013 to October 2014.

[31] Each day's weather conditions could not be used because of the limitations of the data processing software.

distance between the aircraft and a "receiver" on the ground. This in turn affects the noise levels propagated to the receiver. The terrain data were obtained from the United States Geological Survey (USGS). [32]

7.3 Radar Flight Tracking Data Processing

Subsections 7.3.1 through 7.3.6 describe the sources of radar flight tracking data and its processing.

7.3.1 Radar Flight Tracking Data Sources

The FAA provided data from two repositories of historical National Airspace System (NAS) Data: PDARS and NOP. Both repositories collect and store similar Instrument Flight Rule (IFR) flight track data from FAA air surveillance systems. Availability of Visual Flight Rule (VFR) flight track data is often limited, as FAA does not always retain this data. In accordance with FAA policy in providing radar flight tracking data, the FAA omitted sensitive military operations and aircraft with an approved Block Aircraft Registration Request.

Table 7-2 lists the radar flight tracking data sources used for the 20 selected airports. Approximately half of the selected airports were served by PDARS and the remaining airports were served by NOP. PDARS and NOP are further described in the following two subsections, respectively.

Table 7-2. Radar Flight Tracking Data Sources

PDARS / ARTCC	NOP
ATL	ABQ
BFI	ALB
DTW	AUS
LAS	BDL
LAX	BIL
LGA	DSM
MEM	LIT
MIA	SAV
ORD	SYR
SJC	TUS
SEA	

Note: SEA was modeled and its results combined with BFI due to SEA's proximity to BFI.

7.3.1.1 PDARS

PDARS gathers information from systems at Air Route Traffic Control Centers (ARTCCs), Terminal Radar and Approach Control (TRACON) facilities and most recently from Air Traffic Control Tower (ATCT) facilities. ARTCCs track and provide service to an aircraft for the duration of its journey. TRACONs track and provide service to aircraft approaching and departing between 5 and 50 miles of an airport. ATCTs track and provide service to aircraft on the airport surface and immediate vicinity.

Ten (10) of the selected airports (plus SEA) were close to TRACONs and thus PDARS radar flight tracking data were available. As the provided PDARS radar flight tracking data did not include city pairs[33], it was supplemented with data from the ARTCC. The ARTCC data includes arrival and departure airports for every flight operation, and these data were used to associate the proper city pair with the PDARS data for as many

[32] Terrain data downloaded from http://viewer.nationalmap.gov/viewer.

[33] City pairs are the two airports between which an aircraft flies. The city pairs are used to determine the distance of the flight. INM represents trip distance with a "stage length" as a surrogate for aircraft takeoff weight (related to amount of fuel required to cover the trip distance). Thus, a city pair is needed to select the best INM departure flight profile (altitudes, power settings and speeds) for each specific aircraft type.

flights as possible. Hence, the constructed database contains city pairs for most flights, which was used to select the proper INM departure stage lengths (see Section 7.4.2).

7.3.1.2 NOP

NOP is operated by the FAA, and collects NAS operational data daily. One of the data items collected is flight tracks. Flight tracks contain identifying flight number and flight status (arrival, departure, or overflight) and position reports including (latitude, longitude, altitude, and time-of-report).

For the remaining ten (10) airports, radar flight tracking data were acquired from the NOP. The NOP radar flight tracking data did not include runway assignments, so spatial analyses were performed to make the runway assignments (see Section 7.3.4).

7.3.2 Dates Included in Radar Flight Tracking Data

The date range of data selected for all airports except ORD is June 1, 2012 to May 31, 2013. For ORD, data from November 1, 2013 to October 31, 2014 was used because of the initiation of the ORD modernization program begun in October 2013. Additionally, due to NOP data issues on December 1, 2012 and December 2, 2012, data for these two days were also removed for all NOP-sourced airports. There were several other unused days for some of the airports because the days were either missing completely, duplicating other days, or contained inaccurate information. Table 7-3 shows the dates excluded from radar flight tracking data for each selected airport.

Table 7-3. Radar Flight Tracking Data Date Summary

Airport Identifier	Total Days Included	Days Not Included
ABQ	354	12/1/2012, 12/2/2012, 1/25/2013 to 2/3/2013
ALB	363	12/1/2012, 12/2/2012
ATL	365	
AUS	363	12/1/2012, 12/2/2012
BDL	363	12/1/2012, 12/2/2012
BFI	365	
BIL	359	12/1/2012 to 12/6/2012
DSM	363	12/1/2012, 12/2/2012
DTW	365	
LAS	365	
LAX	365	
LGA	362	3 days excluded due to Hurricane Sandy
LIT	363	12/1/2012, 12/2/2012
MEM	365	
MIA	365	
ORD	361	12/1/2013, 2/23/2014, 3/8/2014, 3/9/2014
SAV	365	12/1/2012, 12/2/2012
SJC	365	
SYR	363	12/1/2012, 12/2/2012
TUS	360	6/23/2012, 8/31/2012, 12/1/2012, 12/2/2012, 12/15/2012
SEA	365	

7.3.3 Initial Data Filtering and Time Zone Adjustment

Through coordination with FAA, HMMH received radar flight tracking data files for each airport. Both types of radar flight tracking data (NOP and PDARS) consist of text files, but the format of the text files is different between them. HMMH used proprietary in-house software to parse the data files and import the data into several tables within a SQL database (one database for each airport).

During the import process, several filtering options were used to exclude and/or modify radar flight tracking data that was deemed unusable or unsatisfactory. These import options included the following options, each of which is discussed in their respective subsections:

- Time Gap Limits,
- Speed Outlier Detection,
- Maximum Range Filtering,
- Maximum Altitude Filtering, and
- Time Zone Adjustment.

7.3.3.1 Time Gap Limits

The Time Gap Limit analysis computed the time difference between consecutive points of a flight track. Radar systems interrogate and supply a data point every 4 to 5 seconds, but in the case of corrupted data received, points from two different flights can be mistakenly joined together as one flight track or unexpected gaps in time greater than the normal can mean the track is unreliable. When two consecutive points of a track had a time difference greater than a specified threshold, the flight track was split into two separate flight tracks at that gap. A large time gap between consecutive points often indicates a problem with the flight track, and the flight track geometry was considered unreliable for the purpose of the research effort.

The time gap threshold used for this project was 270 seconds (4.5 minutes).

7.3.3.2 Speed Outlier Detection

Speed is reported in the raw data. The Speed Outlier Detection analysis identified flight track points whose speed exceeded a specified threshold, i.e., a flight segment of such speed would not make sense in the context of “near-airport” aircraft operations. If the speed specified in the radar flight tracking data was greater than a specified threshold, the flight track point was considered an outlier or corrupt and not uploaded to the SQL database. The resultant flight track would be derived from the remaining points for that flight.

The speed threshold used for this project was 320 meters per second (622 knots; 716 miles per hour).

7.3.3.3 Maximum Range Filtering

Maximum Range Filtering excluded flight track points whose distance from the airport of interest exceeded a specified threshold distance. The flight tracks were “clipped” at the threshold distance to exclude data not in the area of interest and would not influence the resultant cumulative noise exposure. This also excluded flight track points that may have been reported incorrectly.

The maximum range threshold used for this project was 200 nautical miles.

7.3.3.4 Maximum Altitude Filtering

The Maximum Altitude Filtering excluded flight track points whose altitude exceeded a specified threshold altitude. The flight tracks were “clipped” at the threshold altitude to exclude data not in the area of interest and would not influence the resultant cumulative noise exposure. This also excludes flight track points that may have been reported incorrectly.

The maximum altitude threshold used for this project was 100,000 feet above Mean Sea Level.

7.3.3.5 Time Zone Adjustment

The PDARS radar flight tracking data timestamp information is reported in local time, appropriate for each airport. However, the NOP radar flight tracking data timestamp information is reported in Coordinated Universal Time (UTC). For the purposes of noise modeling, it is important to convert these timestamps into a local time zone to determine DNL period (day or night). Each airport with NOP data was converted to the appropriate local time zone for that airport. Table 7-4 lists the time zone adjustments applied to each airport.

Table 7-4. Time Zone Adjustments for Airports with NOP Data

Airport Identifier	Local Time Zone (US)	UTC Standard Offset	UTC Daylight Savings Time Offset
ABQ	Mountain	UTC-7	UTC-6
ALB	Eastern	UTC-5	UTC-4
AUS	Central	UTC-6	UTC-5
BDL	Eastern	UTC-5	UTC-4
BIL	Mountain	UTC-7	UTC-6
DSM	Central	UTC-6	UTC-5
LIT	Central	UTC-6	UTC-5
SAV	Eastern	UTC-5	UTC-4
SYR	Eastern	UTC-5	UTC-4
TUS	Mountain	UTC-7	UTC-6

Note: Daylight Savings Time runs from the second Sunday in March at 02:00 a.m. until the first Sunday in November at 02:00 a.m., in all zones, except TUS.

7.3.4 Runway Assignment, Data Reduction and Final Filtering

7.3.4.1 Runway Assignment

Spatial analyses were performed on each airport's data to make and/or verify the runway assignments reported in the radar flight tracking data. These spatial analyses include the calculations of [1] angle between "closest" flight track segment and assigned runway and [2] distance between "closest" flight track segment and assigned runway.

These spatial calculations helped determine runway assignment for each flight track. As the NOP radar flight tracking data did not include runway assignments, spatial analysis was used to make the runway assignments. As the PDARS radar flight tracking data included runway assignments, spatial analysis was used to verify the runway assignments.

7.3.4.2 Extraneous Points

Once the geometric analyses had been performed, the Ramer-Douglas-Peucker algorithm (Ramer 1972, Douglas and Peucker 1973) was applied to the flight track points. The purpose of the algorithm is, given a curve composed of line segments, to find a similar curve with fewer points. The algorithm defines 'dissimilar' based on the maximum distance between the original curve and the simplified curve, i.e., the Hausdorff distance between the curves (Hausdorff 1914). The simplified curve consists of a subset of the points that defined the original curve.

Reducing the number of flight track points while maintaining the flight track shape reduces analysis time, reduces noise modeling run time, and reduces data storage requirements.

7.3.4.3 Final Filtering

Within the SQL databases for each airport, some flight operations were tagged as "Bad Data," indicating that they were not usable for noise modeling. There are several reasons that an operation may have been deemed unusable for noise modeling purposes, including erroneous flight track geometry, a lack of information to assign to an aircraft type, duplicate operations, or the operation was an overflight, i.e., not an operation associated with the airport of interest. Averaging all airports, discarded (filtered out) data comprised five percent of the non-overflight airport-specific operations, due to the reasons summarized above.

7.3.5 Data Checking

Flight tracks from the radar data were visually inspected to ensure:

- Assignment to the correct runway,
- Alignment with the assigned runway, and
- Arrivals and departures were correctly identified.

Flight track inspection also determined the altitudes of the downwind legs of "circuit" (touch and go or other types of closed pattern) flights.

Figure 7-1 shows a typical example of the arrival and departure data for one of the 20 selected airports, while Figure 7-2 is a closer view in which it is possible to see that the alignments are reasonable (red are arrivals, green are departures). Ultimately, as the radar tracks were converted to INM tracks, the tracks were extended or trimmed to connect with the proper runway ends.

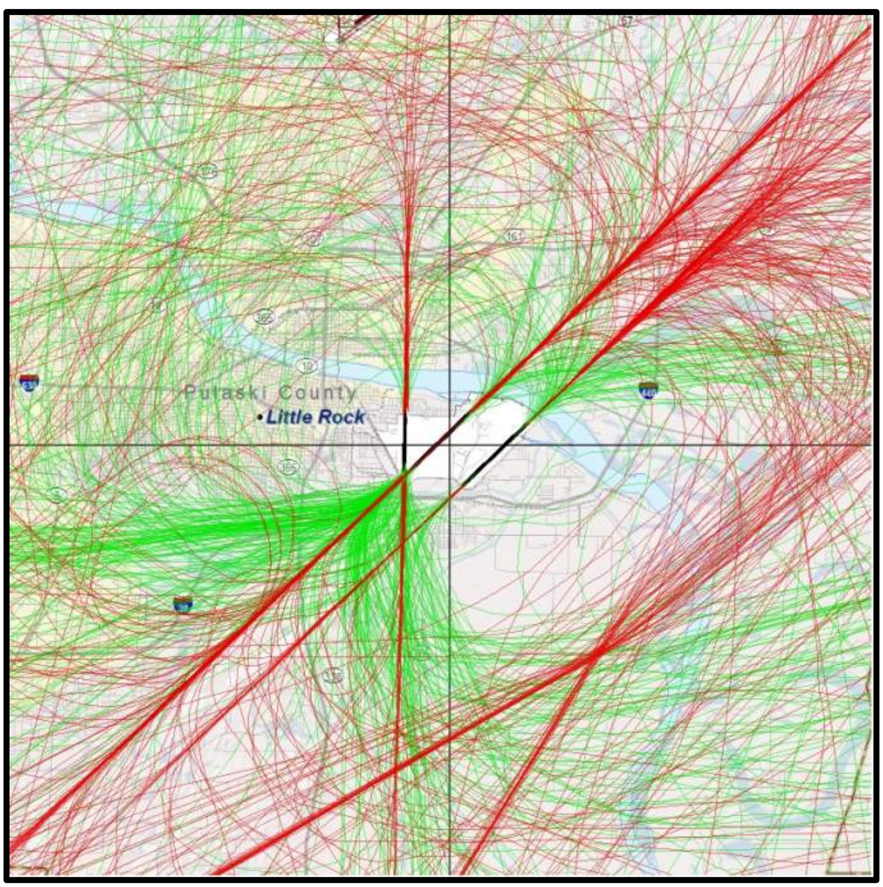

Figure 7-1. Overview of Typical Radar Track Arrivals and Departures

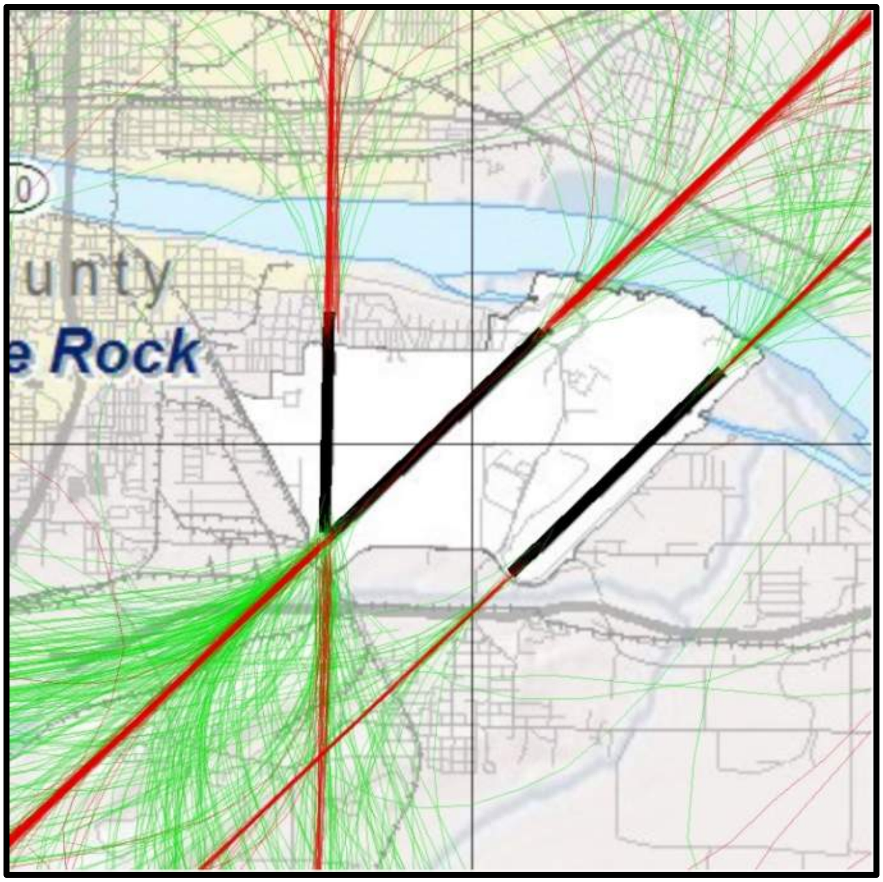

Figure 7-2. Close-up View to Check Alignment with Runways

Closed pattern flight tracks, or “Circuits”, were also examined. Modeling circuit tracks with the INM requires special consideration. Generally, these tracks depart and arrive on a single runway and in the INM must be treated as the combination of separate takeoff and landing segments. In general, circuits consist of a departure segment, a level “downwind” segment and an arrival segment. For the downwind segment, INM requires an altitude or pattern height. Pattern altitudes were determined from published sources but if they were not published, the pattern altitudes were determined from examination of the most common long level segment. Each circuit is counted as two operations in the ATADS counts to which the modeled operations were scaled.

Figure 7-3 shows an example of a flight track identified as a circuit. The track shown in the figure is for a C-130 Hercules conducting two separate patterns – the large pattern was flown first, followed by the smaller pattern.

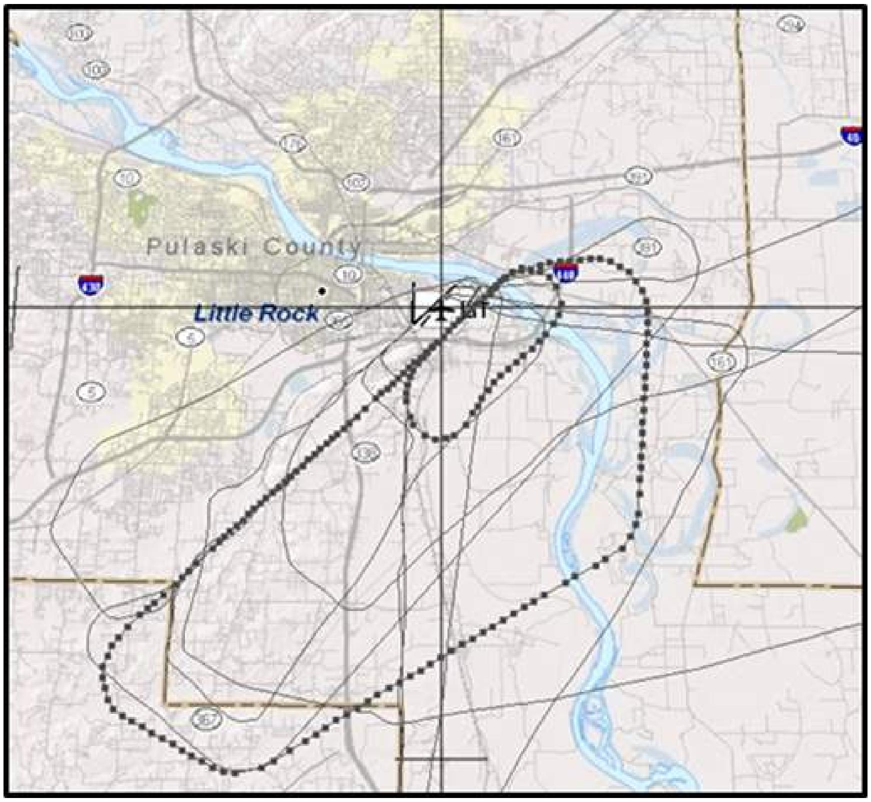

Figure 7-3. Circuit Tracks in the Flight Tracking Data with C-130 Circuit Identified

The particular track of Figure 7-3 is noteworthy because it demonstrates how two different altitudes may be flown and both must be identified and modeled. Figure 7-4 shows a graph of altitude versus elapsed time for the identified flight of Figure 7-3. Figure 7-4 shows the large pattern's downwind leg is at 2000 feet Above Field Elevation (AFE), while the small pattern's downwind leg is at approximately 1,200 feet AFE. For some airports, it was necessary to develop two circuit profiles for other purposes such as differentiating altitudes between non-jet and jet or military aircraft.

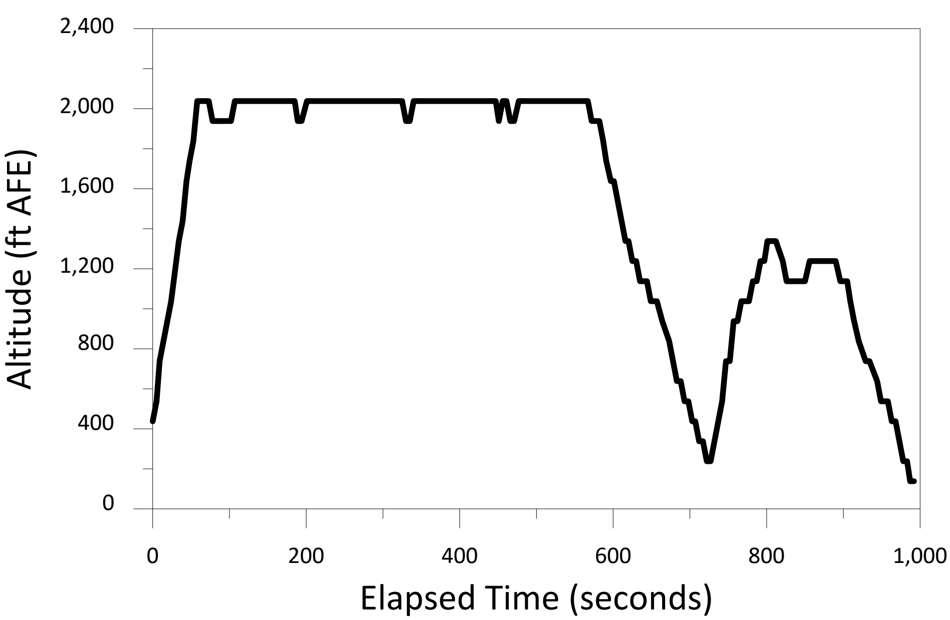

Figure 7-4. Representative Altitude Profile for the Aforementioned C-130 Circuits

7.3.6 Extended Flight Profiles

To ensure that DNL as low as 50 dB could be modeled accurately, the maximum cumulative flight track distances for each INM standard flight profile were compared against the expected flight track distances from the flight tracking data. The latter distances were found to exceed those in the standard INM flight profile database. Therefore, all arrivals were extended at constant approach thrust and angle from 6,000 feet AFE to 10,000 feet AFE, and all departures were extended at constant climb thrust and angle from 10,000 feet AFE to 18,000 feet AFE. Best modeling practices previously approved for INM were used to modify the standard profiles.

7.4 Final Data Processing

Subsections 7.4.1 through 7.4.5 describe five facets of the final data processing.

7.4.1 Generating INM Input

Using the database of flights conditioned as described in the above subsections, each available aircraft flight track was prepared for input into INM, conducting the following pre-modeling checks for compatibility with the INM:

- Examined each track for sufficient length (adequate number of radar returns to model the full profile),
- Checked that a runway assignment exists for all tracks,
- Cut the arrival track where the aircraft descended through 500 feet AFE and then connected the track to the appropriate runway end[34], and
- Checked aircraft type and whether or not the type is acceptable for the runway assigned. Occasionally, through improper coding or typographical error, departing aircraft are assigned to a runway from which they are incapable of taking off. In other words, their distance required to rotate or takeoff exceeds the length of the runway. The software equivalent of look-up tables of acceptable aircraft types for each runway was prepared and used to avoid this error.

Having eliminated tracks with insufficient or incorrect data[35], the INM input was generated. The process itself does not modify INM "standard" noise, performance or aircraft substitution data, but rather selects the best standard data or FAA approved non-standard data, available to INM for each individual flight track.

To create the INM input, the following functions were performed:

- Directly converted the radar flight track from PDARS or NOP for every identified aircraft operation to an INM-formatted track;
- Modeled each ground track as it was flown, including deviations (due to weather, safety or other reasons) from the typical flight patterns;
- Modeled each operation:
  - On the specific runway that was actually used and
  - In the period (i.e. day = 7 a.m. to 9:59 p.m. and night = 10 p.m. to 6:59 a.m.) in which that operation occurred.

[34] INM requires arrival tracks to end (or begin in reverse) precisely at the runway endpoint whereas radar data rarely ends exactly at the runway endpoint.

[35] Across the 20 airports, eliminated (insufficient or incorrect) radar tracks ranged from less than 1 percent (LAX) to 10 percent (ABQ). The 20-airport average was 4 percent.

- Selected the specific airframe and engine combination to model, on an operation-by-operation basis, by using the aircraft type designator associated with the flight plan and, if available, the registration number and the published composition of the individual operator's aircraft inventory (see Section 7.4.4); and
- Used the city-pair distances (the Great Circle distance around the globe connecting a departing and arriving airport) to select a standard INM departure stage length. Stage length is an index associated with a range of trip distance. Where no city-pair was available, stage length was selected by comparing the radar flight track altitude profile to the standard INM aircraft departure profiles (see Section 7.4.2).

7.4.2 Flight Profiles

The stage length for individual departure flights having city pairs was calculated based on the destination airport (city-pair) on the flight plan. Each flight's city-pair great-circle distance was compared to the stage lengths available in the default INM database and an appropriate selection was made. INM does not have all stage lengths available for all aircraft. In cases where the stage length determined by city-pair was not available in the INM or would result in aircraft over-running the runway on departure, the maximum stage length available not causing the aircraft to overrun the runway was selected. If a particular INM aircraft had multiple available default profiles in INM for a given stage length or an operation did not have a city pair, the flight track's altitude profile was compared to the available default INM profiles, and a default INM profile was assigned based on the closest match.

7.4.3 Day / Night Assignment

The flight tracking data included timestamp data for each operation. For arrivals and circuits, the flight's end time (last radar ping) was used to determine if the flight belonged to the DNL nighttime period (10:00 p.m. through 6:59 a.m.). For departures, the flight's start time (first radar ping) was used.[36] The INM applies the DNL-defined 10 dB "penalty" to all operations occurring at night.

7.4.4 Aircraft Types

The INM aircraft database contains noise and performance data for over 100 different aircraft types. The aircraft types given in the radar flight tracking data were converted to the most appropriate INM aircraft type contained within the INM database. The conversion to INM type consisted of several look-up tables, including (in order of priority) FAA registration data lookups, published airline and nationwide fleet mix data (J.P. Airline Fleet International 2013/2014), and HMMH experience.

Table 7-5 shows the modeled annual flight "events"[37] by aircraft category to convey a sense of how predominant aircraft categories varied across the airports. Commercial Jet events dominated other categories at all airports for both data years except: a) BFI and BIL, where Civilian Props dominated for both data years; and b) TUS, where Civilian Props dominated for 2015. TUS had the highest Military Fighter Jet percentage of all airports at 14-16 percent; Military Fighter Jet aircraft were likely a large contributor to the DNL at TUS.

Table 7-5 also shows the events data for both data years for which DNL was computed (initially for sampling purposes using 2012-2013 data and the second time for final DNL at each respondent using 2015 data). Total events decreased from the 2012-2013 data year to 2015 by an average of 2.4 percent across the set of airports. Figure 7-5 presents the total flight events for both data years graphically. MEM experienced the

[36] Note that these nighttime percentages were computed from 2012-2013/2014 radar data and thus reflect the best available operations numbers for each airport information and most accurate nighttime percent, Section 7.4.3; the error discussed in Section 3.5.2, Percentage of Nighttime Operations, had no effect on DNL computations.

[37] The term 'event' is intentionally used instead of the term 'operation'. An event is an arrival, departure or pattern (or circuit) where a pattern is counted as one event. An operation is an arrival, departure or pattern where a pattern is counted as two operations.

greatest decrease in total events (15.6 percent). SJC experienced the greatest increase in total events (9.6 percent). If SEA is included, the average decrease in total events is 1.4 percent and SEA would be the airport with the greatest increase in total events at 19 percent.

Table 7-5. Annual Flight Events by Aircraft Family

Airport Identifier	Commercial Jet	Civilian Jet, Other	Civilian Prop	Civilian Rotorcraft	Military Jet, Fighter	Military Jet, Other	Military Prop	Military Rotorcraft	Total
2012-2013									
ABQ	64,949	4,800	40,923	3,318	1,386	637	8,817	8,387	133,217
ALB	32,895	3,281	26,755	2,791	-	93	1,464	2,512	69,791
ATL	904,914	4,934	10,929	-	7	190	102	-	921,076
AUS	107,847	17,213	38,823	2,698	680	398	2,841	2,260	172,760
BDL	69,727	9,361	10,776	2,470	7	1,385	571	1,331	95,628
BFI	19,253	31,724	111,615	-	458	100	110	-	163,260
BIL	12,360	3,518	52,638	1,542	8	104	337	62	70,569
DSM	41,003	10,101	19,178	440	27	189	185	64	71,187
DTW	414,973	4,393	4,539	-	17	111	60	-	424,093
LAS	356,971	36,821	20,255	107,488	369	268	611	-	522,783
LAX	532,903	16,008	51,090	-	-	-	-	-	600,001
LGA	360,467	5,782	5,502	363	-	-	-	-	372,114
LIT	40,504	12,341	30,774	3,122	165	2,575	8,830	618	98,929
MEM	224,272	11,432	16,395	-	307	496	562	-	253,464
MIA	354,369	14,161	23,413	-	3	472	477	-	392,895
ORD*	858,143	5,475	5,483	-	-	175	18	-	869,294
SAV	32,120	12,905	26,946	1,574	2,796	1,028	2,757	658	80,784
SJC	95,412	16,236	20,542	-	-	42	232	-	132,464
SYR	32,740	3,001	24,643	1,479	26	285	489	395	63,058
TUS	44,129	10,361	42,063	6,826	16,663	1,237	1,314	407	123,000
SEA	215,792	2,307	90,819	-	-	-	-	-	308,918
2015									
ABQ	56,819	4,958	38,751	3,047	1,501	494	6,985	9,112	121,667
ALB	30,575	3,469	25,171	2,716	-	78	1,195	2,090	65,294
ATL	870,252	4,640	6,948	-	16	417	224	-	882,497
AUS	122,269	16,927	38,718	2,593	922	539	3,856	3,060	188,884
BDL	70,792	8,812	8,702	2,325	5	1,112	461	1,063	93,272
BFI	19,276	28,265	96,709	-	724	158	175	-	145,307
BIL	12,516	3,671	53,939	1,565	7	113	278	50	72,139
DSM	38,741	9,685	16,920	397	86	490	534	203	67,056
DTW	371,878	4,359	3,037	-	9	60	32	-	379,375
LAS	365,623	36,173	19,504	101,983	472	343	781	-	524,879
LAX	598,879	17,257	38,357	-	-	-	-	-	654,493

Table 7-5. Annual Flight Events by Aircraft Family (continued)

Airport Identifier	Commercial Jet	Civilian Jet, Other	Civilian Prop	Civilian Rotorcraft	Military Jet, Fighter	Military Jet, Other	Military Prop	Military Rotorcraft	Total
2015									
LGA	358,443	5,327	4,258	334	-	-	-	-	368,362
LIT	32,647	11,807	30,558	2,405	152	2,356	8,059	566	88,550
MEM	191,334	12,662	12,798	-	534	864	979	-	219,171
MIA	379,172	13,862	18,658	-	3	606	613	-	412,914
ORD	864,798	5,394	4,810	-	-	130	5	-	875,137
SAV	35,724	12,314	26,082	1,370	3,154	1,195	3,192	772	83,803
SJC	106,195	17,837	22,169	-	-	42	226	-	146,469
SYR	31,973	3,013	21,679	1,416	27	220	579	405	59,312
TUS	41,215	10,134	43,562	6,749	20,002	1,354	1,568	508	125,092
SEA	271,392	2,658	107,233	-	-	-	-	-	381,283

* For ORD, "2012-2013" is actually 2013-2014.

7.4.5 Define Study Area for Each Airport

INM requires a contour grid area to be defined for each airport. It is standard practice to base the extent of this area on the lowest value of DNL to be contoured or computed. For this project, the lowest DNL to be contoured is 50 dB. Although this project is basing its results on annual average daily operations, best practice is to base the extents of the study area on the 'busiest' day, i.e., the day with the most operations, because the DNL 50 dB contour of the busiest day will always be larger than the DNL 50 dB contour of the average day. Hence, once the pre-modeling runs were done and all days were ready for INM processing, the busiest day was selected and run to determine the size and shape of the DNL 50 dB contour with the following steps:

- Dominant operational flow days, i.e., days with most operations in each flow condition, were identified,
- DNL contours for dominant operational flow days were computed,
- Maximum extent of DNL 50 dB contour was determined from the DNL contours for the dominant operational flow days,
- Grid size was set to cover the maximum extent of the DNL 50 dB contour and
- Terrain grid was cropped to one nautical mile larger than the noise grid extent.

Additionally, all daily DNL 50 dB contours were examined to insure that none extended beyond the planned study area.

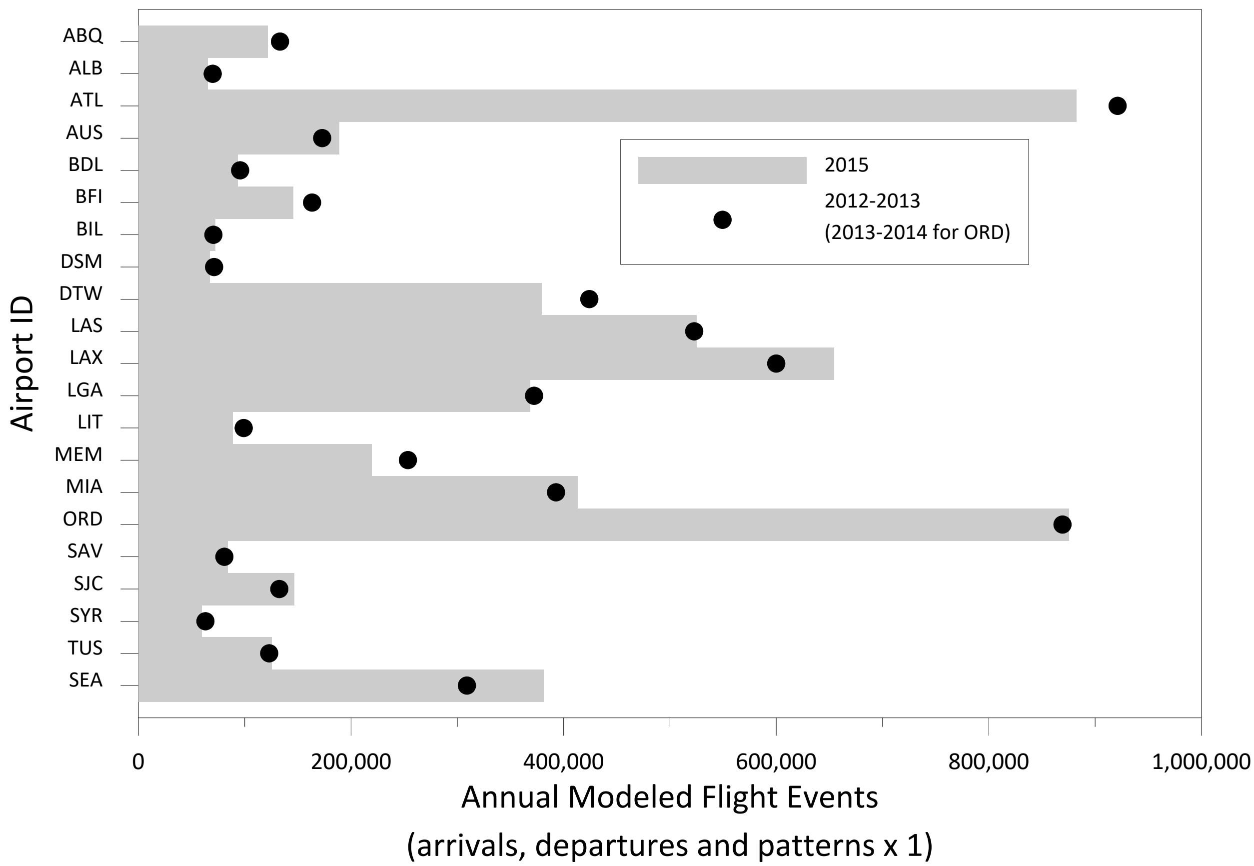

Figure 7-5. Total Flight Events for Both Data Years

7.5 Numbers of Operations and Final DNL Computations

Having created all the necessary model input data, as described in the preceding sections, only adjustments to operations numbers and error checking remained before producing the final output runs. Sections 7.5.1 through 7.5.2 detail the adjustments made and the output processing, respectively.

7.5.1 Scale and Balance Operations

The data source and standard for numbers of annual flight operations for each airport was traffic counts from the FAA's ATADS for 2015. Because the operations numbers derived from flight tracking data may not have been equal to the ATADS counts, the former needed to be reconciled – scaled and balanced – to the 2015 ATADS counts. Scaling means adjusting the modeled operations to equal the FAA's annual counts by aircraft category. Balancing means making the modeled arrival operations equal the modeled departure operations by aircraft type and FAA aircraft category. Aircraft categories were (FAA 2014):

- Air Carrier: Operations by aircraft capable of holding 60 seats or more and are flying using a three-letter company designator.
- Air Taxi: Operations by aircraft less than 60 seats and are flying using a three letter company designator or the prefix "Tango".
- Military: all classes of military operations.
- General Aviation: Civil (non-military) aircraft operations not otherwise classified under air carrier or air taxi.

Operations were assigned to the FAA aircraft categories given the airline code from the radar flight tracking data and INM's aircraft database (Weight and Owner Categories of the INM 'aircraft.dbf' file) and by manual inspection. Appendix F shows the ATADS data and its evolution through the scaling process. Except for the overall numbers of flight operations, the final noise modeling did not account for operational changes occurring at some of the study airports during the period between 2012 and 2015, nor any changes occurring during the survey period in 2015/2016.

Table 7-6 shows the total number of radar tracks used and the total number of operations modeled on those tracks because of the scaling and balancing process that assigned the total number of operations to the total number of usable radar tracks. For the 2015 data year, the ratios ranged from 1.02 (MEM)) to 1.95 (BFI), averaging 1.16. BFI, BIL and TUS had the highest ratios of the set of airports, i.e., between 1.46 and 1.95.

Table 7-6. Total Number of Tracks and Operations Modeled

Airport Identifier	Number of Flight Tracks	2012-2013* Annual Flight Operations Modeled (ATADS counts scaled to Number of Data Days)	2012-2013* Ratio of Operations to Flight Tracks	2015 Annual Flight Operations Modeled	2015 Ratio of Operations to Flight Tracks
ABQ	115,036	138,797	1.21	124,184	1.08
ALB	60,829	74,322	1.22	69,865	1.15
ATL	912,968	921,077	1.01	882,497	0.97
AUS	157,269	174,105	1.11	191,193	1.22
BDL	89,513	95,902	1.07	93,507	1.04
BFI	84,772	187,016	2.21	165,571	1.95
BIL	52,953	79,783	1.51	81,040	1.53
DSM	62,377	73,777	1.18	69,387	1.11
DTW	420,749	424,093	1.01	379,376	0.90
LAS	497,494	522,784	1.05	524,878	1.06
LAX	593,065	600,001	1.01	654,493	1.10
LGA	358,160	372,113	1.04	368,362	1.03
LIT	87,439	105,077	1.20	99,039	1.13
MEM	248,129	253,464	1.02	219,171	0.88
MIA	386,554	392,894	1.02	412,915	1.07
ORD	839,073	869,294	1.04	875,136	1.04
SAV	68,102	88,567	1.30	88,932	1.31
SJC	130,949	134,953	1.03	148,669	1.14
SYR	55,756	65,985	1.18	61,227	1.10
TUS	98,321	139,008	1.41	143,435	1.46
SEA	303,793	308,918	1.02	381,283	1.26

Note: Daylight Savings Time runs from the second Sunday in March at 02:00 a.m. until the first Sunday in November at 02:00 a.m. in all zones.

7.5.2 Final DNL Computations

After flight track counts were corrected, scaled and balanced, the data was packaged into an INM "Study" to produce a validation or "test" run. Once each test run of INM for each airport was verified to be error-free, a final run of all data days produced daily DNL values at each subject location.[38] Finally, the annual average DNL for each subject location was computed by energy averaging all results at every computation point[39] for each airport.

[38] The final modeling missed between 1 and 9 annual flight events at eight of the modeled airports and 275 flight events at BIL. The missing events did not significantly affect the resultant dose-response curves. See Appendix F for more detail.

[39] INM's detailed grid method was used to compute the specific values at each subject location.

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8 Dose-Response Curves

The main purpose of the NES was to produce updated dose-response curves relating the predicted annual average daily noise exposure of residents near airports with their self-reported levels of annoyance. This section provides individual dose-response curves for each of the 20 airports (Section 8.1) and the dose-response curve for all 20 airports together, referred to as the national curve (Section 8.2). These curves were developed using a statistical model based upon all mail questionnaire responses, which allowed for variation among the airports while combining them to produce a national curve.

The logistic regression model from FICON (1992) was used as the basis of the functional form of the individual airport and national curves. In addition to the historical consistency of this choice, alternative models were examined with the result that the model fit for logistic regression was found to require the fewest assumptions, offer the greatest flexibility, and yet provide a good fit to the observed data (see Appendix G). OMB also approved the method. The model in Equation (8.1) gives the predicted percent HA:

$$\text{Percent HA} = \frac{100\ \exp(\beta_0 + \beta_1 DNL)}{1 + \exp(\beta_0 + \beta_1 DNL)}. \tag{8.1}$$

Details of the mathematical formulations of the individual airport and national models and of the computational methods used to fit the models are given in Appendix H. All data analyses in Chapters 8 and 9, and in Appendices E, G, H, I and J, were generated using SAS/STAT® software, Version 9.4.[40]

The outcome variable HA was defined using the responses to Question 5e of the mail questionnaire. Question 5 asked: “Thinking about the last 12 months or so, when you are here at home, how much does each of the following bother, disturb or annoy you?” and part e of the question asked about “Noise from aircraft.” HA was set equal to one if the respondent reported being “very” or “extremely” annoyed by aircraft noise, and was set equal to zero if the respondent reported being “not at all,” “slightly,” or “moderately” annoyed by aircraft noise.[41]

8.1 Dose-Response Curves for Individual Airports

Table 8-1 gives the model coefficients, standard errors, and 95 percent confidence intervals for the fitted curves from each of the 20 sampled airports. Figure 8-1 displays the 20 individual airport curves.[42] Separate graphs for each airport, showing the curve, 95 percent confidence bands, and data points summarizing percent HA for groups of respondents, are presented in Appendix I.

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[41] Sixty-seven of the respondents checked more than one response to Question 5e. For example, 13 respondents checked both 4 (very) and 5 (extremely) annoyed. For respondents who checked more than one response, we calculated the average of the checked values and defined HIGH_ANNOY to be one if the average was 4 or greater and zero otherwise. For 40 of the 67 cases, the checked categories were entirely within the set {1, 2, 3} or the set {4, 5}.

[42] To protect the confidentiality of the respondents, each curve is drawn from DNL 50 dB to a maximum value of DNL that is rounded to a multiple of 5 near the highest DNL value. The range of DNL displayed for each airport was determined as follows. The respondents were categorized into five DNL groups: 55 dB or less, 55-60 dB, 60-65 dB, 65-70 dB, 70 dB or greater. The number of respondents in each group was calculated, and the graph was extended to the boundary of the largest DNL group that has at least 20 respondents, where the boundary of the highest DNL group is set to 75 dB. For example, if an airport has 250 respondents with DNL less than 55 dB, 250 respondents in the range 55-60 dB, and 3 respondents above 60 dB, the curve is displayed from DNL 50 dB to DNL 60 dB. Alternatively, if an airport has 240 respondents with noise exposure less than 55 dB, 240 respondents in 55-60 dB, and 23 respondents in 60-65 dB, the curve is displayed from DNL 50 dB to DNL 65 dB.

Table 8-1. Model Coefficients for Individual Airport Curves

Airport Identifier	Intercept	Standard Error of Intercept	Lower 95% Confidence Limit of Intercept	Upper 95% Confidence Limit of Intercept	Slope	Standard Error of Slope	Lower 95% Confidence Limit of Slope	Upper 95% Confidence Limit of Slope
ABQ	-6.1563	2.1591	-10.4250	-1.9521	0.1093	0.0406	0.0302	0.1894
ALB	-8.2847	1.5698	-11.4155	-5.2521	0.1355	0.0279	0.0815	0.1911
ATL	-8.3554	1.0956	-10.5485	-6.2480	0.1379	0.0182	0.1027	0.1743
AUS	-11.4847	1.6807	-14.8551	-8.2546	0.1903	0.0298	0.1330	0.2499
BDL	-6.9470	1.3290	-9.5961	-4.3781	0.1124	0.0233	0.0674	0.1587
BFI	-6.5752	1.1655	-8.8959	-4.3210	0.1031	0.0195	0.0652	0.1419
BIL	-13.8302	2.2344	-18.3277	-9.5522	0.2395	0.0407	0.1614	0.3213
DSM	-8.6299	1.4657	-11.5504	-5.7968	0.1387	0.0254	0.0895	0.1892
DTW	-5.9880	1.3581	-8.6806	-3.3507	0.1059	0.0237	0.0598	0.1530
LAS	-6.6325	1.0178	-8.6646	-4.6697	0.1025	0.0169	0.0699	0.1361
LAX	-5.7330	0.8695	-7.4677	-4.0548	0.0930	0.0137	0.0665	0.1204
LGA	-13.1473	1.2944	-15.7651	-10.6832	0.2125	0.0214	0.1718	0.2556
LIT	-8.0593	1.4986	-11.0430	-5.1606	0.1395	0.0271	0.0871	0.1934
MEM	-8.9629	1.0223	-11.0252	-7.0113	0.1388	0.0163	0.1077	0.1715
MIA	-12.6290	1.2452	-15.1485	-10.2599	0.2005	0.0201	0.1622	0.2412
ORD	-10.5999	1.1034	-12.8285	-8.4963	0.1840	0.0185	0.1488	0.2214
SAV	-9.1981	1.9600	-13.0964	-5.4026	0.1566	0.0355	0.0878	0.2270
SJC	-10.7487	1.4209	-13.6010	-8.0228	0.1782	0.0245	0.1312	0.2273
SYR	-3.4425	1.3248	-6.0567	-0.8563	0.0489	0.0234	0.00307	0.0951
TUS	-7.3388	1.3725	-10.0761	-4.6882	0.1399	0.0242	0.0933	0.1882

This graph displays the estimated dose-response curve for each airport. The y-axis is the estimated percent highly annoyed and the x-axis is the noise exposure, measured by the DNL in decibels. At noise exposure of DNL 50 dB, at the left side of the graph, the predicted percent highly annoyed ranged from about 7 percent to 40 percent. At noise exposure of DNL 75 dB, the four airports with this level of noise exposure have percent highly annoyed ranging from about to 75 percent for LAX to about 95 percent for ORD. The individual airport curves do not independently provide a complete picture of the national response to aircraft noise.

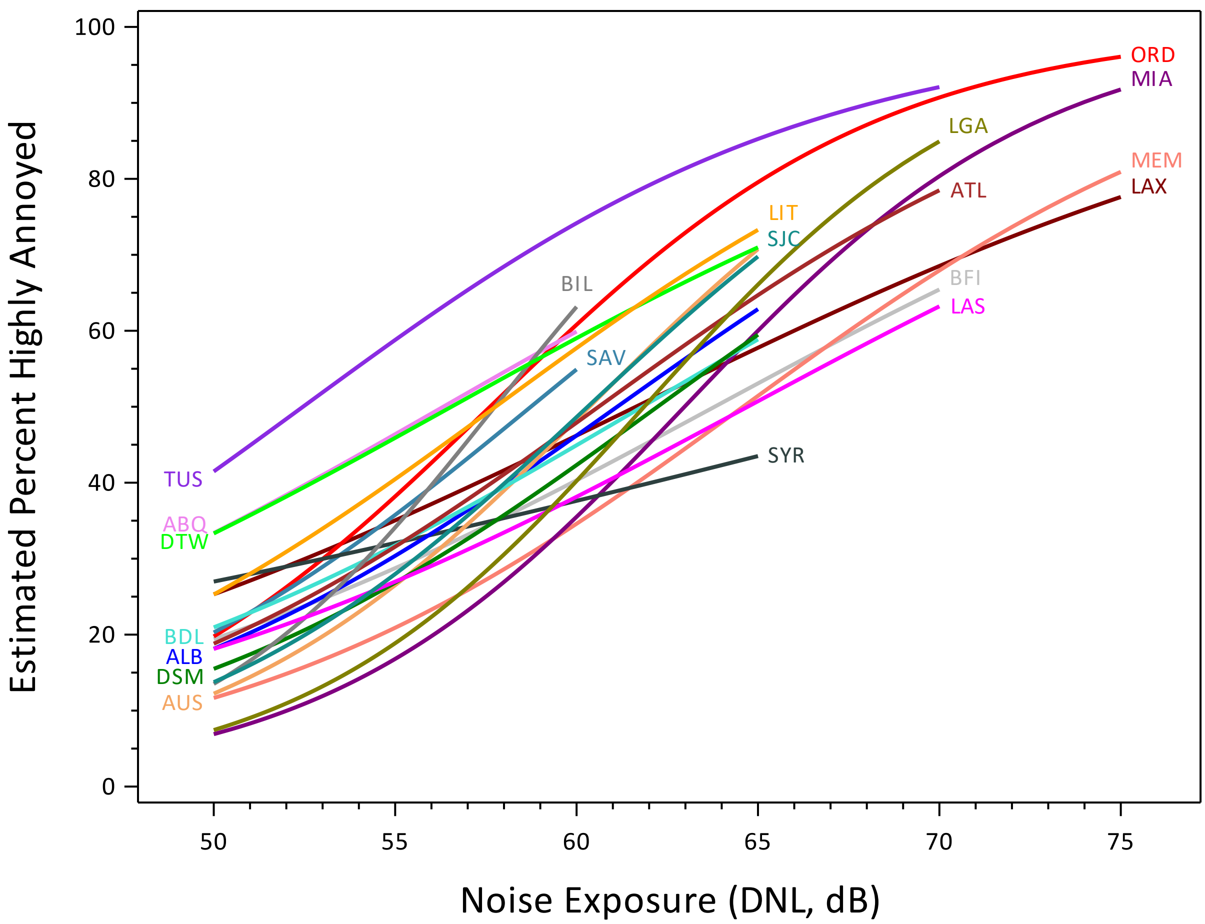

Figure 8-1. Individual Dose-Response Curves for all 20 Airports

8.2 National Dose-Response Curve

The national curve is a current national estimate of the relationship between noise and perceived annoyance based on a representative sample of airports and of residents living near them. It was created by combining the data from all of the individual airports into a single dataset. That combined dataset was used to estimate the parameters in a model that included the airports as random effects, (i.e., treating them as a random sample that is drawn from a larger population of all airports), thereby incorporating an estimate of the variation present had we drawn a different sample of airports. The approach uses all available data to create a national curve, while at the same time provides an estimated dose-response curve for each individual airport. In this way, the national curve can be considered a weighted average of all the sampled airports, taking into account how precisely the model fits each airport. The dose response is similar for most of the airports. Consequently, this approach gives more precise estimates of the model parameters by combining all airport data in a single model than if separate estimates for each airport, based on their own smaller sample, were simply averaged. In this analysis, airports with a more precise fit are given somewhat greater weight in producing the national average.

An alternative approach would have been to create separate curves for each airport independently, and then average equally the resulting slopes and intercepts to obtain a national curve. For comparison purposes, this method was evaluated and was shown to produce results within a few percentage points of the selected method. Appendix H (Section H.2) gives the mathematical formulation of this model. The alternative approach, while potentially more straightforward, would not have produced individual airport curves, a national curve, and tests for all the parameter estimates in a single analysis informed by all the data. However, the method employed herein is able to do all of this.

Equation (8.2) displays the equation for the national curve.

$$\text{Percent HA} = \frac{100\ \exp(-8.4304 + 0.1397\ DNL)}{1 + \exp(-8.4304 + 0.1397\ DNL)}. \tag{8.2}$$

Table 8-2 repeats the model's coefficients, and provides their standard errors and 95 percent confidence intervals.

Table 8-2. Model Coefficients for the National Dose-Response Curve

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-8.4304	0.5789	-9.6420	-7.2187
Slope, β_1	0.1397	0.0098	0.1192	0.1602

Figure 8-2 graphically displays the dose-response curve and can be used to estimate a 95 percent confidence interval on an estimated percent HA for a given DNL. The dashed lines result from incorporating all responses from all sample airports into a single model estimating both the predicted annoyance and the confidence interval for that estimate. The national curve results in approximately 20 percent HA at DNL 50 dB, 66 percent HA at DNL 65 dB and 79 percent HA at DNL 70 dB. See Appendix H for definition of the 95 percent confidence interval.

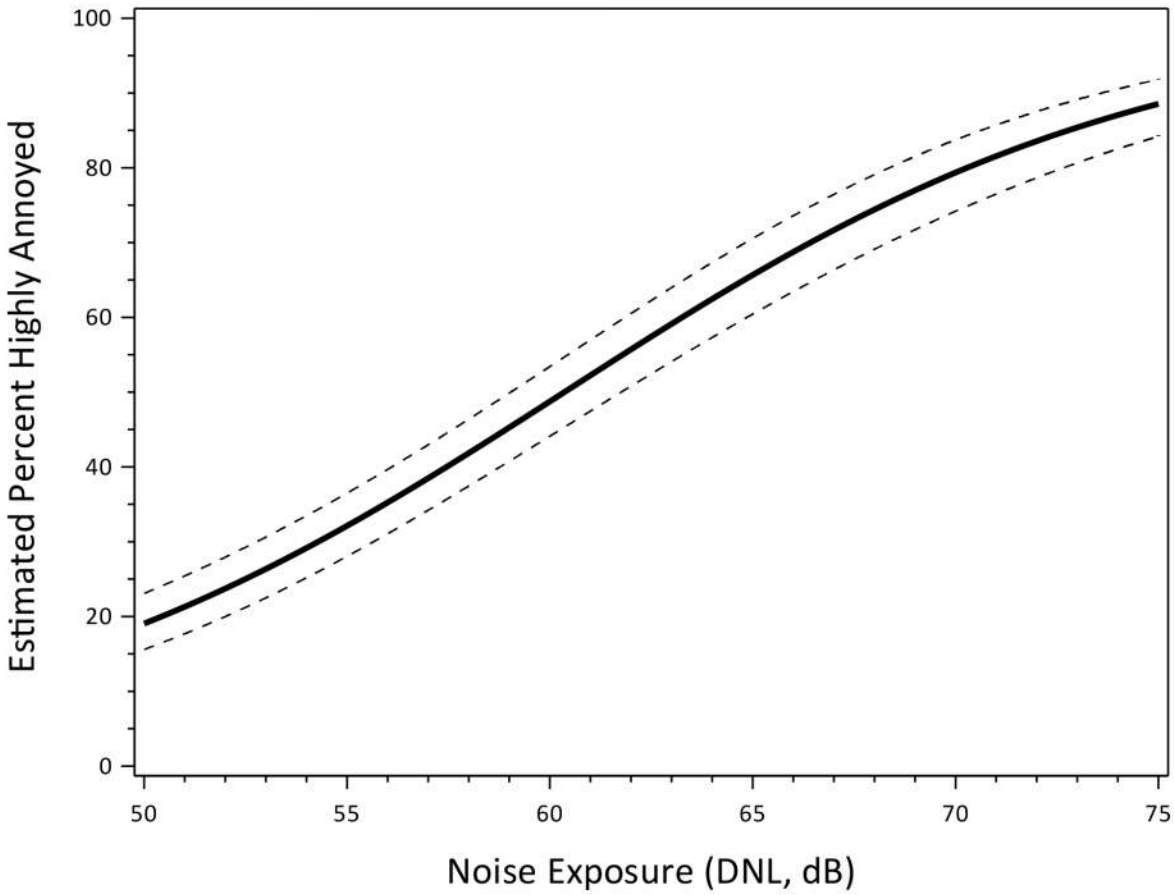

Figure 8-2. National Dose-Response Curve (solid line), with 95 Percent Confidence Intervals on Annoyance for a Given DNL (dashed lines)

Figure 8-3 displays the national curve along with a shaded region showing the range of the curves for each of the 20 airports from Figure 8-1. The national curve is approximately in the middle of the range of the individual airport curves. See Section 9.4 for discussion of airport-to-airport differences.

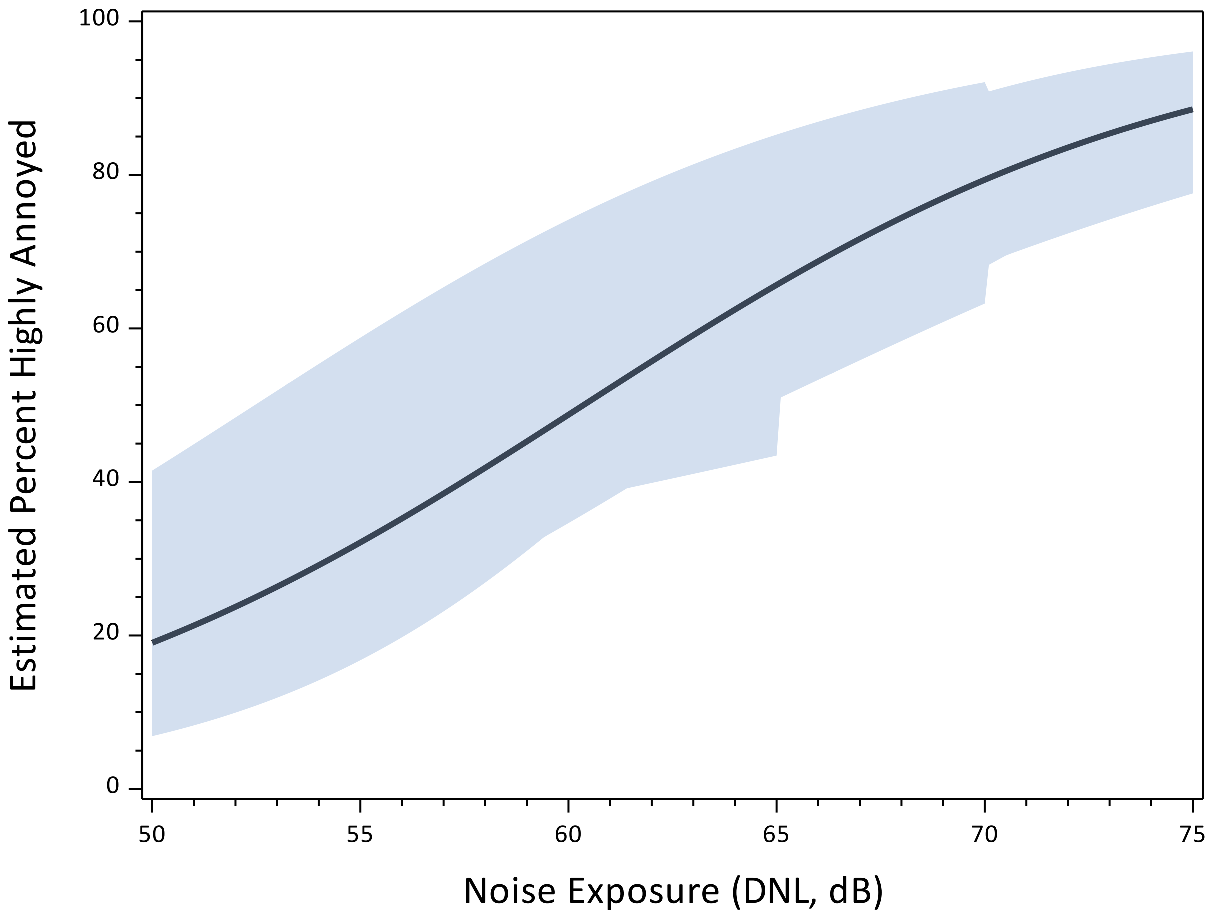

Figure 8-3. National Dose-Response Curve (solid line), Compared to Range (shaded area) of the 20 Individual Airport Dose-Response Curves

Figure 8-4 compares the national curve to four other curves from frequently cited research:

- the FICON (1992) curve,
- two community tolerance level analyses from Equation (G.1) of the International Organization for Standardization (ISO) (2016), and
- the Netherlands Organisation for Applied Scientific Research (TNO) curve at the bottom of page 4 of Janssen and Vos (2011), also given as Equation (H.3) in ISO (2016).

The dashed lines indicate the 95 percent confidence interval for a predicted percent HA for a given DNL.

The FICON, ISO and TNO equations are shown below as Equations (8.3) through (8.5), respectively. In Equation (8.4), the value of the constant depends on the adjustment used for aircraft noise. Figure 8-4 shows the ISO curve for values of the constant equal to 65 and 68, to represent the range of recommended adjustments for aircraft noise.

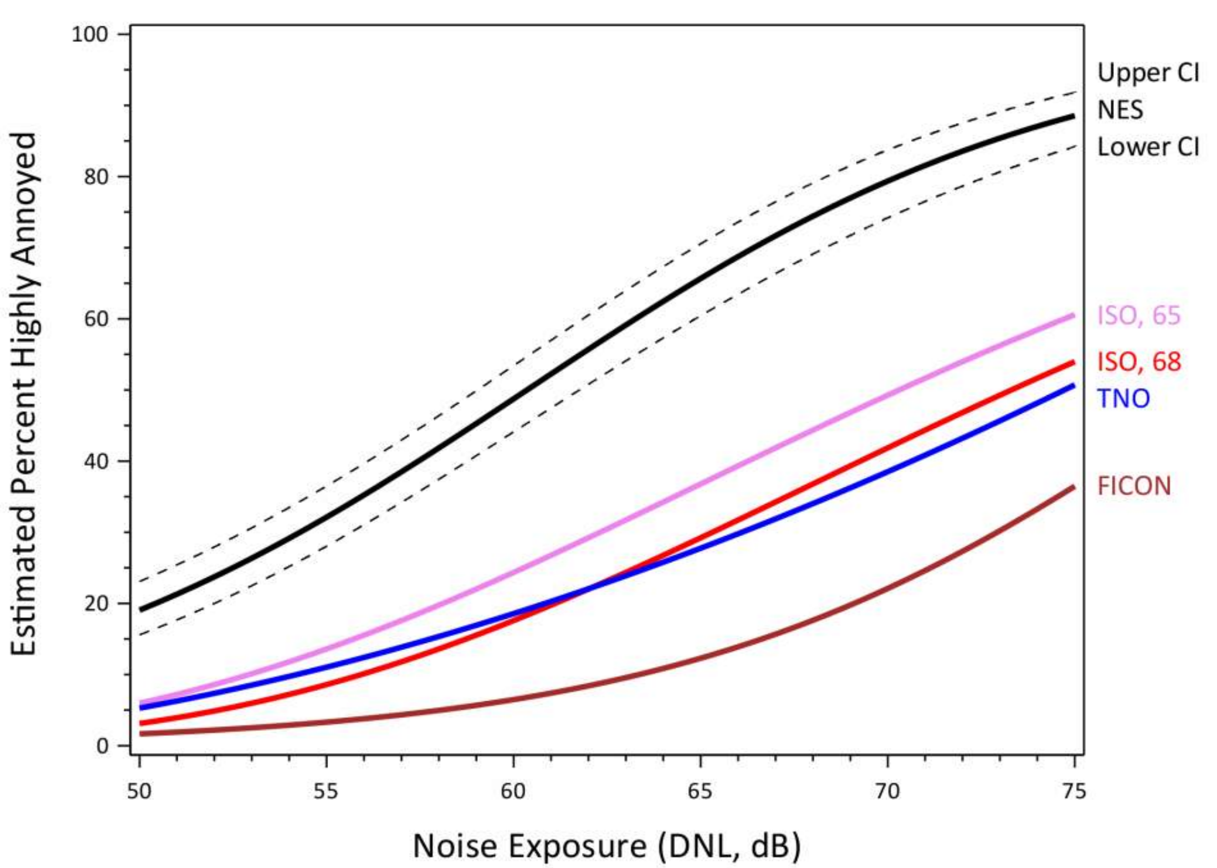

Figure 8-4. National Dose-Response Curve (NES), with 95 Percent Confidence Intervals (CI) on Annoyance for a given DNL. TNO, FICON and ISO Curves with Constants 65 and 68 are Shown Below the National Curve

$$\text{Percent HA}_{\text{FICON 1992}} = \frac{100\ \exp(-11.13 + 0.141\ DNL)}{1 + \exp(-11.13 + 0.141\ DNL)} \quad (8.3)$$

$$\text{Percent HA}_{\text{CTL ISO 2016}} = 100 \exp\left\{-\left[\frac{1}{10^{0.1[DNL-\text{constant}]}}\right]^{0.3}\right\} \quad (8.4)$$

$$\text{Percent HA}_{\text{TNO}} = \text{-1.395E-04}\times(DNL\text{-}42)^3 + \text{4.081E-02}\times(DNL\text{-}42)^2 + 0.342\times(DNL\text{-}42) \quad (8.5)$$

Figure 8-5 shows the curve along with estimates of percent HA for groups of observations from the individual airports.[43] Note that the dashed lines in Figure 8-5 and their actual values given in Table 8-3 describe the precision of estimated HA for a given DNL from the national model. They are not a reflection of the much more variable distribution of the points, which represent the variation in individual annoyance responses. In a similar way, the sample mean is much less variable than the individual observations used to compute it.

In Figure 8-5, the national curve is near the middle of the points from DNL 50 dB up to about DNL 68 dB. Above DNL 68 dB, there is some divergence between the curve and the data points from the airports that have high noise exposure. This divergence occurs in part because the national curve can be thought of as “averaging” the individual dose-response curves (Appendix H, Section H.2), and the results greater than DNL 70 dB are extrapolated for the thirteen airports (see Table 4-4) that have no data greater than DNL 70 dB.

Figure 8-5 has been simplified with DNL aggregated into eight bins to address Personally Identifiable Information (PII) considerations (i.e., to protect respondent anonymity). However, the actual curve fitting was conducted with the original non-binned data.

Sensitivity analyses, presented in Appendix G, confirmed that the curve fits the data well under alternative models for DNL less than 70 dB: The curves from the alternative models were inside the confidence limits shown in Figure 8-2 for all values of DNL between 50 and 70 dB. However, some of the alternative models predicted less annoyance than the curve shown in Figure 8-2 for values of DNL greater than 70 dB. Caution should be used when employing the logistic regression curve to predict a national value of percent HA for values of DNL greater than 70 dB. There were relatively few observations in the data set greater than 70 dB, so the data provide less information for the form of the curve in that region than in the region with DNL less than 70 dB.

[43] The data points were calculated as follows. For each airport, the respondents were classified into DNL groups of width 3 dB: less than 52.5, 52.5 to 55.5, 55.5 to 58.5, 58.5 to 61.5, 61.5 to 64.5, 64.5 to 67.5, 67.5 to 70.5, and 70.5+. Any group with fewer than 20 respondents was merged with the group to its left to protect respondent confidentiality. The percent HA was calculated for each group and airport was plotted against the midpoint of the DNL range (the midpoints are 51, 54, 57, 60, 63, 66, 69, and 72). All 20 airports had points plotted at DNL 51 dB; only the four airports with at least 20 respondents above DNL 70.5 dB had points plotted at DNL 72 dB.

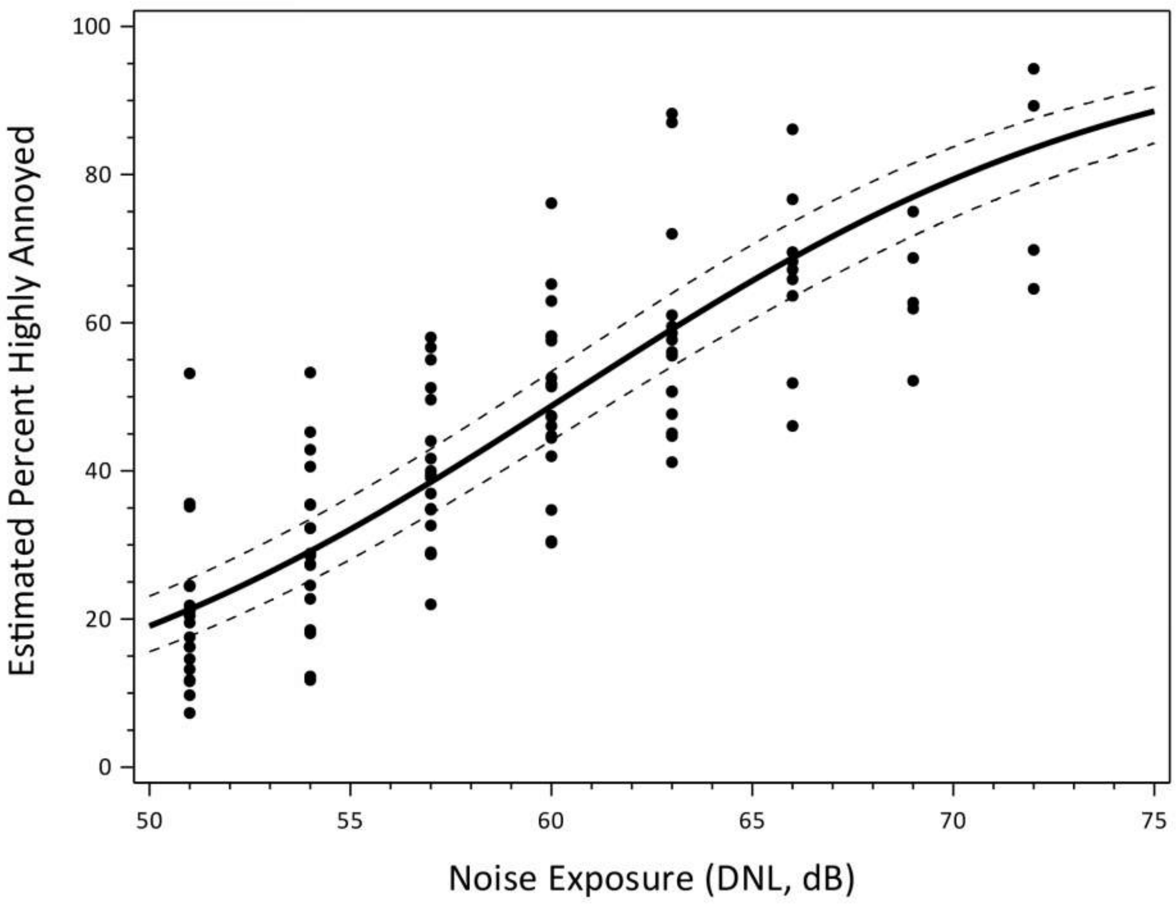

Figure 8-5. National Dose-response Curve, With 95 Percent Confidence Intervals on Annoyance for a given DNL, Displayed with 5-dB binned (see previous footnote) Point Estimates of Percent HA from Individual Airports

Table 8-3 shows the predicted percent HA from the model in Equation 8.2, for DNL between 50 and 70 dB.

Table 8-3. Predicted Percent HA at Selected Noise Exposures, from National Dose-response Curve

DNL Value (dB)	Predicted Percent HA	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
50	19.1	1.9	15.4	23.4
51	21.3	2.0	17.5	25.7
52	23.7	2.0	19.8	28.2
53	26.4	2.1	22.2	30.9
54	29.2	2.1	24.9	33.8
55	32.1	2.2	27.8	36.8
56	35.2	2.2	30.8	40.0
57	38.5	2.2	33.9	43.3
58	41.8	2.3	37.2	46.7
59	45.3	2.3	40.5	50.2
60	48.8	2.4	43.8	53.7
61	52.2	2.4	47.1	57.3
62	55.7	2.5	50.5	60.8
63	59.1	2.5	53.7	64.3
64	62.5	2.6	57.0	67.7
65	65.7	2.6	60.1	70.9
66	68.7	2.6	63.1	73.9
67	71.7	2.6	66.0	76.7
68	74.4	2.6	68.7	79.4
69	77.0	2.5	71.3	81.8
70	79.4	2.4	73.8	84.0

8.3 Considerations for Interpreting the Curves

The interpretation of a regression model for summarizing the relationship between a response variable y (here, the indicator variable percent HA defined at the beginning of this section) and an explanatory variable x (here, DNL) in a population depends on several factors:

1. Representativeness of the sample with respect to the population,
2. Functional form of the regression model and how well it fits the data,
3. Method for measuring y and the accuracy of the y values, and
4. Method for measuring x and the accuracy of the x values.

In the NES, residents in each of the 20 airport communities were surveyed with the same survey design and protocol, using the same questionnaire, and over the same period. Previous studies used different survey methods and measurements of annoyance. Janssen et al. (2011) reviewed literature finding that some of the differences among previous studies could be explained by the study design and sample selection methods. Some of the studies that served as the foundation of the ISO, TNO, and FICON curves used telephone or face-to-face survey administration, or used different mailing and nonresponse follow-up protocols for a mail survey; measured highly annoyed using a different instrument or different scale; had different response rates; surveyed the population for only part of a year rather than the whole year; and used different methods for computing DNL for respondents. The data for the studies were collected from different countries and in different languages. Importantly, many of the prior studies included noise from a variety of transportation sources.

The ISO and TNO curves from Equations (8.4) and (8.5) were fit using statistical models of different form than the two-parameter logistic regression model in Equation (8.1). The ISO curve used a log-log link function instead of the logit link function used in Equation (8.1), and it fixed the slope of the equation at a predetermined value instead of estimating it from the data see Appendix G, Section G.4 for a discussion of the model used for the ISO curve. The TNO model (Janssen and Vos, 2011) is a polynomial approximation to the results from a grouped regression model (Groothuis-Oudshoorn and Miedema, 2006) in which the individual airport study intercepts are random effects; as discussed in Appendix H, Section H.2, the model used for the national curve in Equation (8.2) uses random effects for both the slopes and the intercepts.

The NES national curve may differ from dose-response curves from other studies because the relationship between noise exposure and annoyance has changed since the earlier studies, but the differences may alternatively be due to differences in study design, implementation, measurement, cultural differences for studies occurring in other countries, or a combination of these factors. In addition, advances in technology and statistical theory have resulted in changes in methodology that were not available for some of the previous studies. Many of these aspects are discussed in the following subsection, along with implications for comparing the estimated dose-response curves from the NES with other dose-response curves in the literature.

8.3.1 Sample Representativeness

As described in Chapter 3, the sample of airports in the NES was selected using balanced probability sampling so that it is representative of the population of 95 airports with respect to the factors listed in Table 3-2. Within each airport, a stratified random sample of addresses, stratified by noise exposure, was taken at each airport, ensuring that the sample of addresses selected from each noise stratum is representative of the population of addresses in that noise stratum.

Although the address-based sampling method used in the NES has been demonstrated to have greater response rates than alternative methods of data collection such as telephone surveys (National Research Council, 2013, Chapter 4) and the ACRP study showed the response rate from the mail administration to be much greater than that of a telephone survey (Miller et al. 2014a), there was still nonresponse to the survey. If the nonrespondents differ from the respondents, and if those differences cannot be controlled for through statistical modeling or weighting, then the sample may not be fully representative of the population (Brick 2013).

The dose-response curves in Sections 8.1 and 8.2 are constructed using data from the respondents to the survey. The survey has no information on the annoyance level of the nonrespondents. Westat conducted analyses to investigate whether respondents and nonrespondents differed on characteristics that are known for every sampled address, whether respondent or not. Appendix E reports the nonresponse bias analyses performed for the survey. To conduct a further exploration of potential nonresponse bias, the model was refit to data using nonresponse-adjusted weights. The curve from this model, reported in Appendix G (Section G.3), was visually indistinguishable from the curve fitted without weights from Figure 8-2. This indicates that the dose-response relationship is unaffected by nonresponse bias adjustments that can be done using information from the sampling frame, and provides evidence that nonresponse bias is not detected from the information known from the sampling frame. However, the information known about both respondents and nonrespondents is limited, and it is possible that respondents and nonrespondents differ on characteristics not known in the sampling frame, including their annoyance to aircraft noise.

8.3.2 Regression Model Form

The analysis reported in this section used the two-parameter logistic regression model from Equation (8.1) to summarize the dose-response relationship, as requested by FAA. The logistic regression model is widely used to model dose-response relationships because it can fit many different possible sigmoidal shapes (Cox and Snell 1989). As with any parametric model, the two-parameter logistic regression model assumes a specific form for the relationship between percent HA and noise exposure. In particular, the logistic model is symmetric about the point where 50 percent are highly annoyed.[44] The model also assumes that the percent HA always increases as DNL increases.

Appendix G evaluates the fit of the model for the individual-airport and national dose-response curves. Overall, for DNL below 70 dB, the predicted percent HA from the two-parameter national logistic model is similar to the predicted percent HA for alternative models that were fit to the data. As shown in Appendix G (Figure G-1), for DNL greater than 70 dB, some of the alternative models predicted less percent HA than the logistic model. An alternative one-parameter model from Fidell et al. (2011) exhibited significant lack of fit for the NES data, as presented in Appendix G (Section G.4).

8.3.3 Methodology and Accuracy of Measurement of Highly Annoyed

Chapter 2 described the development of the NES methodology and the question used to classify a respondent as being highly annoyed. Annoyance was measured following procedures developed by ICBEN (Fields et al. 2001), recommended by ISO (2016), including the use of a five-point verbal scale, which is widely used in current surveys. Respondents answering "Very" or "Extremely" annoyed are counted as HA as opposed to those answering "Not at all", "Slightly" or "Moderately" annoyed. Some laboratory research has shown that people rate "Very" and "High" as expressing equivalent degrees of annoyance (Fields et al. 2001). Many earlier surveys, including many of those in the FICON analysis (1992), derived their annoyance indicator from survey questions that differed in such features as: the use of numeric rather than verbal scales, the language of administration, the reaction (not always "annoyance"), the number of scale points, the verbal labels for the scale points ("highly" has not been offered as a choice in surveys), and whether the scale is presented in as single question or is broken into two parts with a screening question. The NES mail questionnaire only asked about aircraft noise annoyance as part of a rating of thirteen neighborhood conditions. As a result, respondents in the NES mail survey, as for most recent surveys, did not know that aircraft noise was the focus of the inquiry when answering the question. Noise annoyance surveys differ considerably from one another in many ways that sometimes affect survey responses (Groves et al. 2011) and might affect annoyance responses. Examples include the season of administration, the mode of questioning (mail, telephone, face-to-face, etc.), the method for identifying households, whether the respondent within a household is self-selected or selected by the survey, and the context set by any introductory materials including the identification of the survey purpose and sponsor.

8.3.4 Methodology and Accuracy of DNL Modeling

Chapter 7 described the methodology used by the NES to calculate the value of DNL for each sampled address in the research effort, and the steps taken by HMMH to ensure the accuracy of those calculations. Westat performed internal consistency checks to verify that the values of DNL used in the model were consistent with the noise contours that had been used when selecting the sample.

8.3.5 Comparison with Other Curves

A comparison of the NES curves to other curves in the literature should consider the populations from the studies and how well the samples represent those populations, and how well the statistical models that are employed summarize the information from those studies. It also needs to account for differences in the methodology for measuring HA and possible differences in the calculation of DNL. The survey methodology used in the NES follows current best practices in public opinion / social science research. These methods

[44] Dobson and Barnett (2008, Section 7.3) review alternative models that can be used for dose-response relationships, including probit and complementary log-log link models. The different models give similar results for predicted percentages between 30 and 70 percent but may differ slightly for predicted percentages close to 0 and 100 percent. In particular, log-log and complementary log-log link models do not have the symmetry property of the logistic and probit models. The log-log link model has a shallower slope than the logistic model when the predicted percentage is close to 100 percent and a steeper slope when the predicted percentage is close to 0 percent.

were tested and refined following a pilot test (ACRP 02-35) and have been commonly used for recent major surveys by other Federal agencies such as the Federal Highway Administration, National Cancer Institute and the Department of Education.[45]

Figure 8-4 shows that the TNO, ISO, and FICON curves fall outside of 95 percent confidence limits for the national curve fit to the NES data. This indicates that the NES curve is statistically significantly different from the mathematical functions used to summarize those curves. However, each of the TNO, ISO, and FICON curves is an estimate based on airport surveys that had been conducted in the past and on samples of respondents in those surveyed airports. These surveys also had sampling and nonsampling errors, and a proper significance test would need to account for the errors in the studies used to construct the TNO, ISO and FICON estimates.

The model for the NES in Equation (8.1) used the same functional form as the FICON (1992) curve. Table 8-4 compares the coefficients from the two curves. The estimated slope from the FICON (1992) curve is close to that of the NES curve. The intercept for the NES curve, however, is greater than the FICON value of -11.13. The estimated coefficients indicate that the rate of increase in percent HA with increasing DNL is consistent with the earlier FICON results. However, it appears that the percent HA for a given DNL has increased over that previously observed in FICON.

Table 8-4. Comparison of NES and FICON (1992) Coefficients

Coefficient	Estimate from NES Curve	Lower 95% Confidence Limit for NES Curve	Upper 95% Confidence Limit for NES Curve	Estimate from FICON (1992)
Intercept, β_0	-8.4304	-9.6420	-7.2187	-11.13
Slope, β_1	0.1397	0.1192	0.1602	0.141

The increase in annoyance at all levels of DNL exposure should be placed in context with the timeframe of this research effort. The FICON curve utilized data from the 1960s through 1980s and is now several decades old. Over that timeframe, the public may have become increasingly sensitive to aircraft noise at a given DNL, perhaps due to differences in the nature of sound exposure (e.g., changes in operations, frequency of flights), differences in study design, country surveyed, implementation and measurement, changes in attitudes, or a combination of these factors. Meta-analysis of more recent studies has also found higher levels of aircraft noise annoyance compared to historical curves (Guski et al. 2017). Further research is underway by the project team to examine historical trends in aircraft noise annoyance data, including comparisons to other recent research.

[45] These recurrent major Federally-funded national surveys have all transitioned from telephone to mail data collection over the past decade: National Household Travel Survey, Federal Highway Administration, Department of Transportation - https://www.nationalhouseholdtravelsurvey.com/

Health Information National Trends Survey (HINTS), National Cancer Institute - https://hints.cancer.gov/

National Household Education Surveys, National Center for Education Statistics, Department of Education - https://nces.ed.gov/nhes/

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9 Additional Factors Analyzed

Additional analyses were performed to investigate whether the airport-to-airport differences in the dose-response curves could be partially explained by other factors. It is important to note that the final list of factors was determined before the end of data collection and before data analysis on the dose-response curves commenced. Thus, they are considered pre-planned hypotheses. The scientific community has established that posing hypotheses after exploring patterns in the data, known as data fishing or p-hacking, leads to more false positive findings (Head et al. 2015). The American Statistical Association Statement on Statistical Significance and P-Values (Wasserstein and Lazar 2016) provides guidance for interpreting the results of statistical tests. Note that although multiple hypotheses are considered in this section, the results presented were not adjusted for multiple testing. The results given below consider the comparison-wise error rate, not the familywise error rate (see Oehlert (2000), Chapter 5, for a discussion of the two error rates).

The FAA identified the following six factors to be examined:

1. Climate
2. “Visible” Flight Events
3. “Noticeable” Flight Events
4. “Relatively Important” Flight Events
5. Race/Ethnicity
6. Income

The factors associated with each analysis area are described briefly in Table 9-1 and in detail in Appendix J along with their rationale. Income was not asked on the NES mail questionnaire and was studied using census block group statistics from the American Community Survey. For race/ethnicity, the variable MINORITY was defined using respondents’ self-reported information. Climate was characterized by the sum of Cooling Degree Days and Heating Degree Days. A flight event was defined as ‘visible’ if it was at least 45° above the horizon and within a slant distance of 12,000 feet of the respondent. A flight event was ‘noticeable’ if it had a Maximum (A-weighted) Sound Level (L_{max}) of at least 50 dB at the respondent’s location.[46] A flight event was ‘relatively important’ if it was one of the events contributing up to 1 dB of the total DNL at the respondent’s location.

The analyses in this section investigate whether, after controlling for DNL, these factors are related to the overall level of aircraft noise annoyance or moderate the relationship between annoyance and noise exposure as measured by DNL. Section 9.1 addresses the climate analysis. Section 9.2 addresses the analyses for the three flight event metrics and Section 9.3 addresses the race/ethnicity and income analyses.

[46] The concept of “noticeability” here means that some aspect of aircraft flights, possibly in addition to their sound level, may raise awareness of the planes and hence increase the annoyance.

Table 9-1. Additional Factors Studied

Factor	Definition
DEGREEDAYS (Climate)	Sum of the number of annual cooling degree days and heating degree days for the airport. A degree day is the difference between the day's mean temperature and 65 degrees Fahrenheit. It is termed a 'cooling degree day' if the day's mean temperature is greater than 65 degrees Fahrenheit and a 'heating degree day' if the day's mean temperature is less than 65 degrees Fahrenheit.
VISIBLE	Number of flights for which the point of closest approach has an elevation angle greater than or equal to 45 degrees above the horizon, and with a slant distance less than 12,000 feet.
NUMBERABOVE50 ('Noticeable')	Number of modeled aircraft events at or above a maximum sound level (L_{max}) of 50 dBA at the sampled address during the calculation period.
IMPORTANT	Number of aircraft operations that produce a DNL value within 1 dB of the total DNL value for all aircraft operations at the sampled address during the calculation period.
MINORITY (Race/Ethnicity)	1 if the respondent reported being Hispanic or selected one or more of the following race categories: Black or African American, American Indian or Alaska Native, Asian, or Native Hawaiian or Other Pacific Islander; 0 if the respondent reported being non-Hispanic and selected only the White category for race.
PCTBELOWPOVERTY (Income)	Percentage of population below the poverty level in the census block group containing the sampled address, calculated from the 2010-2014 American Community Survey five-year estimates.

9.1 Degree Heating and Cooling Days

The variable DEGREEDAYS is an airport-level characteristic, i.e., the variable has the same value for all addresses at an airport. The other variables in Table 9-1 vary among respondents from the same airport community. While the variable DEGREEDAYS could potentially be associated with differences in the overall level of annoyance between airports, it cannot be used to explain differences among households residing near the same airport.

The variable DEGREEDAYS was analyzed by including an extra term in the model in Equation (8.1), as described in Section G.3. The model fit is Equation (9.1).

$$\text{Percent HA} = \frac{100\ \exp(\beta_0 + \beta_1 DNL + \beta_2\ DEGREEDAYS)}{1 + \exp(\beta_0 + \beta_1 DNL + \beta_2\ DEGREEDAYS)}. \tag{9.1}$$

The estimated model coefficients, along with standard errors and 95 percent confidence intervals, are given in Table 9-2.

Table 9-2. Model Coefficients for Model with DEGREEDAYS

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-8.4154	0.6862	-9.8516	-6.9792
DNL, β_1	0.1397	0.0100	0.1187	0.1607
DEGREEDAYS, β_2	-0.000003	0.00005	-0.0001	0.0001

The estimated coefficient for DEGREEDAYS (β_2) is not significantly different from zero (T = 0.003, p-value = 0.96). There is no evidence that households near airports with higher total degree heating and cooling days have higher, or lower, levels of annoyance to aircraft noise.

The results from the model reported in Table 9-2 indicate that a linear term for DEGREEDAYS does not help explain airport-to-airport differences in annoyance. Because DEGREEDAYS is an airport-level characteristic, an additional graphical analysis could be performed to display the lack of relationship between DEGREEDAYS and percent HA. Figure 9-1 displays the predicted percent HA at DNL 55 dB for each of the 20 sampled airports, related the value of DEGREEDAYS for that airport. The predicted values of percent HA were calculated by substituting the airport-specific regression coefficients from Table 8-1 into the model in Equation (8.1).[47] If DEGREEDAYS helped explain airport-to-airport differences in annoyance at DNL 55 dB, one would expect to see a trend in the graph. However, there is no apparent trend in Figure 9-1: airports with high values of percent HA at DNL 55 dB, and airports with low values of percent HA at DNL 55 dB, appear at high, low, and middle values of DEGREEDAYS. Figures 9-2 and 9-3 show a similar lack of relationship between DEGREEDAYS and predicted percent HA at DNL 60 dB and predicted percent HA at DNL 65 dB, respectively.

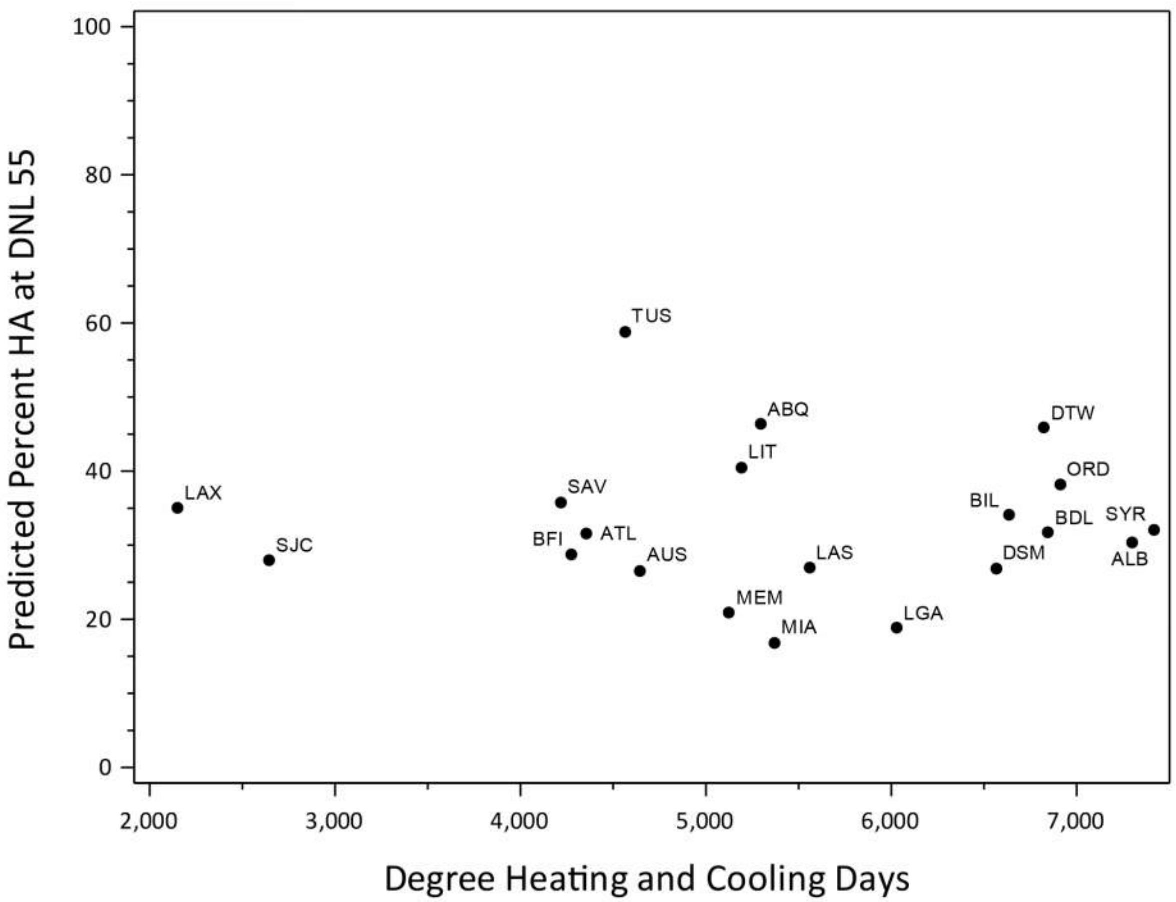

Figure 9-1. Estimated Percent HA at DNL 55 dB by Airport Total Degree Days

[47] For example, the predicted percent HA for ABQ at DNL 55 dB was calculated as 100 exp(-6.1563 + 0.1093 x 55) /[1 + exp (-6.1563 + 0.1093 x 55)] = 46.38 percent. The predicted percentage from the model was used so that all airports would be compared on the same footing. Because different airports have different distributions of DNL values, a comparison of average percent HA across airports would result in some airports having higher percent HA merely because they had more sampled households with high DNL value.

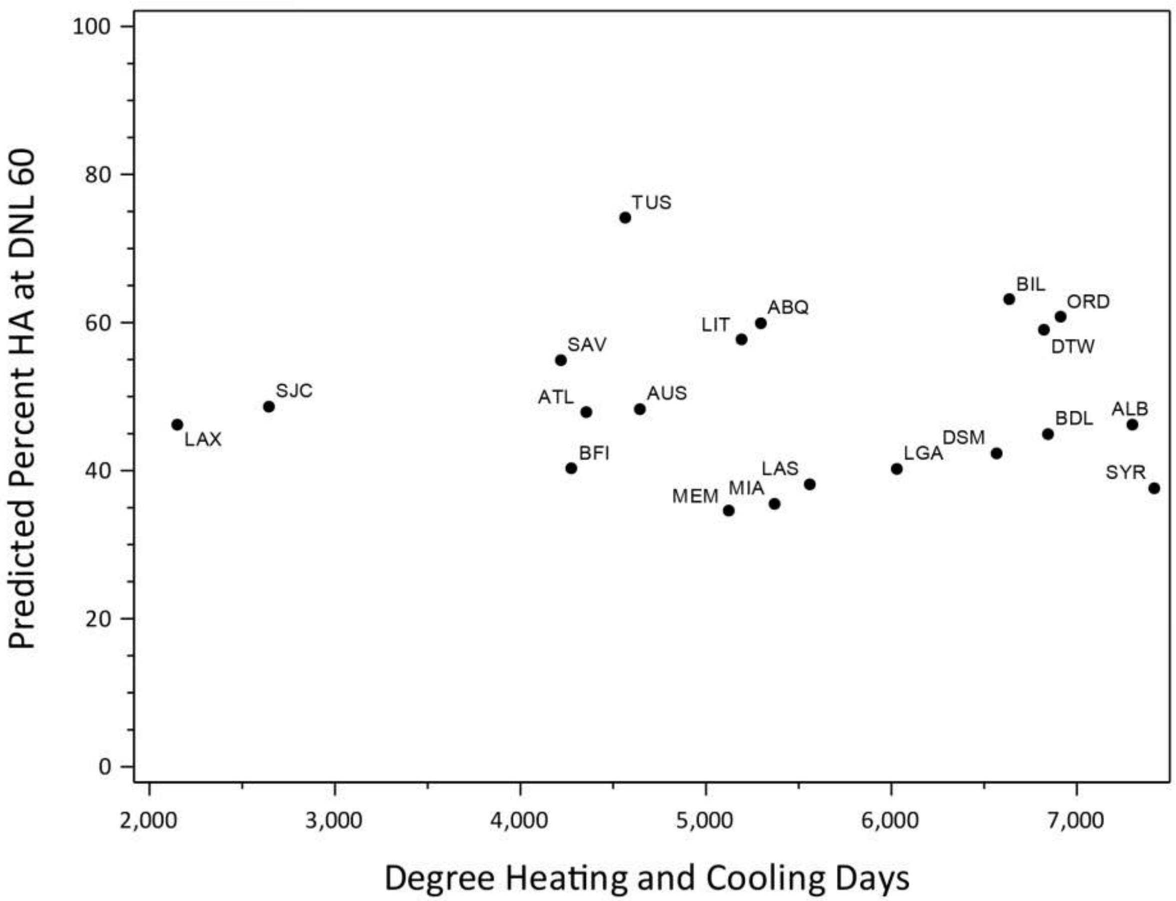

Figure 9-2. Estimated Percent HA at DNL 60 dB by Airport Total Degree Days

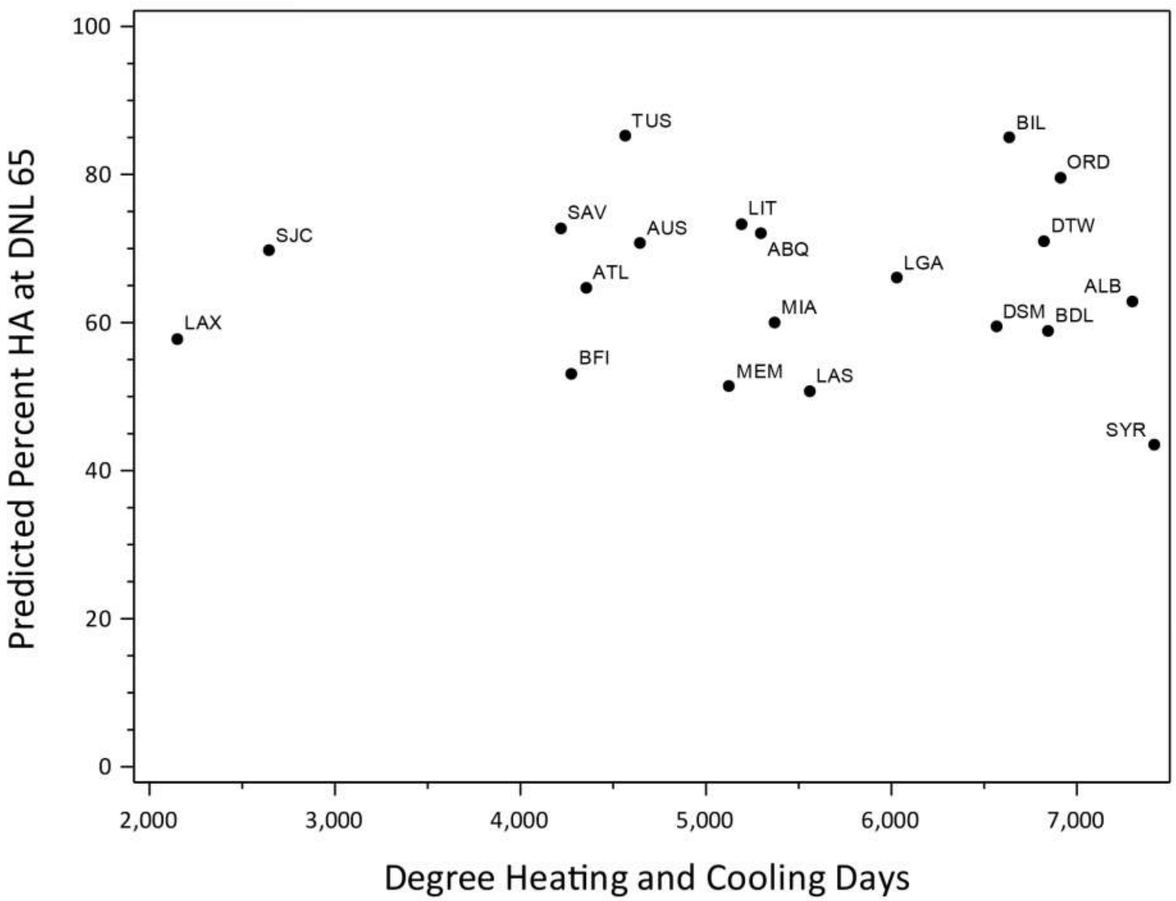

Figure 9-3. Estimated Percent HA at DNL 65 dB by Airport Total Degree Days

9.2 Additional Metrics

The values of the metrics IMPORTANT, NUMBERABOVE50, and VISIBLE differ among respondents in an airport community. Therefore, the model used to investigate the relationship of each FACTOR to annoyance includes terms for the modification the overall level of annoyance (β_2) and for the modification of the slope (β_3):

$$\text{Percent HA} = \frac{100\ \exp(\beta_0 + \beta_1 DNL + \beta_2\ FACTOR + \beta_3 FACTOR \times DNL)}{1 + \exp(\beta_0 + \beta_1 DNL + \beta_2\ FACTOR + \beta_3 FACTOR \times DNL)}. \quad (9.2)$$

The statistical models and tests used to evaluate the association between these factors and annoyance to aircraft noise are described in Appendix G (Section G.3). Tables 9-3 through 9-5 present the model coefficients, standard errors, and 95 percent confidence intervals for the variables VISIBLE, NUMBERABOVE50, and IMPORTANT, respectively.

Table 9-3. Model Coefficients for Model with VISIBLE

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-7.9988	0.5440	-9.1374	-6.8603
DNL, β_1	0.1317	0.0095	0.1119	0.1516
VISIBLE, β_2	-0.0034	0.0032	-0.0101	0.0034
VISIBLE x DNL, β_3	0.000062	0.00005	-0.00004	0.00017

Table 9-4. Model Coefficients for Model with NUMBERABOVE50

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-9.9748	1.0179	-12.1054	-7.8443
DNL, β_1	0.1673	0.0181	0.1295	0.2051
NUMBERABOVE50, β_2	0.0043	0.0018	0.0006	0.0080
NUMBERABOVE50x DNL, β_3	-0.00008	0.00003	-0.00014	-0.00001

Table 9-5. Model Coefficients for Model with IMPORTANT

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-8.6774	0.8855	-10.5307	-6.8240
DNL, β_1	0.1446	0.0161	0.1110	0.1782
IMPORTANT, β_2	0.0022	0.0056	-0.0096	0.0139
IMPORTANT x DNL, β_3	-0.00004	0.0001	-0.0003	0.0002

For the factor NUMBERABOVE50, the coefficients for the intercept and DNL appear quite different from those in the model in Table 8-2 containing only those variables. This occurs because of multicollinearity in the data: the variable NUMBERABOVE50 is highly correlated with DNL, and that correlation causes the estimated regression coefficients to be unstable as reflected in the increased standard errors for those coefficients. For predicting percent HA, each model needs to be considered in its entirety. Belsley et al. (1980) discuss multicollinearity and its implications for interpreting regression coefficients. [48]

The model in Equation (9.2) has two more terms than the model in Equation (8.1). A Wald test statistic, described in Equation (G.6) of Section G.3, was used to test the null hypothesis that both β_2 and β_3 are 0. This test considers whether either FACTOR, FACTOR x DNL, or both together, explain any of the variability in the response HA after controlling for DNL. For VISIBLE, the test statistic is 4.0 with p-value > 0.10. For NUMBERABOVE50, the test statistic is 6.0 with p-value = 0.05. For IMPORTANT, the test statistic is 0.46 with p-value > 0.10. Thus, VISIBLE and IMPORTANT are not statistically significantly related to HA after controlling for the effect of DNL; NUMBERABOVE50 is marginally significant, but the effect is not large and the result needs further investigation because of the high correlation between NUMBERABOVE50 and DNL. The analysis indicates that after accounting for the effect of DNL, VISIBLE and IMPORTANT do not provide additional information that can explain annoyance.

[48] If there were no multicollinearity, the model in Equation (9.2) could be used to describe how the dose-response curve relating percent HA and DNL differs when the extra variable in the model takes different values. For example, from Table 9-4, the predicted relationship between percent HA and DNL when NUMBERABOVE50 = 500 is

$$\text{Percent HA when (NUMBERABOVE50} = 500) = \frac{100\ \exp(-7.82 +\ 0.127\ DNL)}{1 + \exp(-7.82 +\ 0.127\ DNL)},$$

where the intercept is calculated as -7.82 = -9.9748 + 0.0043 (500) and the slope is calculated as 0.1673 – 0.00008 (500) = 0.127. Similarly, the predicted relationship between percent HA and DNL when NUMBERABOVE50 = 1,000 is

$$\text{Percent HA when (NUMBERABOVE50} = 1000) = \frac{100\ \exp(-5.67 +\ 0.087\ DNL)}{1 + \exp(-5.67 +\ 0.087\ DNL)}.$$

However, because NUMBERABOVE50 and DNL are highly correlated, the relationships in each of the two equations above are likely valid only for a small range of DNL values. For example, there are almost no addresses in the sample where NUMBERABOVE50 is less than or equal to 500 and DNL is greater than 60 dB, or where NUMBERABOVE50 is greater than or equal to 1,000 and DNL is less than 55 dB. Thus, an attempt to apply the model to predict percent HA when NUMBERABOVE50 = 500 and DNL = 65 is an extrapolation outside the range of the data. Note that the multicollinearity affects the estimated coefficients of the model. The predicted values of percent HA, however, are consistent with those from the model in Equation (8.2) as long as the prediction is made for values of DNL and NUMBERABOVE50 that are jointly in the range of the data.

9.3 Race/Ethnicity and Poverty Status

Tables 9-6 and 9-7 present the results of the analysis of the variables MINORITY and PERCENTBELOWPOVERTY. The Wald test statistic for MINORITY is Q = 1.2 with p-value = 0.55; the test statistic for PERCENTBELOWPOVERTY is Q = 0.4 with p-value > 0.80. Neither variable is statistically significantly associated with HA, after controlling for the effect of DNL. The analysis indicates that the dose-response curve is essentially unaffected by consideration of minority status or the percent below poverty in the census block group.

Table 9-6. Model Coefficients for Model with MINORITY

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-8.8753	0.8210	-10.5936	-7.1570
DNL, β_1	0.1478	0.0144	0.1177	0.1779
MINORITY, β_2	0.5412	0.7271	-0.9805	2.0629
MINORITY x DNL, β_3	-0.0106	0.0125	-0.0367	0.0156

Table 9-7. Model Coefficients for Model with PERCENTBELOWPOVERTY

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-8.8369	1.0783	-11.0938	-6.5800
DNL, β_1	0.1470	0.0189	0.1074	0.1866
PERCENTBELOWPOVERTY, β_2	0.0199	0.0323	-0.0476	0.0874
PERCENTBELOWPOVERTY x DNL, β_3	-0.0004	0.0006	-0.0016	0.0009

The difference in percent HA between minority and non-minority respondents exposed to the same DNL values was not statistically significant. In addition, airports with greater percentages of minority residents did not exhibit different values of percent HA at specific DNL values than airports with lower percentages of minority residents.

As stated in Table 9-1, PERCENTBELOWPOVERTY is the percentage below poverty in the census block group containing the respondent's address. It is a neighborhood characteristic, and does not describe the poverty status of the respondent's household. The analysis presented in Table 9-7 indicates that respondents in high-poverty block groups have similar relationships between annoyance and DNL exposure as do respondents in low-poverty block groups.

9.4 Summary

This section presented the results of the analyses of factors that had been hypothesized, prior to the data collection, as potential causes of differences among the individual dose-response curves for different airports. Of the six factors studied – climate, "visible" flight events, "noticeable" flight events, "relatively important" flight events, race/ethnicity, and income – only the factor "noticeable" exhibited any ability to explain differences in the dose-response relationships among individuals or airports, and for that factor the relationship was only marginally statistically significant.

Although different airports do have different relationships between percent HA and noise exposure as measured by DNL, none of the factors studied in this section provided a compelling explanation for why those relationships may differ.

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10 Data Files Available for Further Analyses

The FAA is making sets of data available for further analyses by others. Section 10.1 provides a synopsis of the noise modeling data set. Other sets of questionnaire output data are in two use classifications – public and restricted. Sections 10.2 and 10.3 describe the Public Use File (PUF) and Restricted Use File (RUF), respectively.

10.1 Noise Modeling Data

Approximately 1.2 terabytes of noise modeling data is available in the following four data categories, each having its own subsection:

1. Radar Flight Tracking Data,
2. Daily INM Studies,
3. DNL Contours, and
4. Daily INM Detailed Grid Results.

10.2 Public Use File

The PUF contains the NES's primary results in a way that protects PII. The following two subsections describe the PUF. Subsection 10.1.3 presents example output from the PUF. The PUF will be made publicly available in comma-separated values (CSV) and SAS® formats.

10.2.1 Key variables

The NES Mail questionnaire instrument consisted of the following 10 questions:

- Question 1 asked if there was more than one person age 18 or older living in the household.
- Question 2 requested the total number of persons age 18 or older if Question 1 was "Yes."
- Question 4 requested the first name of the person completing the questionnaire.
- Question 5, parts A-M asked the level of annoyance with various environmental factors.
- Question 6 requested the respondent to rate their neighborhood on a scale of 0-10.
- Question 7 asked the respondent's year of birth.
- Question 8 requested the respondent's gender.
- Question 9 asked the respondents Hispanic origin.
- Question 10 requested the respondent's race.
- Question 11 asked the sex, age, and month born of all adults in the household.

Question 3 was an instruction for the adult with the next birthday to complete the questionnaire and did not request data.

10.2.2 Excluded Information

PII was removed from the PUF. This means that the data set does not include, at a minimum, any of the following: name, address, telephone, or latitude and longitude (geolocation) of respondents' residence.

Detailed indirect identifiers would greatly increase the chance of successfully identifying a respondent if released to the public and are not included in the file. Additional such variables include airport identifier, continuous DNL value, birth year, race/ethnicity with more detailed categories, and variables from the telephone instrument that are more sensitive and increase the risk of data disclosure.

10.2.3 Example Output

Derived from the PUF, Table 10-1 presents the percentages for each annoyance category (numerically 1 through 5) for most of the variables listed in Section 10.1.1. Table 10-1 also summarizes the percentage *HA* for each variable listed in the mail questionnaire, e.g., 9 percent are highly annoyed by undesirable business, institution or industrial property in their neighborhood. In general, between 9 and 22 percent of those surveyed were highly annoyed by items not related to aircraft noise, whereas 42 percent were highly annoyed by aircraft noise.

Table 10-1. Example Output Data from PUF – Survey Questions

Survey Question	Percent HA (score of 4 & 5)	Percent of Responses Within Each Category				
		Not at All Annoyed	Slightly Annoyed	Moderately Annoyed	Very Annoyed	Extremely Annoyed
		1	2	3	4	5
Noise from cars, truck or other road traffic	17	29	31	23	10	7
Smells or dirt from road traffic	11	53	23	13	6	5
Smoke, gas or bad smells from anything else	13	49	24	14	7	6
Litter or poorly kept up housing	22	35	26	17	12	10
Noise from aircraft	42	14	20	24	18	24
Your neighbors' noise or other activities	13	40	30	17	8	5
Any other noises you hear when are here at home	16	52	19	13	8	8
Undesirable business, institutional or industrial property	9	68	15	8	5	4
A lack of parks or green spaces	17	52	17	14	9	8
Inadequate public transportation	15	55	17	13	8	7
The amount of neighborhood crime	20	31	29	20	11	9
Poor city or county services	18	42	24	16	9	9

Note: Percentages for intermediate responses (e.g., 1.5, 2.5, etc.) were combined with next highest integer response. For example, percentages associated with "1.5" were added to percentages associated with "2"; 1 thru 5 sum horizontally to 100 percent.

Table 10-2 summarizes the data with regard to the aircraft DNL groupings. Twenty-five percent of respondents exposed to DNL less than or equal to 55 dB were highly annoyed whereas 74 percent of respondents exposed to DNL greater than 70 dB were highly annoyed. The overall data trends are also true in the individual categories with over one-fifth of the respondents being extremely annoyed in the range of DNL 55 to 60 dB and one-third of the respondents being extremely annoyed in the range of DNL 60 to 65 dB.

Table 10-2. Example Output Data from PUF – Aircraft DNL

Aircraft DNL	Percent HA (score of 4 & 5)	Percent of Responses Within Each Category (1)				
		Not at All Annoyed	Slightly Annoyed	Moderately Annoyed	Very Annoyed	Extremely Annoyed
		1	2	3	4	5
Less than or equal to 55 dB	25	22	26	27	14	11
55-60 dB (2)	40	13	20	27	19	21
60-65 dB (2)	55	7	16	22	21	34
65-70 dB (2)	66	6	9	19	21	45
Greater than 70 dB (2)	74	3	9	14	17	57

Notes:

1) Percentages for intermediate responses (e.g., 1.5, 2.5, etc.) were combined with next highest integer response. For example, percentages associated with "1.5" were added to percentages associated with "2"; 1 thru 5 sum horizontally to 100 percent.
2) Exclusive of lower bound.

10.3 Restricted Use File

The RUF contains more detailed data than the PUF, including PII. Due to the data's sensitivity and non-disclosure requirements, the RUF can be provided by the FAA but only on a case-by-case basis.

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Analysis of the Neighborhood Environmental Survey

Volume 2 of 4: Appendices A through E

Contracts DTFACT-15-D-00008 and DTFACT-15-D-00007

HMMH Report No. 308520.004.001
January 2021

Prepared for:

Federal Aviation Administration
William J. Hughes Technical Center
4th Floor, M26
Atlantic City International Airport
Atlantic City, NJ 08405

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Appendix A Mail Survey Instrument and Materials

A.1 Mail Survey Instrument

A.1.1 English Version

OMB #2120-0762
Exp. 04/30/2018

START HERE:

This survey should be filled out by an adult household member living at this address.

Please use a blue or black pen if available.

These first questions ask about your household.

1. Is there more than one person age 18 or older living in this household?

☐ Yes
☐ No → **GO TO number 5 on the next page**

2. Including yourself, how many people age 18 or older live in this household?

☐☐

3. The adult with the next birthday should complete this questionnaire. This way, across all households, this survey will include responses from adults of all ages.

4. Please write the first name, nickname or initials of the adult with the next birthday. This is the person who should complete the questionnaire.

☐

5. Thinking about the last 12 months or so, when you are here at home, how much does each of the following bother, disturb or annoy you?

	Not at all ▼	Slightly ▼	Moderately ▼	Very ▼	Extremely ▼
a. Noise from cars, trucks or other road traffic	☐	☐	☐	☐	☐
b. Smells or dirt from road traffic	☐	☐	☐	☐	☐
c. Smoke, gas or bad smells from anything else	☐	☐	☐	☐	☐
d. Litter or poorly kept up housing	☐	☐	☐	☐	☐
e. Noise from aircraft	☐	☐	☐	☐	☐
f. Your neighbors' noise or other activities	☐	☐	☐	☐	☐
g. Any other noises you hear when you are here at home **If this bothers or annoys you, what is the noise?** ______	☐	☐	☐	☐	☐
h. Undesirable business, institutional or industrial property	☐	☐	☐	☐	☐
i. A lack of parks or green spaces	☐	☐	☐	☐	☐
j. Inadequate public transportation	☐	☐	☐	☐	☐
k. The amount of neighborhood crime	☐	☐	☐	☐	☐
l. Poor city or county services	☐	☐	☐	☐	☐
m. Any other problems that you notice when you are here at home **If this bothers or annoys you, what is the problem?** ______	☐	☐	☐	☐	☐

6. Now considering how you feel about everything in your neighborhood, how would you rate your neighborhood as a place to live on a scale from 0 to 10 where 0 is worst and 10 is best?

Worst 0	1	2	3	4	5	6	7	8	9	Best 10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

These last questions are about you and your household.

7. In what year were you born?

Y	Y	Y	Y

8. Are you male or female?

☐ Male
☐ Female

9. Are you Spanish, Hispanic, or Latino?

☐ Yes
☐ No

10. What is your race? One or more categories may be selected.

Mark ☒ one or more.

☐ White
☐ Black or African American
☐ American Indian or Alaska Native
☐ Asian
☐ Native Hawaiian or Other Pacific Islander

11. Starting with yourself, please mark the sex, and write in the age and month of birth for each adult 18 years of age or older living at this address.

	Sex	Age	Month Born (01-12)
SELF	☐ Male ☐ Female	☐☐☐	☐☐
Adult 2	☐ Male ☐ Female	☐☐☐	☐☐
Adult 3	☐ Male ☐ Female	☐☐☐	☐☐
Adult 4	☐ Male ☐ Female	☐☐☐	☐☐
Adult 5	☐ Male ☐ Female	☐☐☐	☐☐

Thank you. Please return this form in the postage paid envelope provided or mail it to:

Neighborhood Environment Survey
Westat
1600 Research Blvd., Room RC B16
Rockville, MD 20850

Toll-free number for questions: 1-855-210-4396

A.1.2 Spanish Version

OMB #2120-0762
Fecha de vencimiento: 04/30/2018

COMIENCE AQUÍ:

Esta encuesta la debe responder un adulto que viva en esta dirección.

Use un bolígrafo de tinta negra o azul.

Las primeras preguntas son sobre su hogar.

1. ¿Hay más de una persona mayor de 18 años que viva en esta casa?

- ☐ Si
- ☐ No → **VAYA a la pregunta 5 en la siguiente página**

2. Incluyéndose a usted, ¿cuántas personas mayores de 18 años viven en esta casa?

☐☐

3. Debe contestar este cuestionario el adulto próximo a cumplir años. De esta manera, en todos los hogares, esta encuesta incluirá respuestas de adultos de todas las edades.

4. Por favor escriba el nombre, apodo o iniciales del adulto próximo a cumplir años. Esta es la persona que debe contestar el cuestionario.

☐

5. Piense en los últimos 12 meses más o menos. Cuando usted está aquí en casa, ¿qué tanto le molesta, perturba o fastidia lo siguiente?

	Nada	Muy poco	Moderadamente	Bastante	Extremadamente
a. Ruido de automóviles, camiones u otro tráfico vial	☐	☐	☐	☐	☐
b. Olores o basura del tráfico vial	☐	☐	☐	☐	☐
c. Humo, gas o malos olores de otra cosa	☐	☐	☐	☐	☐
d. Basuras o viviendas en mal estado	☐	☐	☐	☐	☐
e. Ruido de aviones	☐	☐	☐	☐	☐
f. El ruido u otras actividades que hacen sus vecinos	☐	☐	☐	☐	☐
g. Otros ruidos que oye cuando está aquí en casa ¿Qué otro ruido le molesta o fastidia? ______________________	☐	☐	☐	☐	☐
h. Negocios o propiedades institucionales o industriales indeseables	☐	☐	☐	☐	☐
i. Falta de parques o zonas verdes	☐	☐	☐	☐	☐
j. Transporte público inadecuado	☐	☐	☐	☐	☐
k. La cantidad de delitos en el vecindario	☐	☐	☐	☐	☐
l. Malos servicios de la ciudad o del condado	☐	☐	☐	☐	☐
m. Otros problemas que nota cuando está aquí en casa ¿Qué otro problema le molesta o fastidia? ______________________	☐	☐	☐	☐	☐

6. Teniendo en cuenta lo que usted piensa acerca de su vecindario, ¿cómo calificaría su vecindario como lugar para vivir en una escala de 0 a 10 donde 0 es lo peor y 10 es lo mejor?

Lo peor 0	1	2	3	4	5	6	7	8	9	Lo mejor 10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Estas últimas preguntas son acerca de usted y de su hogar.

7 ¿En qué año nació usted?

☐	☐	☐	☐
A	A	A	A

8. ¿Es usted de sexo masculino o femenino?

- ☐ Masculino
- ☐ Femenino

9. ¿Es usted hispano o latino?

- ☐ Si
- ☐ No

10. ¿Cuál es su raza? Puede marcar más de una respuesta.

Marque con una ☒ una o más opciones.

- ☐ Blanca
- ☐ Negra o africana americana
- ☐ India americana o nativa de Alaska
- ☐ Asiática
- ☐ Nativa de Hawái o de otras islas del Pacífico

11. <u>Comenzando con usted,</u> por favor marque el sexo y escriba la edad y mes de nacimiento de cada adulto mayor de 18 años que vive en esta dirección.

	Sexo	**Edad**	**Mes de nacimiento (01-12)**
USTED	☐ Masculino ☐ Femenino	☐☐☐	☐☐
Adulto 2	☐ Masculino ☐ Femenino	☐☐☐	☐☐
Adulto 3	☐ Masculino ☐ Femenino	☐☐☐	☐☐
Adulto 4	☐ Masculino ☐ Femenino	☐☐☐	☐☐
Adulto 5	☐ Masculino ☐ Femenino	☐☐☐	☐☐

Muchas gracias. Por favor envíe este formulario en el sobre adjunto cuyos gastos de envío ya han sido pagados o envíelo por correo a:

Neighborhood Environment Survey
Westat
1600 Research Blvd., Room RC B16
Rockville, MD 20850

Línea directa y gratuita para preguntas: 1-855-210-4396

A.2 Mail Survey Materials

A.2.1 Cover Letter for Mail

A.2.1.1 English Version

Neighborhood Environment Survey

Sponsored by U.S. Department of Transportation

«City» Resident
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Dear «City» Resident:

Your household has been selected to take part in an important study for the United States Department of Transportation, a branch of the Federal Government. Since 1967, the United States Department of Transportation has been responsible for ensuring a fast, safe, efficient, accessible and convenient transportation system. We consider neighborhood environmental quality when planning, developing and revising transportation-related policies. The Neighborhood Environment Survey results will be used to update policies that affect the environment in American neighborhoods.

Your household is part of a scientific sample that represents the people who live in neighborhoods like yours. We have asked Westat, a statistical social science firm to obtain your views.

In order to make sure we get responses from a wide variety of people, please have the adult in your household with the next birthday complete and return this questionnaire in the next two weeks. If you are the only adult in the household, we ask that you complete this survey. We have enclosed $2 as a token of our appreciation for your participation.

Your participation is voluntary. However, your household’s participation will help inform us about your neighborhood and the views of people who live in neighborhoods like yours. The information you provide will be maintained confidential to the extent allowed by law. If you have any questions about this study please call Westat toll-free at 1-855-210-4396.

Thank you in advance for your cooperation.

Sincerely,

Barbara McCann
Director, Office of Safety, Energy, and Environment

A.2.1.2 Spanish Version

Encuesta del medio ambiente de los vecindarios

Patrocinada por el Departamento de Transporte de Estados Unidos

Habitante de «City»
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Estimado(a) habitante de «City»:

Su hogar ha sido seleccionado para participar en un importante estudio para el Departamento de Transporte de Estados Unidos, una rama del gobierno federal. Desde 1967, el Departamento de Transporte de Estados Unidos ha sido el responsable de asegurarse de que el sistema de transporte sea rápido, seguro, eficiente, accesible y conveniente. Nosotros tenemos en cuenta la calidad medioambiental del vecindario cuando planificamos, desarrollamos y revisamos políticas relacionadas con el transporte. Los resultados de la Encuesta del medio ambiente de los vecindarios se usarán para actualizar políticas que afectan al medio ambiente en los vecindarios de Estados Unidos.

Su hogar forma parte de una muestra científica que representa a las personas que viven en vecindarios como el suyo. Le hemos pedido a Westat, una compañía de estudios de ciencias sociales, que obtenga sus comentarios.

Con el fin de asegurarnos de recibir respuestas de una gran variedad de personas, quisiéramos que el adulto próximo a cumplir años conteste y nos devuelva este cuestionario dentro de las próximas dos semanas. Si usted es el único adulto del hogar, le pedimos que conteste esta encuesta. Hemos adjuntado 2 dólares como muestra de nuestro agradecimiento por su participación.

Su participación es voluntaria. Sin embargo, la participación de su hogar nos ayudará a informarnos acerca de su vecindario y de las opiniones de las personas que viven en vecindarios como el suyo. La información que usted nos dé se mantendrá de manera confidencial hasta donde lo permite la ley. Si usted tiene alguna pregunta acerca de este estudio llame a la línea directa y gratuita de Westat al 1-855-210-4396.

Le agradecemos de antemano por su colaboración.

Atentamente,

Barbara McCann
Directora, oficina de seguridad, energía y medio ambiente

A.2.2 Mail Postcard

A.2.2.1 English Version

A few weeks ago you received an invitation to take part in the Neighborhood Environment Survey, a survey sponsored by the United States Department of Transportation. If you have already completed and returned this survey, we are very grateful and thank you. If you have not, we encourage you to do so.

In order to make sure we get responses from a wide variety of people, we ask that the adult in your household with the next birthday complete the mail survey. If you are the only adult in the household, we ask that you complete the survey.

This is an important survey that will help provide information that will be used to develop and revise transportation-related policies that affect neighborhoods like yours. We are very grateful for your participation.

{RETURN ADDRESS/LOGO}

{CITY} RESIDENT
{ADDRESS LINE 1}
{ADDRESS LINE 2}
{CITY}, {STATE} {ZIP}

A.2.2.2 Spanish Version

Hace unas semanas usted recibió una invitación para participar en la Encuesta del medio ambiente de los vecindarios, una encuesta patrocinada por el Departamento de Transporte de Estados Unidos. Si usted ya ha contestado y enviado esta encuesta, se lo agradecemos mucho. Si usted todavía no lo ha hecho, lo animamos a que lo haga.

Con el fin de asegurarnos de recibir respuestas de una gran variedad de personas, quisiéramos que el adulto próximo a cumplir años conteste la encuesta por correo. Si usted es el único adulto del hogar, le pedimos que conteste esta encuesta.

Se trata de una importante encuesta que puede ayudar a brindar información que se usará para desarrollar y revisar políticas relacionadas con el transporte que afectan a vecindarios como el suyo. Le agradecemos mucho su participación.

{RETURN ADDRESS/LOGO}

HABITANTE DE {CITY}
{ADDRESS LINE 1}
{ADDRESS LINE 2}
{CITY}, {STATE} {ZIP}

A.2.3 Mail NR Follow-up Letter

A.2.3.1 English Version

Neighborhood Environment Survey

Sponsored by U.S. Department of Transportation

«City» Resident
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Dear «City» Resident:

Recently you received a letter inviting you to take part in an important environmental study for the United States Department of Transportation. Unfortunately we have not yet received a reply from your household. If you have already sent in the survey, thank-you very much for your help. If you haven't yet had time to respond, we encourage you to do so. Your participation in this study is important because your views will help the Department of Transportation update transportation-related policies that affect people in neighborhoods like yours.

For your convenience we've enclosed a replacement to the original survey that was sent to your household.

In order to make sure we get responses from a wide variety of people, please have the adult in your household with the next birthday complete and return this questionnaire in the next two weeks to Westat, the statistical social science firm that is conducting the study. If you are the only adult in the household, we ask that you complete this survey.

Your participation is voluntary. However, your participation is essential to inform us about your neighborhood and the views of people who live in neighborhoods like yours. The information you provide will be maintained confidential to the extent allowed by law. If you have any questions about this study please call Westat toll-free at 1-855-210-4396.

Thank you in advance for your cooperation.

Sincerely,

Barbara McCann
Director, Office of Safety, Energy, and Environment

A.2.3.2 Spanish Version

Encuesta del medio ambiente de los vecindarios

Patrocinada por el Departamento de Transporte de Estados Unidos

Habitante de «City»
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Estimado(a) habitante de «City»:

Hace poco usted recibió una carta informándole que iba a recibir una llamada para participar en un importante estudio medioambiental para el Departamento de Transporte de Estados Unidos. Lamentablemente todavía no hemos recibido la respuesta de su hogar. Si usted ya ha enviado la encuesta, le agradecemos mucho su colaboración. Si usted todavía no ha tenido tiempo para contestarla, lo animamos a que lo haga. Su participación en este estudio es importante, ya que sus opiniones ayudarán al Departamento de Transporte a actualizar políticas relacionadas con el transporte que afectan a personas en vecindarios como el suyo.

Para su comodidad, hemos incluido un reemplazo del cuestionario original que enviaron a su hogar.

Con el fin de asegurarnos de recibir respuestas de una gran variedad de personas, quisiéramos que el adulto próximo a cumplir años conteste y nos devuelva este cuestionario dentro de las próximas dos semanas a Westat, la compañía de estudios de ciencias sociales que lleva a cabo el estudio. Si usted es el único adulto del hogar, le pedimos que conteste esta encuesta.

Su participación es voluntaria. Sin embargo, la participación de su hogar nos ayudará a informarnos acerca de su vecindario y de las opiniones de las personas que viven en vecindarios como el suyo. La información que usted nos dé se mantendrá de manera confidencial hasta donde lo permite la ley. Si usted tiene alguna pregunta acerca de este estudio llame a la línea directa y gratuita de Westat al 1-855-210-4396.

Le agradecemos de antemano por su colaboración.

Atentamente,

Barbara McCann

Barbara McCann
Directora, oficina de seguridad, energía y medio ambiente

Appendix B Telephone Survey Instrument and Materials

B.1 Telephone Survey Instrument

B.1.1 English Version

Neighborhood Environment Survey

Hello. My name is ___ and I'm calling about a neighborhood environment survey being conducted for the United States Department of Transportation. We recently sent you a letter about this survey and will provide you with ten dollars as a token of our appreciation upon completion of the interview. {DISPLAY D4}

Are you {DISPLAY D5} at least 18 years old? (If 'NO" ask for an adult household member.)

D4	*IF THIS IS A CELL PHONE (BASE.LANDCELL = 2)*	"If you are currently driving a car or doing any activity that requires your full attention, I need to call you back at a later time."
i	*IF CELL OR LANDLINE STATUS IS UNKNOWN (BASE.LANDCELL = 3)*	"If I have reached you on a cell phone and you are currently driving a car or doing any activity that requires your full attention I need to call you back at a later time."
	ELSE	BLANK
D5	*IF THIS IS A LANDLINE (BASE.LANDCELL = 1)*	"a member of this household and"
	ELSE	BLANK

PROGRAMMING NOTE: If probable business, continue to verify address (A3) to verify accuracy of phone match.

INTRO: This information is being collected as part of a neighborhood environment survey for the United States Department of Transportation which is being conducted by Westat, a social science research firm. The information will be used to measure residents' attitudes about their environment.

A3. Before I get started, I'd like to determine the eligibility of your household to participate in the survey. Is your home address {DISPLAY ADDRESS}

[VERIFY SPELLING. RECORD CHANGES OR PRESS ENTER IF NO CHANGE.]

PROGRAMMING NOTE: If address does not match, case is finalized; there is no need to ask A3_1.

A3_1. Is this address…
a business only,
a residence only, or
both?

PROGRAMMING NOTE: If business only, case becomes ineligible. This is after address has been verified and indicates that a business was sampled. This is for both the phone match and phone numbers collected by mail groups.

A4. Including yourself, how many adults age 18 and older, currently live in your household? [IF NEEDED: Include adults who think of this household as their primary place of residence. Include adults who usually stay in the household but are temporarily away on business, vacation, or in a hospital.]

[Implement Rizzo respondent selection algorithm].

OBS. IS THE ORIGINAL RESPONDENT SELECTED TO DO THE SURVEY?

YES..1 (GO TO Short Intro)
NO..2 (Continue)

A5.1 [NUMBER OF ADULTS = 2] Please tell me just the first name of the other adult in this household.

Is this person male or female?

MALE	1
FEMALE	2
REFUSED	-7
DON'T KNOW	-8

A5.2 [NUMBER OF ADULTS > 2] Please tell me just the first name of the adult in this household, **other than yourself**, who will have the next birthday.

Is this person male or female?

MALE	1
FEMALE	2
REFUSED	-7
DON'T KNOW	-8

A6. May I please speak to [NAME/GENDER].

Full Introduction *[If interview is with person who did not answer above questions.]*

My name is ___ and I'm calling about the Neighborhood Environment Survey. We recently sent you a letter about this survey which is sponsored by the United States Department of Transportation. As noted in the letter we will provide you with ten dollars as a token of our appreciation upon completion of the interview.

Westat, a social science research firm, is contacting households around America to help the U.S. Department of Transportation learn more about the environmental conditions of neighborhoods like yours. This information will be used to update transportation-related policies.

Your household is one of a small number that has been selected from the [CITY] area. Your participation will represent the views of many others in neighborhoods like yours. Participation in this survey is completely voluntary. You may skip any questions that you don't want to answer and you can stop at any time. The survey should take about 20 minutes.

May I continue with the survey?

CONTINUE 1
GO TO RESULT ....GT

Short Introduction

OK, it looks like you are eligible for the survey. As a reminder, we are contacting households in neighborhoods like yours around America to help the U.S. Department of Transportation learn more about the environmental conditions of neighborhoods like yours. Your household is one of a small number that has been selected from the [CITY] area. Your participation will represent the views of many others in communities like yours.

Participation in this survey is completely voluntary. You may skip any questions that you don't want to answer and you can stop at any time. The survey should take about 20 minutes.

May I continue with the survey?

CONTINUE 1
GO TO RESULT ....GT

[IF SCREENER RESPONDENT IS SELECTED RESPONDENT]

A7.1 The following questions will ask you about things you may notice when you are "here at home". By here at home we mean the address that we confirmed with you.

[IF SCREENER RESPONDENT IS NOT THE SELECTED RESPONDENT]

A7.2 The following questions will ask you about things you may notice when you are "here at home". By here at home we mean the following address:

[DISPLAY ADDRESS CONFIRMED IN A3, CONTINUE TO QUESTION 1]

1. Thinking about the last 12 months or so, when you are here at home, how much does [INSERT TEXT FROM A-M] bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?

	Not at all	Slightly	Moderately	Very	Extremely	Refused	Don't know
a. Noise from cars, trucks or other road traffic	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
b. Smells or dirt from road traffic	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
c. Smoke, gas or bad smells from anything else	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
d. Litter or poorly kept up housing	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
e. Noise from aircraft	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
f. Your neighbors' noise or other activities	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
g. Are there any other noises you hear when you are here at home? 1 = YES 2 = NO [IF YES] What is that noise? [DESCRIBE IN BOX BELOW.] Thinking about the last 12 months or so, when you are here at home, how much does (DESCRIBED NOISE) bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
Describe: ______________________________							
h. Undesirable business, institutional or industrial property	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
i. A lack of parks or green spaces	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
j. Inadequate public transportation	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
k. The amount of neighborhood crime	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
l. Poor city or county services	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8

	Not at all	Slightly	Moderately	Very	Extremely	Refused	Don't know
m. Are there any other problems that you notice when you are here at home? 1 = YES 2 = NO [IF YES]: What is that problem? [DESCRIBE IN BOX BELOW.] Thinking about the last 12 months or so, when you are here at home, how much does (DESCRIBED PROBLEM) bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
Describe: ____________________							

2. Now considering how you feel about everything in your neighborhood, how would you rate your neighborhood as a place to live on a scale from 0 to 10 where 0 is worst and 10 is best?

|__|__|

REFUSED.. -7
DON'T KNOW................................. -8

3. Now please rate noise on a 0 to 10 opinion scale for how much the noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose 0; if you are extremely annoyed choose 10; if you are somewhere in between, choose a number between 0 and 10.

First about noise in general.

Thinking about the last 12 months or so, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by the noise in general when you are here at home?

|__|__|

REFUSED.. -7
DON'T KNOW................................. -8

4. Thinking about the last 12 months or so, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by the noise from cars or trucks or other road traffic?

|__|__|

REFUSED.. -7
DON'T KNOW................................ -8

5. Thinking about the last 12 months or so, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by the noise from aircraft?

|__|__|

REFUSED.. -7
DON'T KNOW................................ -8

BOX 1
[IF RESPONDENT ANSWERS "NOT AT ALL ANNOYED" BY AIRCRAFT IN BOTH THE PREVIOUS 5-POINT VERBAL-SCALE AND 0-10 SCALE AIRCRAFT NOISE QUESTIONS → GO TO Q6. OTHERWISE GO TO Q7.

6. [ASK ONLY IF "NOT AT ALL ANNOYED" BY AIRCRAFT IN BOTH THE PREVIOUS 5-POINT VERBAL-SCALE AND 0-10 SCALE AIRCRAFT NOISE QUESTIONS]

Have you ever heard the sound from an aircraft when you were here at home?

YES.. 1 (GO TO 7)
NO.. 2 (BOX 2)

BOX 2
Even if the aircraft noise has not annoyed you during the last year, we still need your views on particular aspects of aircraft. If you don't notice them, please say so. If you do notice them, that's fine, too. Just tell us about your views and we can move right along.

7. Has an aircraft ever [waked you or kept you awake at night] when you are at home?

	Yes	No	Don't notice aircraft	Refused	Don't know
a. waked you up or kept you awake at night?	☐1	☐2	☐-6	☐-7	☐-8
b. Startled or surprised you?	☐1	☐2	☐-6	☐-7	☐-8
c. Frightened you?	☐1	☐2	☐-6	☐-7	☐-8

[INTRO8] The next questions ask whether or not aircraft actually bothered, disturbed, or annoyed you in different ways during the last 12 months when you have been here at home.

[ASK ONLY SPECIFIC TYPES OF DISTURBANCES WHICH WERE IDENTIFIED IN QUESTION 7]

8. Thinking about <u>the last 12 months or so</u>, when you are at home, have the aircraft bothered, disturbed or annoyed you by [READ FIRST ITEM THAT WAS NOTICED]

Would you say: extremely, very, moderately, slightly, or not at all?

	Extremely	Very	Moderately	Slightly	Not at all	Refused	Don't know
a. Waking you up or keeping you awake at night	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
b. Startling or surprising you	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
c. Frightening you	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8

To understand why aircraft noise may or may not affect you, we ask you to consider your situation here at home, your observations about aircraft flights here and the actions authorities have been taking.

Your next answers provide background for understanding your living situation in this area.

9. Which of the following best describes the building where you live?

A mobile home? .... 1 (Go to 10)
A one-family house detached from any other house? .... 2 (Go to 10)
A one-family house attached to one or more houses? .... 3 (Go to 10)
A building with two or more apartments? 4
Some other type of place?
What type of building is that? (DESCRIBE) ________ 5 (Go to 10)
REFUSED .... -7 (Go to 10)
DON'T KNOW .... -8 (Go to 10)

9a. Approximately, how many apartments are there in your building??

2 APARTMENTS	1
3 or 4 APARTMENTS	2
5 TO 9 APARTMENTS	3
10 TO 19 APARTMENTS	4
20 TO 49 APARTMENTS	5
50 OR MORE APARTMENTS	6

10. Do you own your home or are you renting?

OWN (INCLUDE OWING A MORTGAGE)	1
RENTING	2
REFUSED	-7
DON'T KNOW	-8

11. How many of the five weekdays from Monday through Friday are you usually out away from home most of the day, that is 8 hours or more? Are you usually away, on all five weekdays, or fewer weekdays, or are you usually not away on any weekday?

[PROBE IF NUMBER OF WEEKDAYS NOT VOLUNTEERED]

How many weekdays are you usually away?

0 NOT AWAY ON ANY WEEKDAY	0
1 DAY	1
2 DAYS	2
3 DAYS	3
4 DAYS	4
5 AWAY ALL 5 WEEKDAYS	5
REFUSED	-7
DON'T KNOW	-8

12. Think about those weeks in the year when you spend the most time out-of-doors in your yard or on your porch, deck or balcony. At that time of year, how many hours a week would you say you are out-of-doors at home?

|__|__|
HOURS

REFUSED	-7
DON'T KNOW	-8

13. In what year and month did you move to your home here?

|__|__|__|__| |__|__|
YEAR MONTH

REFUSED.. -7
DON'T KNOW................................. -8

14. Since you moved here, has the total amount of aircraft noise increased, decreased or stayed about the same?

INCREASED 1
STAYED ABOUT THE SAME 2
DECREASED 3
NEVER HEARD ANY AIRCRAFT (VOLUNTEERED) .... -6
REFUSED.. -7
DON'T KNOW.. -8

15. What do you think aircraft noise will be like here in the next few years: Do you think the total amount of aircraft noise will increase, decrease or stay about the same here?

INCREASE 1
STAY ABOUT THE SAME 2
DECREASE 3
WILL CONTINUE TO NEVER HEAR ANY AIRCRAFT
(VOLUNTEERED).. -6
REFUSED.. -7
DON'T KNOW.. -8

16. When you are at home, have you ever heard aircraft sitting on the ground or moving around on the ground on the airport property?

YES 1
NO 2
REFUSED .... -7
DON'T KNOW................................. -8

17. [ASK IF "HEARD" IN PREVIOUS QUESTION] Thinking about the last 12 months or so, when you are at home, how much have the aircraft sitting on the ground or moving around on the ground on the airport property bothered, disturbed or annoyed you: extremely, very, moderately, slightly, or not at all?

EXTREMELY	1
VERY	2
MODERATELY	3
SLIGHTLY	4
NOT AT ALL	5
REFUSED	-7
DON'T KNOW	-8

Next we ask you to provide some background about this area and the airport.

18. How knowledgeable are you about noise and other community environmental issues in the [CITY NAME] area: Are you extremely knowledgeable, very knowledgeable, moderately knowledgeable, slightly knowledgeable, or not at all knowledgeable?

EXTREMELY KNOWLEDGEABLE	1
VERY KNOWLEDGEABLE	2
MODERATELY KNOWLEDGEABLE	3
SLIGHTLY KNOWLEDGEABLE	4
NOT AT ALL KNOWLEDGEABLE	5
REFUSED	-7
DON'T KNOW	-8

19. About how many trips a year do you and other members of your household make from the [LOCAL AIRPORT]?

One trip is considered as round-trip travel and includes all family members traveling together. If any family members travel separately, please count those as separate trips as long as they use [LOCAL AIRPORT].

|__|__|
NUMBER OF TIMES

REFUSED	-7
DON'T KNOW	-8

20. Do you or anyone else in your household work at [LOCAL AIRPORT] or work for a company or organization that does business with [LOCAL AIRPORT])?

YES 1
NO 2
REFUSED.. -7
DON'T KNOW................................. -8

21. How much have you learned about your community's aircraft noise issues from media reports in the newspaper or on radio or TV: a great deal, somewhat, a little or nothing at all?

A GREAT DEAL 1
SOMEWHAT, ... 2
A LITTLE 3
NOTHING AT ALL 4
REFUSED .... -7
DON'T KNOW................................. -8

22. How about a more local information source? How much have you learned about your community's aircraft noise issues from a community newspaper or other more local organization, newsletter or local internet source: a great deal, somewhat, a little or nothing at all?

A GREAT DEAL 1
SOMEWHAT, ... 2
A LITTLE 3
NOTHING AT ALL 4
REFUSED .... -7
DON'T KNOW................................. -8

23. How about your closest neighbors making their views known about aircraft noise: Have they clearly made their views known, have they revealed only a little about their views, or have they kept their views to themselves?

MADE THEIR VIEWS CLEARLY KNOWN...................... 1
REVEALED A LITTLE, ... 2
KEPT VIEWS TO THEMSELVES...................................... 3
REFUSED... -7
DON'T KNOW... -8

24. As far as you know, have there ever been disputes between airport authorities and community residents about aircraft noise around (…LOCAL AIRPORT…)?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

25. Are any community groups or other organizations trying to reduce aircraft noise or don't you know?

GROUP IS	1
GROUP IS NOT	2
REFUSED	-7
DON'T KNOW	-8

26. Have you or anyone in your household ever tried to get something done about aircraft noise such as telephoning the airport, sending a message, writing a letter, contacting an official, going to a meeting, joining a group or doing something else?

YES	1	(GO TO 26a)
NO	2	(-6, -7, -8 GO TO 27)
DON'T NOTICE ANY AIRCRAFT (VOLUNTEERED)	-6	
REFUSED	-7	
DON'T KNOW	-8	

26a. Was the airport contacted directly?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

27. If someone wants to make a complaint about aircraft noise these days, do you know if there is a convenient way to contact (…LOCAL AIRPORT…)?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

28. How much do you think that residents' actions and views can influence (…LOCAL AIRPORT…) noise policy? Do you think that residents' views can very greatly influence policy, greatly influence policy, moderately influence, slightly influence, or not at all influence policy?

VERY GREATLY INFLUENCE	5
GREATLY INFLUENCE	4
MODERATELY INFLUENCE	3
SLIGHTLY INFLUENCE	2
NOT AT ALL INFLUENCE	1
REFUSED	-7
DON'T KNOW	-8

29. Has your home been sound insulated?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

Next we ask for your views about the local officials and managers at the airport who oversee aircraft operations in this area.

30. To what extent do you think [LOCAL AIRPORT] officials recognize the community residents' feelings about aircraft noise? Do you think the officials recognize the residents' feelings extremely well, very well, moderately well, slightly, or not at all?

EXTREMELY WELL	5
VERY WELL	4
MODERATELY WELL	3
SLIGHTLY	2
NOT AT ALL	1
REFUSED	-7
DON'T KNOW	-8

31. How fully do you feel the [LOCAL AIRPORT] officials keep community residents informed about the planning for airport changes? Do you think the officials keep communities extremely well informed, very well informed, moderately well informed, slightly informed, or not at all informed?

EXTREMELY WELL	5
VERY WELL	4
MODERATELY WELL	3
SLIGHTLY	2
NOT AT ALL	1
REFUSED	-7
DON'T KNOW	-8

32. How completely do you feel you can trust the [LOCAL AIRPORT] officials to work fairly with the community by following official, agreed-upon procedures and providing accurate information? Do you feel you can rely upon the [LOCAL AIRPORT] officials completely, considerably, moderately, slightly or not at all?

COMPLETELY	1
CONSIDERABLY	2
MODERATELY	3
SLIGHTLY	4
NOT AT ALL	5
REFUSED	-7
DON'T KNOW	-8

33. How much do you think [INSERT TEXT FROM A-C] could reduce the aircraft noise around here: Could [INSERT TEXT FROM A-C] reduce the noise very greatly, greatly, moderately, slightly or not at all?

	Very greatly	Greatly	Moderately	Slightly	Not at all	Refused	Don't know
a. The officials who run [LOCAL AIRPORT]	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
b. Other government officials	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
c. The pilots flying the planes	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8

34. As far as you know, have the authorities at [LOCAL AIRPORT] ever taken steps to try to reduce or control the amount of aircraft noise here?

YES	1	(GO TO 40a)
NO	2	(GO TO 41)
REFUSED	-7	(GO TO 41)
DON'T KNOW	-8	(GO TO 41)

34a. What did they do?

____

____

35. How important do you think that [LOCAL AIRPORT] is for the [CITY NAME] area: Is [LOCAL AIRPORT] extremely important, very important, moderately important, slightly important or not at all important?

EXTREMELY	5
VERY	4
MODERATELY	3
SLIGHTLY	2
NOT AT ALL	1
REFUSED	-7
DON'T KNOW	-8

We just have a couple more opinion questions and then a little background information before we are finished.

36. How sensitive are you generally to noise of all kinds: extremely sensitive, very sensitive, moderately sensitive, slightly sensitive, or not at all sensitive?

EXTREMELY SENSITIVE	5
VERY SENSITIVE	4
MODERATELY SENSITIVE	3
SLIGHTLY SENSITIVE	2
NOT AT ALL SENSITIVE	1
REFUSED	-7
DON'T KNOW	-8

37. To summarize your opinion about aircraft noise in this neighborhood, please consider all we have discussed and use a zero to four opinion thermometer where zero is not at all annoyed, four is extremely annoyed and one to three are in between.

What number from zero to four shows how much you are bothered or annoyed by aircraft noise in this neighborhood?

|__|

REFUSED	-7
DON'T KNOW	-8

Next we need to learn where the aircraft are flying in this area.

38. Are most of the aircraft that you notice from your home coming down for a landing at the airport, taking off from the airport, are about half landing and about half taking off, are they doing something else, or don't you know?

LANDING 1
ABOUT HALF AND HALF 2
TAKING OFF 3
DOING SOMETHING ELSE
(PROBE: **What are they doing**?) _________________ 4
DON'T NOTICE ANY AIRCRAFT (VOLUNTEERED) .... -6
REFUSED .... -7
DON'T KNOW .... -8

39. Thinking about all the aircraft you notice when you are at home, about what percent fly directly over your property?

|__|__|__|%

DON'T NOTICE ANY AIRCRAFT
(VOLUNTEERED) .... -6
REFUSED .... -7
DON'T KNOW .... -8

40. When you are at home or around the neighbourhood, how fearful or concerned are you that an aircraft might crash nearby: Are you extremely, very, moderately, slightly, or not at all concerned that an aircraft might crash?

EXTREMELY 5
VERY 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED .... -7
DON'T KNOW .... -8

41. When you are at home, how concerned are you that an aircraft crash might actually hurt you or your own property: Are you extremely, very, moderately, slightly, or not at all concerned that an aircraft might hurt you or your property?

EXTREMELY 5
VERY 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED .... -7
DON'T KNOW .... -8

Now consider your feelings about possible car or truck road traffic accidents or possible passenger or freight train railway derailments or crashes in this area.

42. When you are at home or around the neighborhood, how fearful or concerned are you that there might be car or truck road traffic accidents nearby: Are you extremely, moderately, slightly, or not at all concerned that there might be a road traffic crash?

EXTREMELY 5
VERY.. 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED... -7
DON'T KNOW................................. -8

43. When you are at home or around the neighborhood, how fearful or concerned are you that there might be a passenger train or freight train derailment or crash nearby? Are you extremely, moderately, slightly, or not at all concerned that there might be a train crash?

EXTREMELY 5
VERY.. 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED... -7
DON'T KNOW................................. -8

44. Which type of traffic, if any, do you feel is the most dangerous for you or your property when you are here at home: road traffic, railway trains or aircraft?

ROAD TRAFFIC.............................. 1
RAILWAY TRAINS 2
AIRCRAFT....................................... 3
NONE ARE DANGEROUS............. 5
REFUSED... -7
DON'T KNOW (INCLUDES NOT
ABLE TO CHOOSE THE MOST
DANGEROUS).............................. -8

45. In what month and year were you born

|__|__| / |__|__|__|__
MONTH YEAR

REFUSED... -7
DON'T KNOW................................. -8

46. What is the highest level of school you have completed or the highest degree you have received?

LESS THAN 1ST GRADE 01
1ST, 2ND, 3RD OR 4TH GRADE 02
5TH OR 6TH GRADE 03
7TH OR 8TH GRADE 04
9TH GRADE 05
10TH GRADE 06
11TH GRADE 07
12TH GRADE, NO DIPLOMA 08
HIGH SCHOOL GRADUATE – HIGH SCHOOL DIPLOMA OR EQUIVALENT (FOR EXAMPLE: GED) 09
SOME COLLEGE BUT NO DEGREE................................ 10
DIPLOMA OR CERTIFICATE FROM A VOCATIONAL, TECHNICAL, TRADE OR BUSINESS SCHOOL BEYOND THE HIGH SCHOOL LEVEL 11
ASSOCIATE DEGREE IN COLLEGE – OCCUPATIONAL/VOCATIONAL PROGRAM 12
ASSOCIATE DEGREE IN COLLEGE – ACADEMIC PROGRAM... 13
BACHELORS DEGREE (FOR EXAMPLE: BA, AB, BS) 14
MASTER'S DEGREE (FOR EXAMPLE: MA, MS, MENG, MED, MSW, MBA) 15
PROFESSIONAL SCHOOL DEGREE (FOR EXAMPLE: MD, DDS, DVM, LLB, JD) 16
DOCTORATE DEGREE (FOR EXAMPLE: PHD, EDD) .. 17
REFUSED.. -7
DON'T KNOW... -8

47. [IF GENDER COLLECTED IN A5.1 OR A5.2 FROM THE SELECTED RESPONDENT (SELECTED RESPONDENT WAS SCREENER RESPONDENT) THEN SKIP 45 AND CONTINUE WITH 46, OTHERWISE ASK IF NOT SURE. OTHERWISE CODE AND CONTINUE WITH 46.]

Are you male or female?

MALE 1
FEMALE... 2
REFUSED .... -7
DON'T KNOW................................. -8

48. Are you Spanish, Hispanic, or Latino?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

49. What race or races do you consider yourself to be? [SELECT ALL THAT APPLY]

WHITE	1
BLACK OR AFRICAN AMERICAN	2
AMERICAN INDIAN OR ALASKA NATIVE	3
ASIAN	4
NATIVE HAWAIIAN OR OTHER PACIFIC ISLANDER	5
REFUSED	-7
DON'T KNOW	-8

50. What is the approximate total income from everyone in this household including such things as wages, salary, interest, pensions, or government payments? Would you say [READ RESPONSES]:

[IF THEY REFUSE TO ANSWER, PROBE:]

Is it less than 25 thousand dollars a year?
from 25 to 50 thousand?
50 thousand and one to 100 thousand?
100 thousand and one to 200 thousand?
or 200 thousand or more a year?

LESS THAN 25,000	1
25,000 – 50,000	2
50,001 – 100,000	3
100,001 – 200,000	4
200,001 or more	5
REFUSED	-7
DON'T KNOW	-8

51. Is there anything more you would like to tell me or are there any questions I can answer for you?

____

____

____

[INT87] Those are all the questions I have. Thank you again for participating in this very important study. [PRESS NEXT TO CONTINUE]

B.1.2 Spanish Version

Neighborhood Environment Survey

Buenos días/Buenas tardes. Mi nombre es ___ y estoy llamando acerca de una encuesta sobre el medio ambiente de los vecindarios que estamos realizando para el Departamento de Transporte de Estados Unidos. Recientemente le enviamos una carta acerca de esta encuesta y le daremos 10 dólares como muestra de agradecimiento después de que completemos la entrevista. {DISPLAY D4}

¿Es usted {DISPLAY D5} mayor de edad, es decir tiene un mínimo de 18 años de edad? (If 'NO" ask for an adult household member.)

D4	*IF THIS IS A CELL PHONE (BASE.LANDCELL = 2)*	"Avíseme si en este momento está manejando o haciendo otra actividad que requiera de su total atención, para poder llamar en otro momento."
i	*IF CELL OR LANDLINE STATUS IS UNKNOWN (BASE.LANDCELL = 3)*	"Si lo he llamado a un teléfono celular y en este momento está manejando o haciendo otra actividad que requiera de su total atención, lo volveré a llamar en otro momento.
	ELSE	BLANK
D5	*IF THIS IS A LANDLINE (BASE.LANDCELL = 1)*	"un miembro de este hogar y "
	ELSE	BLANK

PROGRAMMING NOTE: If probable business, continue to verify address (A3) to verify accuracy of phone match.

<u>INTRO</u>: Estamos reuniendo esta información como parte de una encuesta sobre el medio ambiente de los vecindarios que realiza Westat, una compañía de estudios en ciencias sociales, para el Departamento de Transporte de Estados Unidos. La información se usará para medir las opiniones de los habitantes de los vecindarios acerca de su medio ambiente.

A3. Antes de comenzar, quisiera determinar si su hogar reúne los requisitos para participar en el estudio. ¿Es la dirección de su hogar {DISPLAY ADDRESS}?

[VERIFY SPELLING. RECORD CHANGES OR PRESS ENTER IF NO CHANGE.]

PROGRAMMING NOTE: If address does not match, case is finalized, there is no need to ask A3_1.

A3_1. ¿Es esta dirección...
únicamente un negocio,
únicamente una vivienda o
ambas cosas?

PROGRAMMING NOTE: If business only, case becomes ineligible. This is after address has been verified and indicates that a business was sampled. This is for both the phone match and phone numbers collected by mail groups.

A4. ¿Cuántos adultos mayores de 18 años viven en su hogar?

[Implement Rizzo respondent selection algorithm].

OBS. IS THE ORIGINAL RESPONDENT SELECTED TO DO THE SURVEY?

YES...1 (GO TO Short Intro)
NO..2 (Continue)

A5.1 [NUMBER OF ADULTS = 2] Por favor dígame únicamente el nombre del otro adulto de este hogar.

¿Es esta persona de sexo masculino o femenino?

MALE 1
FEMALE 2
REFUSED -7
DON'T KNOW -8

A5.2 [NUMBER OF ADULTS > 2] Por favor dígame únicamente el nombre del adulto de este hogar, **aparte de usted**, que tendrá el próximo cumpleaños.

¿Es esta persona de sexo masculino o femenino?

MALE 1
FEMALE 2
REFUSED -7
DON'T KNOW -8

A6. ¿Puedo hablar con [NAME/GENDER]?

Full Introduction *[If interview is with person who did not answer above questions.]*

Mi nombre es ___ y estoy llamando acerca de la Encuesta del medio ambiente de los vecindarios. Recientemente le enviamos una carta acerca de esta encuesta que patrocina el Departamento de Transporte de Estados Unidos. Como se menciona en la carta, le daremos diez dólares como muestra de nuestro agradecimiento después de que complete la entrevista.

Westat, una compañía de estudios de ciencias sociales, está contactando a hogares en todo Estados Unidos para ayudarle al Departamento de Transporte de Estados Unidos a saber más acerca de las condiciones medioambientales de vecindarios como el suyo. Esta información se usará para actualizar las políticas relacionadas con el transporte.

Su hogar es uno de un pequeño número que ha sido seleccionado en la zona de [CITY]. Su participación representará las opiniones de muchas otras personas en vecindarios como el suyo. La participación en esta encuesta es completamente voluntaria. Puede dejar de contestar preguntas que prefiera no contestar y puede detener la entrevista en cualquier momento. La encuesta tomará unos 20 minutos.

¿Puedo continuar con la encuesta?

CONTINUE 1
GO TO RESULT ....GT

Short Introduction

Muy bien. Parece que usted reúne los requisitos para participar en la encuesta. Queremos recordarle que estamos contactando a hogares en todo Estados Unidos para ayudarle al Departamento de Transporte de Estados Unidos a saber más acerca de las condiciones medioambientales de vecindarios como el suyo. Su hogar es uno de un pequeño número que ha sido seleccionado en la zona de [CITY]. Su participación representará las opiniones de muchas otras comunidades como la suya.

La participación en esta encuesta es completamente voluntaria. Puede dejar de contestar preguntas que prefiera no contestar y puede detener la entrevista en cualquier momento. La encuesta tomará unos 20 minutos.
¿Puedo continuar con la encuesta?

CONTINUE 1
GO TO RESULT ....GT

[IF SCREENER RESPONDENT IS SELECTED RESPONDENT]

A7.1 Las siguientes preguntas son acerca de cosas que posiblemente note cuando está "aquí en casa". Al decir aquí en casa nos referimos a la dirección que hemos confirmado con usted.

[IF SCREENER RESPONDENT IS NOT THE SELECTED RESPONDENT]

A7.2 Las siguientes preguntas son acerca de cosas que posiblemente note cuando está "aquí en casa". Al decir aquí en casa nos referimos a la siguiente dirección:

[DISPLAY ADDRESS CONFIRMED IN A3, CONTINUE TO QUESTION 1]

1. Piense en los <u>últimos 12 meses más o menos.</u> Cuando usted está aquí en casa, ¿qué tanto le molesta, perturba o fastidia [INSERT TEXT FROM A-M]? ¿Diría que nada, muy poco, moderadamente, bastante o extremadamente?

	Nada	Muy poco	Moderadamente	Bastante	Extremadamente	Refused	Don't know
a. El ruido de automóviles, camiones u otro tráfico vial	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
b. Los olores o basura del tráfico vial	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
c. El humo, gas o malos olores de otra cosa	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
d. Las basuras o viviendas en mal estado	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
e. El ruido de aeronaves	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
f. El ruido u otras actividades que hacen sus vecinos	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
g. ¿Hay otros ruidos que escucha cuando está aquí en casa? 1 = YES 2 = NO [IF YES] ¿Qué ruidos? [DESCRIBE IN BOX BELOW.] Piense en los <u>últimos 12 meses más o menos</u>. Cuando usted está aquí en casa, ¿qué tanto le molesta, perturba o fastidia (DESCRIBED NOISE)? ¿Diría que nada, muy poco, moderadamente, bastante o extremadamente?	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
Describa: ______________________________							
h. Negocios o propiedades institucionales o industriales indeseables	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
i. La falta de parques o zonas verdes	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
j. El transporte público inadecuado	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
k. La cantidad de delitos en el vecindario	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8

	Nada	Muy poco	Moderadamente	Bastante	Extremadamente	Refused	Don't know
l. Los malos servicios de la ciudad o del condado	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
m. ¿Hay algún otro problema que ha notado cuando está aquí en casa? 1= YES 2 = NO [IF YES]: ¿Qué problema? Piense en los <u>últimos 12 meses más o menos.</u> Cuando usted está aquí en casa, ¿qué tanto le molesta, perturba o fastidia (DESCRIBED NOISE)? ¿Diría que nada, muy poco, moderadamente, bastante o extremadamente?	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
Describa: ____________________							

2. Teniendo en cuenta lo que usted piensa acerca de su vecindario, ¿cómo calificaría su vecindario como lugar para vivir en una escala de 0 a 10 donde 0 es lo peor y 10 es lo mejor?

|__|__|

REFUSED.. -7
DON'T KNOW................................ -8

3. Ahora por favor califique al ruido en una escala de 0 a 10 respecto a qué tanto el ruido le molesta, perturba o fastidia cuando está aquí en casa. Si no le fastidia nada, elija 0; si le fastidia en extremo, elija 10. Si se siente en un punto intermedio, elija un número entre 0 y 10.

Primero acerca del ruido en general.

Piense en los <u>últimos 12 meses más o menos.</u> ¿Qué número de 0 a 10 describe mejor cuánto le molesta, perturba o fastidia el ruido en general cuando está aquí en casa?

|__|__|

REFUSED.. -7
DON'T KNOW................................ -8

4. Piense en los <u>últimos 12 meses más o menos.</u> ¿Qué número de 0 a 10 describe mejor cuánto le molesta, perturba o fastidia el ruido de automóviles, camiones u otro tráfico vial?

|__|__|

REFUSED.. -7
DON'T KNOW................................ -8

5. Piense en los <u>últimos 12 meses más o menos.</u> ¿Qué número de 0 a 10 describe mejor cuánto le molesta, perturba o fastidia el ruido de aeronaves?

|__|__|

REFUSED.. -7
DON'T KNOW................................ -8

BOX 1

[IF RESPONDENT ANSWERS "NOT AT ALL ANNOYED" BY AIRCRAFT IN BOTH THE PREVIOUS 5-POINT VERBAL-SCALE AND 0-10 SCALE AIRCRAFT NOISE QUESTIONS → GO TO Q6.

OTHERWISE GO TO Q7.

6. [ASK ONLY IF "NOT AT ALL ANNOYED" BY AIRCRAFT IN BOTH THE PREVIOUS 5-POINT VERBAL-SCALE AND 0-10 SCALE AIRCRAFT NOISE QUESTIONS]

¿Alguna vez ha oído el ruido de una aeronave cuando está aquí en casa?

YES... 1 (GO TO 7)
NO.. 2 (BOX 2)

BOX 2

Incluso si el ruido de aeronaves no lo ha fastidiado durante los últimos 12 meses, quisiéramos conocer su opinión acerca de aspectos particulares de las aeronaves. Si no las nota, por favor díganoslo. Si las nota, está bien. Simplemente cuéntenos su opinión y continuaremos con la encuesta.

7. ¿Alguna vez una aeronave [lo ha despertado o no lo ha dejado dormir en la noche] cuando usted está en casa?

	Yes	No	Don't notice aircraft	Refused	Don't know
a. ¿Lo ha despertado o no lo ha dejado dormir en la noche?	☐1	☐2	☐-6	☐-7	☐-8
b. ¿Lo ha sobresaltado o sorprendido?	☐1	☐2	☐-6	☐-7	☐-8
c. ¿Lo ha asustado?	☐1	☐2	☐-6	☐-7	☐-8

Las siguientes preguntas son acerca de si las aeronaves lo han molestado, perturbado o fastidiado de distintas maneras en los últimos 12 meses cuando ha estado aquí en casa.

[ASK ONLY SPECIFIC TYPES OF DISTURBANCES WHICH WERE IDENTIFIED IN QUESTION 7]

8. Piense en los últimos 12 meses más o menos, cuando está aquí en casa. ¿Lo han molestado, perturbado o fastidiado las aeronaves al...? [READ FIRST ITEM THAT WAS NOTICED]

¿Diría que: extremadamente, bastante, moderadamente, muy poco o nada?

	Extremadamente	Bastante	Moderadamente	Muy poco	Nada	Refused	Don't know
a. Despertarlo o no dejarlo dormir en la noche	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
b. Sobresaltarlo o sorprenderlo	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
c. Asustarlo	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8

Para entender por qué el ruido de aeronaves podría o no podría afectarlo, queremos pedirle que considere su situación aquí en casa, sus observaciones acerca de vuelos de aeronaves aquí y las acciones que las autoridades han tomado.

Sus respuestas nos dan información general para entender su condición de vivienda en esta zona.

9. ¿Cuál de las siguientes opciones describe mejor el lugar donde usted vive?

¿Una casa móvil?	1	(Go to 10)
¿Una casa para una familia que no está adosada a otra casa?......	2	(Go to 10)
¿Una casa para una familia que está adosada a una o más casas?	3	(Go to 10)
¿Un edificio de dos o más apartamentos?..................................	4	
¿Otro tipo de lugar?		
¿Qué tipo de lugar? (Descríbalo) ________________	5	(Go to 10)
REFUSED..	-7	(Go to 10)
DON'T KNOW..	-8	(Go to 10)

9a. Aproximadamente, ¿cuántos apartamentos hay en su edificio?

2 APARTMENTS..	1
3 or 4 APARTMENTS..	2
5 TO 9 APARTMENTS..	3
10 TO 19 APARTMENTS	4
20 TO 49 APARTMENTS	5
50 OR MORE APARTMENTS..	6

10. ¿Es usted el dueño de su vivienda o paga alquiler?

OWN (INCLUDE OWING A MORTGAGE)	1
RENTING..	2
REFUSED..	-7
DON'T KNOW..	-8

11. ¿Cuántos días entresemana, de lunes a viernes, está usted fuera de casa la mayor parte del día, es decir 8 horas o más? ¿Normalmente está fuera los cinco días entresemana o menos días o normalmente no está fuera ningún día entresemana?

[PROBE IF NUMBER OF WEEKDAYS NOT VOLUNTEERED]

¿Cuántos días entresemana normalmente está fuera?]

0 NOT AWAY ON ANY WEEKDAY ...	0
1 DAY	1
2 DAYS..	2
3 DAYS..	3
4 DAYS..	4
5 AWAY ALL 5 WEEKDAYS...............	5
REFUSED..	-7
DON'T KNOW..	-8

12. Piense en esas semanas del año cuando usted pasa la mayor parte del día afuera en su jardín, terraza o balcón. En esa época del año, ¿cuántas horas al día diría que usted pasa afuera en su casa?

|__|__|
HOURS

REFUSED.. -7
DON'T KNOW................................ -8

13. ¿En qué año y mes se mudó a su casa aquí?

|__|__|__|__| |__|__|
YEAR MONTH

REFUSED.. -7
DON'T KNOW................................ -8

14. Desde que usted se mudó aquí, ¿el total de ruido de aeronaves ha aumentado, disminuido o permanecido igual?

INCREASED 1
STAYED ABOUT THE SAME 2
DECREASED 3
NEVER HEARD ANY AIRCRAFT (VOLUNTEERED).... -6
REFUSED.. -7
DON'T KNOW.. -8

15. ¿Cómo cree que será el ruido de aeronaves aquí en los próximos años? ¿Cree que el total de ruido de aeronaves aumentará, disminuirá o permanecerá igual aquí?

INCREASE 1
STAY ABOUT THE SAME 2
DECREASE.. 3
WILL CONTINUE TO NEVER HEAR ANY AIRCRAFT
(VOLUNTEERED)... -6
REFUSED.. -7
DON'T KNOW.. -8

16. Cuando está en casa, ¿ha escuchado alguna vez las aeronaves cuando están en tierra o cuando se mueven en tierra en el aeropuerto?

YES 1
NO 2
REFUSED .... -7
DON'T KNOW................................. -8

17. [ASK IF "HEARD" IN PREVIOUS QUESTION] Piense en los últimos 12 meses más o menos, cuando está aquí en casa. ¿Qué tanto lo molestan, perturban o fastidian las aeronaves cuando están en tierra o se mueven en tierra en el aeropuerto? ¿Extremadamente, bastante, moderadamente, muy poco o nada?

EXTREMELY 1
VERY.. 2
MODERATELY 3
SLIGHTLY 4
NOT AT ALL 5
REFUSED.. 6
DON'T KNOW................................. 7

Ahora queremos preguntarle información general acerca de esta área y del aeropuerto.

18. ¿Qué tanto conocimiento tiene usted acerca del ruido y otros problemas ambientales de la comunidad en la zona de [CITY NAME]? ¿Es usted extremadamente conocedor, bastante conocedor, moderadamente conocedor, poco conocedor o nada conocedor?

EXTREMELY KNOWLEDGEABLE 1
VERY KNOWLEDGEABLE.. 2
MODERATELY KNOWLEDGEABLE 3
SLIGHTLY KNOWLEDGEABLE 4
NOT AT ALL KNOWLEDGEABLE 5
REFUSED.. -7
DON'T KNOW... -8

19. Aproximadamente, ¿cuántos viajes al año hace usted u otros miembros de su hogar desde el aeropuerto [LOCAL AIRPORT]?

Un viaje es un viaje de ida y vuelta e incluye a todos los miembros de la familia que viajan juntos. Si algún miembro de la familia viaja por separado, cuente esos viajes por separado siempre y cuando viajen desde el aeropuerto [LOCAL AIRPORT].

|__|__|
NUMBER OF TIMES

REFUSED.. -7
DON'T KNOW................................. -8

20. ¿Alguien en su hogar trabaja en el aeropuerto [LOCAL AIRPORT] o trabaja para una compañía u organización que hace negocios con el aeropuerto [LOCAL AIRPORT])?

YES 1
NO 2
REFUSED.. -7
DON'T KNOW................................. -8

21. ¿Qué tanto ha aprendido acerca de los problemas por ruido de aeronaves en su comunidad de informes en periódicos, la radio o la televisión? ¿Bastante, algo, muy poco o nada?

A GREAT DEAL	1
SOMEWHAT,	2
A LITTLE	3
NOTHING AT ALL	4
REFUSED	-7
DON'T KNOW	-8

22. ¿Y de alguna fuente más local de información? ¿Qué tanto ha aprendido acerca de los problemas por ruido de aeronaves en su comunidad de un periódico comunitario u otra organización más local, boletín o fuente local en Internet? ¿Bastante, algo, muy poco o nada?

A GREAT DEAL	1
SOMEWHAT,	2
A LITTLE	3
NOTHING AT ALL	4
REFUSED	-7
DON'T KNOW	-8

23. ¿Y sus vecinos más cercanos han dado su opinión acerca del ruido de aeronaves? ¿Han dado a conocer su opinión abiertamente, han dado a conocer muy poco sobre su opinión o han guardado su opinión?

MADE THEIR VIEWS CLEARLY KNOWN	1
REVEALED A LITTLE,	2
KEPT VIEWS TO THEMSELVES	3
REFUSED	-7
DON'T KNOW	-8

24. ¿Hasta dónde usted sabe alguna vez ha habido disputas entre la autoridad aeroportuaria y los residentes de la comunidad acerca del ruido de aeronaves alrededor del aeropuerto (…LOCAL AIRPORT…)?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

25. ¿Hay algún grupo comunitario u otras organizaciones tratando de reducir el ruido de aeronaves?

GROUP IS	1
GROUP IS NOT	2
REFUSED	-7
DON'T KNOW	-8

26. ¿Alguna vez ha tratado usted o alguien de su hogar de hacer algo respecto al ruido de aeronaves como por ejemplo, llamar al aeropuerto, enviar un mensaje, escribir una carta, comunicarse con un funcionario, asistir a una reunión, unirse a un grupo o hacer alguna otra cosa?

YES	1	(GO TO 31a)
NO	2	(GO TO 32)
DON'T NOTICE ANY AIRCRAFT (VOLUNTEERED)	-6	(GO TO 32)
REFUSED	-7	(GO TO 32)
DON'T KNOW	-8	

26a. ¿Se contactó al aeropuerto directamente?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

27. Si hoy día alguien desea presentar una queja acerca del ruido de aeronaves, ¿sabe si hay una manera conveniente de contactar a (…LOCAL AIRPORT…)?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

28. ¿Qué tanto cree que las acciones y opiniones de los residentes pueden influir en las políticas del ruido del aeropuerto (…LOCAL AIRPORT…)? ¿Cree usted que las opiniones de los residentes pueden tener una muy gran influencia en las políticas, pueden tener gran influencia, pueden tener una influencia moderada, pueden tener poca influencia o no tienen ninguna influencia?

VERY GREATLY INFLUENCE	5
GREATLY INFLUENCE	4
MODERATELY INFLUENCE	3
SLIGHTLY INFLUENCE	2
NOT AT ALL INFLUENCE	1
REFUSED	-7
DON'T KNOW	-8

29. ¿Tiene su casa insolación contra el ruido?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

Ahora queremos preguntarle acerca de su opinión sobre los funcionarios locales y directivos del aeropuerto quienes supervisan las operaciones de aeronaves en esta zona.

30. ¿En qué medida cree usted que los funcionarios del aeropuerto [LOCAL AIRPORT] reconocen lo que piensan los residentes de la comunidad respecto al ruido de aeronaves? ¿Cree que los funcionarios reconocen lo que piensan los residentes extremadamente bien, muy bien, moderadamente bien, muy poco o para nada?

EXTREMELY WELL	5
VERY WELL	4
MODERATELY WELL	3
SLIGHTLY	2
NOT AT ALL	1
REFUSED	-7
DON'T KNOW	-8

31. ¿Qué tan bien cree usted que los funcionarios del aeropuerto [LOCAL AIRPORT] mantienen informados a los residentes de la comunidad respecto a la planeación de cambios en el aeropuerto? ¿Cree que los funcionarios mantienen a las comunidades excelentemente informadas, muy bien informadas, moderadamente informadas, poco informadas o nada informadas?

EXTREMELY WELL	5
VERY WELL	4
MODERATELY WELL	3
SLIGHTLY	2
NOT AT ALL	1
REFUSED	-7
DON'T KNOW	-8

32. ¿Qué tan bien cree usted que puede confiar en que los funcionarios del aeropuerto [LOCAL AIRPORT] trabajan de manera justa con la comunidad al seguir procedimientos oficiales acordados y dar información veraz? ¿Cree que puede confiar en los funcionarios del aeropuerto [LOCAL AIRPORT] completamente, considerablemente, moderadamente, poco o nada?

COMPLETELY 1
CONSIDERABLY 2
MODERATELY 3
SLIGHTLY 4
NOT AT ALL 5
REFUSED .... -7
DON'T KNOW .... -8

33. ¿Cuánto cree usted que [INSERT TEXT FROM A-C] podrían reducir el ruido de aeronaves en esta zona. ¿Podrían [INSERT TEXT FROM A-C] reducir el ruido en extremo, bastante, moderadamente, muy poco o nada?

	En extremo	Bastante	Moderadamente	Muy poco	Nada	Refused	Don't know
a. Los funcionarios a cargo del aeropuerto [LOCAL AIRPORT]	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
b. Otros funcionarios del gobierno..............................	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8
c. Los pilotos de los aviones ...	☐5	☐4	☐3	☐2	☐1	☐-7	☐-8

34. Hasta donde usted sabe ¿alguna vez han tomado medidas las autoridades en el aeropuerto [LOCAL AIRPORT] para tratar de reducir o controlar la cantidad de ruido de aeronaves aquí?

YES .... 1 (GO TO 40a)
NO .... 2 }
REFUSED .... -7 }(GO TO 41)
DON'T KNOW .... -8 }

34a. ¿Qué hicieron?

____

____

35. ¿Qué tan importante cree usted que es el aeropuerto [LOCAL AIRPORT] para la zona de [CITY NAME]? ¿Es el aeropuerto [LOCAL AIRPORT] extremadamente importante, muy importante, moderadamente importante, poco importante o nada importante?

EXTREMELY 5
VERY.. 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED... -7
DON'T KNOW................................. -8

Tenemos un par de preguntas más acerca de su opinión y después algunas preguntas generales antes de terminar.

36. ¿Qué tan sensible es usted al ruido en general? ¿Es extremadamente sensible, muy sensible, moderadamente sensible, poco sensible o nada sensible?

EXTREMELY SENSITIVE 5
VERY SENSITIVE 4
MODERATELY SENSITIVE.......... 3
SLIGHTLY SENSITIVE.................. 2
NOT AT ALL SENSITIVE 1
REFUSED... -7
DON'T KNOW................................. -8

37. Para resumir su opinión acerca del ruido de aeronaves en este vecindario por favor tenga en cuenta todo sobre lo que hemos hablado y use una escala de cero a cuatro, en la que cero significa que el ruido no le fastidia en absoluto, cuatro significa que le fastidia en extremo y uno y tres son puntos intermedios.

¿Qué número entre cero y cuatro muestra cuánto le molesta o fastidia el ruido de aeronaves en este vecindario?

|__|

REFUSED... -7
DON'T KNOW................................. -8

Ahora queremos saber dónde vuelan las aeronaves en esta zona.

38. ¿La mayoría de aeronaves que escucha desde su casa van a aterrizar en el aeropuerto, están despegando del aeropuerto, un 50 por ciento está despegando y otro 50 por ciento está aterrizando, están haciendo algo más o no sabe?

LANDING 1
ABOUT HALF AND HALF 2
TAKING OFF 3
DOING SOMETHING ELSE
(PROBE: **¿Qué están haciendo**?) __________________ 4
DON'T NOTICE ANY AIRCRAFT (VOLUNTEERED) .... -6
REFUSED .... -7
DON'T KNOW .... -8

39. Piense en las aeronaves que escucha cuando está en casa. ¿Aproximadamente qué porcentaje vuela directamente sobre su propiedad?

|__|__|__|%

DON'T NOTICE ANY AIRCRAFT
(VOLUNTEERED) .... -6
REFUSED .... -7
DON'T KNOW .... -8

40. Cuando está en casa o en el vecindario, ¿qué tanto le preocupa o asusta que una aeronave se estrelle cerca de donde usted está? ¿Le preocupa en extremo, bastante, moderadamente, muy poco o nada que una aeronave se pueda estrellar?

EXTREMELY 5
VERY 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED .... -7
DON'T KNOW .... -8

41. Cuando está en casa, ¿qué tanto le preocupa que un accidente de una aeronave lo haga daño a usted o a su propiedad? ¿Le preocupa en extremo, bastante, moderadamente, muy poco o nada que una aeronave le haga daño a usted o a su propiedad?

EXTREMELY 5
VERY.. 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED... -7
DON'T KNOW................................. -8

Ahora tenga en cuenta lo que usted piensa acerca de posibles accidentes de tránsito o un posible accidente de un tren de pasajeros o carga en esta zona.

42. Cuando está en casa o en el vecindario, ¿qué tanto le preocupa o asusta que haya un accidente de tránsito cerca de donde usted está? ¿Le preocupa en extremo, bastante, moderadamente, muy poco o nada que haya un accidente de tránsito?

EXTREMELY 5
VERY.. 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED... -7
DON'T KNOW................................. -8

43. Cuando está en casa o en el vecindario, ¿qué tanto le preocupa o asusta que haya un accidente de un tren de pasajeros o carga cerca de donde usted está? ¿Le preocupa en extremo, bastante, moderadamente, muy poco o nada que haya un accidente de un tren?

EXTREMELY 5
VERY.. 4
MODERATELY 3
SLIGHTLY 2
NOT AT ALL 1
REFUSED... -7
DON'T KNOW................................. -8

44. ¿Qué tipo de tráfico cree usted es el más peligroso para usted o para su propiedad cuando usted está aquí en casa: tráfico vial, trenes o aeronaves?

ROAD TRAFFIC	1
RAILWAY TRAINS	2
AIRCRAFT	3
NONE ARE DANGEROUS	5
REFUSED	-7
DON'T KNOW (INCLUDES NOT ABLE TO CHOOSE THE MOST DANGEROUS)	-8

45. ¿En qué mes y año nació usted?

|__|__| / |__|__|__|__
MONTH YEAR

REFUSED	-7
DON'T KNOW	-8

46. ¿Cuál es el grado más alto de escuela que ha completado o el título más alto que ha recibido?

LESS THAN 1ST GRADE 01
1ST, 2ND, 3RD OR 4TH GRADE 02
5TH OR 6TH GRADE 03
7TH OR 8TH GRADE 04
9TH GRADE 05
10TH GRADE 06
11TH GRADE 07
12TH GRADE, NO DIPLOMA 08
HIGH SCHOOL GRADUATE – HIGH SCHOOL DIPLOMA OR EQUIVALENT (FOR EXAMPLE: GED) 09
SOME COLLEGE BUT NO DEGREE................................ 10
DIPLOMA OR CERTIFICATE FROM A VOCATIONAL, TECHNICAL, TRADE OR BUSINESS SCHOOL BEYOND THE HIGH SCHOOL LEVEL 11
ASSOCIATE DEGREE IN COLLEGE – OCCUPATIONAL/VOCATIONAL PROGRAM 12
ASSOCIATE DEGREE IN COLLEGE – ACADEMIC PROGRAM.. 13
BACHELORS DEGREE (FOR EXAMPLE: BA, AB, BS) 14
MASTER'S DEGREE (FOR EXAMPLE: MA, MS, MENG, MED, MSW, MBA) 15
PROFESSIONAL SCHOOL DEGREE (FOR EXAMPLE: MD, DDS, DVM, LLB, JD) 16
DOCTORATE DEGREE (FOR EXAMPLE: PHD, EDD) .. 17
REFUSED...-97
DON'T KNOW...-98

47. [IF GENDER COLLECTED IN A5.1 OR A5.2 FROM THE SELECTED RESPONDENT (SELECTED RESPONDENT WAS SCREENER RESPONDENT) THEN SKIP 45 AND CONTINUE WITH 46, OTHERWISE ASK IF NOT SURE. OTHERWISE CODE AND CONTINUE WITH 46.]

¿Es usted de sexo masculino o femenino?

MALE 1
FEMALE... 2
REFUSED .... -7
DON'T KNOW................................. -8

48. ¿Es usted hispano o latino?

YES	1
NO	2
REFUSED	-7
DON'T KNOW	-8

49. ¿De qué raza o razas se considera usted? [SELECT ALL]

WHITE	1
BLACK OR AFRICAN AMERICAN	2
AMERICAN INDIAN OR ALASKA NATIVE	3
ASIAN	4
NATIVE HAWAIIAN OR OTHER PACIFIC ISLANDER	5
REFUSED	-7
DON'T KNOW	-8

50. ¿Cuál es el ingreso total aproximado de todos en este hogar, incluyendo cosas como pagas, salarios, intereses, pensiones o pagos del gobierno? ¿Diría que [READ RESPONSES]:

[GO THROUGH LIST UNTIL RESPONDENT GIVES ANSWER]

es menos de 25,000 dólares al año, de 25,000 a 50,000 dólares al año, de 50,000 a 100,000 dólares al año, de 100,000 a 200,000 dólares al año o más de 200,000 dólares al año? [IF GIVE A BORDERLINE. PROBE]: "¿Diría que probablemente fue un poco más o un poco menos que [BORDERLINE VALUE]?]

LESS THAN 25,000	1
25,000 – 50,000	2
50,000 – 100,000	3
100,000 – 200,000	4
Over 200,000	5
REFUSED	-7
DON'T KNOW	-8

51. ¿Tiene algún otro comentario u opinión o tiene alguna pregunta para mí?

____

____

____

Esas son todas las preguntas que tengo. Muchas gracias por su participación en este importante estudio.

B.2 Telephone Survey Materials

B.2.1 Match Phone Advance Letter

B.2.1.1 English Version

Neighborhood Environment Survey

Sponsored by U.S. Department of Transportation

«City» Resident
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Dear «City» Resident:

Someone in your household recently completed the Neighborhood Environment Survey. Thank-you for participating in this important study. We would like to ask some follow-up questions in a telephone interview. As a reminder, this study is sponsored by the United States Department of Transportation, a branch of the Federal Government. Since 1967, the United States Department of Transportation has been responsible for ensuring a fast, safe, efficient, accessible and convenient transportation system. We consider neighborhood environmental quality when planning, developing and revising transportation-related policies. The Neighborhood Environment Survey results will be used to update policies that affect the environment in American neighborhoods.

We have asked Westat, a statistical social science firm to obtain your views. Westat will call in the next few days to conduct a brief interview with an adult in your household. Upon completion of the telephone interview we will provide that person with $10 as a token of our appreciation.

Participation in this study is voluntary. However, your household's participation will help inform us about your neighborhood and the views of people who live in neighborhoods like yours. The information you provide will be maintained confidential to the extent allowed by law. If you have any questions about this study please call Westat toll-free at 1-855-210-4396.

Thank you in advance for your cooperation.

Sincerely,

Barbara McCann

Barbara McCann
Director, Office of Safety, Energy, and Environment

B.2.1.2 Spanish Version

Encuesta del medio ambiente de los vecindarios

Patrocinada por el Departamento de Transporte de Estados Unidos

Habitante de «City»
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Estimado(a) habitante de «City»:

Una persona de su hogar contestó hace poco la Encuesta del medio ambiente de los vecindarios. Muchas gracias por su participación en este importante estudio. Quisiéramos hacerle unas preguntas de seguimiento en una entrevista telefónica. Queremos recordarle que el estudio lo patrocina el Departamento de Transporte de Estados Unidos, una rama del gobierno federal. Desde 1967, el Departamento de Transporte de Estados Unidos ha sido el responsable de asegurarse de que el sistema de transporte sea rápido, seguro, eficiente, accesible y conveniente. Nosotros tenemos en cuenta la calidad medioambiental del vecindario cuando planificamos, desarrollamos y revisamos políticas relacionadas con el transporte. Los resultados de la Encuesta del medio ambiente de los vecindarios se usarán para actualizar políticas que afectan al medio ambiente en los vecindarios de Estados Unidos.

Le hemos pedido a Westat, una compañía de estudios de ciencias sociales, que obtenga sus comentarios. Westat llamará en los siguientes días para realizar una breve entrevista con un adulto de su hogar. Después de completar la entrevista le daremos a esta persona 10 dólares como una muestra de nuestro agradecimiento.

La participación en este estudio es voluntaria. Sin embargo, la participación de su hogar nos ayudará a informarnos acerca de su vecindario y de las opiniones de las personas que viven en vecindarios como el suyo. La información que usted nos dé se mantendrá de manera confidencial hasta donde lo permite la ley. Si usted tiene alguna pregunta acerca de este estudio llame a la línea directa y gratuita de Westat al 1-855-210-4396.

Le agradecemos de antemano por su colaboración.

Atentamente,

Barbara McCann
Directora, oficina de seguridad, energía y medio ambiente

B.2.2 Invalid Phone Match Letter

B.2.2.1 English Version

Neighborhood Environment Survey

Sponsored by U.S. Department of Transportation

«City» Resident
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Dear «City» Resident:

Recently you received a letter informing you that you would be receiving a call to take part in an important environmental study for the United States Department of Transportation. Unfortunately we did not have a correct phone number to reach you. Your participation in this study is important, because your views will help the Department of Transportation update transportation-related policies that affect people in neighborhoods like yours.

We ask that you return the enclosed brief questionnaire to correct the phone number we have for your household. After you return this questionnaire, an interviewer will call to conduct an interview with an adult in your household. Upon completion of the interview we will provide that person with $10 as a token of our appreciation.

Participation in this study is voluntary. However, your household's participation will help inform us about your neighborhood and the views of people in neighborhoods like yours. We have asked Westat, a statistical social science firm to obtain your views. The information you provide will be maintained confidential to the extent allowed by law. If you have any questions about this study please call Westat toll-free at 1-855-210-4396.

Thank you in advance for your cooperation.

Sincerely,

Barbara McCann
Director, Office of Safety, Energy, and Environment

B.2.2.2 Spanish Version

Encuesta del medio ambiente de los vecindarios

Patrocinada por el Departamento de Transporte de Estados Unidos

Habitante de «City»
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Estimado(a) habitante de «City»:

Hace poco usted recibió una carta informándole que iba a recibir una llamada para participar en un importante estudio medioambiental para el Departamento de Transporte de Estados Unidos. Lamentablemente no tenemos un número de teléfono correcto para comunicarnos con usted. Su participación en este estudio es importante, ya que sus opiniones ayudarán al Departamento de Transporte a actualizar políticas relacionadas con el transporte que afectan a personas en vecindarios como el suyo.

Le pedimos que nos devuelva el breve cuestionario adjunto para corregir el número de teléfono que tenemos de su hogar. Luego de devolver este cuestionario, un entrevistador lo llamará para llevar a cabo una entrevista con un adulto de su hogar. Después de completar la entrevista le daremos a esta persona 10 dólares como una muestra de nuestro agradecimiento.

La participación en este estudio es voluntaria. Sin embargo, la participación de su hogar nos ayudará a informarnos acerca de su vecindario y de las opiniones de las personas en vecindarios como el suyo. Le hemos pedido a Westat, una compañía de estudios de ciencias sociales, que obtenga sus comentarios. La información que usted nos dé se mantendrá de manera confidencial hasta donde lo permite la ley. Si usted tiene alguna pregunta acerca de este estudio llame a la línea directa y gratuita de Westat al 1-855-210-4396.

Le agradecemos de antemano por su colaboración.

Atentamente,

Barbara McCann
Directora, oficina de seguridad, energía y medio ambiente

B.2.3 Phone Request

B.2.3.1 English Version

This survey will be conducted by telephone. In order to get in touch with you, we need to collect some information on your household.

Please have this filled out by an adult household member living at this address.

Please use a blue or black pen if available.

1. **Including yourself, how many people age 18 or older live in this household? (Please include any persons who are temporarily away at this time, for example, anyone temporarily hospitalized or on a vacation or business trip.)**

   ☐☐

2. **What is the best phone number to use to contact you? (This phone number will only be used for the purpose of this research study.)**

   (☐☐☐) ☐☐☐ - ☐☐☐☐

Thank you. Please return this form in the postage paid envelope provided or mail it to:

Neighborhood Environment Survey
Westat
1600 Research Blvd., Room RC B16
Rockville, MD 20850

Toll-free number for questions: 1-855-210-4396

B.2.3.2 Spanish Version

Esta encuesta se hará por teléfono. Para poder comunicarnos con usted debemos reunir una información acerca de su hogar.

Un adulto que viva en el hogar debe contestar esta información.

Por favor use un bolígrafo de tinta negra o azul.

1. **Incluyéndose a usted, ¿cuántas personas mayores de 18 años viven en esta casa? (Incluya a las personas que están temporalmente fuera de casa, por ejemplo alguien que está hospitalizado temporalmente, de vacaciones o en un viaje de negocios.)**

   ☐☐

2. **¿Cuál es el mejor número de teléfono para comunicarse con usted? (Este número solo se usará para fines de este estudio de investigación.)**

   (☐☐☐) ☐☐☐ - ☐☐☐☐

Muchas gracias. Por favor envíe este formulario en el sobre adjunto cuyos gastos de envío ya han sido pagados o envíelo por correo a:

Neighborhood Environment Survey
Westat
1600 Research Blvd., Room RC B16
Rockville, MD 20850

Línea directa y gratuita para preguntas: 1-855-210-4396

B.2.4 Phone Request Cover Letter

B.2.4.1 English Version

Neighborhood Environment Survey

Sponsored by U.S. Department of Transportation

«City» Resident
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Dear «City» Resident:

Someone in your household recently completed the Neighborhood Environment Survey. Thank-you for participating in this important study. We would like to ask some follow-up questions in a telephone interview. As a reminder, this study is sponsored by the United States Department of Transportation, a branch of the Federal Government. Since 1967, the United States Department of Transportation has been responsible for ensuring a fast, safe, efficient, accessible and convenient transportation system. We consider neighborhood environmental quality when planning, developing and revising transportation-related policies. The Neighborhood Environment Survey results will be used to update policies that affect the environment in American neighborhoods.

We have asked Westat, a statistical social science firm to obtain your views. We ask that you return this brief questionnaire in the next two weeks. After you return the enclosed questionnaire, Westat will call to conduct a brief interview with an adult in your household. Upon completion of the telephone interview we will provide that person with $10 as a token of our appreciation.

Participation in this study is voluntary. However, your household's participation will help inform us about your neighborhood and the views of people who live in neighborhoods like yours. The information you provide will be maintained confidential to the extent allowed by law. If you have any questions about this study please call Westat toll-free at 1-855-210-4396.

Thank you in advance for your cooperation.

Sincerely,

Barbara McCann

Barbara McCann
Director, Office of Safety, Energy, and Environment

B.2.4.2 Spanish Version

Encuesta del medio ambiente de los vecindarios

Patrocinada por el Departamento de Transporte de Estados Unidos

Habitante de «City»
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Estimado(a) habitante de «City»:

Una persona de su hogar contestó hace poco la Encuesta del medio ambiente de los vecindarios. Gracias por participar en este importante estudio. Quisiéramos hacerle unas preguntas de seguimiento mediante una entrevista telefónica. Queremos recordarle que el estudio lo patrocina el Departamento de Transporte de Estados Unidos, una rama del gobierno federal. Desde 1967, el Departamento de Transporte de Estados Unidos ha sido el responsable de asegurarse de que el sistema de transporte sea rápido, seguro, eficiente, accesible y conveniente. Nosotros tenemos en cuenta la calidad medioambiental del vecindario cuando planificamos, desarrollamos y revisamos políticas relacionadas con el transporte. Los resultados de la Encuesta del medio ambiente de los vecindarios se usarán para actualizar políticas que afectan al medio ambiente en los vecindarios de Estados Unidos.

Le hemos pedido a Westat, una compañía de estudios de ciencias sociales, que obtenga sus comentarios. Le pedimos que nos devuelva este breve cuestionario en las siguientes dos semanas. Luego de devolver este cuestionario, un entrevistador lo llamará para llevar a cabo una entrevista con un adulto de su hogar. Después de completar la entrevista le daremos a esta persona 10 dólares como una muestra de nuestro agradecimiento.

La participación en este estudio es voluntaria. Sin embargo, la participación de su hogar nos ayudará a informarnos acerca de su vecindario y de las opiniones de las personas que viven en vecindarios como el suyo. La información que usted nos dé se mantendrá de manera confidencial hasta donde lo permite la ley. Si usted tiene alguna pregunta acerca de este estudio llame a la línea directa y gratuita de Westat al 1-855-210-4396.

Le agradecemos de antemano por su colaboración.

Atentamente,

Barbara McCann
Directora, oficina de seguridad, energía y medio ambiente

B.2.5 Phone Request Postcard

B.2.5.1 English Version

A few weeks ago you received a request asking you to provide a phone number we can use to reach this household. The phone number you provide will **only** be used for the Neighborhood Environment Survey, a survey sponsored by the United States Department of Transportation. If you have already completed and returned the request for your phone number, we are very grateful and thank you. If you have not, we encourage you to do so.

The phone number you provide will not be used for any other purpose and will not be shared with anyone. Once we receive your phone number a member of our interviewing staff will contact your household to complete this brief survey.

This is an important survey that can help provide information that will be used to develop and revise transportation-related policies that affect neighborhoods like yours. We are very grateful for your participation.

{RETURN ADDRESS/LOGO}

{CITY} RESIDENT
{ADDRESS LINE 1}
{ADDRESS LINE 2}
{CITY}, {STATE} {ZIP}

B.2.5.2 Spanish Version

Hace unas semana usted recibió una solicitud pidiéndole que de un número de teléfono para poder comunicarnos con este hogar. El número de teléfono que dé únicamente su usará para la Encuesta del medio ambiente de los vecindarios, una encuesta patrocinada por el Departamento de Transporte de Estados Unidos. Si usted ya ha contestado y enviado la solicitud de su número de teléfono, se lo agradecemos mucho. Si usted todavía no lo ha hecho, lo animamos a que lo haga.

El número de teléfono que nos dé no se usará para otros fines y no se compartirá con ninguna persona. Una vez que recibamos su número de teléfono, un miembro de nuestro equipo de entrevistadores se comunicará con su hogar para completar una breve encuesta.

Se trata de una importante encuesta que puede ayudar a brindar información que se usará para desarrollar y revisar políticas relacionadas con el transporte que afectan a vecindarios como el suyo. Le agradecemos mucho su participación.

{RETURN ADDRESS/LOGO}

HABITANTE DE {CITY}
{ADDRESS LINE 1}
{ADDRESS LINE 2}
{CITY}, {STATE} {ZIP}

B.2.6 Phone Request NR Follow-up Letter

B.2.6.1 English Version

Neighborhood Environment Survey

Sponsored by U.S. Department of Transportation

«City» Resident
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Dear «City» Resident:

Recently you received a letter inviting you to take part in an important environmental study for the United States Department of Transportation. Unfortunately we have not yet received a reply from your household. If you have already sent in the survey, thank-you very much for your help. If you haven't yet had time to respond, we encourage you to do so. Your participation in this study is important because your views will help the Department of Transportation update transportation-related policies that affect people in neighborhoods like yours.

For your convenience we've enclosed a replacement to the original questionnaire that was sent to your household requesting your phone number. That number will only be used to conduct a brief interview with an adult in your household. We have asked Westat, a statistical social science firm to conduct these interviews. Upon completion of the telephone interview we will provide that person with $10 as a token of our appreciation.

Participation in the study is voluntary. However, your household's participation will help inform us about your neighborhood and the views of people who live in neighborhoods like yours. The information you provide will be maintained confidential to the extent allowed by law. If you have any questions about this study please call Westat toll-free at 1-855-210-4396.

Thank you in advance for your cooperation.

Sincerely,

Barbara McCann
Director, Office of Safety, Energy, and Environment

B.2.6.2 Spanish Version

Encuesta del medio ambiente de los vecindarios

Patrocinada por el Departamento de Transporte de Estados Unidos

Habitante de «City»
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Estimado(a) habitante de «City»:

Hace poco usted recibió una carta informándole que iba a recibir una llamada para participar en un importante estudio medioambiental para el Departamento de Transporte de Estados Unidos. Lamentablemente todavía no hemos recibido la respuesta de su hogar. Si usted ya ha enviado la encuesta, le agradecemos mucho su colaboración. Si usted todavía no ha tenido tiempo para contestarla, lo animamos a que lo haga. Su participación en este estudio es importante, ya que sus opiniones ayudarán al Departamento de Transporte a actualizar políticas relacionadas con el transporte que afectan a personas en vecindarios como el suyo.

Para su comodidad, hemos incluido un reemplazo del cuestionario original que enviaron a su hogar solicitando su número de teléfono. Ese número se usará únicamente para llevar a cabo una breve entrevista con un adulto de su hogar. Le hemos pedido a Westat, una compañía de estudios de ciencias sociales, que realice estas entrevistas. Después de completar la entrevista le daremos a esta persona 10 dólares como una muestra de nuestro agradecimiento.

La participación en el estudio es voluntaria. Sin embargo, la participación de su hogar nos ayudará a informarnos acerca de su vecindario y de las opiniones de las personas que viven en vecindarios como el suyo. La información que usted nos dé se mantendrá de manera confidencial hasta donde lo permite la ley. Si usted tiene alguna pregunta acerca de este estudio llame a la línea directa y gratuita de Westat al 1-855-210-4396.

Le agradecemos de antemano por su colaboración.

Atentamente,

Barbara McCann

Barbara McCann
Directora, oficina de seguridad, energía y medio ambiente

B.2.7 Phone Thank You Letter

B.2.7.1 English Version

Neighborhood Environment Survey

Sponsored by U.S. Department of Transportation

«Name»
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Dear «Name»:

Thank you for completing the Neighborhood Environment Study phone survey. We have enclosed $10 as a sign of our appreciation for your participation. The Neighborhood Environment Survey results will be used to update policies that affect the environment in American neighborhoods.

If you have any questions about this study please call Westat toll-free at 1-855-210-4396.

Thank you for your cooperation.

Sincerely,

Barbara McCann
Director, Office of Safety, Energy, and Environment

B.2.7.2 Spanish Version

Encuesta del medio ambiente de los vecindarios

Patrocinada por el Departamento de Transporte de Estados Unidos

«Name»
«Address1»
«Address2»
«City», «State» «Zip»-«Zip4»

Estimado(a) «Name»:

Gracias por completar la encuesta telefónica del Estudio del medio ambiente de los vecindarios. Hemos adjuntado 10 dólares como muestra de nuestro agradecimiento por su participación. Los resultados de la Encuesta del medio ambiente de los vecindarios se usarán para actualizar políticas que afectan al medio ambiente en los vecindarios de Estados Unidos.

Si usted tiene alguna pregunta acerca de este estudio llame a la línea directa y gratuita de Westat al 1-855-210-4396.

Le agradecemos su colaboración.

Atentamente,

Barbara McCann

Barbara McCann
Directora, Oficina de seguridad, energía y medio ambiente

B.3 Variable Names Assigned to Survey Questions

Q#	Variable	Label	Question Text
1a	PALNseTraffic	Phone AL: Noise from Traffic	Thinking about the last 12 months or so, when you are here at home, how much does noise from cars, trucks or other road traffic bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1b	PALSmellTraffic	Phone AL: Smells Dirt from Traffic	Thinking about the last 12 months or so, when you are here at home, how much does smells or dirt from road traffic bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1c	PALSmellOther	Phone AL: Smoke Gas Bad Smells Else	Thinking about the last 12 months or so, when you are here at home, how much does smoke, gas or bad smells from anything else bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1d	PALLitter	Phone AL: Litter Poorly Kept Housing	Thinking about the last 12 months or so, when you are here at home, how much does litter or poorly kept up housing bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1e	PALAC	Phone AL: Noise Aircraft	Thinking about the last 12 months or so, when you are here at home, how much does noise from aircraft bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1f	PALNeighbor	Phone AL: Neighbors Noise	Thinking about the last 12 months or so, when you are here at home, how much does your neighbors' noise or other activities bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1g	POtherNse	Phone Other Annoying Noise	Are there any other noises you hear when you are here at home?
1gOS	PALOtherNse	Phone AL: Other Noise	Thinking about the last 12 months or so, when you are here at home, how much does <OTHER NOISE> bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1h	PALBusiness	Phone AL: Undesirable Business Property	Thinking about the last 12 months or so, when you are here at home, how much does undesirable business, institutional or industrial property bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1i	PALNoParks	Phone AL: Lack of Parks	Thinking about the last 12 months or so, when you are here at home, how much does a lack of parks or green spaces bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1j	PALPubTransit	Phone AL: Inadequate Public Transportation	Thinking about the last 12 months or so, when you are here at home, how much does inadequate public transportation bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?

Q#	Variable	Label	Question Text
1k	PALCrime	Phone AL: Crime	Thinking about the last 12 months or so, when you are here at home, how much does the amount of neighborhood crime bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1l	PALCitySvces	Phone AL: Poor City County Services	Thinking about the last 12 months or so, when you are here at home, how much does poor city or county services bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
1m	POthProb	Phone Other Annoying Problems	Are there any other problems that you notice when you are here at home?
1mOS	PALOthProb	Phone AL: Other Problems	Thinking about the last 12 months or so, when you are here at home, how much does <OTHER PROBLEM> bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
2	PRateNeighborhood	Phone Neighborhood Rating	Now considering how you feel about everything in your neighborhood, how would you rate your neighborhood as a place to live on a scale from 0 to 10 where 0 is worst and 10 is best?
3	PGenNseRt	Phone General Noise Rating	Now please rate noise on a 0 to 10 opinion scale for how much the noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose 0; if you are extremely annoyed choose 10; if you are somewhere in between, choose a number between 0 and 10. First about noise in general. Thinking about the last 12 months or so, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by the noise in general when you are here at home?
4	PGenNseRtTraffic	Phone General Noise from Traffic Rating	Thinking about the last 12 months or so, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by the noise from cars or trucks or other road traffic?
5	PGenNseRtAC	Phone General Noise from Aircraft Rating	Thinking about the last 12 months or so, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by the noise from aircraft?
6	PHearAC	Phone Ever Heard The Sound from Aircraft At Home	Have you ever heard the sound from an aircraft when you were here at home?
7a	PACWake	Phone Ever Waked up from Aircraft	Has an aircraft ever waked you up or kept you awake at night when you are at home?
7b	PACStartle	Phone Ever Startled Surprised from Aircraft	Has an aircraft ever startled or surprised you when you are at home?
7c	PACFrighten	Phone Ever Frightened from Aircraft	Has an aircraft ever frightened you when you are at home?
8a	PALACWake	Phone AL: Waking You up at Night	Thinking about the last 12 months or so, when you are at home, have the aircraft bothered, disturbed or annoyed you by waking you up or keeping you awake at night? Would you say extremely, very, moderately slightly, or not at all?

Q#	Variable	Label	Question Text
8b	PALACStartle	Phone AL: Startling Surprising You	Thinking about the last 12 months or so, when you are at home, have the aircraft bothered, disturbed or annoyed you by startling or surprising you? Would you say extremely, very, moderately slightly, or not at all?
8c	PALACFrighten	Phone AL: Frightening You	Thinking about the last 12 months or so, when you are at home, have the aircraft bothered, disturbed or annoyed you by frightening you? Would you say extremely, very, moderately slightly, or not at all?
9	PBldgTp	Phone Describe Building Where Live	To understand why aircraft noise may or may not affect you, we ask you to consider your situation here at home, your observations about aircraft flights here and the actions authorities have been taking. Your next answers provide background for understanding your living situation in this area. Which of the following best describes the building where you live?
9a	PNumApts	Phone Apartments in Building	Approximately, how many apartments are there in your building?
10	POwnRent	Phone Own or Rent Home	Do you own your home or are you renting?
11	PWkDayNotHome	Phone Weekdays Away from Home	How many of the five weekdays from Monday through Friday are you usually out away from home most of the day, that is 8 hours or more? Are you usually away, on all five weekdays, or fewer weekdays, or are you usually not away on any weekday? [PROBE IF NUMBER OF WEEKDAYS NOT VOLUNTEERED: How many weekdays are you usually away?]
12	PHrOutside	Phone Hours Week Out-of-Doors	Think about those weeks in the year when you spend the most time out-of-doors in your yard or on your porch, deck or balcony. At that time of year, how many hours a week would you say you are out-of-doors at home?
13MTH	PMonthMovedToHome	Phone Month Moved to Home	In what year and month did you move to your home here?
13YR	PYearMovedToHome	Phone Year Moved to Home	In what year and month did you move to your home here?
14	PACNseChg	Phone Aircraft Noise Increase Decrease Same	Since you moved here, has the total amount of aircraft noise increased, decreased or stayed about the same?
15	PACNseFuture	Phone Aircraft Noise in Next Few Years	What do you think aircraft noise will be like here in the next few years: Do you think the total amount of aircraft noise will increase, decrease or stay about the same here?
16	PHrdACGrd	Phone Heard Aircraft on the Ground	When you are at home, have you ever heard aircraft sitting on the ground or moving around on the ground on the airport property?
17	PALACGrd	Phone AL: Aircraft on the Ground	Thinking about the last 12 months or so, when you are at home, how much have the aircraft sitting on the ground or moving around on the ground on the airport property bothered, disturbed or annoyed you: extremely, very, moderately, slightly, or not at all?

Q#	Variable	Label	Question Text
18	PKnowCommIssues	Phone Knowledgeable About Community Issues	Next we ask you to provide some background about this area and the airport. How knowledgeable are you about noise and other community environmental issues in the <BASECITY> area: Are you extremely knowledgeable, very knowledgeable, moderately knowledgeable, slightly knowledgeable, or not at all knowledgeable?
19	PAPTripsYr	Phone How Many Trips from Airport	About how many trips a year do you and other members of your household make from the <AIRPORT>? One trip is considered as round-trip travel and includes all family members traveling together. If any family members travel separately, please count those as separate trips as long as they use <AIRPORT>.
20	PWrkAtAP	Phone Work at Airport	Do you or anyone else in your household work at <AIRPORT> or work for a company or organization that does business with <AIRPORT>?
21	PLrnMedia	Phone Learn Aircraft Noise Issues: Media	How much have you learned about your community's aircraft noise issues from media reports in the newspaper or on radio or TV: a great deal, somewhat, a little or nothing at all?
22	PLrnLocalInfo	Phone Learn Aircraft Noise Issues: Local Info	How about a more local information source? How much have you learned about your community's aircraft noise issues from a community newspaper or other more local organization, newsletter or local internet source: a great deal, somewhat, a little or nothing at all?
23	PNbrsViewACNse	Phone Neighbors Views Known On Aircraft Noise	How about your closest neighbors making their views known about aircraft noise: Have they clearly made their views known, have they revealed only a little about their views, or have they kept their views to themselves?
24	PAuthDisputes	Phone Disputes between Airport and Residents	As far as you know, have there ever been disputes between airport authorities and community residents about aircraft noise around <AIRPORT>?
25	PCommGroup	Phone Community Groups Reduce Aircraft Noise	Are any community groups or other organizations trying to reduce aircraft noise or don't you know?
26	PHHActOnACNse	Phone HH Done Anything about Aircraft Noise	Have you or anyone in your household ever tried to get something done about aircraft noise such as telephoning the airport, sending a message, writing a letter, contacting an official, going to a meeting, joining a group or doing something else?
26a	PContactAP	Phone HH Contact Airport Directly	Was the airport contacted directly?
27	PWayToComplain	Phone Convenient Way to Make Complaint	If someone wants to make a complaint about aircraft noise these days, do you know if there is a convenient way to contact <AIRPORT>?
28	PResInfluenAP	Phone Can Residents Action Influence Airport	How much do you think that residents' actions and views can influence <AIRPORT> noise policy? Do you think that residents' views can very greatly influence policy, greatly influence policy, moderately influence, slightly influence, or not at all influence policy?
29	PHomeInsulate	Phone Has Home Been Sound Insulated	Has your home been sound insulated?

Q#	Variable	Label	Question Text
30	PAPRcgnzRes	Phone Airport Recognize Residents Feelings	Next we ask for your views about the local officials and managers at the airport who oversee aircraft operations in this area. To what extent do you think <AIRPORT> officials recognize the community residents' feelings about aircraft noise? Do you think the officials recognize the residents' feelings extremely well, very well, moderately well, slightly, or not at all?
31	PAPInformRes	Phone Airport Keeps Residents Informed	How fully do you feel the <AIRPORT> officials keep community residents informed about the planning for airport changes? Do you think the officials keep communities extremely well informed, very well informed, moderately well informed, slightly informed, or not at all informed?
32	PAPTrusted	Phone Can Trust Airport to Work Fairly	How completely do you feel you can trust the <AIRPORT> officials to work fairly with the community by following official, agreed-upon procedures and providing accurate information? Do you feel you can rely upon the <AIRPORT> officials completely, considerably, moderately, slightly or not at all?
33a	PRedACNseAPOff	Phone Could Officials of Airport Reduce Noise	How much do you think the officials who run <AIRPORT> could reduce the aircraft noise around here: Could the officials who run <AIRPORT> reduce the noise very greatly, greatly, moderately, slightly or not at all?
33b	PRedACNseAPOthGov	Phone Could Other Gov Officials Reduce Noise	How much do you think other government officials could reduce the aircraft noise around here: Could other government officials reduce the noise very greatly, greatly, moderately, slightly or not at all?
33c	PRedACNseAPilots	Phone Could Pilots Reduce Noise	How much do you think the pilots flying the planes could reduce the aircraft noise around here: Could the pilots flying the planes reduce the noise very greatly, greatly, moderately, slightly or not at all?
34	PAPRedACNse	Phone Authorities Taken Steps Reduce Noise	As far as you know, have the authorities at <AIRPORT> ever taken steps to try to reduce or control the amount of aircraft noise here?
35	PAPImportant	Phone Importance of Airport for City	How important do you think that <AIRPORT> is for the <BASECITY> area: Is <AIRPORT> extremely important, very important, moderately important, slightly important or not at all important?
36	PRespSenstve	Phone Sensitive to Noise	We just have a couple more opinion questions and then a little background information before we are finished. How sensitive are you generally to noise of all kinds: extremely sensitive, very sensitive, moderately sensitive, slightly sensitive, or not at all sensitive?
37	PRespBothrdACNse	Phone Bothered by Aircraft Noise	To summarize your opinion about aircraft noise in this neighborhood, please consider all we have discussed and use a zero to four opinion thermometer where zero is not at all annoyed, four is extremely annoyed and one to three are in between. What number from zero to four shows how much you are bothered or annoyed by aircraft noise in this neighborhood?

Q#	Variable	Label	Question Text
38	PACTakeOffLand	Phone Aircraft Landing Taking off Both	Next we need to learn where the aircraft are flying in this area. Are most of the aircraft that you notice from your home coming down for a landing at the airport, taking off from the airport, are about half landing and about half taking off, are they doing something else, or don't you know?
39	PACPctFlyOverH	Phone Percent Aircraft Fly Directly Over	Thinking about all the aircraft you notice when you are at home, about what percent fly directly over your property?
40	PCNACCrash	Phone Concern: Aircraft Crash Nearby	When you are at home or around the neighborhood, how fearful or concerned are you that an aircraft might crash nearby: Are you extremely, very, moderately, slightly, or not at all concerned that an aircraft might crash?
41	PCNACHurtYou	Phone Concern: Aircraft Hurt You or Property	When you are at home, how concerned are you that an aircraft crash might actually hurt you or your own property: Are you extremely, very, moderately, slightly, or not at all concerned that an aircraft might hurt you or your property?
42	PCNTrfAccdnt	Phone Concern: Traffic Accidents Nearby	Now consider your feelings about possible car or truck road traffic accidents or possible passenger or freight train railway derailments or crashes in this area. When you are at home or around the neighborhood, how fearful or concerned are you that there might be car or truck road traffic accidents nearby: Are you extremely, moderately, slightly, or not at all concerned that there might be a road traffic crash?
43	PCNTrnCrash	Phone Concern: Train Crash Nearby	When you are at home or around the neighborhood, how fearful or concerned are you that there might be a passenger train or freight train derailment or crash nearby? Are you extremely, moderately, slightly, or not at all concerned that there might be a train crash?
44	PDangerTrf	Phone Most Danger: Traffic Trains Aircraft	Which type of traffic, if any, do you feel is the most dangerous for you or your property when you are here at home: road traffic, railway trains or aircraft?
45MTH	PMonthBorn	Phone Month Born	In what month and year were you born?
45YR	PYearBorn	Phone Year Born	In what month and year were you born?
46	PHighestEd	Phone Highest Level of School	What is the highest level of school you have completed or the highest degree you have received?
47	PGender	Phone Gender	[ASKED IF NOT SURE.] Are you male or female?
48	PHispanic	Phone Spanish Hispanic Latino	Are you Spanish, Hispanic, or Latino?
49	PRaceEthnicity	Phone Respondent Race/Ethnicity	What race or races do you consider yourself to be? [SELECT ALL THAT APPLY.]
50	PHHIncome	Phone Total Income Household	What is the approximate total income from everyone in this household including such things as wages, salary, interest, pensions, or government payments? Would you say [READ RESPONSES]: [IF THEY REFUSE TO ANSWER, PROBE:] Is it less than 25 thousand dollars a year? From 25 to 50 thousand? 50 to 100 thousand? 100 to 200 thousand? Or over 200 thousand a year?

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Appendix C Description of Balanced Sampling

C.1 Balanced Sampling Procedure

A balanced sampling procedure was used for the NES, ensuring that the sample has approximately the same proportion of airports as the population with respect to each of the balancing factors chosen by the FAA listed in Table 3-2.

Balanced sampling is a more general form of stratification and is sometimes used when the number of desired stratification factors for a stratified random sample is larger than the sample size will support (Tillé 2011). Stratified random sampling relies on the randomization to approximately balance factors not used in the stratification. With a large sample size, these are expected to be approximately balanced, but with a smaller sample size the sample that is chosen may be unrepresentative on one or more factors not used in the stratification. Balanced sampling allows selection of a sample that is representative on a larger number of factors than can be handled with stratification, and thus guarantees that the 20 airports chosen for the NES will be similar to the 95 airports in the population on all balancing factors listed in Table 3-2.

The procedure used to select the balanced sample was designed to:

1. Include ATL, LAX, and ORD in the sample.
2. Include exactly one of the three major New York City-area airports (JFK, LGA or EWR) in the sample.
3. Choose the 16 remaining airports for the sample so that the full sample of 20 airports meets the balancing constraints for the factors in Table 3-2.

Table C-1 gives the population proportions and desired sample sizes for each of the balancing variables. The sample size given in the table is the closest value for matching the proportion of airports in that class. For FAA region, both ANE (New England) and ANM (Northwest Mountain) gave an unrounded sample size of 1.5: this was resolved by allotting two airports to ANM and one to ANE.

Table C-1. Population Proportion and Desired Sample Size for Each Balancing Factor

Factor	Number of airports in sampling frame	Proportion of airports in sampling frame	Sample size (unrounded)	Sample size required to meet balancing criterion
FAA Region (contiguous US)				
Central (ACE)	3	3.2%	0.6	1
Eastern (AEA)	16	16.8%	3.4	3
Great Lakes (AGL)	11	11.6%	2.3	2
New England (ANE)	7	7.4%	1.5	1
Northwest Mountain (ANM)	7	7.4%	1.5	2
Southern (ASO)	21	22.1%	4.4	4
Southwest (ASW)	13	13.7%	2.7	3
Western Pacific (AWP)	17	17.9%	3.6	4
Temperature (degrees F)				
Greater than or Equal to 70	9	9.5%	1.9	2
Between 55.1 and 69.9 (inclusive)	49	51.6%	10.3	10
Less than or equal to 55	37	38.9%	7.8	8
Percent DNL Nighttime Operations (see Note 1)				
Greater than or Equal to 20%	36	37.9%	7.6	8
Less than 20%	59	62.1%	12.4	12
Average Daily Flight Operations				
Greater than or Equal to 300	48	50.5%	10.1	10
Less than 300	47	49.5%	9.9	10
Fleet Mix Ratio				
Greater than or equal to 1	57	60.0%	12	12
Less than 1	38	40.0%	8	8
Population within 5 Miles				
Greater than or Equal to 230,000	35	36.8%	7.4	7
Fewer than 230,000	60	63.2%	12.6	13

Notes:
1) DNL nighttime is 10:00 pm to 6:59 am. See Table 3-2 regarding division value.

Restricted random sampling (Valliant, Dorfman and Royall 2000) with a modification to include the directed airports of ATL, ORD and LAX, was used to select a sample that had the sample sizes for each category given in Table C-1. Restricted random sampling consists of the following three steps:

1. Generate a large number of random samples of size 20 from the population.
2. Reject the samples that do not meet the balancing constraints.
3. Select one sample at random from the remaining samples (all of which meet the balancing constraints).

To modify this procedure to include the certainty airports, Westat first generated 250,000 stratified random samples using the strata given in Table C-2. Generating stratified samples as the first step ensured that all of these 250,000 candidate samples had the correct number of airports from each of the eight FAA regions, and always included ATL, LAX, ORD, and one of the New York City-area airports chosen at random. This occurred because each of ATL, LAX, and ORD was selected with certainty from its stratum, and exactly one airport was selected from the stratum consisting of EWR, JFK, and LGA. Region was chosen as the basis of the stratification factor because it has the most categories.[1]

Table C-2. Strata Used in Initial Step of Generating Candidate Samples

Stratum	Number of airports in population	Number of airports in sample
ACE	3	1
AEA (minus EWR, JFK, LGA)	13	2
AGL (minus ORD)	10	1
ANE	7	1
ANM	7	2
ASO (minus ATL)	20	3
ASW	13	3
AWP (minus LAX)	16	3
ATL	1	1
LAX	1	1
ORD	1	1
EWR, JFK, LGA	3	1
Total	95	20

Of the 250,000 stratified samples that were generated, 55 also met the balancing criteria on the other factors. The sample for this study was selected randomly from this set of 55. Although the three airports ATL, LAX and ORD were directed to be in the sample, the remainder of the sample was drawn using random selection methods. This ensures that while the sample as a whole is balanced, all airports except for the three certainty airports were chosen randomly and not purposively.

C.2 Description of Balancing Factor Divisions and Airport Factor Values

The following five subsections address the balancing factors of temperature, nighttime operations, average daily operations, fleet mix ratio and population. The data for each of these factors for each of the 95 airports are in Table C-3. This data are presented in alphabetical order of the airport ID, whereas plots of the data introduced in each of the subsections is shown in descending order of value of the balancing factor. The selected airports are shown in bold.

[1] This was done purely for computational efficiency and does not imply FAA region is more important than other factors. By using the first factor, FAA Region, in Table 2-1 for generating the candidate samples, the computational effort was substantially reduced. This is because every generated sample was balanced for each of the eight FAA regions and only needed to be checked for whether it was also balanced on the other six factors. The same procedure would work (and would produce similar samples) if, say, the initial samples had been stratified on temperature, but in that case each sample would have needed to be checked for balance on 11 other criteria, so a much higher fraction of the generated samples would be rejected.

Table C-3. Balancing Factor Data for All Airports in Sampling Frame

Selected Airports Shown in Bold

Airport Identifier	Airport Name	Annual Average Daily Temperature (degrees F)	Original Percent of Operations During DNL Nighttime (%)	Revised/corrected Percent of Operations During DNL Nighttime (%)	2011 ETMS Average Daily Flight Operations	Ratio of Commuter/Small Flight Operations to Large Aircraft Flight Operations	Population Within 5 Miles of Airport
ABQ	**Albuquerque Intl Sunport**	**58.04**	**17.0**	**11.8**	**274.7**	0.6	**144,952**
ALB	**Albany Intl**	**48.65**	**27.2**	**21.7**	**163.0**	1.4	**114,935**
APA	Centennial	50.02	15.2	12.5	158.6	17805.0	175,093
ATL	**Hartsfield-Jackson Atlanta Intl**	**62.34**	**7.2**	**8.6**	**2518.1**	0.4	**212,823**
AUS	**Austin-Bergstrom Intl**	**71.01**	**18.6**	**13.2**	**385.1**	0.7	**88,849**
BDL	**Bradley Intl**	**50.63**	**26.2**	**17.6**	**266.4**	1.1	**43,567**
BED	Laurence G Hanscom Field	50.05	10.9	6.7	116.9	73.8	83,189
BFI	**Boeing Field/King County Intl**	**53.70**	**17.8**	**12.7**	**184.4**	2.5	**291,268**
BHM	Birmingham Intl	63.01	18.3	13.2	240.6	1.8	122,517
BIL	**Billings Logan Intl**	**47.86**	**21.3**	**15.2**	**106.7**	2.1	**93,175**
BNA	Nashville Intl	59.88	14.1	10.7	448.3	1.1	156,815
BOI	Boise Air Terminal/Gowen Field	52.95	20.2	12.9	173.4	1.2	133,467
BOS	General Edward Lawrence Logan Intl	51.47	18.3	13.1	952.4	0.6	491,152
BTR	Baton Rouge Metropolitan, Ryan Field	67.18	17.1	12.0	106.7	147.2	103,711
BTV	Burlington Intl	46.48	19.9	14.1	105.2	14.3	74,691
BUF	Buffalo Niagara Intl	48.51	25.7	16.6	239.7	1.4	225,144
BUR	Bob Hope	63.98	11.7	4.7	319.4	0.6	539,666
BWI	Baltimore/Washington Intl Thurgood Marshall	55.77	13.7	10.7	731.5	0.2	175,445
CAE	Columbia Metropolitan	63.63	23.3	19.1	118.2	5.1	67,415
CAK	Akron-Canton Regional	49.92	22.8	15.9	103.6	1.6	82,632
CHS	Charleston Air Force Base/Intl	65.48	18.0	13.0	190.9	2.0	116,289
CLE	Cleveland-Hopkins Intl	51.07	21.8	9.3	513.3	2.5	211,482

Airport Identifier	Airport Name	Annual Average Daily Temperature (degrees F)	Original Percent of Operations During DNL Nighttime (%)	Revised/corrected Percent of Operations During DNL Nighttime (%)	2011 ETMS Average Daily Flight Operations	Ratio of Commuter/Small Flight Operations to Large Aircraft Flight Operations	Population Within 5 Miles of Airport
CLT	Charlotte/Douglas Intl	60.76	9.7	10.7	1455.4	1.3	94,245
CMH	Port Columbus Intl	53.27	21.5	14.4	352.5	2.5	241,443
CVG	Cincinnati/Northern Kentucky Intl	54.05	24.4	18.3	435.0	2.3	110,969
DAL	Dallas Love Field	67.31	11.8	8.4	446.3	0.7	299,718
DCA	Ronald Reagan Washington National	57.89	12.5	9.8	772.8	1.5	650,983
DFW	Dallas/Fort Worth Intl	66.25	9.4	7.7	1767.5	0.6	143,253
DSM	**Des Moines Intl**	**50.55**	**24.4**	**14.9**	**165.2**	3.8	**118,690**
DTW	**Detroit Metropolitan Wayne County**	**50.37**	**23.6**	**7.1**	**1216.2**	1.8	**88,989**
ELP	El Paso Intl	65.82	18.2	13.8	176.8	0.7	198,467
EWR	Newark Liberty Intl	55.24	20.0	15.0	1111.4	0.6	705,858
FAT	Fresno Yosemite Intl	64.29	27.6	20.3	102.0	4.5	343,067
FLL	Fort Lauderdale/Hollywood Intl	77.18	18.0	13.8	672.6	0.2	268,341
FSD	Joe Foss Field	46.35	25.4	17.0	133.0	3.6	99,444
FXE	Fort Lauderdale Executive	76.05	14.3	8.6	115.2	2315.0	431,855
GEG	Spokane Intl	48.08	26.4	20.6	145.1	0.3	23,782
HOU	William P. Hobby	69.92	12.3	8.4	474.6	0.6	306,751
HPN	Westchester County	51.84	14.6	9.5	321.2	25.2	144,067
IAD	Washington Dulles Intl	55.15	14.9	14.2	965.8	1.6	151,207
IAH	George Bush Intercontinental/Houston	69.12	21.2	15.9	1444.6	1.2	117,326
IND	Indianapolis Intl	53.31	33.7	22.9	425.6	1.1	103,671
JAX	Jacksonville Intl	67.67	16.5	11.5	239.4	1.0	32,293
JFK	John F. Kennedy Intl	54.08	19.9	16.6	1122.1	0.4	725,214
LAS	**McCarran Intl**	**69.42**	**15.2**	**10.5**	**1107.1**	0.2	**379,622**
LAX	**Los Angeles Intl**	**62.38**	**19.5**	**17.7**	**1636.7**	0.3	**513,937**
LGA	**LaGuardia**	**55.55**	**16.4**	**8.6**	**1007.2**	1.2	**235,506**
LGB	Long Beach/Daugherty Field	63.85	8.0	2.0	130.7	0.7	686,242

Airport Identifier	Airport Name	Annual Average Daily Temperature (degrees F)	Original Percent of Operations During DNL Nighttime (%)	Revised/corrected Percent of Operations During DNL Nighttime (%)	2011 ETMS Average Daily Flight Operations	Ratio of Commuter/Small Flight Operations to Large Aircraft Flight Operations	Population Within 5 Miles of Airport
LIT	**Bill and Hillary Clinton National**	**62.51**	**15.7**	**11.2**	**196.1**	2.6	**62,879**
MCO	Orlando Intl	71.66	13.0	9.6	859.4	0.1	83,097
MDW	Chicago Midway Intl	51.88	11.2	9.8	651.9	0.3	687,736
MEM	**Memphis Intl**	**62.86**	**32.2**	**30.3**	**833.3**	0.7	**182,538**
MHT	Manchester	49.75	28.8	22.0	146.1	1.1	114,100
MIA	**Miami Intl**	**76.65**	**14.4**	**11.6**	**1001.1**	0.2	**531,630**
MKE	General Mitchell Intl	48.45	16.2	11.5	456.0	1.0	229,049
MSN	Dane County Regional	47.45	15.7	11.2	122.2	6.9	94,834
MSP	Minneapolis-St. Paul Intl	46.63	10.3	8.4	1178.3	1.3	274,649
MSY	Louis Armstrong New Orleans Intl	69.37	18.7	12.2	298.5	0.4	159,362
OAK	Metropolitan Oakland Intl	57.65	22.9	17.0	402.6	0.2	324,655
OKC	Will Rogers World	60.23	22.2	15.7	206.8	1.6	119,005
OMA	Eppley Airfield	51.32	20.9	15.1	250.4	2.0	132,853
ONT	Ontario Intl	64.28	29.0	26.2	211.6	0.2	316,731
ORD	**Chicago O'Hare Intl**	**50.47**	**11.2**	**8.4**	**2394.9**	1.5	**257,655**
ORF	Norfolk Intl	60.65	28.5	14.3	205.7	2.2	240,746
PBI	Palm Beach Intl	75.29	13.9	10.3	312.4	1.1	262,326
PDK	Dekalb-Peachtree	62.53	8.9	5.9	172.5	6868.0	293,275
PDX	Portland Intl	54.27	21.3	16.8	558.2	0.3	316,661
PHL	Philadelphia Intl	56.06	14.4	13.5	1215.4	1.2	253,078
PHX	Phoenix Sky Harbor Intl	74.92	14.3	8.9	1229.8	0.3	333,915
PIT	Pittsburgh Intl	54.65	21.0	14.4	388.6	1.4	52,658
PNS	Pensacola Gulf Coast Regional	68.01	20.6	15.3	108.1	2.3	107,206
PSP	Palm Springs Intl	76.06	16.8	12.2	105.2	2.4	97,126
PVD	Theodore Francis Green State	51.49	24.2	15.6	174.1	1.0	184,465
PWM	Portland Intl Jetport	46.75	22.0	17.4	113.9	4.9	112,143
RDU	Raleigh-Durham Intl	59.83	17.2	13.1	463.6	1.7	92,617
RIC	Richmond Intl	58.26	22.9	18.6	224.2	2.9	64,993

Airport Identifier	Airport Name	Annual Average Daily Temperature (degrees F)	Original Percent of Operations During DNL Nighttime (%)	Revised/corrected Percent of Operations During DNL Nighttime (%)	2011 ETMS Average Daily Flight Operations	Ratio of Commuter/Small Flight Operations to Large Aircraft Flight Operations	Population Within 5 Miles of Airport
RNO	Reno/Tahoe Intl	53.57	15.0	9.8	171.8	0.5	201,855
ROC	Greater Rochester Intl	48.45	27.7	19.4	164.0	2.7	197,791
SAN	San Diego Intl	62.99	16.6	12.2	495.9	0.2	389,036
SAT	San Antonio Intl	69.03	20.1	14.0	399.9	0.8	268,037
SAV	**Savannah / Hilton Head Intl**	**65.90**	**15.0**	**11.5**	**156.5**	4.8	**29,087**
SBA	Santa Barbara Municipal	58.95	13.1	8.7	117.6	78.8	77,453
SDF	Louisville Intl-Standiford Field	57.81	48.7	39.3	403.3	0.6	235,856
SEA	Seattle-Tacoma Intl	52.12	19.2	15.9	854.9	0.1	189,518
SFO	San Francisco Intl	57.02	23.2	13.9	1090.4	0.3	191,527
SJC	**Norman Y. Mineta San Jose Intl**	**60.75**	**13.2**	**10.3**	**336.1**	0.5	**562,139**
SNA	John Wayne Airport-Orange County	63.96	10.2	3.4	337.1	0.4	540,237
STL	Lambert-St. Louis Intl	57.14	15.9	10.6	490.9	0.6	195,758
SYR	**Syracuse Hancock Intl**	**48.65**	**24.1**	**20.3**	**149.9**	3.5	**147,814**
TEB	Teterboro	53.99	11.7	9.4	397.7	2229.0	625,053
TPA	Tampa Intl	72.71	15.3	11.0	496.7	0.1	225,867
TUL	Tulsa Intl	60.89	21.0	13.2	196.6	1.8	103,273
TUS	**Tucson Intl**	**69.85**	**20.7**	**12.4**	**200.1**	1.6	**121,790**
TYS	McGhee Tyson	58.81	21.2	6.6	189.7	5.9	52,198
VNY	Van Nuys	65.68	14.8	10.1	125.7	87.8	712,651

C.2.1 Average Daily Temperature

One of the few airport variables that have been found to affect annoyance is climate, with warmer climates resulting in higher annoyance (Miller et al. 2014a). The divisions of 55 °F and 70 °F were selected to ensure all climate zones of the contiguous US would be sampled. These divisions guarantee the sample percentage of airports in each of the three average daily temperature ranges—below 55 °F, between 55 and 70 °F, and above 70 °F — matches the population percentage in that category.[2]

The average daily temperature data were provided by the FAA, and were based on 10-year annual averages.[3] Table C-3 gives the average daily temperatures for all 95 airports with the selected airports in bold. The description of the weather data used to determine the sampling frame is given in Table C-4. Figure C-1 graphs the average daily temperatures for each of the 95 airports, shows the factor division, and highlights the selected airports in black.

Table C-4. Weather Data Description

Item	Description	Field Type	Field Size	Units	Source	Comments
Mean Temperature	Mean annual temperature	real	7.2	Degrees Fahrenheit	NOAA (GSSD or 30-year normal)	In US; 30-year normal used for this value
Sea Level Pressure	Mean annual sea level pressure	real	8.2	Millibars	NOAA (GSSD)	
Station Pressure	Mean annual station pressure	real	8.2	Millibars	NOAA (GSSD)	
Dew Point	Mean annual dew point	real	7.2	Degrees Fahrenheit	NOAA (GSSD)	
Relative Humidity	Mean annual relative humidity	float	6.2	Percentage	NOAA (GSSD)	Calculated from dew point and temperature
Wind Speed	Mean annual wind speed	real	6.2	Knots	NOAA (GSSD)	
Average Temperature	Average annual temperature	real	7.2	Degrees Fahrenheit	NOAA (GSSD or 30-year normal)	In US; 10 year average used for this value

[2] Only two balancing factors are needed for this since when the percentages below 55 °F and the percentages above 70 °F match for the sample and population, the percentage between 55 and 70 °F must match as well.
[3] The weather data period was June 2012 through May 2013.

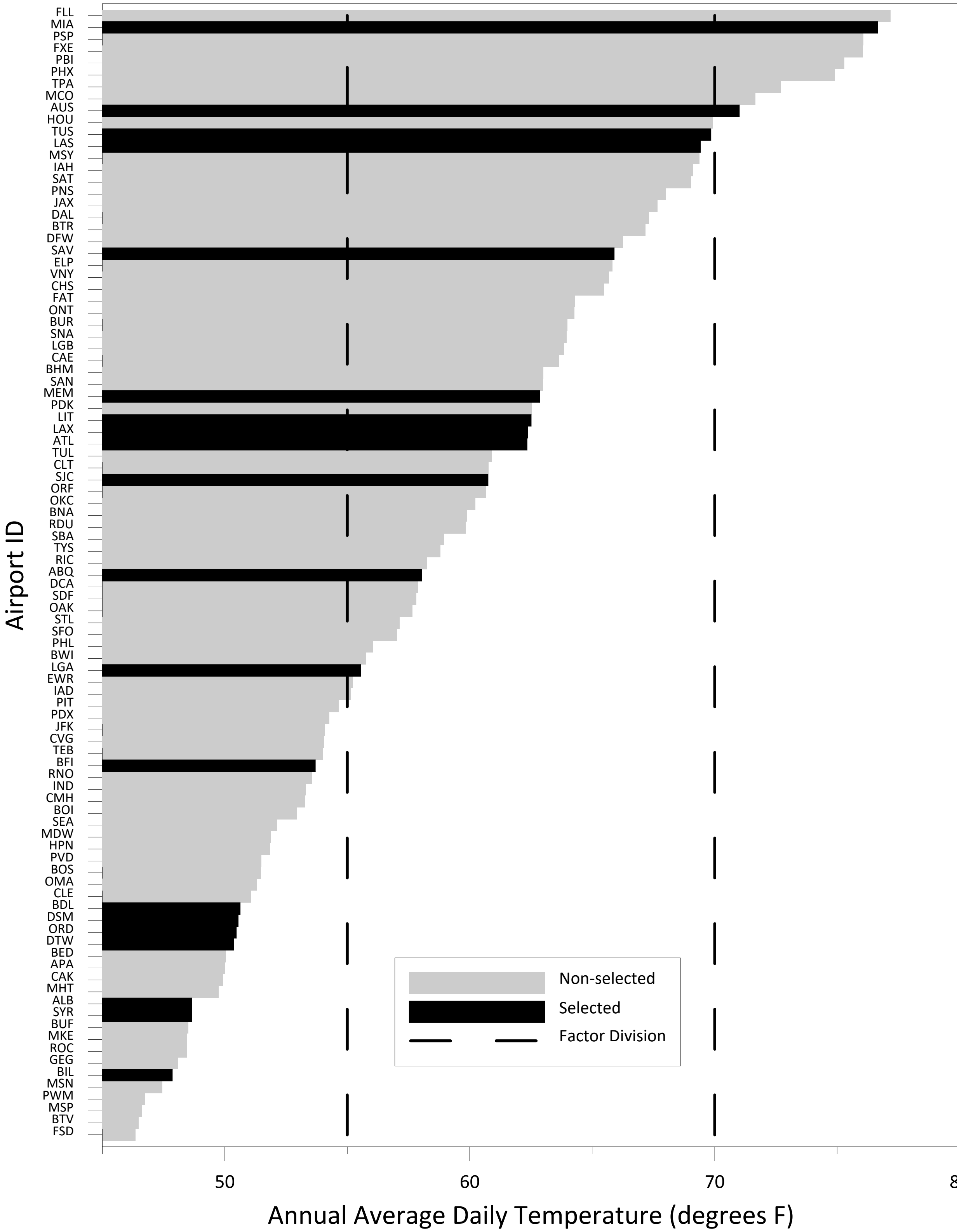

Figure C-1. Average Temperatures: All Airports with Selected Airports Identified

Factor Divisions are shown

C.2.2 Percentage of Nighttime Operations

It was hypothesized that a larger percent of operations during the DNL nighttime period (10 p.m. – 7 a.m.) might be associated with higher annoyance responses. For all airports in the sampling frame, annual operations were downloaded from FAA's Traffic Flow Management System Counts (TFMSC)[4] data for the period November 1, 2011 to October 31, 2012. This database provides operations counts by weight class, aircraft type, and arrival or departure time (by hour) and permits determination of nighttime operations. The original division used for this balancing factor was 20 percent of operations at night.

However, post-survey review showed that percentages were unrealistically high. The original analyses had misidentified aircraft flights with no arrival or departure hours given, marked as "N/A", were included in the nighttime operations counts. The revised analyses ignored all "N/A" flights and recomputed the nighttime percentages. Both values are given in Table C-3. Figure C-2 graphs the original values, shows the factor division, and identifies the selected airports in black. Figure C-3 graphs the revised values, the median used as the division, and the twenty selected airports. The desired goal for number of airports greater than the balancing factor of 20 percent (median value rounded up) was 8 airports. As shown in Figure C-2 (original analysis) and Figure C-3 (revised analysis), both distributions of the 20 selected airports meet this goal.

This error in the original calculations does not affect the representativeness of the sample – balanced sampling guarantees that the sample is representative on any factors used in the design – and in fact, the sample closely matches the population distribution for the corrected values of percentage nighttime operations. The population distribution of percentage nighttime operations has 25th, 50th, and 75th percentiles of 9.8 percent, 12.8 percent, and 15.8 percent, respectively; the corresponding percentiles for the sample are 9.93 percent, 12.6 percent, and 17.0 percent.

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[4] TFMSC is the system / website that may be accessed for the counts. The Traffic Flow Management System (TFMS) is a data exchange system for supporting the management and monitoring of national air traffic flow. TFMS processes all available data sources such as flight plan messages, flight plan amendment messages, and departure and arrival messages. The FAA's airspace lab assembles TFMS flight messages into one record per flight. TFMS is restricted to the subset of flights that fly under Instrument Flight Rules (IFR) and are captured by the FAA's enroute computers. Most Visual Flight Rules (VFR) and some non-enroute IFR traffic is excluded.

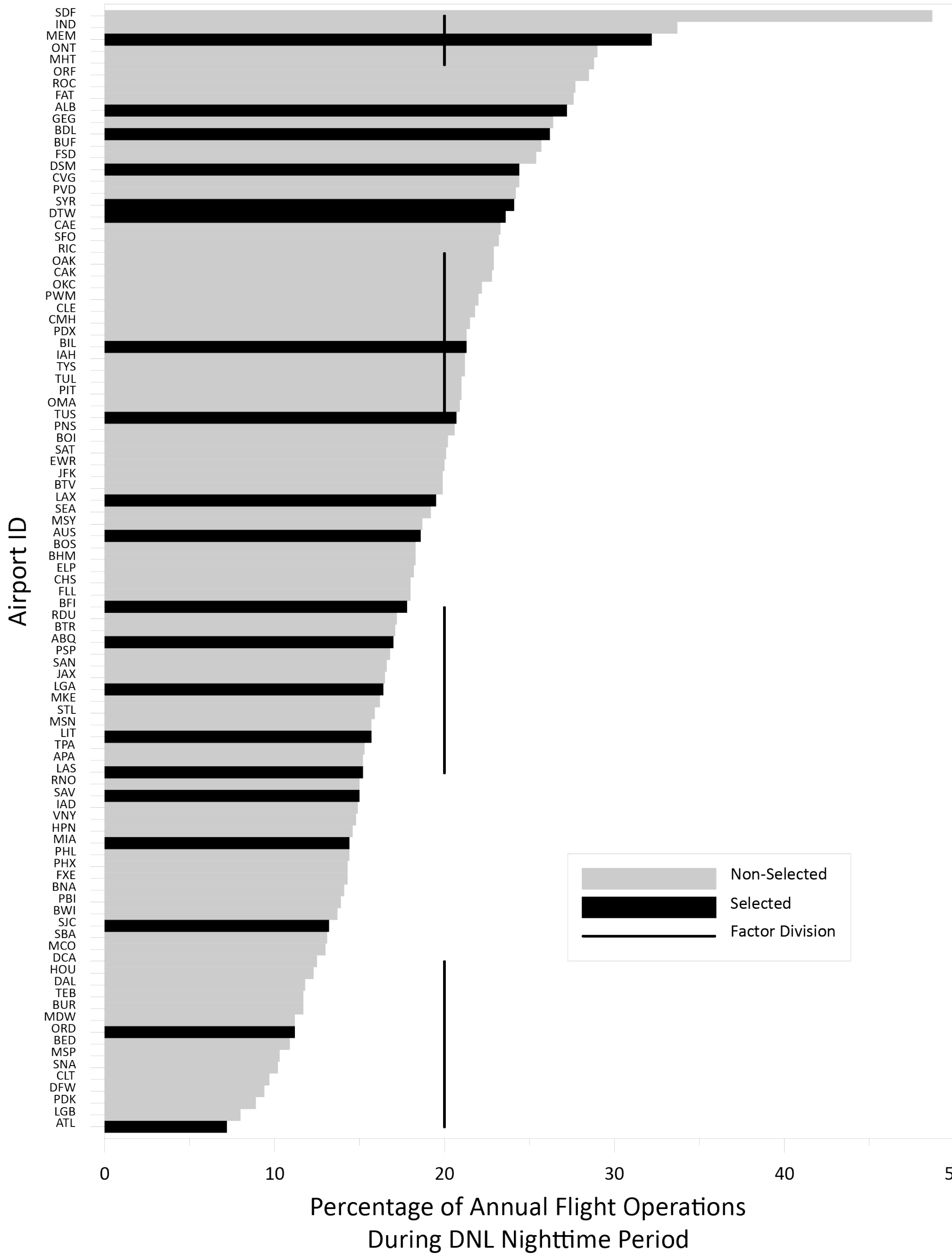

Figure C-2. Average Nighttime Operations Original Percent: All Airports with Selected Airports Identified

Factor Division Shown

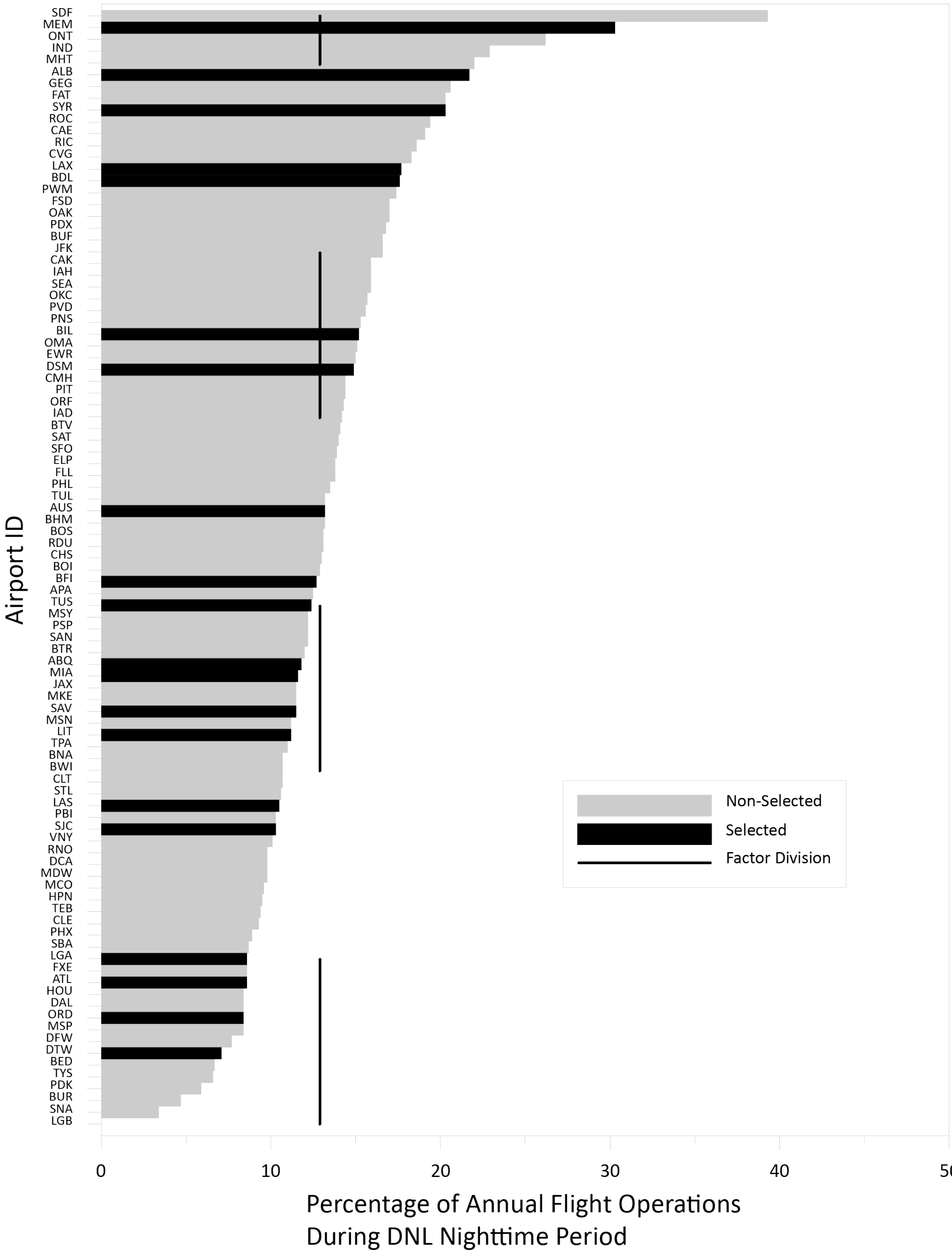

Figure C-3. Average Nighttime Operations Revised Percent: All Airports with Selected Airports Identified

Factor Division Shown (median)

C.2.3 Average Daily Flight Operations

Because the primary objective of the survey is to develop a nationally applicable relationship between annoyance and noise exposure, the sample should represent the smaller, less busy airports as well as the larger, busier ones. Thus, one of the balancing factors was number of average daily flight operations, which help ensure the sample can be used to study differences that might be due to having a large number of operations. The approximate median for all 95 airports (300 average daily flight operations) was chosen as the determinant of the sample division between “large” and “small” airports.

Annual operations for all sampling frame airports were derived from the 2011 Enhanced Traffic Management System (ETMS) data provided by the FAA’s Office of Environment and Energy (AEE). Table C-3 lists operations for all ninety-five airports with the twenty sample airports highlighted in bold. Figure C-4 graphs the operations for each of the 95 airports and shows the factor division. The 20 selected airports are shown in black.

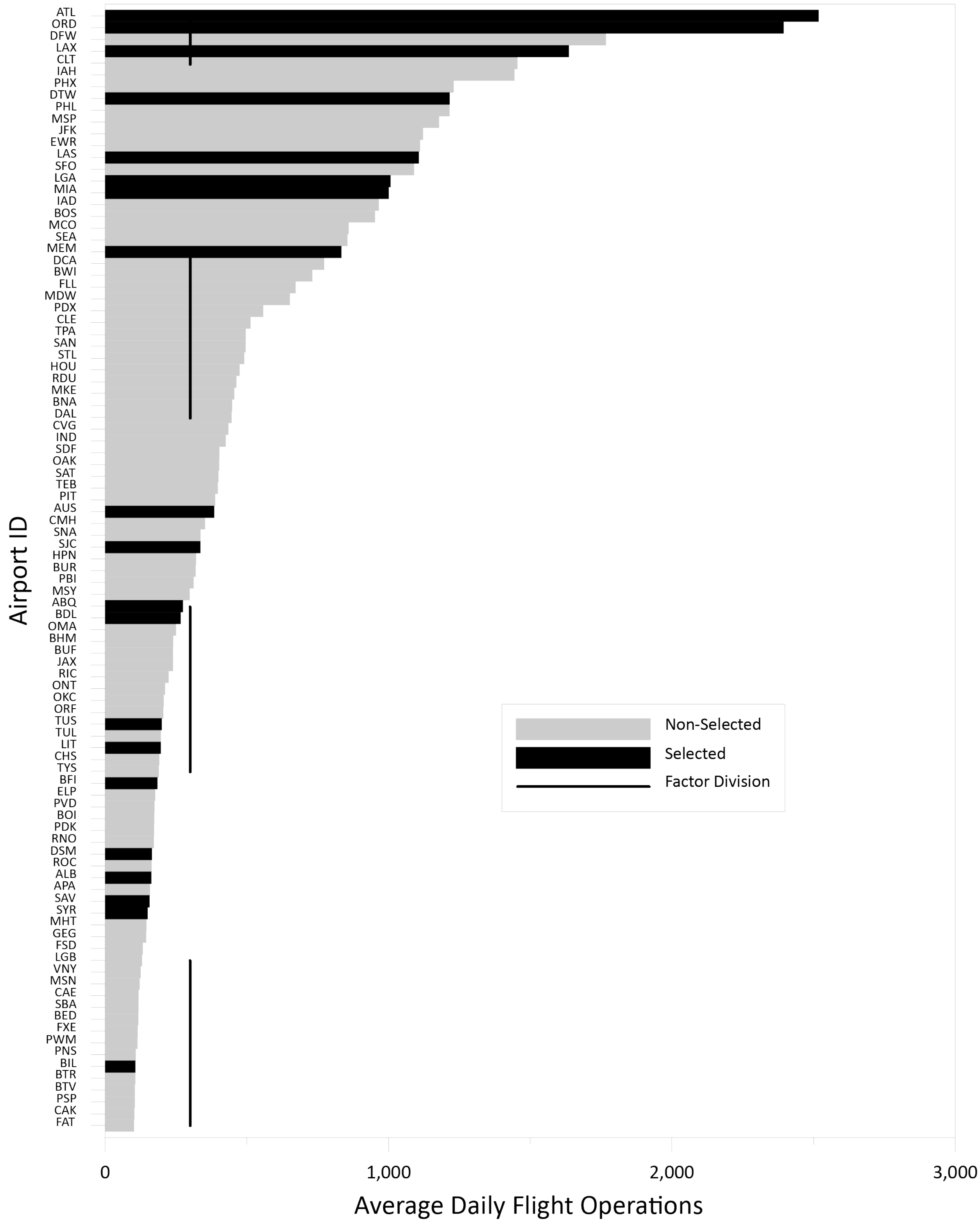

Figure C-4. Average Daily Operations: All Airports with Selected Airports Identified

Factor Division Shown

C.2.4 Fleet Mix Ratio

It is possible that for a given noise exposure, annoyance reactions may be different depending on fleet mix. Smaller, lighter aircraft generally tend to be somewhat quieter than larger heavier aircraft. Consequently, greater numbers of overflights of the smaller aircraft would be required to produce a cumulative noise exposure equivalent to that produced by a lesser number of large aircraft. The balancing factor of fleet mix ratio ensures the sample can be used to study differences that might be due to having different fleet mix ratios.

TFMSC data in the "city pair" view and "weight class" grouping identify the weight class for every flight, the arrival and departure times, as well as other data. The classes are:

- **A** Heavy: Any aircraft weighing more than 255,000 pounds, such as the Boeing 747 or Airbus A340;
- **B** B757: Boeing 757 all series;
- **C** Large Jet: Large jet aircraft weighing more than 41,000 pounds and up to 255,000 pounds, such as the Boeing 737 or Airbus A320;
- **D** Large Commuter: Large non-jet aircraft (such as the Aerospatiale/Alenia ATR-42 and the Saab SF 340), and small regional jets (such as the Bombardier Canadair Regional Jet), weighing more than 41,000 pounds and up to 255,000 pounds;
- **E** Medium: Small commuter aircraft including business jets weighing more than 12,500 pounds and up to 41,000 pounds, such as the Embraer 120 or the Learjet 35; and
- **F** Small: Small, single, or twin engine aircraft weighing 12,500 pounds or less, such as the Beech 90 or the Cessna Caravan.

An additional class, "Unknown", refers to unspecified equipment.

TFMSC data were analyzed using Sound Exposure Level (SEL) values from the FAA's Integrated Noise Model (INM) aircraft noise database to estimate the best grouping into "large" and "commuter / small" aircraft on the basis of sound level produced on the ground. The resulting large aircraft group included the above mentioned classes (A) through (C), and the commuter/light aircraft group included classes (D) through (F) and the "unknown" category. In terms of energy average SEL for the fleets of the 95 airports, the difference between large and commuter/small in total sound produced was about 7 dB. An equal sound energy division of 5 times as many light as heavy aircraft operations for this factor was initially considered. However, such a division would over-represent the airports with many light aircraft. A ratio of commuter/light (classes D through F) to large (classes A through C) of 1 was selected by FAA as the dividing value.

Table C-3 gives the flight mix ratios for all 95 airports with the sample twenty airports in bold. Figure C-5 graphs the fleet mix ratios for each of the 95 airports, shows the factor division, and highlights the selected airports in black.

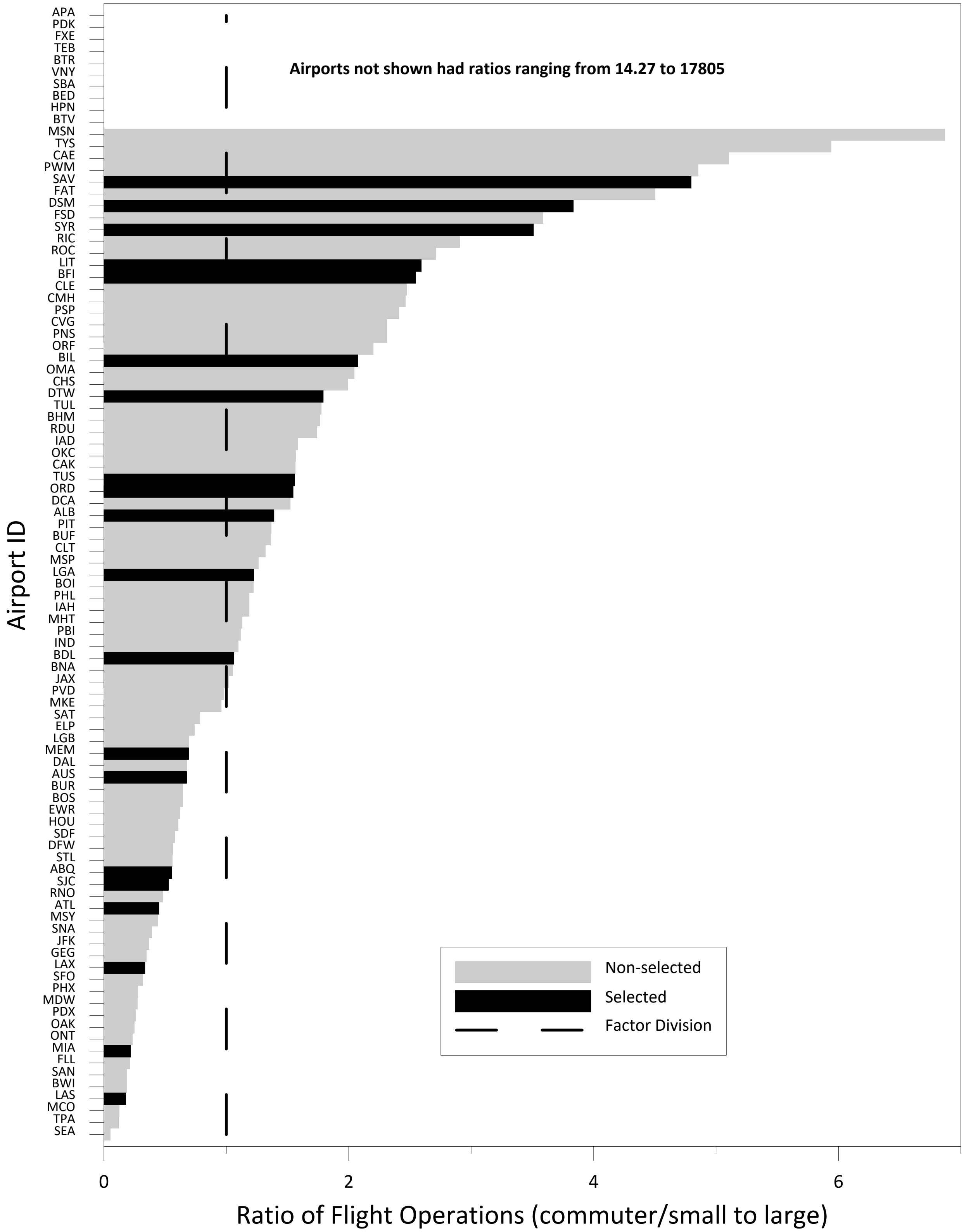

Figure C-5. Fleet Mix Ratios: All Airports with the Selected Airports Identified

Factor Division is Shown

C.2.5 Population within Five Miles of Airport

It was also hypothesized that the population density around an airport could bear some relationship to aircraft noise annoyance. Population density has been a surrogate for local ambient (non-aircraft, non-major nearby highway) noise levels (Schomer et al. 2011). The local noise could distract from or increase awareness of aircraft noise, though clear evidence is lacking (Miller et al. 2014a). Fidell (1978) suggested that population density may be associated with lifestyles, and that apartment dwellers in high density areas may have different opinions than suburban residents. At least one study suggests the more important population effect is whether people do or do not perceive the area to be overpopulated (Verbrugge and Taylor 1980).

Population within the area defined by a five (5) mile radius of each airport's reference point was determined, used as an indicator of population density, and a mean of approximately 230,000 residents per 78.5 sq. mi.[5] was used to divide the sample.[6] US census tract data from 2010 and airport location were used to compute populations within 5 miles of the airport. Table C-3 gives the populations for all 95 airports with the selected sample in bold. Figure C-6 graphs the population values for each of the 95 airports, shows the factor division, and highlights the selected airports in black.

[5] The area, in square miles, contained within a five-mile radius.
[6] The true average is 231,707, but 230,000 was selected for simplicity and does not alter the dividing point insofar as the 95 airports are concerned.

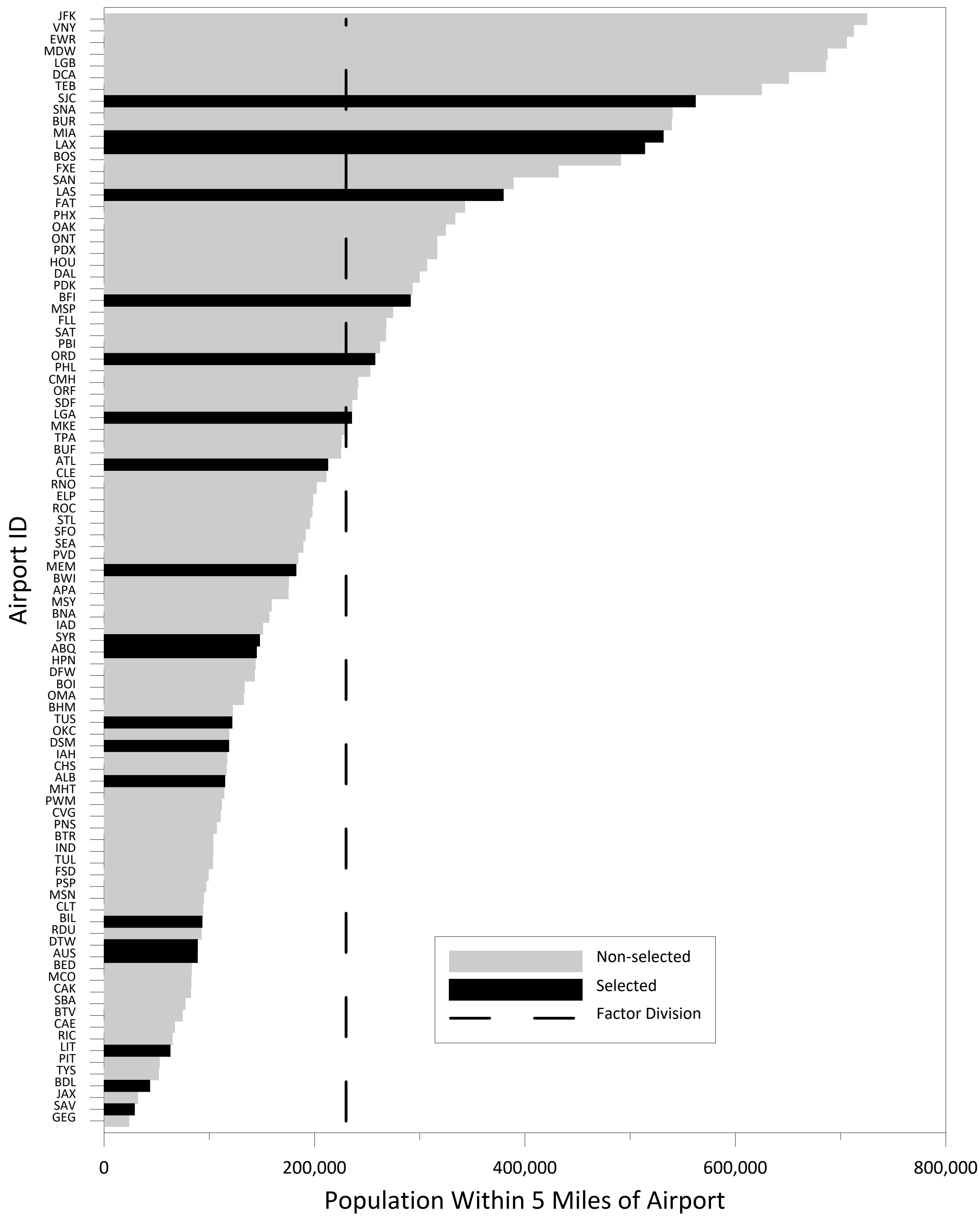

Figure C-6. Populations within 5 Miles: All Airports with Selected Airports Identified Factor Division Shown

C.2.6 Overview of the Balancing Factors and the Selected Airports

Figure C-7 gives scatterplots of the sampled airports with respect to the nongeographic factors used in balancing. Each plot in the figure is a scatterplot of the x and y variables given by the column name and row name, respectively.

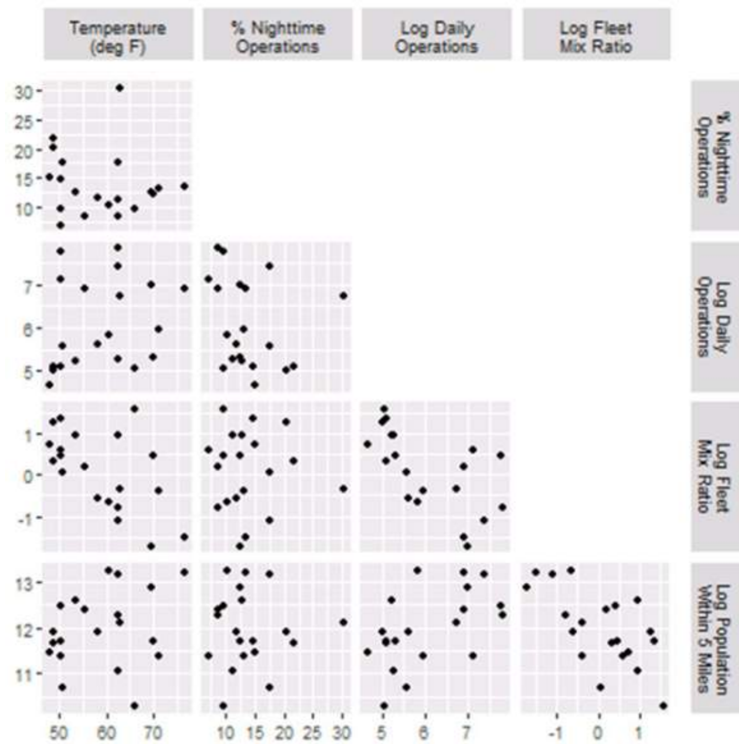

Figure C-7. Scatterplot Matrix of Balancing Factors, for the Selected Sample

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Appendix D Analysis of Telephone Survey Data

This appendix contains seven subsections. Section D.1 serves as an Introduction and high-level summary of the appendix. Sections D.2 through D.4 contain the details of the three initial exploratory analyses of the telephone survey data. Sections D.5 and D.6 present technical details supporting the aforementioned analysis sections. Section D.7 lists some general caveats and cautions about the telephone survey and conclusions drawn from it.

D.1 Introduction and Summary

As described in Section 2, two survey instruments were administered to adult residents within the NES: a mail questionnaire and, for those who responded to that, a follow-up telephone interview. The mail survey forms the basis of the dose-response relationship of aircraft noise and annoyance. The broader telephone survey was designed to obtain further information about attitudes towards airports and airport policies, to explore the potential cause of the annoyance to aircraft noise and examine why some people are highly annoyed by aircraft noise at a particular noise exposure while others at the same noise exposure are not. The telephone interview (see Appendix B for the survey instrument) asked detailed questions on a number of areas including respondents' opinions on noise, exposure to aircraft noise, relationship to the airport, concerns about aircraft operations, views on airport community relations, among others. The phone survey data was not used to calculate the dose-response curve as all responding households were already represented in the mail survey.

In this appendix, we present the results of *initial* analyses conducted on the telephone survey data. From the wide range of topics covered in the telephone questionnaire, the scope of the analysis was designed to provide a thorough, but not necessarily exhaustive, review of the information. Future research on this data may provide additional insights. The following three exploratory analyses were conducted:

1) Comparison with mail survey results in Section D.2,

2) Exploratory factor analysis (EFA) in Section D.3, and

3) Characteristics of highly and not-highly annoyed respondents in Section D.4.

The results are summarized below.

Comparison of telephone dose-response curve to the mail survey results. The dose-response curve generated from the telephone survey indicates less highly annoyed responses versus the mail survey. Three hypotheses were suggested to explain the difference in reported percent highly annoyed across survey modes. The best explanation was that of social desirability bias of the telephone survey, i.e., people responded differently when the survey was interviewer-administered (telephone) versus self-administered (mail).

Exploratory factor analysis (EFA). EFA is a statistical technique to find one or more groups of variables, called "factors", which summarize complex inter-relationships of observed variables. For the telephone survey, an EFA was conducted to better understand the relationship of the answers given by the respondents to their annoyance from aircraft noise, as captured by the survey's focus question: "Thinking about the last 12 months or so, when you are here at home, how much does [noise from aircraft] bother, disturb or annoy you?" The EFA identified seven factors (see Table D-8). Interpreting the top-ranked factor, Factor 7, as an example, people's degree of being highly annoyed by aircraft noise correlated to their degree of being startled, frightened and/or awakened by aircraft noise.

Twenty-two questions had weak connections with other questions in the survey and could not be grouped into factors, but when comparing their overall strengths of association with the survey's focus question to the Factors' strengths, five of the 7 factors, i.e., Factors 7, 3, 4, 2 and 1, ranked higher than these 22 questions. As shown in Table D-9, Factors 5 and 6 were outranked by three of the ungrouped questions in terms of their importance to aircraft noise annoyance.

The strength of association with the survey's focus question was also examined across four DNL stratum, for each of the factors and remaining questions. Factors 3 and 7 were consistently ranked first or second across all of the DNL strata. That is, the correlation of aircraft noise annoyance with being startled/frightened/awakened and their general traffic noise/smells rating were stronger than all other factors/questions, regardless of DNL.

Characteristics of highly and not-highly annoyed respondents. Another type of statistical analysis, called a Classification and Regression Tree (CART) analysis, was undertaken to identify characteristics of highly and not-highly annoyed respondents in the four DNL strata listed above. In all DNL strata, the most important characteristic for predicting highly annoyed respondents is being startled, frightened, or awakened by aircraft noise. The next most important characteristic for predicting highly annoyed respondents is the belief that the airport is not working collaboratively with them, however, this was limited to the 50-55 dB DNL and 60-65 dB DNL strata.

D.2 Comparison of Dose-Response Curves

Section D.2.1 compares characteristics of the mail and telephone respondents. Although the primary result of the mail survey was the national dose-response curve, a dose-response curve from the telephone survey was generated to examine potential survey mode differences in reported annoyance, and is discussed and shown in Section D.2.2. Section D.2.3 offers hypotheses for the differences in annoyance between the two survey modes.

D.2.1 Respondents

NES mail survey respondents were invited to participate in a follow-up telephone survey. As such, the telephone surveys represent a subset of households responding to the mail survey. Of the 10,328 households responding to the mail survey, 2,328 (23 percent) also responded to the telephone survey.

The telephone interview typically occurred from a couple weeks up to a few months after the mail survey was received. The average number of days between the two was 40 (median = 36) with a range from 11 to 229 days. The "next birthday" method (see Sections 4.3 and 4.4) of respondent selection was utilized for both the mail and telephone surveys. The telephone and mail respondents may not have been the same person for a number of reasons, such as:

- In households with more than one adult, a birthday may have occurred between surveys,
- Respondents may not have followed selection instructions of either survey,
- Respondents may have provided a different birth month and year across surveys, or
- The occupancy of a household/address may have changed between surveys.

Answers to month and year of birth variables from the mail and phone surveys were compared. Based on this comparison, approximately half the households with responses to the mail and phone surveys were answered by a different person within the household.

Month and year of birth were missing for either the telephone or mail survey for 136 of the 2,328 (6 percent) telephone respondents. Of those that provided a response for both the mail and telephone surveys, 1,050 (50 percent) provided the same month and year of birth for both surveys. Given the time between surveys we would expect some difference in respondents across surveys, but without further analysis the exact percentages are unknown.

To consider any differences in the distribution of mail and phone survey respondents across the range of aircraft noise exposures, Table D-1 presents a comparison stratified by DNL intervals of 5 dB. The percentages are nearly identical except for one percent differences in the lowest and highest strata. A chi-square test[7] was performed and verified that no statistically significant difference between the two distributions occurred.

[7] The chi-square test yielded a p-value of 0.1096

Table D-1. Percentages of Mail and Telephone Respondents by DNL Stratum

DNL Stratum (dB)	Percent of Mail Respondents	Percent of Telephone Respondents
50-55	35%	36%
55-60	33%	33%
60-65	20%	20%
65-70	9%	9%
70+	3%	2%
Total	**100%**	**100%**

D.2.2 Dose-Response Curves

For comparative purposes, a dose-response curve from the telephone survey was generated in a manner identical to the national dose-response curve from the mail survey[8], as described in Chapter 8. Unlike the national dose-response curve, the telephone survey-derived curve could not be generated for each individual airport due to the telephone survey's small sample size.

The respondent's answers to the telephone survey's question 1e[9] were fit to the same logistic regression model shown in Equation 8.1. Question 1e was given the variable name of PALAC. Table D-2 provides the model's coefficients, their standard errors and 95 percent confidence intervals for the telephone survey dose-response curve. These are analogous the curve parameters shown in Table 8-2 for the national curve.

Table D-2. Model Coefficients for the Dose-response Curve Derived from the Telephone Survey

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-7.5620	0.7649	-9.1630	-5.9610
Slope, β_1	0.1172	0.0132	0.0897	0.1448

Comparable to the results of the national dose-response curve shown in Table 8-3, Table D-3 presents the predicted percent HA from the model for DNL between 50 and 70 dB from the phone survey question 1e.

[8] The national dose-response curve is based on data from the mail survey only.

[9] The question was "Thinking about the last 12 months or so, when you are here at home, how much does *noise from aircraft* bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?"

Table D-3. Predicted Percent HA at Selected Noise Exposures, from Telephone Survey Dose-response Curve

DNL Value (dB)	Predicted Percent HA	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
50	15.4	1.9	11.9	19.7
51	17.0	1.9	13.5	21.3
52	18.8	1.9	15.1	23.1
53	20.6	1.9	16.9	24.9
54	22.6	2.0	18.8	26.9
55	24.7	2.0	20.8	29.1
56	27.0	2.0	22.9	31.4
57	29.3	2.1	25.1	33.9
58	31.8	2.2	27.4	36.6
59	34.4	2.3	29.7	39.4
60	37.1	2.5	32.1	42.4
61	39.9	2.7	34.5	45.5
62	42.7	2.9	36.9	48.8
63	45.6	3.1	39.3	52.1
64	48.5	3.3	41.7	55.4
65	51.5	3.5	44.1	58.7
66	54.4	3.7	46.5	62.0
67	57.3	3.9	48.9	65.2
68	60.1	4.1	51.3	68.3
69	62.9	4.2	53.7	71.2
70	65.6	4.3	56.0	74.0

Figure D-1 compares the national dose-response curve of Figure 8-2 (shown in black lines), which was based on 10,328 (mail) respondents, to the curve generated by the parameters in Table D-2 (shown in red lines), which was based on 2,328 (telephone) respondents. Each curve models the percent indicating a highly annoyed response as a function of DNL. Identical to the mail survey's Question 5e, the telephone respondent was given choices of "not at all," "slightly," "moderately," "very," or "extremely" to the telephone survey's Question 1e. A respondent was identified to be 'highly annoyed' if they answered either of the latter two choices (very or extremely). The dashed lines represent the confidence interval surrounding the curves.

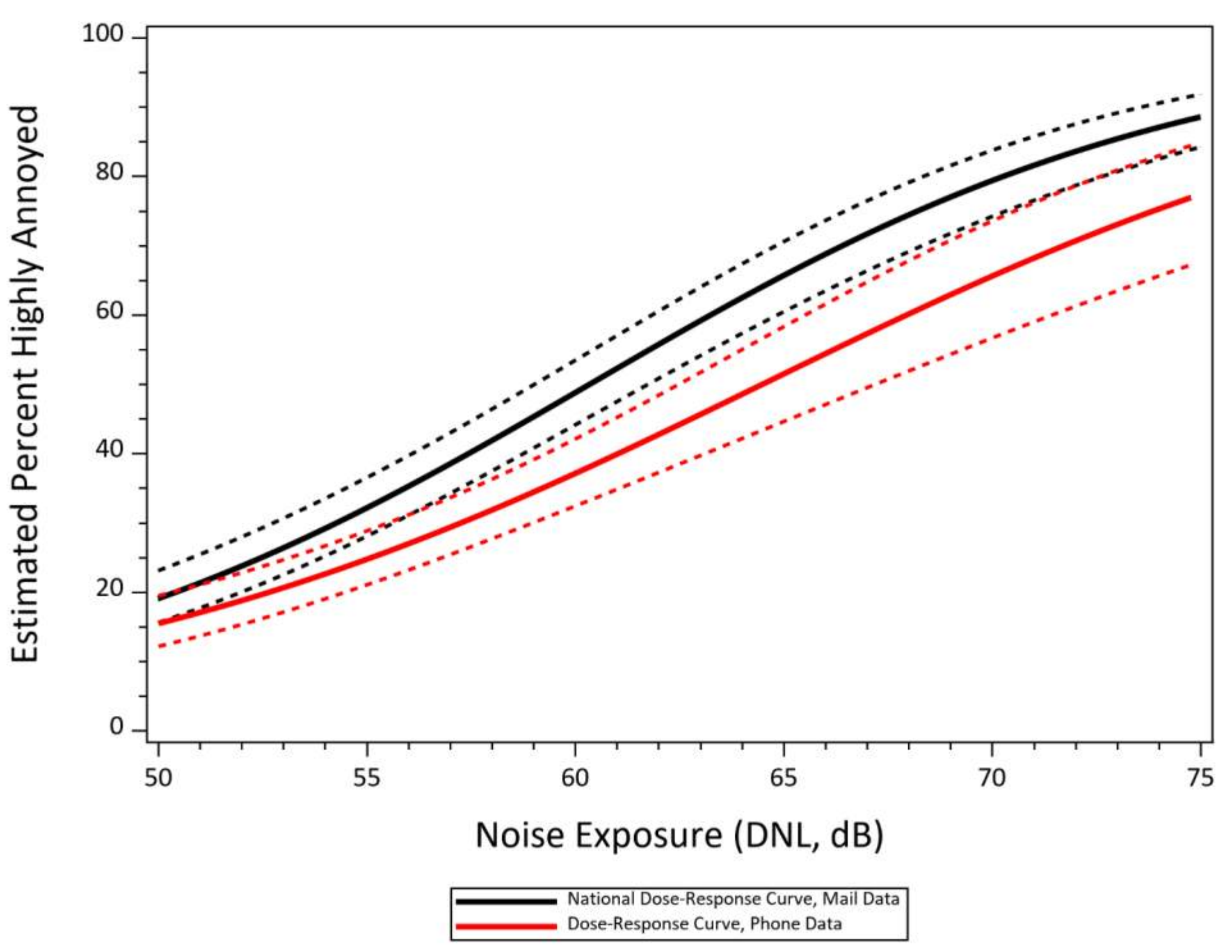

Figure D-1. Comparison of National Dose-response Curve (black lines) to Telephone Survey-derived Dose-response Curve (red lines), with 95 Percent Confidence Intervals on Annoyance for a given DNL (dashed lines)

Figure D-2 shows the curves of Figure D-1 with curves generated from subsets of respondents from both surveys. The blue curve represents the annoyance response to the mail survey, but limited to the households who also responded to the telephone survey (n=2,328). The green curve represents the annoyance response to the telephone survey, but for a subset of households where the same of respondent is thought to have answered both the mail and phone surveys -- as described in Section D.2.1 (n=1,050).

From Figure D-2, it is clear that there is very little difference in the annoyance reported in the mail survey between households who responded to the telephone survey versus all mail respondents (blue and black lines). However, there is a difference in annoyance levels reported in the telephone survey versus the mail survey (red and black lines). The reported telephone survey-derived annoyance level is generally lower than the reported mail annoyance level. Further, when we limit the phone data to those respondents we suspect are the same across modes, we see that they exhibit a similar dose-response to all phone respondents (green and red lines).

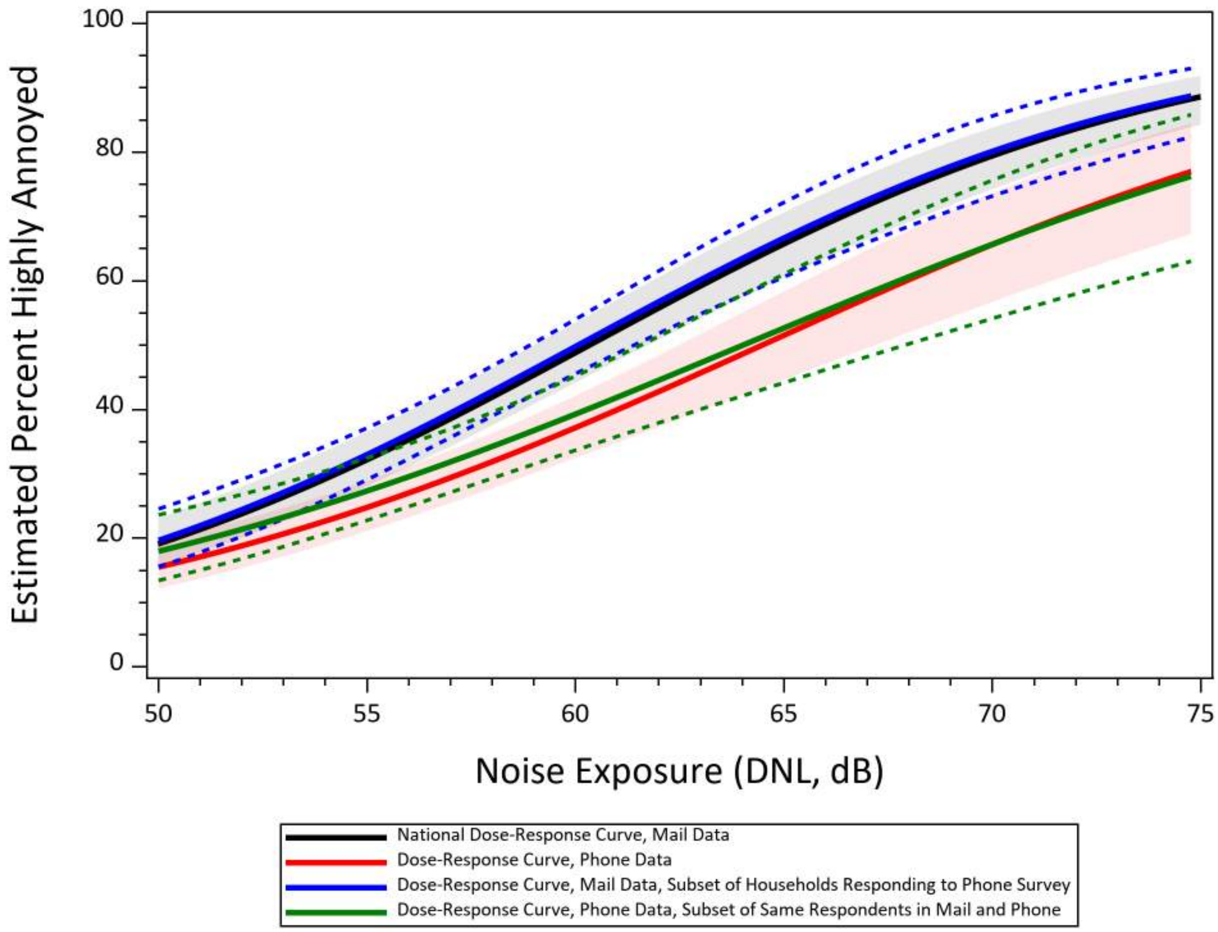

Figure D-2. Reported Annoyance as a Function of DNL for Mail and Telephone Respondents, with 95 Percent Confidence Intervals on Annoyance for a given DNL (dashed lines and shaded areas)

Table D-4 provides a cross tabulation of highly annoyed responses for the mail and telephone surveys for the telephone respondents. Nearly 78 percent (1,810) of respondents provided the same level of annoyance in both surveys (shown in bold).

Table D-4. Highly Annoyed Responses for Mail and Telephone Surveys for Telephone Respondents

Mail response	Telephone response	
	Not highly annoyed	Highly annoyed
Not highly annoyed	**1207 (52%)**	147 (6%)
Highly annoyed	371 (16%)	**603 (26%)**

Table D-5 is set-up identically to Table D-4 except the analysis was restricted to those in which it appears the same person (based on birth date) responded to both the mail and telephone surveys. In this subset, 836 (79 percent) of respondents provided the same level of annoyance in both surveys. We find that even for those respondents who we believe are the same for both surveys, the response to the survey was different between the two modes for more than 20 percent of respondents. This is essentially the same result as when looking at all telephone respondents. A paired t-test, comparing the mail response to the telephone response for those that responded to both surveys, yielded a p-value of less than 0.001, indicating a significant difference between the two responses.

Table D-5. Highly Annoyed Responses for Mail and Telephone Surveys where Telephone Respondent appears to be the Same as the Mail Respondent

Mail response	Telephone response	
	Not highly annoyed	Highly annoyed
Not highly annoyed	**550 (52%)**	76 (7%)
Highly annoyed	138 (13%)	**286 (27%)**

Table D-6 shows the inverse of Table D-5, i.e., it shows the annoyance responses across surveys in households where the respondent may be different, based on birth month and year, between the mail and telephone surveys. Here again, we see a similar trend in that the annoyance reported in the telephone survey trends lower on average. In this subset, 974 (76 percent) of respondents provided the same level of annoyance in both surveys. Where they differed, they were more likely to report lower annoyance in the telephone survey.

Table D-6. Highly Annoyed Responses for Mail and Telephone Surveys where Telephone Respondent appears to be Different than the Mail Respondent

Mail response	Telephone response	
	Not highly annoyed	Highly annoyed
Not highly annoyed	**657 (51%)**	71 (6%)
Highly annoyed	233 (18%)	**317 (25%)**

D.2.3 Hypotheses Explaining the Differences in Annoyance between Surveys

Keeping in mind that the majority of respondents did not change their annoyance report, there are several possible explanations for the difference in responses by mail and telephone among those who did change. We offer the following three hypotheses to explain the difference:

1. Respondents did not follow the random selection protocol (adult with next birthday) for the mail survey and instead the most annoyed respondent participated, whereas the telephone survey had higher adherence to the random selection protocol.

2. The telephone survey was impacted by non-response bias, whereas the more highly annoyed respondents were less inclined to participate.
3. Telephone respondents were exhibiting social desirability bias, whereby they reported lower levels of annoyance during the interviewer-administered questionnaire.

Each hypothesis is described below.

Hypothesis 1 – self-selection bias. This hypothesis supposes the more highly annoyed respondents self-selected into mail versus phone survey. The ACRP 02-35 study (Miller et al. 2014a) had an 86 percent adherence rate to its selection protocol, which is a better rate than in other studies (Lind, Link, and Oldendick 2000; Olson, Stange, and Smyth 2014). While the adherence rate was not calculated for the NES, it is not expected to explain the dose-response differences, because as indicated in Tables D-4 through D-6, percent highly annoyed tended to be higher for the mail survey; regardless of who in the household responded to the two survey modes.

Hypothesis 2 – non-response bias on the phone survey. The second hypothesis presumes that the more highly annoyed respondents in the mail survey did not participate in the phone survey. The curves presented in Figure D-2 do not support this hypothesis. When controlled for households that responded to the phone survey, we see that the mail-reported annoyance (blue line) is essentially the same as the full sample of mail respondents (which includes the approximately 75 percent of households who did not participate in the telephone survey).

Hypothesis 3 – *social desirability bias*. The third hypothesis presumes there is a mode effect, i.e., people respond differently when the survey was interviewer-administered (telephone) versus self-administered (mail). In other words, we may have observed what is termed a social desirability bias between the two modes (de Leeuw 2005; Kreuter et al. 2008). If this is the case, on average, respondents may have been less willing to report being highly annoyed during the interviewer-administered survey (telephone) than in the more anonymous self-administered mode (mail survey). The reason for this response is to sound more agreeable or exhibit more socially acceptable/desirable behavior. The mode effect between mail and telephone responses was explored in Chapter 8 of the ACRP 02-35 study and the results were inconclusive due to small sample sizes.

To further explore this concept in the NES data, Figure D-3 compares the average reported annoyance level on all items[10] in the survey across mail and telephone modes. The average annoyance level reported in the telephone surveys are the same or lower for all items, except for the two items titled “Other Noises” and “Other Problems.” Further, as evidenced in Figure D-2 above, when controlling for the same respondents across modes (green line), the phone percent highly annoyed is similar to the percent highly annoyed of all phone respondents (red line).

[10] These are parts ‘a’ through ‘m’ of the mail questionnaire’s question 5 and the telephone interview’s question 1. The questions were “Thinking about the last 12 months or so, when you are here at home, how much does *insert text from a-m* bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?”

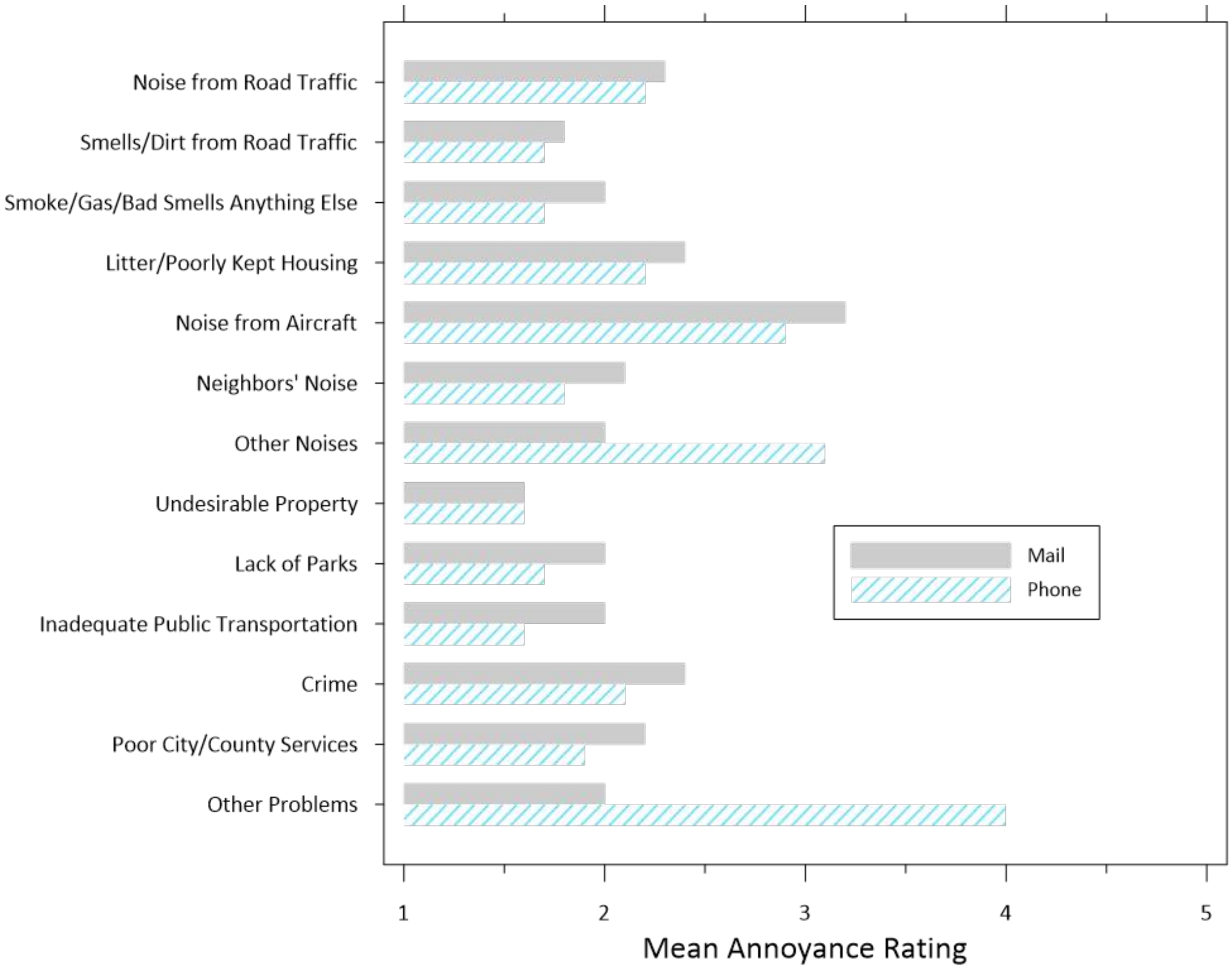

Figure D-3. Average Annoyance Reported on Mail and Telephone Surveys by Item

In conclusion, with the available evidence, the third hypothesis (social desirability) seems to be the best explanation for the difference in reported percent highly annoyed across survey modes. Given what is known about survey mode effects, we suggest the mail response was closer to the "truth" than the phone response because the respondents would have been less inclined to temper their responses in the self-administered mail survey. In addition, the mail survey obtains significantly higher response rates, thus capturing the percent highly annoyed from a larger set of the population.

D.3 Exploratory Factor Analysis

In order to better understand the relationship of the answers given by the respondents to their annoyance from aircraft noise in PALAC, an Exploratory Factor Analysis (EFA) was conducted.[11] In addition to the summary provided here, Section D.5 provides further technical details on EFA, including how the factors were developed.

Due to the potential non-response bias and because these analyses are based on unweighted data, caution should be used before utilizing these data to inform any potential actions. The phone survey findings should therefore be viewed as exploratory topics, which may provide direction for further research.

The telephone survey's questions resulted in 87 analytic variables[12], the focus of which was the variable PALAC (Question 1e). Of the remaining 86 variables, the 17 variables listed in Table D-7 were excluded from the EFA because of one of the following reasons:

1. Less than 50 percent of the respondents provided an answer
2. Exploring latent structures that represent demographic information is not desirable and any factor(s) identified would be hard to interpret
3. Their correlations to aircraft noise annoyance are highly similar to PALAC

The objective of an EFA is to find one or more groups of variables, called "factors", which summarize complex inter-relationships of observed variables. The EFA of the survey's 69 applicable variables (from 54 questions) resulted in the grouping of 32 variables into seven (7) factors, shown in Table D-8. To evaluate the importance of factor to the outcome of interest, i.e., to rank the factors, a set of multinomial logistic regression models[13] was run with PALAC as the outcome and each factor score as the predictor. The "pseudo R-square" value was output to reflect the amount of information gain after adding the predictor, compared to the model without any predictor. It is called *pseudo* because it does not reflect the amount of variance explained by the predictor as in a linear regression model.[14] However, similar to the regular R-square index, the larger the value of pseudo R-square, the stronger the relationship between PALAC and the extracted factor.

Table D-8 lists the pseudo R-square values for each Factor. Factor 7 (Startle, Frighten or Awaken) had the largest pseudo R-square value meaning it had the strongest association with the PALAC rating, followed by Factor 3 (General traffic noise/smells rating) then Factor 4 (Safety concerns).

[11] Using the SAS procedure called PROC FACTOR

[12] To facilitate interpretation of EFA estimates, questions with nominal options (e.g., categories that do not have a natural order such as male/female) need to be dummy-coded. The number of dummy variables is one less than the valid response levels, where one level is chosen as a reference group to avoid redundant information. The result is that we end up with more analytic variables for the EFA than numbered survey questions. Further, some question numbers comprise multiple questions, such as the annoyance questions in Q1 (e.g., 1a, 1b, 1c, etc.).

[13] Using PROC LOGISTIC in SAS

[14] Pseudo R-square is an analog of the usual R-square in multiple linear regression.

Table D-7. Variables Excluded from the EFA

Reason for Excluding from EFA	Variable Name	Telephone Survey Question No.	Telephone Survey Question
Less than 50% of respondents provided an answer (primarily due to skip patterns)	PALOtherNse	1gOS	{T12H}, how much does <OTHER NOISE> bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
	PALOthProb	1mOS	{T12H}, how much does <OTHER PROBLEM> bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
	PHearAC	6	Have you ever **heard the sound from an aircraft** when you were here at home? (y/n)
	PALACWake	8a	{T12H}, have the aircraft bothered, disturbed or annoyed you **by waking you up or keeping you awake at night**? Would you say extremely, very, moderately slightly, or not at all?
	PALACStartle	8b	{T12H}, have the aircraft bothered, disturbed or annoyed you **by startling or surprising you**? Would you say extremely, very, moderately slightly, or not at all?
	PALACFrighten	8c	{T12H}, have the aircraft bothered, disturbed or annoyed you **by frightening you**? Would you say extremely, very, moderately slightly, or not at all?
	PNumApts	9a	Approximately, how many apartments are there in your building?
	PALACGrd	17	{T12H}, how much have the **aircraft sitting on the ground or moving around on the ground** on the airport property bothered, disturbed or annoyed you: extremely, very, moderately, slightly, or not at all?
	PContactAP	26a	Was the **airport contacted** directly? (y/n)
Undesirable latency/Difficult Interpretation	PAgeCat	45	In what month and year were you born?
	PHighestEd	46	What is the **highest level of school** you have completed or the highest degree you have received?
	PGender	47	[ASKED IF INTERVIEWER WAS NOT SURE] Are you male or female?
	PHispanic	48	Are you Spanish, Hispanic, or Latino?
	PRaceEthnicity	49	What **race or races** do you consider yourself to be? [GIVEN A LIST and asked to SELECT ALL THAT APPLY.]
	PHHIncome	50	What is the approximate **total income** from everyone in this household including such things as wages, salary, interest, pensions, or government payments? Would you say [READ RESPONSES]: [IF THEY REFUSE TO ANSWER, PROBE:] Is it less than 25 thousand dollars a year? From 25 to 50 thousand? 50 to 100 thousand? 100 to 200 thousand? Or over 200 thousand a year?
Highly similar to PALAC	PGenNseRtAC	5	{T12}, what number from 0 to 10 best shows **how much you are bothered, disturbed or annoyed by the noise from aircraft**?
	PRespBothrdACNse	37	To summarize your opinion about aircraft noise in this neighborhood, please consider all we have discussed and use a zero to four opinion thermometer where zero is not at all annoyed, four is extremely annoyed and one to three are in between. What number from zero to four shows **how much you are bothered or annoyed by aircraft noise in this neighborhood**?

{T12} is an abbreviation for the phrase "Thinking about the last 12 months or so,"
{T12H} is an abbreviation for the phrase "Thinking about the last 12 months or so, when you are here at home,"

Table D-8. Factors and their Composition, sorted by their Pseudo R-square Value

Factor	Factor Theme	Pseudo R-Square	Question No.	Variable Name	Survey Question
7	Startle, Frighten or Awaken	0.373	7a	PACWake	Has an aircraft ever **waked you up or kept you awake** at night when you are at home? (y/n)
			7b	PACStartle	Has an aircraft ever **startled or surprised** you when you are at home? (y/n)
			7c	PACFrighten	Has an aircraft ever **frightened** you when you are at home? (y/n)
3	General traffic noise/smells rating	0.247	1a	PALNseTraffic	{T12H}, how much does **noise from cars, trucks or other road traffic** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1b	PALSmellTraffic	{T12H}, how much does **smells or dirt from road traffic** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1c	PALSmellOther	{T12H}, how much does **smoke, gas or bad smells from anything else** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			3	PGenNseRt	Now please rate noise on a 0 to 10 opinion scale for how much the noise bothers, disturbs or annoys you when you are here at home. First about **noise in general**. {T12}, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by the noise in general when you are here at home?
			4	PGenNseRtTraffic	{T12}, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by the **noise from cars or trucks or other road traffic**?
4	Safety concerns	0.175	40	PCNACCrash	When you are at home or around the neighborhood, how fearful or concerned are you that an **aircraft might crash nearby**: Are you extremely, very, moderately, slightly, or not at all concerned that an aircraft might crash?
			41	PCNACHurtYou	When you are at home, how concerned are you that an **aircraft crash might actually hurt you or your own property**: Are you extremely, very, moderately, slightly, or not at all concerned that an aircraft might hurt you or your property?
			43	PCNTrnCrash	When you are at home or around the neighborhood, how **fearful or concerned are you that there might be a passenger train or freight train derailment or crash nearby**? Are you extremely, moderately, slightly, or not at all concerned that there might be a train crash?
2	Airport effort to deal with aircraft noise	0.17	28	PResInfluenAP	How much do you think that **residents' actions and views can influence <AIRPORT> noise policy**? Do you think that residents' views can very greatly influence policy, greatly influence policy, moderately influence, slightly influence, or not at all influence policy?
			30	PAPRcgnzRes	To what extent do you think <AIRPORT> **officials recognize the community residents' feelings about aircraft noise?** Do you think the officials recognize the residents' feelings extremely well, very well, moderately well, slightly, or not at all?
			32	PAPTrusted	How completely do you feel you can **trust the <AIRPORT> officials to work fairly with the community by following official, agreed-upon procedures and providing accurate information?** Do you feel you can rely upon the <AIRPORT> officials completely, considerably, moderately, slightly or not at all?
			31	PAPInformRes	How fully do you feel the <AIRPORT> **officials keep community residents informed about the planning for airport changes?** Do you think the officials keep communities extremely well informed, very well informed, moderately well informed, slightly informed, or not at all informed?

Abbreviations: {T12H} Thinking about the last 12 months or so, when you are here at home; {T12} Thinking about the last 12 months or so.

Factor	Factor Theme	Pseudo R-Square	Question No.	Variable Name	Survey Question
1	Concerns or complaints with neighborhood	0.153	1b	PALSmellTraffic	{T12H}, how much does **smells or dirt from road traffic** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1c	PALSmellOther	{T12H}, how much does **smoke, gas or bad smells from anything else** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1d	PALLitter	{T12H}, how much does **litter or poorly kept up housing** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1f	PALNeighbor	{T12H}, how much does your **neighbors' noise or other activities** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1h	PALBusiness	{T12H}, how much does **undesirable business, institutional or industrial property** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1i	PALNoParks	{T12H}, how much does a **lack of parks or green spaces** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1j	PALPubTransit	{T12H}, how much does **inadequate public transportation** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1k	PALCrime	{T12H}, how much does the **amount of neighborhood crime** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1l	PALCitySvces	{T12H}, how much does **poor city or county services** bother, disturb, or annoy you: not at all, slightly, moderately, very, or extremely?
			1m	POthProb	Are there any other problems that you notice when you are here at home?
			2	PRateNeighborhood	Now considering how you feel about everything in your neighborhood, how would you **rate your neighborhood as a place to live** on a scale from 0 to 10 where 0 is worst and 10 is best?
5	Knowledge of aircraft noise issues	0.066	18	PKnowCommIssues	How **knowledgeable are you about noise and other community environmental issues** in the <BASECITY> area: Are you extremely knowledgeable, very knowledgeable, moderately knowledgeable, slightly knowledgeable, or not at all knowledgeable?
			21	PLrnMedia	How much have you **learned about your community's aircraft noise issues from media reports in the newspaper or on radio or TV**: a great deal, somewhat, a little or nothing at all?
			22	PLrnLocalInfo	How much have you **learned about your community's aircraft noise issues from a community newspaper or other more local organization, newsletter or local internet source:** a great deal, somewhat, a little or nothing at all?
			25	PCommGroup	Are any **community groups or other organizations trying to reduce aircraft noise or don't you know?** y/n
			26	PHHActOnACNse	Have you or anyone in your household **ever tried to get something done about aircraft noise** such as telephoning the airport, sending a message, writing a letter, contacting an official, going to a meeting, joining a group or doing something else? y/n
6	Beliefs about noise reduction by officials or pilots	0.016	33a	PRedACNseAPOff	How much do you think the **officials who run <AIRPORT> could reduce the aircraft noise** around here: Could the officials who run <AIRPORT> reduce the noise very greatly, greatly, moderately, slightly or not at all?
			33b	PRedACNseAPOthGov	How much do you think **other government officials could reduce the aircraft noise around here:** Could other government officials reduce the noise very greatly, greatly, moderately, slightly or not at all?
			33c	PRedACNseAPilots	How much do you think the **pilots flying the planes could reduce the aircraft noise around here:** Could the pilots flying the planes reduce the noise very greatly, greatly, moderately, slightly or not at all?

Abbreviations: {T12H} Thinking about the last 12 months or so, when you are here at home; {T12} Thinking about the last 12 months or so.

Twenty-two questions from the phone survey were not well represented by the extracted factor structure. In other words, each of these questions has a weak connection with the other questions in the survey. Therefore, they could not be grouped with others through EFA. These 22 questions' association with PALAC were evaluated and ranked by their pseudo R-square value. Table D-9 shows the Factors from Table D-8 and the remaining 22 questions and their pseudo R-square values – overall and for each of four (4) strata of aircraft noise exposure in 5-dB intervals of DNL.[15]

The top eight (8) values overall and within each DNL stratum have been color-coded to provide a visual of the trends in rankings across the DNL strata. As shown in Table D-9, key takeaways are:

- Factor 7 was the highest ranked in all but one DNL strata and Factor 3 was the second highest, except in the 65+ stratum, where the two Factors switched rankings
- Questions 39 (PACPctFlyOverHCAT: What percent fly directly over your property) or 23 (PNbrsViewACNse: Closest neighbors making their views known about aircraft noise) came into the top-5 ranking in many DNL strata
- Factors 5 and 6 were outranked by several individual variables
- Question 29 (PhomeInsulat: Has your home been sound insulated) was the lowest ranked variable or Factor

Note that while Question 29 (PHomeInsulat: Has your home been sound insulated?) had the lowest overall value among all ranked factors and variables, it may have been due to a misunderstanding of the survey question. The intended purpose for this question/variable was to determine if respondents whose homes were sound insulated through an FAA-sponsored residential sound insulation program were more or less annoyed than those who were not sound insulated. About ten percent of the respondents were not sure if their homes had been sound insulated. Of the remainder, about two-thirds indicated their home had been sound insulated and these respondents had a lower mean percent highly annoyed by aircraft noise. However, a significant proportion of those who claimed their homes were sound insulated also did not live in proximity to the airport and, therefore, were not likely to be eligible for FAA-sponsored sound insulation.[16]

The poor performance of this variable is, therefore, likely due to the wording of the question, which did not make it sufficiently clear that it was referring to FAA-sponsored residential sound insulation programs. Some respondents may have also considered their home sound insulated if only limited treatments had been applied, such as for a media room. Additionally, many homes have some form of insulation for non-acoustical purposes, which may have caused further confusion with this question.

[15] The dose-response curve from the mail component of the NES was based on responses in five (5) intervals/strata of DNL: 50-55 decibels (dB), 55-60 dB, 60-65 dB, 65-70 dB and 70 DNL or more ("70+"). As the telephone survey had only 52 respondents in the 70+ stratum, that group was combined with the 65-70 dB stratum to allow for increased statistical power. The combined stratum is denoted as "65+".

[16] FAA sound insulation eligibility requires that homes are exposed to DNL of at least 65 dB. For complete residential sound insulation eligibility requirements, see FAA Order 5100.38D, National Policy, Airport Improvement Program Handbook, September 30, 2014.

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Table D-9. Ranking Factors and Questions by DNL Stratum

Factor	Question No.	Variable Name	Factor Theme or Survey Question	Pseudo R-Square Values (with rank of top 8)				
					DNL Stratum (dB)			
				Overall	50-55	55-60	60-65	65+
F7			Startle, Frighten or Awaken	0.373 (1)	0.319 (1)	0.377 (1)	0.348 (1)	0.300 (2)
F3			General traffic noise/smells rating	0.247 (2)	0.201 (2)	0.239 (2)	0.273 (2)	0.314 (1)
F4			Safety concerns	0.175 (3)	0.148 (4)	0.109 (7)	0.177 (5)	0.150 (8)
F2			Airport effort to deal with aircraft noise	0.170 (4)	0.148 (5)	0.165 (3)	0.166 (6)	0.179 (6)
F1			Concerns or complaints with neighborhood	0.153 (5)	0.124 (8)	0.139 (4)	0.187 (3)	0.186 (5)
n/a	39	PACPctFlyOverHCAT	Thinking about all the aircraft you notice when you are at home, about **what percent fly directly over your property?**	0.152 (6)	0.156 (3)	0.134 (5)	0.132 (7)	0.217 (3)
n/a	23	PNbrsViewACNse (1)	How about your **closest neighbors making their views known about aircraft noise:** Have they clearly made their views known, have they revealed only a little about their views, or have they kept their views to themselves?	0.150 (7)	0.129 (6)	0.132 (6)	0.179 (4)	0.188 (4)
n/a	14	PACNseChg	Since you moved here, has the total **amount of aircraft noise increased, decreased or stayed about the same?**	0.118 (8)	0.128 (7)	0.090 (7)	0.125 (8)	0.164 (7)
n/a	44	PDangerTrf	Which type of **traffic, if any, do you feel is the most dangerous for you or your property** when you are here at home: road traffic, railway trains or aircraft?	0.095	0.097	0.045	0.115	0.120
n/a	15	PACNseFuture (1)	What do you think **aircraft noise will be like here in the next few years:** Do you think the total amount of aircraft noise will increase, decrease or stay about the same here?	0.092	0.095	0.066	0.103	0.128
F5			Knowledge of aircraft noise issues	0.066	0.063	0.041	0.044	0.104
n/a	36	PRespSenstve	How **sensitive are you generally to noise** of all kinds: extremely sensitive, very sensitive, moderately sensitive, slightly sensitive, or not at all sensitive?	0.057	0.075	0.078	0.070	0.097
n/a	24	PAuthDisputes (1)	As far as you know, have there ever been **disputes between airport authorities and community residents about aircraft noise** around <AIRPORT>? y/n	0.043	0.023	0.054	0.059	0.081
n/a	38	PACTakeOffLand (1)	Are most of the aircraft that you notice from your home **coming down for a landing at the airport, taking off from the airport, are about half landing and about half taking off, are they doing something else, or don't you know?**	0.031	0.041	0.056	0.039	0.071
n/a	42	PCNTrfAccdnt	When you are at home or around the neighborhood, **how fearful or concerned are you that there might be car or truck road traffic accidents nearby:** Are you extremely, moderately, slightly, or not at all concerned that there might be a road traffic crash?	0.029	0.058	0.045	0.058	0.110
n/a	34	PAPRedACNse (1)	How fully do you feel the <AIRPORT> officials **keep community residents informed about the planning for airport changes?** Do you think the officials keep communities extremely well informed, very well informed, moderately well informed, slightly informed, or not at all informed?	0.028	0.025	0.048	0.051	0.064

Factor	Question No.	Variable Name	Factor Theme or Survey Question	Pseudo R-Square Values (with rank of top 8)				
					DNL Stratum (dB)			
				Overall	50-55	55-60	60-65	65+
n/a	35	PAPImportant	How **important do you think that <AIRPORT> is** for the <BASECITY> area: Is <AIRPORT> extremely important, very important, moderately important, slightly important or not at all important?	0.026	0.038	0.039	0.060	0.071
n/a	12	PHrOutsideCAT	Think about those weeks in the year when you spend the most time out-of-doors in your yard or on your porch, deck or balcony. At that time of year, **how many hours a week would you say you are out-of-doors at home?**	0.025	0.031	0.019	0.003	0.019
n/a	16	PHrdACGrd	When you are at home, have you **ever heard aircraft sitting on the ground or moving around on the ground** on the airport property? y/n	0.016	0.023	0.062	0.055	0.063
F6			Beliefs about noise reduction by officials or pilots	0.016	0.026	0.012	0.010	0.017
n/a	11	PWkDayNotHome	How many of the five weekdays from Monday through Friday are you usually out away from home most of the day that is 8 hours or more? Are you usually away, on all five weekdays, or fewer weekdays, or are you usually not away on any weekday? **How many weekdays are you usually away?**	0.012	0.030	0.031	0.043	0.060
n/a	19	PAPTripsYrCAT	About how many **trips a year do you and other members of your household make from the <AIRPORT>?** One trip is considered as round-trip travel and includes all family members traveling together. If any family members travel separately, please count those as separate trips as long as they use <AIRPORT>.	0.010	0.030	0.019	0.042	0.062
n/a	9	PBldgTp	Which of the following best **describes the building** where you live?	0.009	0.029	0.022	0.038	0.065
n/a	1g1	POtherNse	Are there **any other noises you hear** when you are here at home? y/n	0.007	0.021	0.012	0.011	0.015
n/a	13	PYrMovedCAT	In what **year and month did you move to your home** here?	0.006	0.019	0.018	0.041	0.089
n/a	27	PWayToComplain (2)	If someone wants to make a complaint about aircraft noise these days, do you know **if there is a convenient way to contact <AIRPORT>?** y/n	0.004	0.007	0.006	0.005	0.032
n/a	10	POwnRent	Do you **own your home or are you renting?**	0.003	0.007	0.005	0.010	0.052
n/a	20	PWrkAtAP	Do you or anyone else in your household **work at <AIRPORT> or work for a company or organization that does business with <AIRPORT>?** y/n	0.002	0.007	0.003	0.008	0.036
n/a	29	PHomeInsulate	Has your home been sound insulated? y/n	0.002	0.006	0.004	0.021	0.025

(1)"Don't Know" was a valid response
(2) "Don't Know" was recoded to "No"

Rank/Color:	1	2	3	4	5	6	7	8

D.4 Characteristics of Highly and Not-highly Annoyed Respondents

Continuing to explore the potential cause of aircraft noise annoyance and examine why some people are highly annoyed by aircraft noise or not, a Classification and Regression Tree (CART) analysis was performed to identify the characteristics of highly and not-highly annoyed respondents. CART analysis is a decision tree method to identify and select predictors that are strongly associated with an outcome while accounting for confounding effects. When a large number of predictors are involved, CART allows for an exploration of complex interactions among predictors. Variable selection in CART is based on the measures of variable importance and overall model performance is evaluated in terms of prediction accuracy through cross-validation. More accurate prediction on the outcome indicates a better model fit.

The CART model employed here was used to identify the factors/variables that best predict a respondent's probability of being highly annoyed (or not). To control for the influence of aircraft noise exposure measured by DNL, CART analysis was conducted separately within four DNL strata. The results of the CART analysis are presented below while technical details are in Section D.6.

Tables D-10 through D-13 present the variables selected in the final model for each DNL stratum, followed by a description of HA and not HA based on the scores of the selected variables. The order of the variables in each stratum reflects the importance of the variables in the decision tree analysis, from highest to lowest. The CART analysis resulted in some strata having a greater number of important variables than other strata.

In all DNL strata, Factor 7 (startled, frightened, or awakened) was found to be the most important predictor of annoyance. With the exception of the DNL 65+ stratum, the CART analysis found additional contributing factors/variables. Each of these additional variables was interrelated with the other items, i.e., a person did not need to exhibit all of these factors to be highly annoyed (or not) and combinations of these variables were at play. However, the presence or absence of Factor 7 was a strong predictor of the degree of aircraft noise annoyance, regardless of the other characteristics.

Table D-10. Variables Selected and Characteristics of HA and Not HA, DNL 50-55 dB

Variable Selected		Description	
		Not Highly Annoyed	Highly Annoyed
Factor 7	Startle, Frighten or Awaken	They are not startled, frightened, or awakened by aircraft.	They are started, frightened, or awakened by aircraft
Factor 2	Airport effort to deal with aircraft	They believe the airport is working collaboratively with them.	They do not believe the airport is working collaboratively with them.
Factor 5	Knowledge of aircraft noise issues	They do not learn much about the aircraft noise issue from various sources.	They learn a lot about the aircraft noise issue from various sources.
Factor 4	Safety concerns	They are not concerned with possible accident or damage from aircraft or road traffic	They are concerned with possible accident or damage from aircraft or road traffic

Table D-11. Variables Selected and Characteristics of HA and Not HA, DNL 55-60 dB

Variable Selected		Description	
		Not Highly Annoyed	Highly Annoyed
Factor 7	Startle, Frighten or Awaken	They are not startled, frightened, or awakened by aircraft.	They are started, frightened, or awakened by aircraft
Factor 3	General traffic noise/smells rating	They are not annoyed by the traffic noise or smells in their neighborhood.	They are annoyed by the traffic noise and smells in their neighborhood.

Table D-12. Variables Selected and Characteristics of HA and Not HA, DNL 60-65 dB

Variable Selected		Description	
		Not Highly Annoyed	Highly Annoyed
Factor 7	Startle, Frighten or Awaken	They are not startled, frightened, or awakened by	They are started, frightened, or awakened by aircraft
Factor 2	Airport effort to deal with aircraft	They believe the airport is working collaboratively with	They do not believe the airport is working collaboratively with
PNbrsViewACNse (Q#23)	Phone Neighbors Views Known On Aircraft Noise	Their neighbors do not reveal their views on aircraft noise.	Their neighbors make their views on aircraft noise clearly known.

Table D-13. Variables Selected and Characteristics of HA and Not HA, DNL 65+ dB

Variable Selected		Description	
		Not Highly Annoyed	Highly Annoyed
Factor 7	Startle, Frighten or Awaken	They are not startled, frightened, or awakened by aircraft.	They are startled, frightened, or awakened by aircraft

D.5 Technical Details of the Exploratory Factor Analysis

This section provides the technical details on factor development for the Exploratory Factor Analysis presented in Section D.3. Section D.5.1 describes how the data was prepared. Section D.5.2 explains how the seven factors were derived. Section D.5.3 shows the loadings and distributions for each of the factors.

D.5.1 Data Preparation

Data preparation began with screening out variables because of missing data and other reasons explained in Section D.4. Data preparation concluded with recoding and dummy coding of variables and treating missing values as described in the following two subsections, respectively.

D.5.1.1 Recode and Dummy Code Variables

Some variables had high levels of "Don't Know" responses, which in most cases would be treated as missing. However, we recoded the "Don't Know" response and included it in the analysis if it met one of two conditions:

- If the question is phrased "Do you know…", then a response of "Don't Know" should be combined with "No" response, e.g., PWayToComplain.
- "Don't Know" indicates that respondents do not have enough information to express an opinion and thus provides useful data on the topic, e.g., PACNseFuture, PACTakeOffLand, PAPRedACNse, PAuthDisputes, PNbrsViewACNse, PCommGroup.

If a variable is nominal, meaning its categories do not have a natural order (e.g. male/female for gender), then we need to dummy code it so the EFA estimates are interpretable. The dummy variables take the value of 0 and 1 to indicate the presence of a response category. The number of dummy variables is one less than the valid response levels of a particular variable, where one level is chosen as a reference group to avoid redundant information. For example, PBldgTp (building type) was replaced by 5-1=4 dummy variables, among which PBldgT1=1 if PBldgTp=1, =0 if PBldgTp= 2,3,4,5 etc. The dummy coding was applied to PBldgTp and PDangerTrf where "Don't Know" was treated as a true missing value, whereas "Don't Know" was valid and used as reference group in the variables PACNseFuture, PACTakeOffLand, PAPRedACNse, PAuthDisputes, PNbrsViewACNse, and PCommGroup.

D.5.1.2 Treatment of Missing Values

Even after data cleaning and recoding, missing values in the remaining variables still caused problems when producing the covariance matrix. To address this we used the following strategy:

- Used pairwise correlation as the input dataset for the EFA. Unlike standard correlation, which deletes the whole record if any missing values are present, pairwise correlation uses all available observations when calculating the correlation between two variables.
- Calculated factor scores for all records using values derived from multiple imputation to replace missing values. Multiple imputation is a statistical technique to fill in missing values by drawing values from a distribution determined by the non-missing variables. This process was repeated multiple times to obtain approximately unbiased estimates of parameters.

D.5.2 Factor Structure Exploration

A primary reason for using EFA is to examine, in a multi-dimensional way, the 'total variance' present in the data. The convention is to consider the total variance as equal to the number of variables analyzed in the EFA. The extent to which a substantial portion of the total variance is explained by far fewer than observed variables, allows us to reduce the dimensionality of the data to a much smaller number of factors.

The following three subsections describe the process for determining the number of factors selected as well as the choices of extraction and rotation methods. The final factor structure is presented in Section D.5.2.4.

D.5.2.1 Scree Plot

The number of factors was determined by examining a scree plot with factors on the x-axis and eigenvalues on the y-axis. Eigenvalues reflect the amount of variance explained by each factor and are produced through principal components analysis. Here, the variance was represented in terms of scores, which sum to the total number of variables in the model, i.e., 69. As shown in Figure D-4, the amount of variance accounted for by the seventh factor and beyond was small and the points form a nearly flat line. However, the first six factors only account for 33 percent of variance in the data. To achieve at least 50 percent explained variance, the number of factors kept was 16. For the initial run, we kept a large number of factors to check the internal association of the variables.

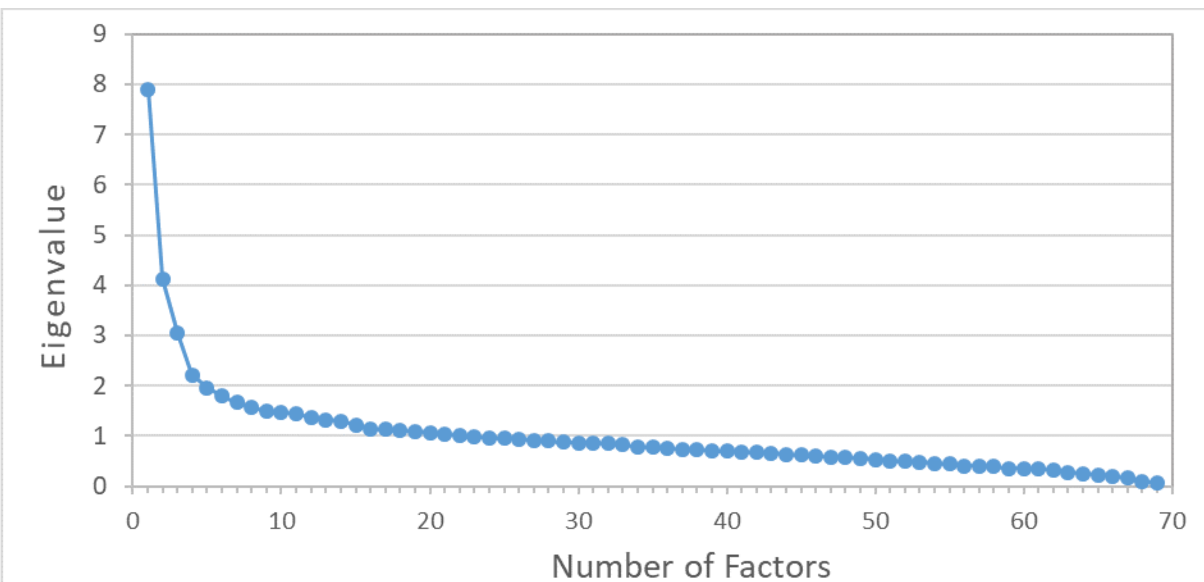

Figure D-4. Scree Plot of Eignenvalues

D.5.2.2 Factor Extraction

The two most commonly used extraction methods are principle axis factoring (PAF) with iterated communalities and maximum likelihood (ML). PAF looks for the least number of factors that explain the shared variance (communality) of observed variables. In the iterated principal factor methods, the communality values are estimated from the loadings obtained from the previous communality estimates. ML extraction seeks to discover factors and factor loadings that optimally reproduce the observed correlation matrix. However, the ML method assumes that the observed variables are normally distributed, which is not held for discrete Likert-scale questions in the current analysis. Since PAF is robust to the requirement of normality, the PAF method was employed to produce factor loadings of every observed variable on every extracted factor.

Factor loadings are the weights of each factor on observed variables. Factor loadings can be positive or negative, which reflect the positive or negative correlations in the correlation matrix. A negative factor loading means that a high value on an observed variable is associated with a low score on the factor. The size, i.e., absolute value, of the loadings determines how the extracted factor is interpreted. As a starting point, an absolute value of 0.3 was the minimum level to consider whether a factor contributes to an observed variable, and an absolute value of 0.5 was considered practically significant. If a variable has low loadings on all extracted factors, this means the particular variable is not well represented in the common factor space.

D.5.2.3 Rotation

The purpose of rotation is to achieve a simple and interpretable factor structure. A simple structure usually means most variables have a large loading on one single factor and small loadings on the others. If the factors are assumed to be uncorrelated with one another, then the rotation is orthogonal, whereas the factors are allowed to be correlated under the oblique rotations. The "promax", an oblique rotation method, was chosen in the current analysis to reflect a more realistic assumption on the relationship between factors, while retaining a simple structure.

If a variable was not loaded highly on any factor after rotation, we excluded the variable from the EFA for its weak association with the other variables in the model. The variables kept were those with a factor loading greater than or equal to 0.25 on one factor in the initial run and 0.3 for later runs. They were loaded on a factor with at least two other questions. If several dummy variables from the same question were loaded on the same factor, we excluded them. This process was repeated until a factor structure where most of variables have only one factor loading over 0.3 was achieved. During the process, 37 variables were excluded. In the end, we extracted seven factors from the 31 variables remaining in the model.

Once the factor structure was decided, factor scores – linear compositions of the observed variables – were calculated and output. The scores were standardized to a mean of 0 and variance of 1 to be used in subsequent analysis. Factor scores were not calculated if any missing values were present. Therefore, we ran 10 imputations to fill in missing values and calculated 10 factor scores for each record based on the imputed data. The final factor scores were obtained by averaging over the 10 factor scores. This analysis included a set of ANOVA, using final factor scores as outcomes and PALAC as a group variable, to test possible group differences among the five rating levels of PALAC. ANOVA, reported as F-test and its associated degrees of freedom, was used to test the null hypothesis that there was no group difference between the factor score means. If the p-value of the F-test was less than 0.05, we rejected the null hypothesis and concluded a significant difference existed.

D.5.2.4 Final Extracted Factors

The variance explained by the seven extracted factors are presented in Table D-16. Among the seven factors, Factor 1 explained the most variance among the 31 variables remaining in the EFA, followed by Factor 3. Table D-17 is the correlation matrix of the extracted factors. We can see that Factor 1 was positively correlated with Factor 3, while Factor 2 and Factor 7 were negatively correlated.

Table D-16. Variance Explained by Extracted Factors Ignoring Other Factors

Factor	Variance
1	4.844
2	2.831
3	4.455
4	3.056
5	2.139
6	1.797
7	2.655

Table D-17. Correlation Matrix of Extracted Factors

Factor	1	2	3	4	5	6	7
1	1	-0.282	0.592	0.329	0.177	0.120	0.300
2	-0.282	1	-0.302	-0.300	0.072	0.060	-0.389
3	0.592	-0.302	1	0.360	0.240	0.146	0.380
4	0.329	-0.300	0.360	1	0.199	0.155	0.370
5	0.177	0.072	0.240	0.199	1	0.243	0.154
6	0.120	0.060	0.146	0.155	0.243	1	0.110
7	0.300	-0.389	0.380	0.370	0.154	0.110	1

Based on the patterns of rotated factor loadings, the seven factors represent the following domains in the phone interview.

- Factor 1: Concerns or complaints with neighborhood
- Factor 2: Airport effort to deal with aircraft noise
- Factor 3: General traffic noise/smells rating
- Factor 4: Safety concerns
- Factor 5: Knowledge of aircraft noise issues
- Factor 6: Beliefs about noise reduction by officials or pilots
- Factor 7: Startle, Frighten or Awaken

D.5.3 Factor Loadings and Distributions

This section presents the variables with absolute values of factor loading greater than 0.3 on extracted factors. In addition to the EFA results, the chi-square tests between the variables and PALAC are also included in the tables. The chi-square test was used to evaluate the dependence between two categorical variables. A p-value less than 0.05 means the two variables are dependent. This additional information is to support further investigation on the interview questions and their relationship with the aircraft annoyance measure.

D.5.3.1 Factor 1: Concerns or Complaints with Neighborhood

Table D-18 presents the variables loaded highly on Factor 1. Using the factor score, the ANOVA result indicates significant group difference between the five rating levels in PALAC ($F_{(4, 2319)}$ = 108.69, $p < 0.0001$).

In Figure D-5 and similar upcoming figures, the boxplots present the distribution of factor scores on the y-axis by the five rating levels of PALAC on the x-axis. In the boxplot, the length of the box represents the distance between the 25th and 75th percentiles, which is called the interquartile range (IQR); the diamond within the box represents the group mean; the horizontal line in the box represents the group median; and the vertical line connects the box and 1.5 times IQR; and the circles are the potential outliers. Any cases falling outside of

3 times IQR are labeled with their record ID. In Figure D-5, the 564th record has an extremely large factor score on Factor 1 versus the other records which selected PALAC=1.

Figure D-5 shows a clearly ascending trend of group means across the five rating levels from 1-Not at all to 5-Extremely bothered/annoyed by aircraft noise. That is, the more annoyed by aircraft noise, the higher the factor score on concerns or complaints with their neighborhood.

The multiple comparison is further used to investigate where the significant difference exists among the five levels of PALAC. The Scheffé's test was employed to control the experiment-wise error rate for all possible contrasts of the group means. The results indicate that the only insignificant difference was between the means of factor scores on PALAC=1 (Not at all) and PALAC=2 (Slightly). All other pairwise comparisons were significant with p less than 0.05.

Table D-18. Questions with High Factor Loadings on Factor 1 (ranked by absolute value of loading)

Variable	Label	Q#	Factor Loading	p value for chi-square test
PALCrime	Phone AL: Crime	1k	0.674	< 0.0001
PALCitySvces	Phone AL: Poor City County Services	1l	0.641	< 0.0001
PALLitter	Phone AL: Litter Poorly Kept Housing	1d	0.615	< 0.0001
PALNoParks	Phone AL: Lack of Parks	1i	0.580	< 0.0001
PRateNeighborhood	Phone Neighborhood Rating	2	-0.580	< 0.0001
PALPubTransit	Phone AL: Inadequate Public Transportation	1j	0.496	< 0.0001
PALNeighbor	Phone AL: Neighbors Noise	1f	0.417	< 0.0001
PALBusiness	Phone AL: Undesirable Business Property	1h	0.410	< 0.0001
POthProb	Phone Other Annoying Problems	1m1	0.322	< 0.0001
PALSmellTraffic*	Phone AL: Smells Dirt from Traffic	1b	0.304	< 0.0001
PALSmellOther*	Phone AL: Smoke Gas Bad Smells Else	1c	0.302	< 0.0001

* PALSmellTraffic and PALSmellOther have factor loadings higher than 0.3 on Factor 3.

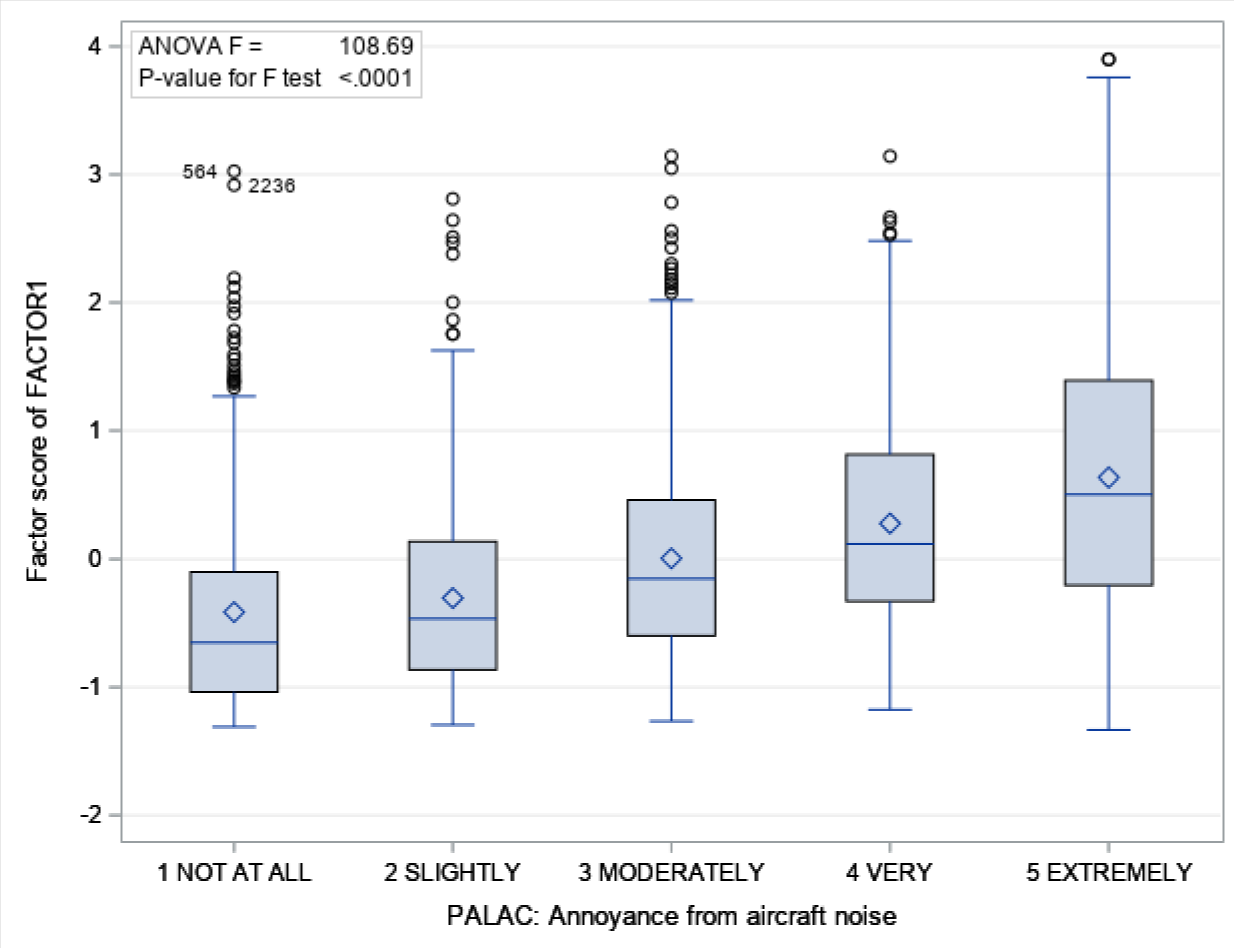

Figure D-5. Distribution of Factor Scores by PALAC for Factor 1

D.5.3.2 Factor 2: Airport Effort to Deal with Aircraft Noise

Table D-19 presents the four variables loaded highly on Factor 2, which are mainly about airport efforts to deal with aircraft noise. The ANOVA was significant ($F_{(4,\,2319)}$ = 121.92, p < 0.0001), and the descending pattern in the distribution of factor scores in Figure D-6 shows that the less respondents believed the airport is making an effort to resolve the aircraft noise issues, the more annoyed they were by aircraft noise. All pairwise comparisons were significant with p less than 0.05, except the comparison between PALAC=1 (Not at all) and 2 (Slightly).

Table D-19. Questions with High Factor Loadings on Factor 2 (ranked by absolute value of loading)

Variable	Label	Q#	Factor Loading	p value for chi-square test
PAPTrusted	Phone Can Trust Airport to Work Fairly	32	0.787	< 0.0001
PAPInformRes	Phone Airport Keeps Residents Informed	31	0.735	< 0.0001
PAPRcgnzRes	Phone Airport Recognize Residents Feelings	30	0.700	< 0.0001
PResInfluenAP	Phone Can Residents Action Influence Airport	28	0.369	< 0.0001

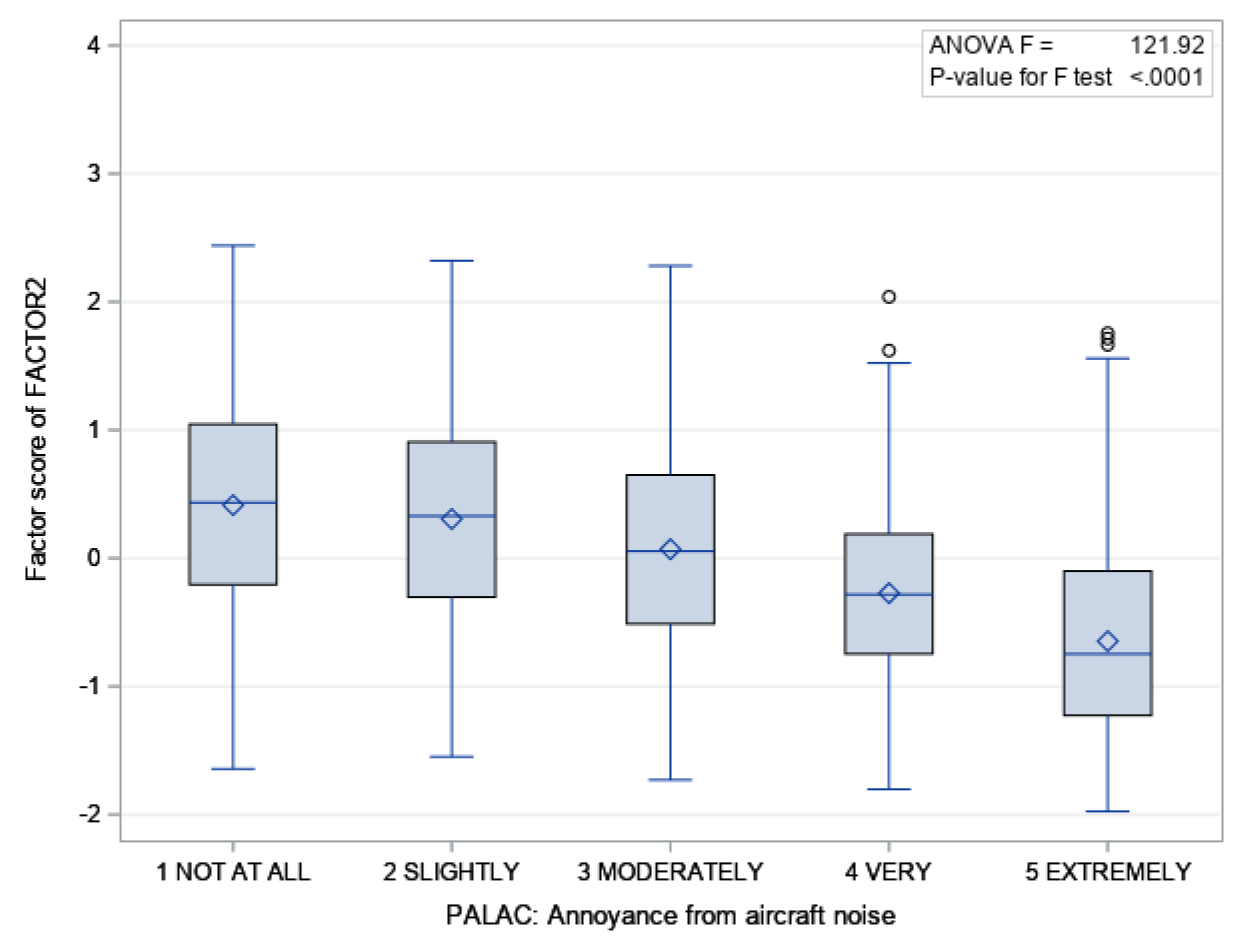

Figure D-6. Distribution of Factor Scores by PALAC for Factor 2

D.5.3.3 Factor 3: General Traffic Noise/Smells Rating

Table D-20 presents the five variables loaded highly on Factor 3. Two of the five questions loaded highly on Factor 3 relate to traffic noise, which was also strongly related to the general noise rating. The significant group difference on PALAC ($F_{(4,2,319)}$ = 200.67, $p < 0.0001$) and the trend of the group means in Figure D-7 indicate that respondents' attitude towards the noise and smells were consistent regardless of the types of noise. All pairwise comparisons were significant with p less than 0.05.

Table D-20. Questions with High Factor Loadings on Factor 3 (ranked by absolute value of loading)

Variable	Label	Q#	Factor Loading	p value for chi-square test
PGenNseRtTraffic	Phone General Noise from Traffic Rating	4	0.818	< 0.0001
PALNseTraffic	Phone AL: Noise from Traffic	1a	0.766	< 0.0001
PGenNseRt	Phone General Noise Rating	3	0.576	< 0.0001
PALSmellTraffic*	Phone AL: Smells Dirt from Traffic	1b	0.411	< 0.0001
PALSmellOther*	Phone AL: Smoke Gas Bad Smells Else	1c	0.318	< 0.0001

* PALSmellTraffic and PALSmellOther have factor loadings higher than 0.3 on Factor 3.

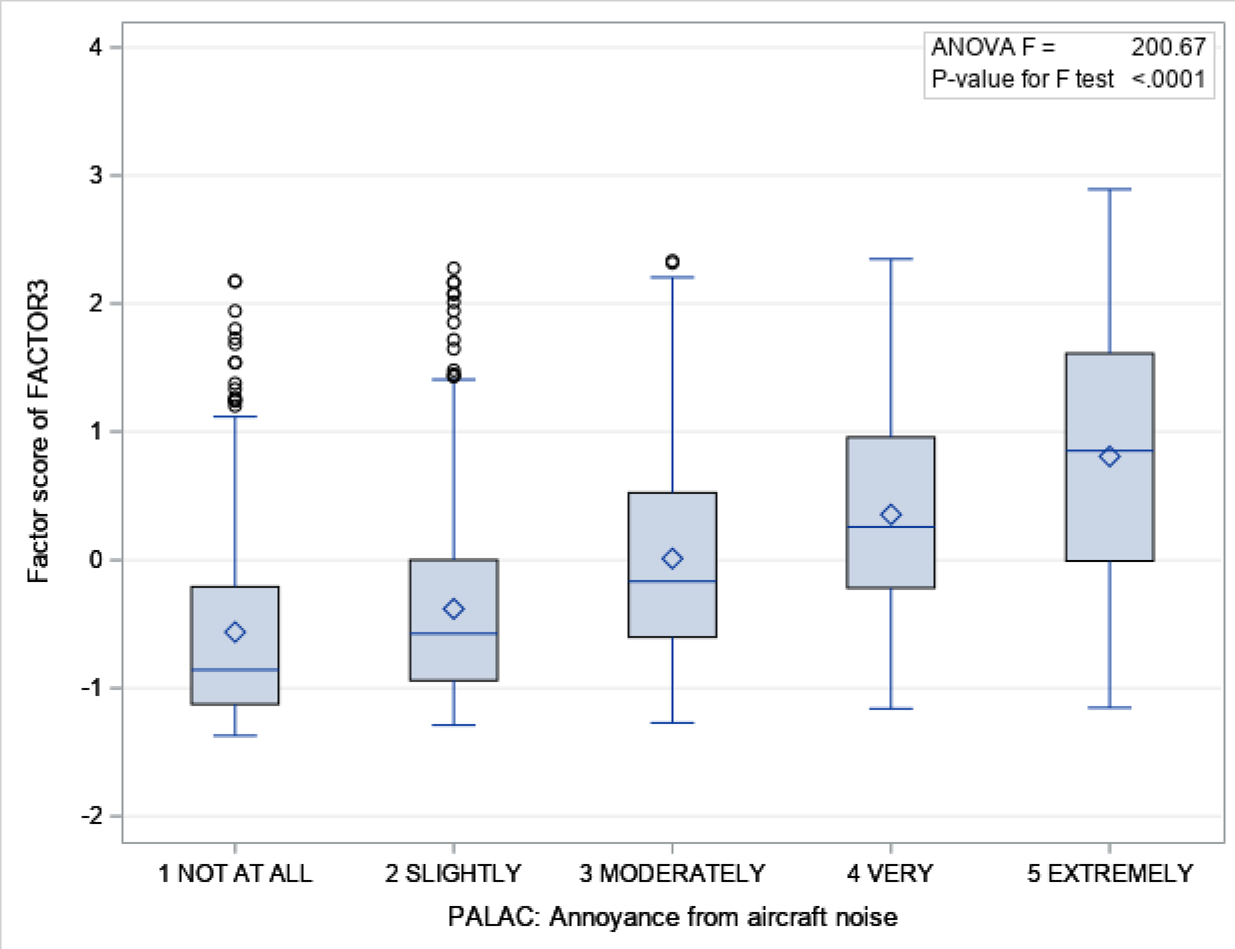

Figure D-7. Distribution of Factor Scores by PALAC for Factor 3

D.5.3.4 Factor 4: Safety Concerns

Table D-21 presents the three variables loaded highly on Factor 4, which relates to safety concerns and possible accidents. The ANOVA indicated a significant group difference ($F_{(4, 2319)}$ = 137.34, p < 0.0001). The trend shown in Figure D-8 shows the more people were bothered/annoyed by aircraft noise, the more they were concerned with accidents from aircraft and train modes of transportation. All pairwise comparisons were significant, with the exception of the comparisons between PALAC=1 (Not at all) and PALAC=2 (Slightly).

Table D-21. Questions with High Factor Loadings on Factor 4 (ranked by absolute value of loading)

Variable	Label	Q#	Factor Loading	p value for chi-square test
PCNACHurtYou	Phone Concern: Aircraft Hurt You or Property	41	0.925	< 0.0001
PCNACCrash	Phone Concern: Aircraft Crash Nearby	40	0.834	< 0.0001
PCNTrnCrash	Phone Concern: Train Crash Nearby	43	0.318	< 0.0001

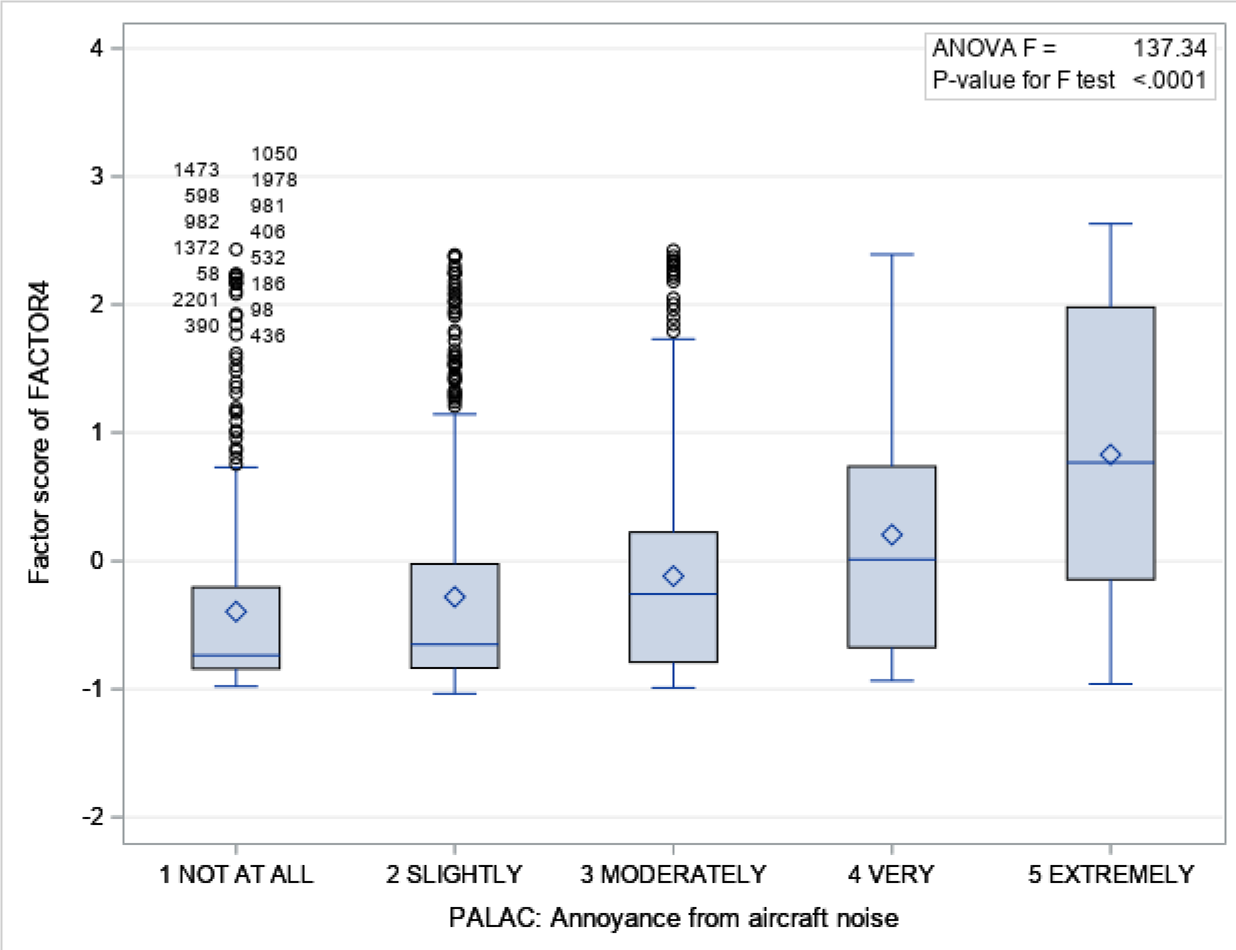

Figure D-8. Distribution of Factor Scores by PALAC for Factor 4

D.5.3.5 Factor 5: Knowledge of Aircraft Noise Issues

Table D-22 presents the five variables loaded highly on Factor 5, which relates to respondents' knowledge of aircraft noise issues. The ANOVA indicated significant group difference on PALAC ($F_{(4, 2319)}$ = 42.55, p < 0.0001). The trend shown in Figure D-9 shows the more respondents were annoyed by aircraft noise, the more knowledge they have about the issue. The pairwise comparisons were not significant between PALAC=1 (Not at all) and 2 (Slightly), and between PALAC=3 (Moderately) and 4 (Very).

Table D-22. Questions with High Factor Loadings on Factor 5 (ranked by absolute value of loading)

Variable	Label	Q#	Factor Loading	p value for chi-square test
PLrnLocalInfo	Phone Learn Aircraft Noise Issues: Local Info	22	0.767	< 0.0001
PLrnMedia	Phone Learn Aircraft Noise Issues: Media	21	0.688	< 0.0001
PCommGroup*	Phone Community Groups Reduce Aircraft	25	0.421	< 0.0001
PHHActOnACNse	Phone HH Done Anything about Aircraft Noise	26	0.401	< 0.0001
PKnowCommIssues	Phone Knowledgeable About Community Issues	18	0.371	< 0.0001

* Dummy coded PCommGroup for the presence of "Group Is"

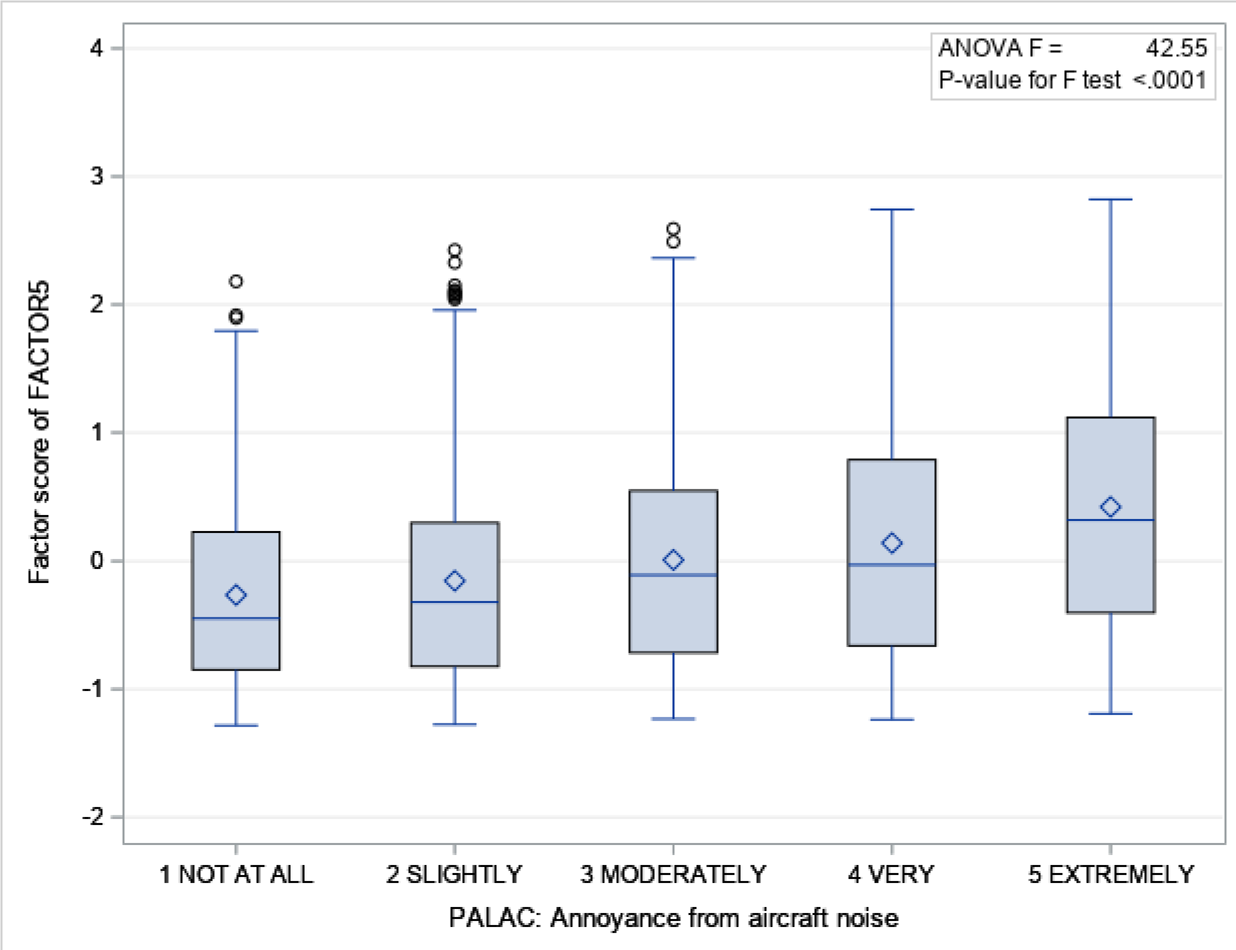

Figure D-9. Distribution of Factor Scores by PALAC for Factor 5

D.5.3.6 Factor 6: Beliefs About Noise Reduction by Officials or Pilots

Table D-23 presents the three variables loaded highly on Factor 6 and Figure D-10 shows the trend of Factor 6 with PALAC. The ANOVA test was significant ($F_{(4, 2319)}$ = 9.69, p < 0.0001). People who were more annoyed by aircraft noise have relatively stronger beliefs that officials or pilots could reduce the noise. The significant pairwise comparisons happened between PALAC=5 (Extremely) and the three adjacent less annoyed groups.

Table D-23. Questions with High Factor Loadings on Factor 6 (ranked by absolute value of loading)

Variable	Label	Q#	Factor Loading	p value for chi-square test
PRedACNseAPOthGov	Phone Could Other Gov Officials Reduce Noise	33b	0.812	< 0.0001
PRedACNseAPOff	Phone Could Officials of Airport Reduce Noise	33a	0.788	< 0.0001
PRedACNseAPilots	Phone Could Pilots Reduce Noise	33c	0.328	0.0028

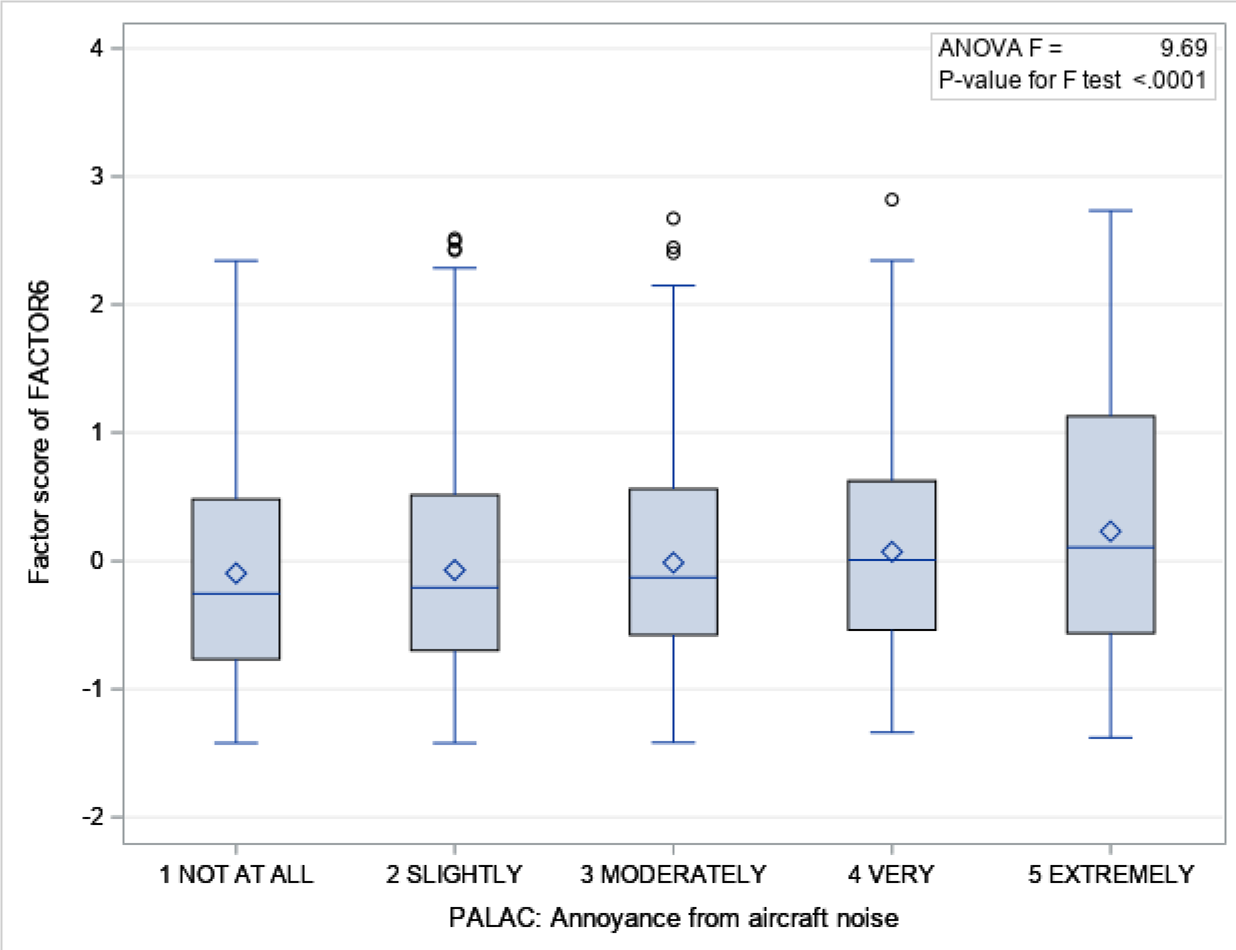

Figure D-10. Distribution of Factor Scores by PALAC for Factor 6

D.5.3.7 Factor 7: Startle, Frighten or Awaken

As shown in Table D-24, the three variables loaded highly on Factor 7 mainly concern disturbances from aircraft noise. It is not surprising the distribution of factor scores also indicated a significant group difference on PALAC ($F_{(4, 2319)}$ = 368.63, p < 0.0001). Figure D-11 shows a similar ascending pattern as in Factor 1 (Figure D-5), meaning the more annoyed by aircraft noise, the greater the startle/fright/awakening from aircraft noise. The pairwise comparisons suggest all tests were significant with p less than 0.05.

Table D-24. Questions with High Factor Loadings on Factor 7 (ranked by absolute value of loading)

Variable	Label	Q#	Factor Loading	p value for chi-square test
PACStartle	Phone Ever Startled Surprised from Aircraft	7b	0.651	< 0.0001
PACFrighten	Phone Ever Frightened from Aircraft	7c	0.569	< 0.0001
PACWake	Phone Ever Waked up from Aircraft	7a	0.476	< 0.0001

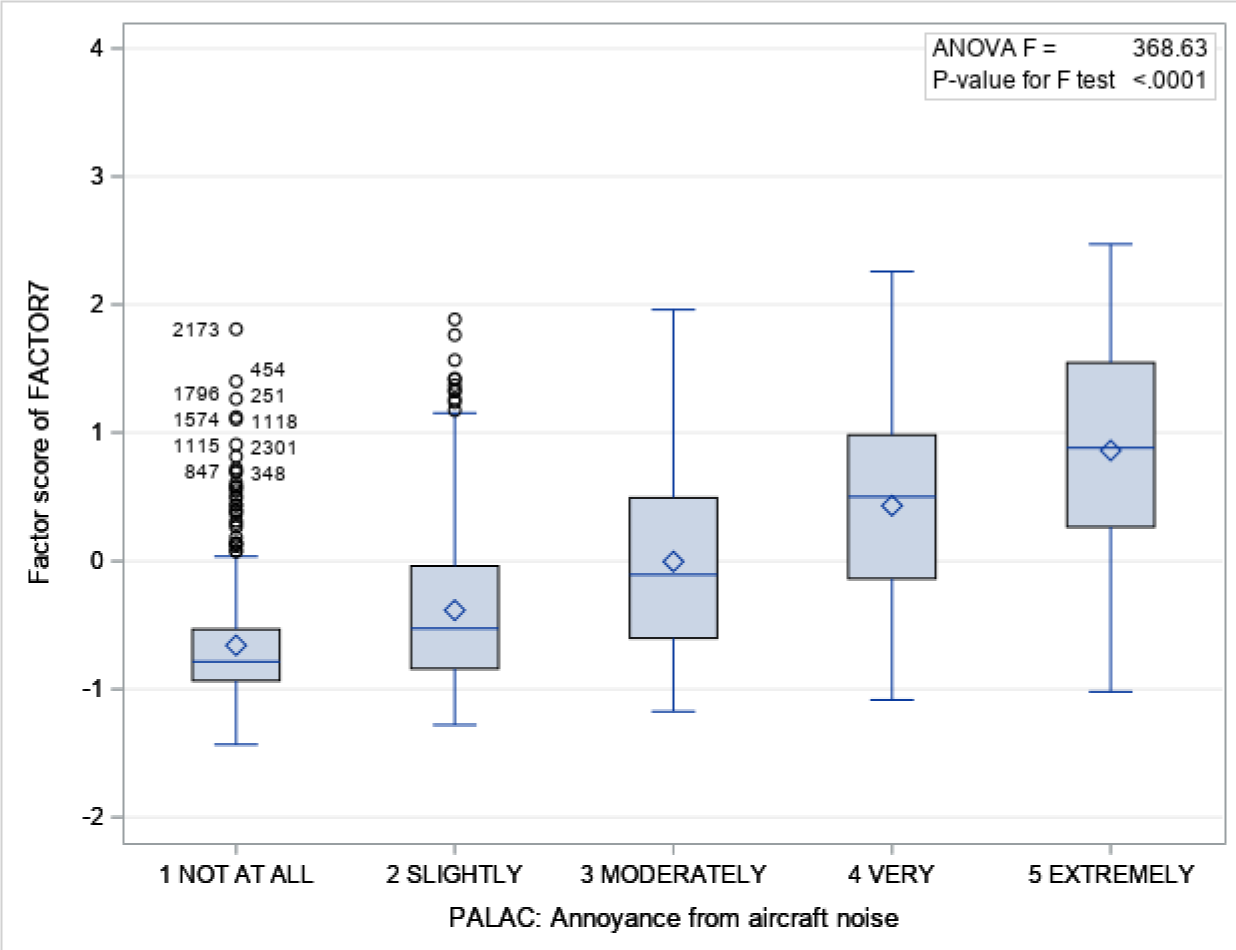

Figure D-11. Distribution of Factor Scores by PALAC for Factor 7

D.6 Technical Details of the CART Analysis

This section contains the supporting details of the Classification and Regression Tree (CART) analysis reported in Section D.4 to characterize highly and not highly annoyed (HA) respondents. Section D.6.1 describes the process for identifying significant predictors of HA by aircraft noise. Section D.6.2 describes the CART analysis procedures and model performance.

D.6.1 Identify Significant Predictors Using Logistic Regression

The HA respondents were defined to have PALAC (annoyance from aircraft noise) equal to a rating of 4 (Very) or 5 (Extremely). To describe the characteristics of HA respondents, we first ran a set of logistic regressions with the dichotomous HA indicator (i.e., HA=1 if highly annoyed, 0 otherwise) and each factor or variable as predictor. If the two HA groups were found to have significant group difference on any factor or variable, it means this factor or variable could be used to distinguish people's reaction on high annoyance. Here, we included five of the six demographic variables in the analysis excluded from the original EFA (see Section D.3). The variable PGender was the one demographic variable excluded from both analyses because of its high proportion of missing values.

Among all the predictors, 23 were found to have significant group difference on HA (meaning the p-value is less than 0.05). The predictors with a significant effect on HA and the direction of the response (not HA vs. HA) are shown in Table D-25. For each factor or question in the table, a respondent with data described in the "Not highly annoyed" column was more likely to be not HA, while a respondent with data described in the "Highly annoyed" column was more likely to be HA. For example, a respondent who reported in PACPctFlyOverH that less than 20 percent of flights are directly over their home was not likely to be HA, while a respondent who indicated in PDangerTrf that aircraft are the most dangerous for themselves and their property at home was likely to be HA. For the factors derived through EFA, the group comparison was based on factor score calculated using factor loadings. The "High" and "Low" results in the table are in terms of the mean of the factor scores. It is worth noting that among the demographic variables excluded from the original EFA, only age group (PAgeCat) was found to be significant.

With further processing described in Section D.6.2, Table D-25 supports the conclusions presented in Section D.4, i.e., the characteristics of highly and not highly annoyed respondents.

D.6.2 CART Analysis by DNL Band

The logistic regression models in the previous section only analyzed the simple relationship between the highly annoyed groups and the predictors. To account for possible confounding effects within the predictors, and to identify the ones with highest predictive power on HA, we further ran a CART analysis using only the significant predictors from Table D-25 for each stratum separately to control for the influence of aircraft noise exposure in 5-dB intervals of DNL. CART analysis is a decision tree method having the same goal as the more common parametric methods, such as linear or logistic regression. The objective was to identify the factors/variables that best predict a respondent's probability of being highly annoyed (or not) at a given DNL. In other words, holding DNL constant (within the group range), what best explains whether or not a respondent will indicate they are highly annoyed by aircraft noise.

Table D-25. Predictors with Significant Effect on HA and Direction of the Response

Predictor	Label	Question No.	Not Highly Annoyed	Highly Annoyed
DNL_Group			50-55	60+
Factor1	Concerns or complaints with neighborhood		Low	High
Factor2	Airport effort to deal with aircraft noise		High	Low
Factor3	General traffic noise/smells rating		Low	High
Factor4	Safety concerns		Slightly low	Slightly high
Factor5	Knowledge of aircraft noise issues		Slightly low	Slightly high
Factor6	Beliefs about noise reduction by officials or pilots		Slightly low	Slightly high
Factor7	Startle, Frighten or Awaken		Low	High
PAgeCat	Phone Categorical Age (Derived from PMonthBorn and PYearBorn)	45	65+, or 18-29	60-64
PACPctFlyOverHCAT	Phone Categorical Percent Aircraft Fly Directly Over (Derived from PACPctFlyOverH)	39	20% -	60% +
PNbrsViewACNse	Phone Neighbors Views Known On Aircraft Noise	23	Keep to themselves	Revealed a little or made clearly known
PACNseChg	Phone Aircraft Noise Increase Decrease Same	14	Stay the same or decreased	Increased
PDangerTrf	Phone Most Danger: Traffic Trains Aircraft	44	Road traffic or None	Aircraft
PACNseFuture	Phone Aircraft Noise in Next Few Years	15	Stay the same or decreased	Increased
PRespSenstve	Phone Sensitive to Noise	36	Not at all or slightly	Very or Extremely
PAuthDisputes	Phone Disputes between Airport and Residents	24	No	Yes
PACTakeOffLand	Phone Aircraft Landing Taking off Both	38	Don't know	About half and half
PCNTrfAccdnt	Phone Concern: Traffic Accidents Nearby	42	Not at all or slightly	Very or Extremely
PAPRedACNse	Phone Authorities Taken Steps Reduce Noise	34	Don't know or Yes	No
PAPImportant	Phone Importance of Airport for City	35	Extremely or slightly or not at all	Very
PHrOutsideCAT	Phone Categorical Hours Week Out-of-Doors (Derived from PHrOutside)	12	13-	21+
PHrdACGrd	Phone Heard Aircraft on the Ground	16	No	Yes
POtherNse	Phone Other Annoying Noise	1g1	No	Yes

In CART, observations are partitioned recursively into smaller sections and a model is fitted in each section. This process is called tree building and a formed section is represented by a node. When the outcome variable is continuous, regression trees are built; whereas classification trees are employed when the outcome variable is categorical. Compared to the parametric methods, CART does not make any distribution assumptions. It offers several sophisticated methods to deal with missing values. When a large number of predictors are involved, CART allows identifying complex interactions between predictors. CART is a useful tool to identify and select predictors that are strongly associated with an outcome.

The variable selection relies on the measures of variable importance. The PROC HPSPLIT function in SAS, for example, evaluates the variable importance based on two types of measures. The count-based measures, e.g., Count in the SAS output, record the number of times in the tree that a particular predictor appears in a split. The residual sum of squares (RSS, a comparison between predicted and observed values)-based measures are based on the change of RSS when a split is made. In the SAS output, the RSS-based measure is called Importance. Another measure, Relative (importance) is calculated as the importance of a particular variable divided by the maximum importance among all the variables that appear in the tree. Larger values indicate a higher importance of that variable in predicting the outcome. These measures are not comparable across models.

The classification tree was built in the current study and the model was evaluated with “10-fold cross-validation”.[17] Cross-validation is a method to assess model performance on unseen data. “10-fold” means the training dataset is randomly divided into 10 folds and one fold, called the validation set, gets excluded during tree building. The built tree was later fit to the holdout fold (validation set) to test how well the model performs with new data. Classification accuracy of the tree model was reported as a measure of model performance. Classification accuracy is the number of persons that have been correctly assigned to the HA group or not HA group. A high accuracy means a better model-fit to the data. And the closer the accuracy between the training set and the validation set, the better the model will predict future data.

Table D-26 shows the classification accuracy for training and cross-validation within each DNL stratum. An accuracy of 80 percent indicates stable/good performance, which is seen in the 50-55 and 55-60 DNL strata. With accuracies between 73 percent and 78 percent, the higher DNL strata had slightly less stable performance. For DNL 50-55 and DNL 60-65, the classification accuracy of the final tree model was slightly higher in the training data than in the validation set, indicating that the model was slightly overfitting the training set. The classification accuracy for DNL 65+ was the lowest among the four DNL strata. This may be due to the small sample size (n=254), which reduced the ability to detect a clear pattern in this group.

Table D-26. Model Performance by DNL Stratum

Classification Accuracy	DNL Stratum (dB)			
	50-55	55-60	60-65	65+
Training	85%	82%	78%	74%
Cross-Validation	80%	81%	73%	73%

[17] Using PROC HPSPLIT in SAS

D.7 Caveats and Cautions

The detailed questions used for the phone questionnaire were not appropriate for the mail questionnaire because the subject matter would have disclosed the purpose of the survey and potentially biased responses to the aircraft annoyance question. Further, the longer content when presented in a mail survey format would likely depress response rates and potentially reduce the statistical representativeness of the findings.

For efficiency, the implemented design of the phone survey relied on re-surveying mail survey respondents. As a result, the phone survey may be subject to a degree of increased non-response bias, i.e., the mail survey had its own non-response and the phone survey's respondents were a subset of those with additional non-response at that stage.

Due to the potential non-response bias and because these analyses are based on unweighted data, caution should be used before utilizing these data to inform any potential actions. The phone survey findings should therefore be viewed as exploratory topics, which may provide direction for further research. Lastly, we do not expect perfect consistency between the mail and phone responses because a different person within the same household may have responded to each survey (see Section D.2.1).

Appendix E Nonresponse Bias Analysis

The U.S. Office of Management and Budget provides guidelines for evaluating potential nonresponse bias:

> A variety of methods can be used to examine nonresponse bias, for example, make comparisons between respondents and nonrespondents across subgroups using available sample frame variables. In the analysis of unit nonresponse, consider a multivariate modeling of response using respondent and nonrespondent frame variables to determine if nonresponse bias exists. Comparison of the respondents to known characteristics of the population from an external source can provide an indication of possible bias, especially if the characteristics in question are related to the survey's key variables. OMB (2006, pp. 16-17)

Section E.1 shows the results of a multivariate modeling of the probability, or propensity, to respond to the survey using sample frame variables that are known for both respondents and nonrespondents. Section E.2 compares characteristics of the respondents from each airport to demographic statistics from the 2010 census and the 2010-2014 American Community Survey (ACS). The set of addresses inside the DNL 50 dB contour for each airport forms an area of irregular shape that does not correspond to census geographic divisions such as census blocks or block groups. Thus, Census Bureau statistics such as the percentage of the population that is Hispanic are unavailable for the study region and for the noise strata within each airport's study region. Section E.2 compares demographic statistics for respondents to the Neighborhood Environmental Survey with statistics from the set of census blocks or block groups that contain sampled addresses.

An additional assessment of nonresponse bias was conducted by constructing nonresponse-adjusted weights and refitting the national curve with these weights. The results of that analysis are in Appendix G (Section G.3).

E.1 Response Propensity Analysis

The primary variable of interest, annoyance to aircraft noise, is of course unknown for the nonrespondents. Nonresponse bias can only be evaluated for variables that are available for both respondents and nonrespondents. For this survey, there is limited information from external sources that can be used to provide an indication of possible bias, because the target population for the NES was addresses exposed to DNL 50 dB or higher and the study region has irregular shape.

The main information available for evaluating potential nonresponse bias comes from the sampling frame information about the sampled addresses. Table E-1 lists the available variables, which represent characteristics known for all sampled addresses, both respondent and nonrespondent, of each airport community. The variables consist of:

- The values of DNL associated with each address in the sample
- Statistics from the 2010 decennial census giving characteristics of the census block containing the address. Each variable is in the form of a percentage of the persons or households in the census block having that characteristic. Note that these variables do not give characteristics of the address itself, but merely of the census block containing the address. Thus, an address may be in a census block with a high percentage of Hispanic residents, but the household members living at that address may be non-Hispanic.
- Statistics from the 2010-2014 ACS giving characteristics of the census block group containing the address. The "five-year" ACS estimates were used because they are available for smaller geographic regions than the one-year estimates (US Census Bureau 2017). Although 2010 census information is

available for census blocks, which are smaller than the block groups published by the ACS, the census had only 10 questions and did not measure income or poverty.

- Information provided by the sample vendor about the characteristics of the address. The variable "Phone match" takes on the value 1 if there is a landline telephone number linked to the address and 0 otherwise. Having a matching phone number has been found to be associated with higher response propensities and with demographic characteristics (Olson and Buskirk 2015). The other characteristic used from the vendor is whether the address is a single-family or multi-family dwelling unit.

Table E-1. Variables Used in Nonresponse Bias Analysis

Variable	Description
DNL	Day-Night Average Sound Level (dB) for each address in the selected sample
Phone match	Landline phone number available from vendor address database: yes vs. no
Multi-family dwelling	Multi-family vs. Single-family housing indicator: yes vs. no
% pop age 65+	Percentage of population age 65 and over in census block (Census 2010)
% pop age < 18	Percentage of population under age 18 in census block (Census 2010)
% pop black	Percentage of population who are black in census block (Census 2010)
% pop hispanic	Percentage of population who are Hispanic in census block (Census 2010)
% pop < poverty level	Percentage of population below poverty in census block group (ACS 2010-14)
% pop with college degree	Percentage of population with college degree in census block group (ACS 2010-14)
% rented HHs	Percentage of housing units that are rented in census block (Census 2010)
% 1-person HHs	Percentage of households containing a single person in census block group (ACS 2010-14)

The main analysis to evaluate potential nonresponse bias was a multivariate modeling of response using the sample frame characteristics from Table E-1. We fit a logistic regression model to the addresses in the selected sample[18] to examine the relationship between being a respondent to the survey and the covariates given in Table E-1. Each airport was fit separately to allow assessment of whether the relationship between propensity to respond and the covariates differs across airports.

The general logistic regression model used for the nonresponse bias analysis has the form:

$$\text{P(household responds to survey)} = \frac{\exp(\beta_0 + \beta_1 DNL + \beta_2 x_2 + \cdots + \beta_k x_k)}{1 + \exp(\beta_0 + \beta_1 DNL + \beta_2 x_2 + \cdots + \beta_k x_k)}, \quad \text{(E.1)}$$

where DNL is the noise exposure level at that address (from the final DNL computations described in Section 7.5), and $x_2 \ldots x_k$ are other characteristics that are known for that sampled address. The coefficients, p-values, and odds ratios for the logistic regression model for each airport are given in Table E-2. A positive coefficient means that higher values of the covariate are associated with higher response rates, while a negative coefficient means that higher values of the covariate are associated with lower response rates.

The logistic regression model in Equation (E.1) can alternatively be written as:

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 DNL + \beta_2 x_2 + \cdots + \beta_k x_k, \quad \text{(E.2)}$$

where p is the probability that someone at the sampled address responds to the survey, DNL is the noise exposure level at that address, and $x_2 \ldots x_k$ are other characteristics that are known for that sampled address.

[18] Addresses that were returned by the Post Office as undeliverable were considered ineligible and not included. Across all 20 airports, a total of 25,467 addresses were used in the modeling.

The coefficients in the logistic regression model may be interpreted as follows: each coefficient gives the expected change in the log odds ratio $\ln\left(\frac{p}{1-p}\right)$ associated with a change of one unit in the covariate when all of the other covariates are held the same. Alternatively, the exponentiated value of the coefficient gives the percentage change in the odds ratio $\frac{p}{1-p}$ associated with a unit change in the covariate. Thus, in the model for the AUS airport, the exponentiated coefficient for Multi-family dwelling is $\exp(-1.0354) =$ 0.36. This may be interpreted as meaning that the estimated odds of responding to the survey are about one-third as great for a household that lives in a single family dwelling as for a household with the same level of the other covariates that lives in a multi-family dwelling.

The coefficients in the model may be used to obtain an estimate of the probability that a household with specified characteristics provides a response to the survey, called the response propensity. Thus, a household in the AUS airport community that has DNL 60 dB; has a matching telephone number; that lives in a multi-family housing unit; lives in a census block in which 20 percent of residents are age 65 and over, 10 percent of residents are under age 18, 15 percent are black, 10 percent are Hispanic, and 10 percent of households rent the housing unit; that lives in a block group in which 1 percent of residents are below the poverty level, 50 percent of the residents have a college degree, and 20 percent of the households have one person, has the following predicted probability of responding to the survey:

$$\text{Predicted probability of responding to survey} = \frac{e^{(-.9920)}}{1+e^{(-.9920)}} = 0.2705, \qquad \text{(E.3)}$$

where the value -0.9920 is calculated using the regression coefficients in Table E-2 as

-0.9920 = 1.4771 - 0.0268 (60) + 0.0226 (1) – 1.0354 (1) + 0.0077 (20) - 0.0218 (0.10) + 0.0083 (0.15) + 0.0079 (0.10) -0.0059 (0.10) – 0.0009 (0.01) + 0.0011 (0.50) – 0.0105 (0.20).

Table E-2. Logistic Regression Response Propensity Model Coefficients for Each Airport

Airport Identifier	Number of Eligible Cases	Variable	Beta	Beta				Odds Ratio	Odds Ratio	
				Std Error	p-value	Lower CL	Upper CL		Lower CL	Upper CL
ABQ	1310	Intercept	3.1374	1.7455	0.0723	-0.3084	6.5415			
		DNL	-0.0718	0.0318	0.0241	-0.1343	-0.0093	0.9307	0.8744	0.9908
		Phone match: yes vs. no	0.6290	0.1271	0.0000	0.3802	0.8786	1.8758	1.4626	2.4075
		Multi-family dwelling: yes vs. no	-0.6052	0.2119	0.0043	-1.0262	-0.1943	0.5460	0.3584	0.8234
		% pop age 65+	0.0110	0.0097	0.2575	-0.0079	0.0301	1.0110	0.9921	1.0305
		% pop age < 18	-0.0158	0.0080	0.0479	-0.0315	-0.0001	0.9843	0.9690	0.9999
		% pop black	-0.0213	0.0083	0.0098	-0.0378	-0.0053	0.9789	0.9629	0.9947
		% pop hispanic	-0.0007	0.0040	0.8650	-0.0084	0.0071	0.9993	0.9916	1.0072
		% pop < poverty level	0.0080	0.0059	0.1773	-0.0036	0.0196	1.0080	0.9964	1.0198
		% pop with college degree	0.0094	0.0058	0.1030	-0.0019	0.0208	1.0095	0.9981	1.0210
		% rented HHs	-0.0069	0.0030	0.0213	-0.0128	-0.0011	0.9931	0.9872	0.9989
		% 1-person HHs	0.0164	0.0070	0.0196	0.0028	0.0303	1.0165	1.0028	1.0307
ALB	982	Intercept	-3.6088	1.3615	0.0080	-6.2981	-0.9550			
		DNL	0.0637	0.0220	0.0038	0.0208	0.1072	1.0658	1.0210	1.1132
		Phone match: yes vs. no	0.3407	0.1462	0.0198	0.0546	0.6280	1.4060	1.0561	1.8739
		Multi-family dwelling: yes vs. no	-0.1812	0.1770	0.3058	-0.5288	0.1656	0.8342	0.5893	1.1801
		% pop age 65+	-0.0085	0.0074	0.2549	-0.0232	0.0061	0.9916	0.9771	1.0061
		% pop age < 18	-0.0007	0.0109	0.9463	-0.0221	0.0207	0.9993	0.9781	1.0209
		% pop black	-0.0055	0.0115	0.6352	-0.0280	0.0171	0.9946	0.9724	1.0172
		% pop hispanic	-0.0161	0.0162	0.3198	-0.0482	0.0155	0.9840	0.9529	1.0156
		% pop < poverty level	-0.0126	0.0125	0.3143	-0.0373	0.0118	0.9875	0.9634	1.0119
		% pop with college degree	0.0053	0.0053	0.3155	-0.0050	0.0157	1.0053	0.9950	1.0159
		% rented HHs	-0.0013	0.0034	0.7098	-0.0080	0.0054	0.9987	0.9921	1.0054
		% 1-person HHs	0.0055	0.0051	0.2859	-0.0046	0.0156	1.0055	0.9954	1.0158
ATL	1478	Intercept	0.1355	0.8232	0.8692	-1.4837	1.7455			
		DNL	-0.0209	0.0116	0.0698	-0.0436	0.0017	0.9793	0.9573	1.0017
		Phone match: yes vs. no	0.5568	0.1258	0.0000	0.3105	0.8037	1.7450	1.3641	2.2339
		Multi-family dwelling: yes vs. no	-0.6027	0.1842	0.0011	-0.9654	-0.2426	0.5473	0.3808	0.7845
		% pop age 65+	0.0068	0.0065	0.2924	-0.0060	0.0195	1.0068	0.9941	1.0197
		% pop age < 18	0.0019	0.0079	0.8059	-0.0134	0.0174	1.0019	0.9867	1.0176
		% pop black	-0.0049	0.0042	0.2480	-0.0131	0.0034	0.9952	0.9870	1.0034
		% pop hispanic	-0.0025	0.0060	0.6744	-0.0143	0.0092	0.9975	0.9858	1.0092
		% pop < poverty level	0.0106	0.0052	0.0428	0.0003	0.0209	1.0107	1.0003	1.0211
		% pop with college degree	0.0042	0.0058	0.4665	-0.0072	0.0157	1.0042	0.9928	1.0158
		% rented HHs	-0.0024	0.0027	0.3781	-0.0078	0.0029	0.9976	0.9922	1.0030
		% 1-person HHs	0.0141	0.0054	0.0096	0.0035	0.0248	1.0142	1.0035	1.0251

Airport Identifier	Number of Eligible Cases	Variable	Beta	Beta				Odds Ratio	Odds Ratio	
				Std Error	p-value	Lower CL	Upper CL		Lower CL	Upper CL
AUS	1456	Intercept	1.4771	1.1598	0.2028	-0.7915	3.7575			
		DNL	-0.0268	0.0180	0.1364	-0.0621	0.0083	0.9736	0.9398	1.0084
		Phone match: yes vs. no	0.0226	0.1178	0.8479	-0.2088	0.2530	1.0228	0.8116	1.2879
		Multi-family dwelling: yes vs. no	-1.0354	0.1618	0.0000	-1.3563	-0.7215	0.3551	0.2576	0.4860
		% pop age 65+	0.0077	0.0065	0.2389	-0.0053	0.0204	1.0077	0.9948	1.0206
		% pop age < 18	-0.0218	0.0093	0.0191	-0.0402	-0.0036	0.9784	0.9606	0.9964
		% pop black	0.0083	0.0042	0.0488	0.0001	0.0167	1.0084	1.0001	1.0168
		% pop hispanic	0.0079	0.0050	0.1152	-0.0019	0.0179	1.0080	0.9981	1.0180
		% pop < poverty level	-0.0059	0.0052	0.2621	-0.0162	0.0044	0.9941	0.9839	1.0044
		% pop with college degree	-0.0009	0.0074	0.9079	-0.0155	0.0135	0.9991	0.9846	1.0136
		% rented HHs	0.0011	0.0029	0.7123	-0.0047	0.0069	1.0011	0.9953	1.0069
		% 1-person HHs	-0.0105	0.0067	0.1183	-0.0237	0.0026	0.9896	0.9765	1.0026
BDL	1016	Intercept	-0.9570	1.1838	0.4188	-3.2876	1.3584			
		DNL	0.0036	0.0175	0.8365	-0.0306	0.0380	1.0036	0.9698	1.0387
		Phone match: yes vs. no	0.5781	0.1372	0.0000	0.3097	0.8477	1.7826	1.3630	2.3344
		Multi-family dwelling: yes vs. no	-0.1765	0.1923	0.3587	-0.5545	0.2003	0.8382	0.5744	1.2218
		% pop age 65+	0.0218	0.0078	0.0052	0.0066	0.0372	1.0220	1.0066	1.0379
		% pop age < 18	-0.0004	0.0098	0.9668	-0.0197	0.0188	0.9996	0.9805	1.0190
		% pop black	0.0125	0.0101	0.2155	-0.0070	0.0326	1.0125	0.9930	1.0332
		% pop hispanic	0.0094	0.0113	0.4027	-0.0126	0.0319	1.0095	0.9875	1.0324
		% pop < poverty level	0.0161	0.0100	0.1077	-0.0035	0.0360	1.0163	0.9965	1.0366
		% pop with college degree	0.0018	0.0050	0.7257	-0.0080	0.0116	1.0018	0.9920	1.0116
		% rented HHs	-0.0118	0.0033	0.0003	-0.0183	-0.0054	0.9883	0.9819	0.9946
		% 1-person HHs	0.0062	0.0081	0.4402	-0.0095	0.0222	1.0063	0.9905	1.0224
BFI	1226	Intercept	-1.3543	1.0342	0.1904	-3.3867	0.6700			
		DNL	0.0043	0.0151	0.7770	-0.0254	0.0340	1.0043	0.9749	1.0346
		Phone match: yes vs. no	0.0640	0.1273	0.6152	-0.1859	0.3132	1.0661	0.8303	1.3678
		Multi-family dwelling: yes vs. no	-0.0632	0.1723	0.7136	-0.4013	0.2747	0.9387	0.6695	1.3161
		% pop age 65+	0.0217	0.0076	0.0044	0.0069	0.0369	1.0220	1.0069	1.0376
		% pop age < 18	0.0168	0.0089	0.0595	-0.0007	0.0343	1.0169	0.9993	1.0349
		% pop black	-0.0068	0.0053	0.2013	-0.0172	0.0036	0.9933	0.9830	1.0036
		% pop hispanic	-0.0064	0.0057	0.2656	-0.0178	0.0048	0.9936	0.9824	1.0048
		% pop < poverty level	-0.0013	0.0054	0.8141	-0.0119	0.0092	0.9987	0.9882	1.0093
		% pop with college degree	0.0199	0.0052	0.0001	0.0099	0.0302	1.0201	1.0100	1.0307
		% rented HHs	-0.0050	0.0029	0.0834	-0.0107	0.0006	0.9950	0.9894	1.0006
		% 1-person HHs	0.0031	0.0046	0.4948	-0.0058	0.0121	1.0031	0.9942	1.0122

Airport Identifier	Number of Eligible Cases	Variable	Beta	Beta				Odds Ratio	Odds Ratio	
				Std Error	p-value	Lower CL	Upper CL		Lower CL	Upper CL
BIL	1058	Intercept	0.7605	1.6015	0.6349	-2.3816	3.9035			
		DNL	-0.0063	0.0294	0.8312	-0.0639	0.0514	0.9938	0.9381	1.0528
		Phone match: yes vs. no	0.2464	0.1372	0.0724	-0.0228	0.5151	1.2794	0.9775	1.6738
		Multi-family dwelling: yes vs. no	-0.1112	0.1758	0.5271	-0.4569	0.2329	0.8948	0.6333	1.2622
		% pop age 65+	0.0094	0.0091	0.3015	-0.0080	0.0278	1.0095	0.9920	1.0282
		% pop age < 18	-0.0011	0.0087	0.8947	-0.0182	0.0158	0.9989	0.9820	1.0160
		% pop black	0.0350	0.0407	0.3899	-0.0403	0.1217	1.0356	0.9605	1.1294
		% pop hispanic	-0.0150	0.0140	0.2840	-0.0425	0.0124	0.9851	0.9584	1.0125
		% pop < poverty level	0.0074	0.0177	0.6776	-0.0271	0.0425	1.0074	0.9732	1.0434
		% pop with college degree	-0.0020	0.0092	0.8291	-0.0200	0.0161	0.9980	0.9802	1.0163
		% rented HHs	-0.0106	0.0035	0.0027	-0.0176	-0.0037	0.9895	0.9826	0.9963
		% 1-person HHs	-0.0055	0.0072	0.4412	-0.0197	0.0086	0.9945	0.9805	1.0086
DSM	1023	Intercept	-0.7446	1.1354	0.5119	-2.9703	1.4836			
		DNL	0.0215	0.0188	0.2527	-0.0153	0.0584	1.0217	0.9848	1.0601
		Phone match: yes vs. no	0.8734	0.1345	0.0000	0.6107	1.1383	2.3949	1.8418	3.1216
		Multi-family dwelling: yes vs. no	-0.6480	0.2928	0.0269	-1.2310	-0.0810	0.5231	0.2920	0.9222
		% pop age 65+	-0.0001	0.0098	0.9936	-0.0193	0.0192	0.9999	0.9809	1.0194
		% pop age < 18	-0.0255	0.0102	0.0124	-0.0456	-0.0056	0.9749	0.9554	0.9944
		% pop black	0.0428	0.0143	0.0028	0.0148	0.0711	1.0438	1.0149	1.0737
		% pop hispanic	-0.0074	0.0085	0.3838	-0.0245	0.0091	0.9926	0.9758	1.0091
		% pop < poverty level	-0.0030	0.0066	0.6478	-0.0159	0.0099	0.9970	0.9842	1.0099
		% pop with college degree	-0.0045	0.0082	0.5845	-0.0207	0.0116	0.9955	0.9795	1.0117
		% rented HHs	-0.0055	0.0040	0.1666	-0.0134	0.0023	0.9945	0.9867	1.0023
		% 1-person HHs	-0.0013	0.0068	0.8467	-0.0147	0.0121	0.9987	0.9854	1.0122
DTW	1181	Intercept	-0.3964	1.2176	0.7448	-2.7874	1.9892			
		DNL	0.0002	0.0194	0.9903	-0.0377	0.0383	1.0002	0.9630	1.0390
		Phone match: yes vs. no	0.6855	0.1279	0.0000	0.4362	0.9379	1.9848	1.5468	2.5546
		Multi-family dwelling: yes vs. no	0.5597	0.2667	0.0359	0.0381	1.0852	1.7501	1.0388	2.9599
		% pop age 65+	-0.0014	0.0059	0.8179	-0.0130	0.0103	0.9986	0.9871	1.0103
		% pop age < 18	-0.0114	0.0084	0.1769	-0.0280	0.0051	0.9887	0.9723	1.0051
		% pop black	-0.0022	0.0020	0.2502	-0.0061	0.0016	0.9978	0.9939	1.0016
		% pop hispanic	0.0238	0.0134	0.0764	-0.0025	0.0503	1.0241	0.9975	1.0516
		% pop < poverty level	-0.0009	0.0047	0.8439	-0.0102	0.0082	0.9991	0.9899	1.0083
		% pop with college degree	0.0051	0.0057	0.3718	-0.0061	0.0164	1.0051	0.9939	1.0165
		% rented HHs	-0.0017	0.0034	0.6294	-0.0085	0.0051	0.9983	0.9915	1.0051
		% 1-person HHs	-0.0026	0.0055	0.6367	-0.0134	0.0082	0.9974	0.9867	1.0082

Airport Identifier	Number of Eligible Cases	Variable	Beta	Beta				Odds Ratio	Odds Ratio	
				Std Error	p-value	Lower CL	Upper CL		Lower CL	Upper CL
LAS	1510	Intercept	-0.2931	0.7984	0.7135	-1.8664	1.2669			
		DNL	0.0049	0.0124	0.6896	-0.0192	0.0294	1.0050	0.9810	1.0298
		Phone match: yes vs. no	0.2595	0.1287	0.0437	0.0063	0.5109	1.2962	1.0063	1.6668
		Multi-family dwelling: yes vs. no	-0.3061	0.1865	0.1007	-0.6722	0.0594	0.7363	0.5106	1.0612
		% pop age 65+	0.0050	0.0057	0.3787	-0.0063	0.0161	1.0050	0.9937	1.0162
		% pop age < 18	-0.0122	0.0095	0.1992	-0.0308	0.0064	0.9879	0.9697	1.0064
		% pop black	0.0181	0.0114	0.1143	-0.0044	0.0405	1.0182	0.9956	1.0413
		% pop hispanic	0.0021	0.0053	0.6880	-0.0083	0.0127	1.0022	0.9917	1.0128
		% pop < poverty level	-0.0055	0.0058	0.3459	-0.0170	0.0059	0.9945	0.9831	1.0059
		% pop with college degree	0.0003	0.0060	0.9583	-0.0114	0.0120	1.0003	0.9887	1.0121
		% rented HHs	-0.0067	0.0031	0.0296	-0.0127	-0.0007	0.9934	0.9874	0.9993
		% 1-person HHs	-0.0002	0.0044	0.9584	-0.0089	0.0085	0.9998	0.9911	1.0085
LAX	1441	Intercept	0.4017	0.8824	0.6489	-1.3286	2.1333			
		DNL	0.0051	0.0089	0.5648	-0.0123	0.0226	1.0051	0.9878	1.0228
		Phone match: yes vs. no	0.3199	0.1156	0.0056	0.0937	0.5469	1.3770	1.0983	1.7279
		Multi-family dwelling: yes vs. no	-0.0268	0.1361	0.8439	-0.2940	0.2398	0.9736	0.7452	1.2709
		% pop age 65+	0.0039	0.0106	0.7161	-0.0172	0.0247	1.0039	0.9829	1.0251
		% pop age < 18	-0.0260	0.0089	0.0036	-0.0435	-0.0085	0.9743	0.9574	0.9915
		% pop black	-0.0083	0.0035	0.0195	-0.0152	-0.0013	0.9918	0.9849	0.9987
		% pop hispanic	-0.0042	0.0044	0.3339	-0.0128	0.0044	0.9958	0.9872	1.0044
		% pop < poverty level	-0.0042	0.0066	0.5202	-0.0171	0.0086	0.9958	0.9830	1.0086
		% pop with college degree	-0.0016	0.0072	0.8195	-0.0157	0.0125	0.9984	0.9844	1.0125
		% rented HHs	-0.0074	0.0027	0.0071	-0.0128	-0.0020	0.9927	0.9873	0.9980
		% 1-person HHs	0.0095	0.0061	0.1178	-0.0024	0.0215	1.0096	0.9976	1.0217
LGA	1435	Intercept	1.5095	0.9012	0.0940	-0.2521	3.2832			
		DNL	-0.0232	0.0118	0.0485	-0.0463	-0.0002	0.9771	0.9547	0.9998
		Phone match: yes vs. no	0.0989	0.1168	0.3971	-0.1303	0.3276	1.1039	0.8779	1.3877
		Multi-family dwelling: yes vs. no	-0.2222	0.1488	0.1355	-0.5141	0.0697	0.8007	0.5980	1.0722
		% pop age 65+	0.0028	0.0067	0.6740	-0.0105	0.0158	1.0028	0.9895	1.0159
		% pop age < 18	-0.0053	0.0115	0.6461	-0.0279	0.0172	0.9948	0.9725	1.0173
		% pop black	0.0009	0.0036	0.8052	-0.0063	0.0080	1.0009	0.9937	1.0081
		% pop hispanic	-0.0036	0.0028	0.2072	-0.0091	0.0020	0.9965	0.9909	1.0020
		% pop < poverty level	0.0028	0.0052	0.5847	-0.0073	0.0130	1.0028	0.9927	1.0131
		% pop with college degree	0.0003	0.0058	0.9635	-0.0112	0.0117	1.0003	0.9889	1.0118
		% rented HHs	-0.0090	0.0028	0.0012	-0.0145	-0.0036	0.9910	0.9856	0.9964
		% 1-person HHs	0.0065	0.0058	0.2649	-0.0049	0.0179	1.0065	0.9951	1.0181

Airport Identifier	Number of Eligible Cases	Variable	Beta	Beta				Odds Ratio	Odds Ratio	
				Std Error	p-value	Lower CL	Upper CL		Lower CL	Upper CL
LIT	1272	Intercept	-0.5013	1.0547	0.6346	-2.5688	1.5684			
		DNL	-0.0027	0.0192	0.8864	-0.0404	0.0348	0.9973	0.9604	1.0354
		Phone match: yes vs. no	0.3358	0.1215	0.0057	0.0978	0.5741	1.3990	1.1027	1.7755
		Multi-family dwelling: yes vs. no	-0.3850	0.2669	0.1492	-0.9177	0.1313	0.6804	0.3995	1.1403
		% pop age 65+	0.0085	0.0061	0.1637	-0.0034	0.0205	1.0085	0.9966	1.0207
		% pop age < 18	0.0020	0.0056	0.7246	-0.0090	0.0130	1.0020	0.9910	1.0131
		% pop black	-0.0017	0.0024	0.4728	-0.0064	0.0030	0.9983	0.9936	1.0030
		% pop hispanic	0.0077	0.0102	0.4502	-0.0124	0.0277	1.0077	0.9877	1.0281
		% pop < poverty level	0.0086	0.0060	0.1497	-0.0031	0.0203	1.0086	0.9969	1.0205
		% pop with college degree	-0.0091	0.0084	0.2764	-0.0257	0.0072	0.9909	0.9747	1.0072
		% rented HHs	-0.0033	0.0027	0.2300	-0.0087	0.0021	0.9967	0.9913	1.0021
		% 1-person HHs	0.0049	0.0084	0.5602	-0.0116	0.0215	1.0049	0.9885	1.0217
MEM	1570	Intercept	0.7333	0.6831	0.2830	-0.6099	2.0695			
		DNL	-0.0126	0.0093	0.1778	-0.0309	0.0058	0.9875	0.9696	1.0058
		Phone match: yes vs. no	0.5846	0.1270	0.0000	0.3358	0.8339	1.7942	1.3990	2.3022
		Multi-family dwelling: yes vs. no	-0.2041	0.1706	0.2316	-0.5387	0.1305	0.8154	0.5835	1.1394
		% pop age 65+	0.0090	0.0073	0.2149	-0.0055	0.0232	1.0091	0.9946	1.0235
		% pop age < 18	-0.0094	0.0079	0.2306	-0.0248	0.0060	0.9906	0.9755	1.0060
		% pop black	-0.0035	0.0022	0.1131	-0.0079	0.0008	0.9965	0.9921	1.0008
		% pop hispanic	-0.0090	0.0069	0.1905	-0.0231	0.0040	0.9910	0.9771	1.0040
		% pop < poverty level	0.0001	0.0047	0.9894	-0.0092	0.0093	1.0001	0.9908	1.0093
		% pop with college degree	0.0029	0.0051	0.5643	-0.0071	0.0129	1.0029	0.9930	1.0129
		% rented HHs	-0.0028	0.0025	0.2716	-0.0077	0.0022	0.9972	0.9923	1.0022
		% 1-person HHs	-0.0080	0.0051	0.1147	-0.0180	0.0019	0.9920	0.9821	1.0019
MIA	1677	Intercept	-1.1313	0.9448	0.2311	-2.9931	0.7135			
		DNL	-0.0025	0.0122	0.8388	-0.0264	0.0216	0.9975	0.9740	1.0218
		Phone match: yes vs. no	0.4560	0.1186	0.0001	0.2235	0.6885	1.5777	1.2504	1.9907
		Multi-family dwelling: yes vs. no	0.0224	0.1327	0.8661	-0.2377	0.2828	1.0226	0.7884	1.3268
		% pop age 65+	0.0196	0.0047	0.0000	0.0104	0.0290	1.0198	1.0104	1.0294
		% pop age < 18	0.0078	0.0096	0.4161	-0.0110	0.0267	1.0078	0.9890	1.0270
		% pop black	-0.0018	0.0065	0.7827	-0.0146	0.0109	0.9982	0.9855	1.0110
		% pop hispanic	-0.0012	0.0052	0.8191	-0.0113	0.0090	0.9988	0.9887	1.0091
		% pop < poverty level	0.0011	0.0049	0.8243	-0.0084	0.0106	1.0011	0.9916	1.0106
		% pop with college degree	0.0064	0.0048	0.1791	-0.0030	0.0157	1.0064	0.9970	1.0158
		% rented HHs	-0.0052	0.0024	0.0278	-0.0098	-0.0006	0.9948	0.9902	0.9994
		% 1-person HHs	0.0042	0.0041	0.3057	-0.0038	0.0121	1.0042	0.9962	1.0122

Airport Identifier	Number of Eligible Cases	Variable	Beta	Beta				Odds Ratio	Odds Ratio	
				Std Error	p-value	Lower CL	Upper CL		Lower CL	Upper CL
ORD	1079	Intercept	1.0559	1.0273	0.3041	-0.9568	3.0745			
		DNL	-0.0135	0.0130	0.2988	-0.0389	0.0119	0.9866	0.9618	1.0120
		Phone match: yes vs. no	0.3777	0.1384	0.0064	0.1061	0.6490	1.4589	1.1119	1.9137
		Multi-family dwelling: yes vs. no	-0.2862	0.1708	0.0939	-0.6214	0.0489	0.7511	0.5372	1.0501
		% pop age 65+	0.0029	0.0068	0.6690	-0.0105	0.0161	1.0029	0.9896	1.0162
		% pop age < 18	0.0046	0.0102	0.6493	-0.0153	0.0247	1.0047	0.9848	1.0250
		% pop black	-0.0038	0.0077	0.6244	-0.0192	0.0113	0.9962	0.9809	1.0114
		% pop hispanic	-0.0055	0.0043	0.2047	-0.0141	0.0030	0.9945	0.9860	1.0030
		% pop < poverty level	0.0043	0.0079	0.5855	-0.0113	0.0198	1.0043	0.9888	1.0200
		% pop with college degree	0.0020	0.0059	0.7379	-0.0096	0.0136	1.0020	0.9904	1.0137
		% rented HHs	-0.0071	0.0028	0.0113	-0.0127	-0.0016	0.9929	0.9874	0.9984
		% 1-person HHs	-0.0091	0.0061	0.1336	-0.0210	0.0028	0.9910	0.9792	1.0028
SAV	1290	Intercept	4.0090	1.7147	0.0194	0.6586	7.3853			
		DNL	-0.0607	0.0287	0.0347	-0.1172	-0.0045	0.9411	0.8894	0.9955
		Phone match: yes vs. no	0.3773	0.1319	0.0042	0.1187	0.6361	1.4583	1.1260	1.8891
		Multi-family dwelling: yes vs. no	0.3436	0.1751	0.0497	0.0015	0.6885	1.4100	1.0015	1.9906
		% pop age 65+	-0.0062	0.0107	0.5651	-0.0273	0.0148	0.9939	0.9731	1.0149
		% pop age < 18	-0.0296	0.0102	0.0037	-0.0499	-0.0098	0.9708	0.9513	0.9903
		% pop black	-0.0123	0.0050	0.0137	-0.0222	-0.0027	0.9878	0.9781	0.9973
		% pop hispanic	-0.0074	0.0066	0.2617	-0.0206	0.0054	0.9926	0.9796	1.0054
		% pop < poverty level	-0.0008	0.0065	0.9061	-0.0136	0.0119	0.9992	0.9865	1.0120
		% pop with college degree	0.0005	0.0063	0.9355	-0.0118	0.0128	1.0005	0.9883	1.0129
		% rented HHs	-0.0099	0.0025	0.0001	-0.0148	-0.0050	0.9901	0.9853	0.9950
		% 1-person HHs	0.0026	0.0067	0.6956	-0.0105	0.0157	1.0026	0.9896	1.0158
SJC	1179	Intercept	-0.1317	0.9167	0.8857	-1.9311	1.6650			
		DNL	-0.0055	0.0144	0.7043	-0.0337	0.0227	0.9946	0.9669	1.0230
		Phone match: yes vs. no	0.3778	0.1440	0.0087	0.0955	0.6604	1.4591	1.1002	1.9356
		Multi-family dwelling: yes vs. no	-0.3204	0.1508	0.0336	-0.6165	-0.0251	0.7258	0.5398	0.9752
		% pop age 65+	0.0152	0.0075	0.0445	0.0006	0.0305	1.0153	1.0006	1.0309
		% pop age < 18	0.0032	0.0095	0.7324	-0.0153	0.0218	1.0032	0.9848	1.0221
		% pop black	0.0189	0.0168	0.2600	-0.0141	0.0523	1.0191	0.9860	1.0537
		% pop hispanic	-0.0026	0.0043	0.5491	-0.0109	0.0058	0.9975	0.9891	1.0058
		% pop < poverty level	0.0024	0.0069	0.7260	-0.0111	0.0158	1.0024	0.9889	1.0159
		% pop with college degree	0.0113	0.0042	0.0069	0.0032	0.0196	1.0114	1.0032	1.0198
		% rented HHs	-0.0060	0.0025	0.0159	-0.0109	-0.0011	0.9940	0.9891	0.9989
		% 1-person HHs	-0.0061	0.0057	0.2861	-0.0173	0.0051	0.9939	0.9829	1.0051

Airport Identifier	Number of Eligible Cases	Variable	Beta	Beta				Odds Ratio	Odds Ratio	
				Std Error	p-value	Lower CL	Upper CL		Lower CL	Upper CL
SYR	952	Intercept	-1.8944	1.3545	0.1620	-4.5661	0.7499			
		DNL	-0.0155	0.0200	0.4378	-0.0549	0.0237	0.9846	0.9466	1.0240
		Phone match: yes vs. no	0.5798	0.1589	0.0003	0.2691	0.8924	1.7857	1.3087	2.4409
		Multi-family dwelling: yes vs. no	-0.8742	0.2693	0.0012	-1.4092	-0.3511	0.4172	0.2443	0.7039
		% pop age 65+	0.0408	0.0096	0.0000	0.0223	0.0598	1.0416	1.0225	1.0616
		% pop age < 18	0.0368	0.0138	0.0076	0.0100	0.0641	1.0375	1.0100	1.0662
		% pop black	0.0088	0.0172	0.6073	-0.0250	0.0426	1.0089	0.9753	1.0436
		% pop hispanic	0.0031	0.0238	0.8961	-0.0437	0.0500	1.0031	0.9573	1.0512
		% pop < poverty level	0.0290	0.0165	0.0799	-0.0033	0.0617	1.0294	0.9967	1.0636
		% pop with college degree	0.0227	0.0080	0.0048	0.0070	0.0386	1.0229	1.0070	1.0393
		% rented HHs	-0.0079	0.0045	0.0789	-0.0167	0.0009	0.9922	0.9835	1.0009
		% 1-person HHs	0.0183	0.0092	0.0473	0.0003	0.0365	1.0185	1.0003	1.0371
TUS	1472	Intercept	1.2850	0.9181	0.1616	-0.5176	3.0842			
		DNL	-0.0126	0.0161	0.4336	-0.0440	0.0190	0.9875	0.9569	1.0192
		Phone match: yes vs. no	0.4793	0.1205	0.0001	0.2430	0.7155	1.6150	1.2751	2.0453
		Multi-family dwelling: yes vs. no	-0.1452	0.1529	0.3425	-0.4460	0.1540	0.8649	0.6402	1.1665
		% pop age 65+	-0.0079	0.0120	0.5076	-0.0317	0.0158	0.9921	0.9688	1.0159
		% pop age < 18	-0.0225	0.0114	0.0481	-0.0449	-0.0003	0.9778	0.9561	0.9997
		% pop black	0.0059	0.0183	0.7460	-0.0301	0.0466	1.0059	0.9703	1.0477
		% pop hispanic	-0.0018	0.0064	0.7747	-0.0144	0.0108	0.9982	0.9857	1.0108
		% pop < poverty level	-0.0042	0.0053	0.4281	-0.0146	0.0061	0.9958	0.9855	1.0061
		% pop with college degree	0.0053	0.0107	0.6205	-0.0157	0.0264	1.0053	0.9844	1.0268
		% rented HHs	-0.0064	0.0028	0.0236	-0.0119	-0.0009	0.9936	0.9882	0.9991
		% 1-person HHs	0.0032	0.0075	0.6644	-0.0114	0.0178	1.0032	0.9887	1.0180

Table E-3 gives the number of airports where each covariate was statistically significant at the 0.05, 0.01, and 0.001 levels of significance.[19] From the model, the following variables are significantly associated with having a higher response propensity for a majority of airports: having a matching telephone number and living in a census block with a high percentage of rented housing units. These variables have been demonstrated to be related to response rates in many other surveys (see, for example, Montaquila et al. 2013), and the NES fits the general pattern. Most importantly, the noise exposure level, measured by DNL, is not significantly associated with the probability of responding to the survey for the majority of airports.

Table E-3. Number of Airports Where Predictor Variable is Statistically Significant

Predictor Variable	Number of Airports where variable is statistically significant with:		
	p-value<.05	p-value<.01	p-value<.001
DNL	3	1	0
Phone match: yes vs. no	16	14	9
Multi-family dwelling: yes vs. no	7	3	1
% pop age 65+	5	4	2
% pop age < 18	6	2	0
% pop black	5	2	0
% pop hispanic	1	0	0
% pop < poverty level	1	0	0
% pop with college degree	3	3	1
% rented HHs	11	6	2
% 1-person HHs	2	0	0

[19] The statistical significance was determined individually for each airport, and the p-values in the table were not adjusted for multiple comparisons. If a multiple comparisons analysis is desired, a Bonferroni correction can be applied to the p-values in Table E-2.

E.2 Comparison with 2010 Census and American Community Survey Statistics

Although Census Bureau statistics on the demographics of the target are unavailable for the sampled region, demographic statistics can be calculated from decennial census information for a somewhat larger region consisting of the set of census blocks that encompass the sampled region. This can give a general idea of the concordance between the characteristics of the respondents and the population, although differences between the census estimates and estimates from the NES could be due to the mismatch between the area sampled (with noise exposure of DNL 50 dB and above) and the larger region that is contained in the census blocks.[20]

Demographic information was obtained from the 2010 census for each census block that contained at least one address in the sampled area. The census estimate of percent Hispanic for an airport community was calculated as (total number of Hispanic adults in the census blocks)/(total number of adults in the census blocks), with similar calculations to find the percent white non-Hispanic, percent male, and percent over age 50 or age 65.

Demographic statistics calculated from the NES are presented in Tables E-4 through E-8. These tables give the percentage of respondents who fall in each demographic category. The estimated percent Hispanic at ABQ in Table E-4, for example, is calculated as (number of respondents at ABQ who report Hispanic for ethnicity)/(number of respondents at ABQ who report a value for ethnicity). Thus, for ABQ, 55.3 percent of the respondents report being Hispanic; the percentage from the census blocks encompassing the sampling region is 60.3 percent. The confidence intervals for the percentages were calculated using a weight of one for every respondent and using the stratification from the sampling design.

Disagreement between the percentage calculated from the NES and the percentage from the 2010 census does not necessarily mean there is nonresponse bias. First, as noted above, the statistics from the 2010 census are for a larger area than the study region in each airport: if, for example, the Hispanic population in the encompassing census blocks is concentrated in the study region, and the households in the parts of those census blocks that are outside of the study region are predominantly non-Hispanic, then the NES percent Hispanic would be expected to be larger than the percent Hispanic from the 2010 census. Second, the census data were collected in 2010, and it is possible that the demographic composition of the region has shifted since then. Third, the NES statistics given are percentages of the respondents, and are not necessarily unbiased estimates of the study region population with those characteristics.[21] Nevertheless, very large differences between the NES statistics and the 2010 census percentages may indicate potential nonresponse bias.

[20] Data from the 2010 census were used for these comparisons instead of data from the more recent ACS because the ACS statistics are only available for the much larger geography of block groups rather than census blocks. If the ACS had been used, there would have been a large difference in the sizes of the regions being compared.

[21] Under design-based inference, sampling weights would be used for estimating population quantities such as the percentage Hispanic for the entire region. The base sampling weight for each responding adult would be calculated as the product of the reciprocal of the probability of selection for each address and the reciprocal of the number of adults in the household. But the NES was designed to estimate a regression relationship, and its design is not efficient for estimating percentages in the region. In most airports, the sampling fraction was much higher in high noise strata than in low noise strata. Thus, respondents in the low noise strata have much higher weights than respondents in the high noise strata. Consequently, weighted estimates rely almost entirely on the data from the low (50-55) noise strata and have much higher standard errors than the unweighted estimates. The unweighted estimates calculate the percentage of respondents in each demographic category. If the census proportions and household sizes are similar in each individual noise stratum, then the unweighted estimates should be approximately equal to the overall census proportions if there is no nonresponse bias.

Table E-4. Comparison with 2010 census: Percent Hispanic

Airport Identifier	Number of Respondents[a]	NES Percent Hispanic	95% Confidence Interval		Census 2010 Percent Hispanic[b]
			Lower	Upper	
ABQ	492	55.3	50.9	59.6	60.6
ALB	488	2.5	1.4	4.2	3.3
ATL	488	5.1	3.5	7.5	6.6
AUS	490	36.3	32.2	40.7	51.6
BDL	501	3.2	2.0	5.1	3.9
BFI	502	6.8	4.9	9.3	10.2
BIL	496	4.0	2.6	6.1	3.6
DSM	519	3.7	2.4	5.6	6.3
DTW	478	2.5	1.4	4.3	3.3
LAS	509	16.9	13.9	20.4	24.9
LAX	497	36.2	32.1	40.5	58.8
LGA	511	36.8	32.7	41.1	44.4
LIT	509	1.2	0.5	2.5	3.0
MEM	496	2.4	1.4	4.2	5.7
MIA	518	84.4	81.0	87.2	78.3
ORD	490	13.5	10.7	16.8	18.3
SAV	509	3.1	1.9	5.0	7.5
SJC	484	21.3	17.9	25.1	29.1
SYR	500	2.0	1.1	3.6	2.1
TUS	508	76.6	72.7	80.0	81.0

[a]Number of respondents with a valid response to the question.
[b]Percent of the population age 18 and over.

Table E-5. Comparison with 2010 census: Percent White non-Hispanic

Airport Identifier	Number of Respondents[a]	NES Percent White, Non-Hispanic	95% Confidence Interval		Census 2010 Percent White, Non-Hispanic[b]
			Lower	Upper	
ABQ	492	34.3	30.3	38.7	29.1
ALB	488	85.7	82.3	88.5	84.6
ATL	488	14.3	11.5	17.7	7.8
AUS	490	36.7	32.6	41.1	21.9
BDL	501	89.0	86.0	91.5	87.0
BFI	502	48.8	44.5	53.2	32.1
BIL	496	90.1	87.2	92.4	90.9
DSM	519	90.8	88.0	93.0	87.0
DTW	478	57.5	53.1	61.9	67.5
LAS	509	57.8	53.4	62.0	50.1
LAX	497	28.8	25.0	32.9	15.6
LGA	511	24.7	21.1	28.6	17.4
LIT	509	26.7	23.1	30.7	29.7
MEM	496	33.7	29.7	37.9	33.9
MIA	518	9.3	7.1	12.1	14.7
ORD	490	76.3	72.4	79.9	65.1
SAV	509	78.6	74.8	81.9	75.0
SJC	484	35.1	31.0	39.5	27.9
SYR	500	92.6	90.0	94.6	92.1
TUS	508	18.5	15.4	22.1	13.2

[a]Number of respondents with a valid response to the question.
[b]Percent of the population age 18 and over.

Table E-6. Comparison with 2010 census: Percent Male

Airport Identifier	Number of Respondents[a]	NES Percent Male	95% Confidence Interval		Census 2010 Percent Male[b]
			Lower	Upper	
ABQ	510	44.3	40.1	48.7	50.1
ALB	501	45.3	41.0	49.7	47.1
ATL	501	38.9	34.8	43.3	44.1
AUS	506	45.5	41.2	49.8	50.1
BDL	516	47.9	43.6	52.2	47.7
BFI	511	48.3	44.0	52.7	50.1
BIL	505	46.5	42.2	50.9	50.1
DSM	527	42.5	38.4	46.8	47.7
DTW	503	41.2	36.9	45.5	47.4
LAS	522	52.7	48.4	56.9	51.3
LAX	518	45.6	41.3	49.9	47.7
LGA	527	42.9	38.7	47.1	46.2
LIT	531	34.1	30.2	38.2	46.8
MEM	508	35.8	31.8	40.1	45.3
MIA	529	45.7	41.5	50.0	48.9
ORD	499	46.9	42.6	51.3	48.3
SAV	526	44.9	40.7	49.1	49.2
SJC	498	53.8	49.4	58.1	51.6
SYR	511	44.0	39.8	48.4	46.5
TUS	518	43.6	39.4	47.9	47.1

[a]Number of respondents with a valid response to the question.
[b]Percent of the population age 18 and over.

Table E-7. Comparison with 2010 census: Percent Over Age 50

Airport Identifier	Number of Respondents[a]	NES Percent over Age 50	95% Confidence Interval		Census 2010 Percent over Age 50
			Lower	Upper	
ABQ	504	67.3	63.0	71.2	35.4
ALB	495	71.1	67.0	74.9	46.8
ATL	495	59.6	55.2	63.8	30.9
AUS	503	50.7	46.3	55.0	31.2
BDL	508	69.1	64.9	73.0	46.2
BFI	507	52.9	48.5	57.2	38.7
BIL	505	61.2	56.9	65.3	45.0
DSM	526	61.2	57.0	65.3	41.7
DTW	492	67.1	62.8	71.1	43.2
LAS	522	54.8	50.5	59.0	33.9
LAX	513	51.9	47.5	56.1	30.6
LGA	518	58.3	54.0	62.5	37.5
LIT	521	72.2	68.2	75.8	45.3
MEM	501	59.7	55.3	63.9	35.7
MIA	524	63.4	59.2	67.4	37.5
ORD	495	57.6	53.2	61.9	42.0
SAV	522	61.3	57.1	65.4	42.6
SJC	496	34.9	30.8	39.2	25.8
SYR	505	70.7	66.6	74.5	48.0
TUS	509	60.5	56.2	64.7	33.0

[a]Number of respondents with a valid response to the question.

Table E-8. Comparison with 2010 census: Percent Over Age 65

Airport Identifier	Number of Respondents[a]	NES Percent over Age 65	95% Confidence Interval		Census 2010 Percent over Age 65
			Lower	Upper	
ABQ	504	27.0	23.3	31.0	12.0
ALB	495	37.6	33.4	41.9	20.4
ATL	495	26.5	22.8	30.5	9.0
AUS	503	26.4	22.8	30.5	11.7
BDL	508	30.1	26.3	34.2	18.6
BFI	507	20.5	17.2	24.2	14.1
BIL	505	25.9	22.3	29.9	16.5
DSM	526	27.8	24.1	31.7	17.1
DTW	492	33.9	29.9	38.2	16.8
LAS	522	19.9	16.7	23.6	12.3
LAX	513	23.8	20.3	27.7	10.2
LGA	518	27.2	23.6	31.2	15.3
LIT	521	35.1	31.1	39.3	18.3
MEM	501	23.6	20.0	27.5	13.2
MIA	524	34.7	30.8	38.9	18.0
ORD	495	28.1	24.3	32.2	19.8
SAV	522	29.1	25.4	33.2	17.7
SJC	496	13.5	10.8	16.8	9.0
SYR	505	38.0	33.9	42.3	21.9
TUS	509	28.1	24.4	32.2	12.3

[a]Number of respondents with a valid response to the question.

Tables E-4 and E-5 indicate that in AUS, LAS, LAX, and LGA, the NES percent Hispanic is lower, and the NES percent white non-Hispanic is higher, than the corresponding statistics from the 2010 census. For most of the other airports, the 2010 census percentage is inside or close to an endpoint of the confidence interval. The analysis in Chapter 9 gave no indication that the national dose-response curve differs for white non-Hispanic and minority respondents.

Table E-6 indicates that the percentage of male respondents from the NES is below 40 percent for LIT and MEM, which is statistically significantly lower than the 2010 census percentage. For the other airports, however, the 2010 census percent male is inside or is close to one of the endpoints of the NES confidence interval.

Tables E-7 and E-8, however, show that the percentages of NES respondents who are over age 50, or who are over age 65, are much higher than the corresponding population percentages from the 2010 census. On average, the percentage of NES respondents who are over age 50 is more than 20 percentage points higher than the 2010 census percent of adults who are over age 50; the average percentage of NES respondents who are over age 65 is more than 12 percentage points higher than the census percentage.

To investigate potential nonresponse bias caused by the overrepresentation of older respondents, Westat fit dose-response curves separately by age groups. An analysis by age group was not one of the pre-planned hypotheses treated in Chapter 9, but was undertaken here to investigate potential nonresponse bias in the curve. Table E-9 gives the logistic regression coefficients and confidence intervals for the models, which were fit to the data from all airports.[22] Figure E-1 displays the two curves for the over-50 and under-50 age groups, and Figure E-2 displays the two curves for the over-65 and under-65 age groups.

Table E-9. Model Coefficients for National Curve, by age group

Age Group	Intercept	Slope	Standard Error (Intercept)	Standard Error (Slope)	Lower 95% Confidence Limit (Intercept)	Upper 95% Confidence Limit (Intercept)	Lower 95% Confidence Limit (Slope)	Upper 95% Confidence Limit (Slope)
All	-8.4304	0.1397	0.5789	0.0098	-9.6420	-7.2187	0.1192	0.1602
Under 50	-8.4240	0.1386	0.6044	0.0104	-9.6890	-7.1590	0.1170	0.1603
Over 50	-8.5339	0.1418	0.6875	0.0116	-9.9727	-7.0950	0.1174	0.1662
Under 65	-8.3284	0.1384	0.6097	0.0101	-9.6045	-7.0522	0.1171	0.1598
Over 65	-8.6232	0.1414	0.8577	0.0152	-10.4185	-6.8279	0.1097	0.1731

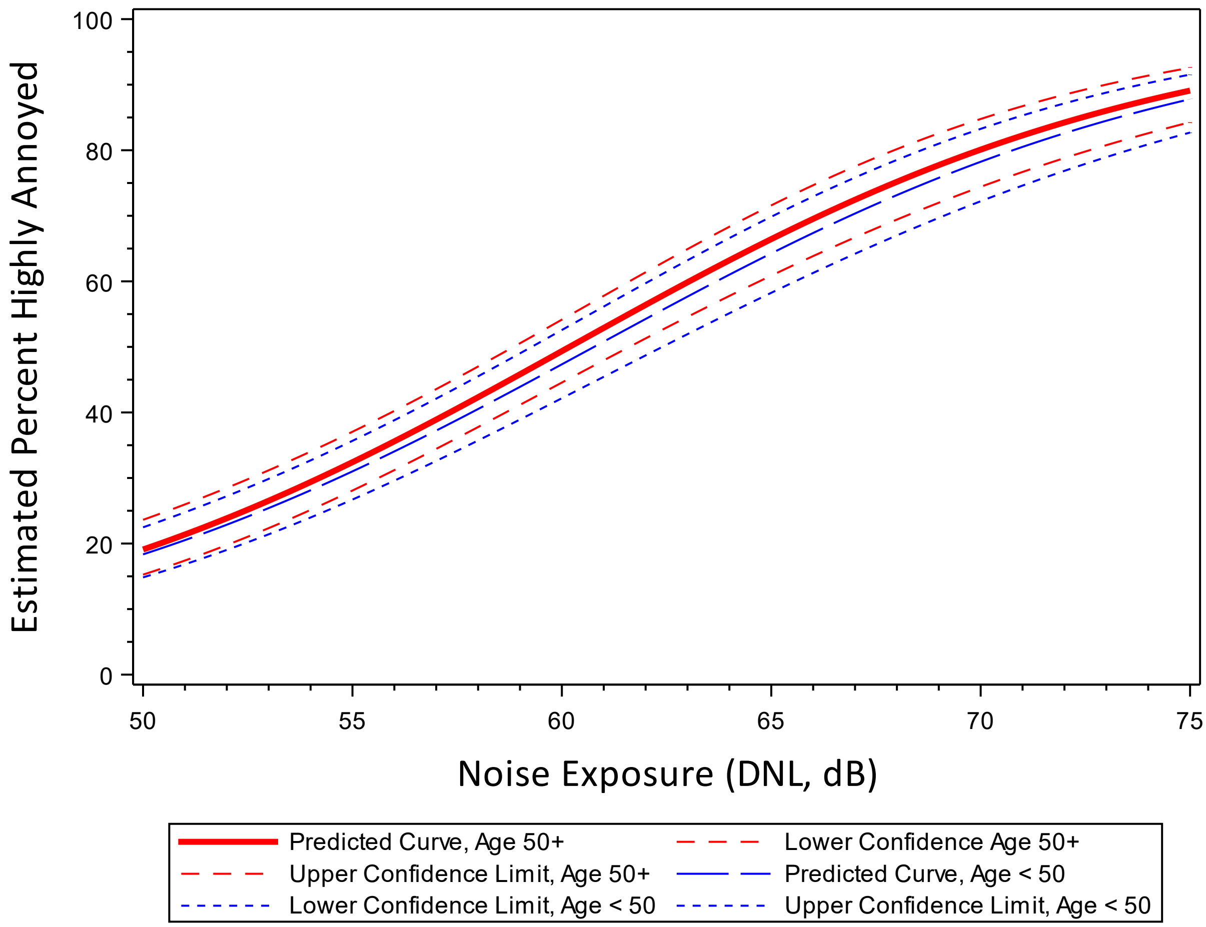

Figure E-1. National dose-response curves for respondents over age 50 and under age 50.

[22] Although the age group subsets have fewer observations, the standard errors for the national curve for each age group subset are only slightly larger than those for the full data set. This is because the primary source of variability for the model coefficients is the airport-to-airport variability, as discussed in Section G.2.

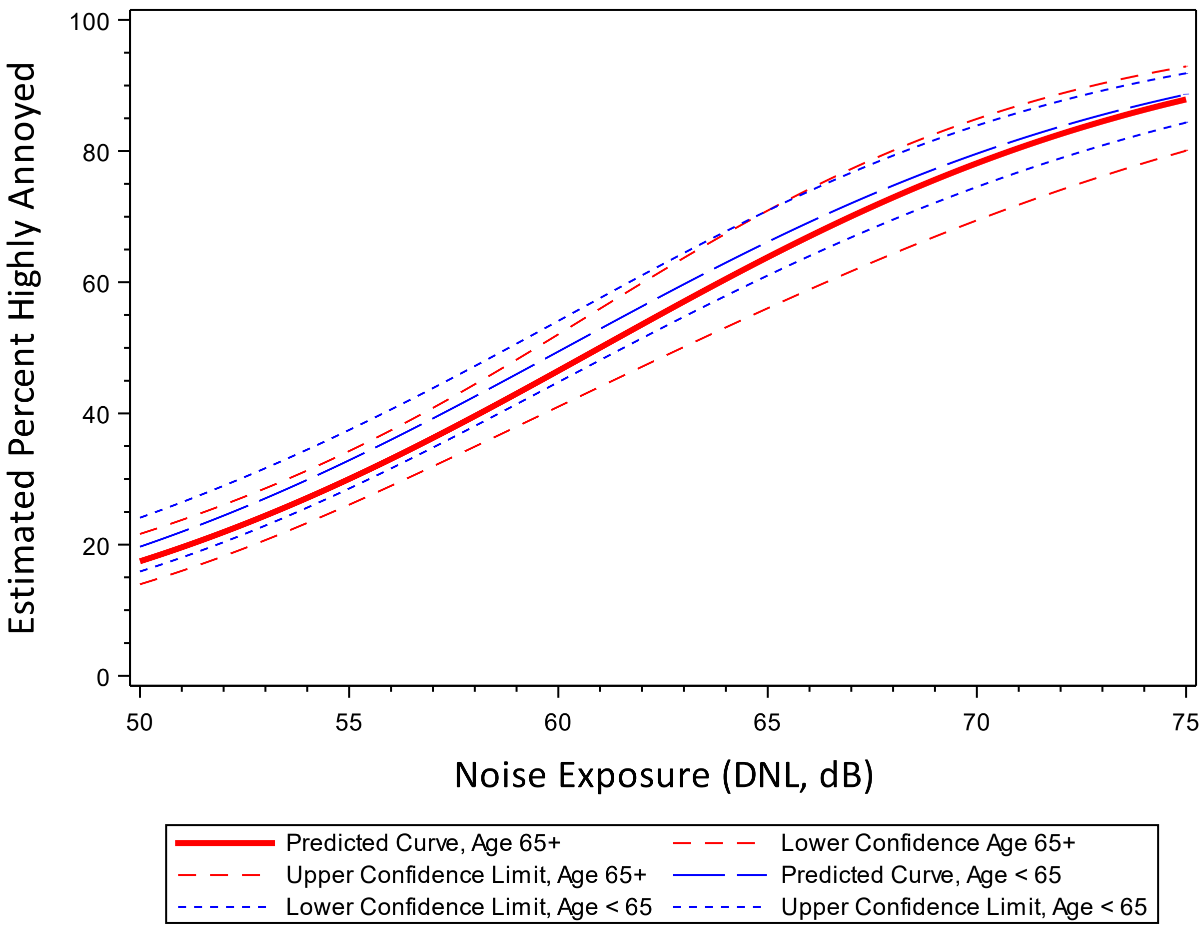

Figure E-2. National dose-response curves for respondents over age 65 and under age 65.

Note that an analysis fitting the model in Equation (9.2) with an indicator variable for OVER50 showed that the curves for the over-50 and under-50 age groups are not statistically significantly different (Q = 5.3; p-value > 0.05). The curves for the over-65 and under-65 age groups are statistically significantly different (Q = 14.7; p-value < 0.001). Figures E-1 and E-2, however, show only a small difference in the dose-response curves by age group.

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Analysis of the Neighborhood Environmental Survey

Volume 3 of 4

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Prepared for:

Federal Aviation Administration
William J. Hughes Technical Center
4th Floor, M26
Atlantic City International Airport
Atlantic City, NJ 08405

Contents of Volume 3

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Appendix F Noise Model Inputs

This appendix provides a summary of the basic data used for modeling each of the airports. This information is not intended to provide sufficient data to repeat the noise calculations. Because a complete year of radar flight track data was used to prepare modeling inputs for the INM, tabulating the full input data is not possible. If the computations are to be repeated, the FAA has access to the full set of INM runs and could produce additional results if desired.

These data are provided primarily as a possible aide to understanding why dose-response relationships differ across airports, and to convey a general sense of airspace use.

The data included are:

1. Name, location, number of runways and helipads, elevation, and notes on operations (ops). Helicopter operations are noted specifically because: 1) helicopter operations are generally on tracks and over locations different from those of fixed wing operations, and 2) helicopters operations may result in reports of higher annoyance at a given DNL value than do fixed wing operations. Knowing the location of the helicopter flight operations may help understand differences, airport to airport, in annoyance reactions.

2. Runway coordinates and physical parameters of elevation, width, usable length, length of displaced threshold and glide slope. Note the length reported here is from INM calculations and output files. Therefore the length may include rounding errors on the order of a few feet compared to published runway length or surveyed length.

3. ATADS counts, Scaled ATADS counts (scaled to the number of data days, if not 365; labeled "ATADS for Data Day" in the tables), radar flight tracks available (labeled "Database" in the tables), and the scale factors used to scale the radar flight track data to the Scaled ATADS counts.[1]

   In some cases, the radar flight track data had few or no operations identified in one or more ATADS categories. In these cases, the ATADS counts in these categories were added to those in related categories for scaling purposes. Details are provided in footnotes to individual airport tables below.

   In reviewing the analysis, it was found that a small number of operations had been rejected during data processing and their effects were not included. Subsequent analysis determined that these missing events had no effect on the results at the level of precision of the model. Details are provided in the following section and in footnotes to individual airport tables below.

4. Modeled average annual daily operations by major aircraft categories. This data will indicate which aircraft categories most frequently use the airport, but not necessarily which aircraft categories are the dominant contributor(s) to DNL.
   a. 'Day' and 'Night' in the tables refer to DNL periods, 7 a.m. to 10 p.m. and 10 p.m. to 7 a.m., respectively.
   b. All occurrences of 'A7D' INM type refers to the modeling of aircraft such as the T-45 Goshawk and AV-8 Harrier with the A-7D Corsair II.
   c. All occurrences of 'V22 Osprey' refer to the modeling of the V-22. The V-22 is a tiltrotor aircraft. It operates like a helicopter for takeoff and landing but like a fixed-wing aircraft for other flight modes. If a V-22 flight track originated or terminated at a helipad, the operation was modeled as an S65

[1] "Scale Factors" in the tables is the ratio of "ATADS for Data Days" to "Database"). Note that the ATADS tables for 2015 do not include a row for "ATADS for Data Days" because the scaling to 2015 ATADS was simplified, and the operations were scaled to the ATADS yearly totals.

helicopter. If the V-22 flight track originated or terminated at a runway end, the operations was modeled as a fixed-wing HS748A.

d. Total operations treat all supporting cells having "<0.01" as 0 operations. Furthermore, the Total operations columns count each circuit as two operations.

5. Numbers of modeled tracks -- counts of tracks by type of operation, i.e., arrival, departure and local (pattern), by general flow direction and by aircraft category. These are provided in conjunction with depictions of the radar flight tracks (see item #6) to give the reader a sense of the quantity of tracks depicted in the graphics. The counts are also provided to compute and show the percentage of events in each flow condition. Note that the total number of modeled tracks (converted to numbers of operations) will generally not equal the total annual numbers of operations (e.g., in the 'database' rows of item #3 above) because not all events captured by the radar flight tracking system are useable in modeling. In cases of insufficient tracks to model all events, single modeled tracks carried more than one operation so that the correct numbers of daily operations were modeled. Overall, each airport's total number of operations (derived from the track count) were within 200 of its modeled total annual flight operations.

6. Depictions of typical flight track distributions for the primary operating modes of the airport. These depictions are provided for different aircraft type categories and are generally produced using only a percentage (extracted by random sample) of the total radar flight tracks available; showing all tracks would, in many cases, result in solid areas of undifferentiated colors. To help the reader see trends, all tracks are shown at 10 percent transparency. Departure tracks are shown as green lines, Arrival tracks are red lines, and Local (pattern) tracks, if applicable, are shown as blue lines.

Missing Operations Discrepancies

In a detailed review of the modeling inputs, it was found the total modeled operations for nine of the 21 airports analyzed for the 2015 case did not precisely match the totals from the Air Traffic Activity Data System (ATADS) shown in the report. This was determined to be due to the INM rejecting a small number of operations in the final modeling stage that had not been rejected for the pre-model stage, which was used for scaling to the ATADS totals.

A sensitivity analysis was performed to estimate if the missing flight events would affect any of the airports' Day-Night Average Sound Levels (DNL) by more than 0.1 dB. If this analysis revealed potentially detectible noise increases within individual aircraft categories, then further analysis would be performed to address the effects of flight track distributions. Only BIL was determined to warrant this additional scrutiny, as detailed below.

Tables F-1 and F-2 show the equivalent missed events and the equivalent annual flight events modeled for the 2015 case for the nine airports, respectively.[2] For all airports except BIL, the missed flight events were less than one percent of the modeled total events in any aircraft category. For BIL, the missed flight events were less than two percent, except for the military jet fighter and military rotorcraft categories, which missed 29 percent and 17 percent, respectively. That said, the missed events constituted less than one-half of one percent of overall annual events at BIL.

The sensitivity analysis determined that these discrepancies would not result in an increase of the sound level within the precision of the model for any aircraft category at any airport, with the exception of military jets and military rotorcraft at BIL, with potential increases of DNL 1.1 dB and DNL 0.7 dB, respectively, of the

[2] Equivalent operations are calculated by multiplying the number of nighttime operations by 10, to account for the 10 dB weighting applied to nighttime operations for the calculation of DNL.

contributions from these categories. Note, however, that these contributions are small due to the small proportion of operations from these aircraft.

Table F-1. Equivalent Annual Events Missed for 2015, rounded

Airport ID	Comm'l Jet	Civilian Jet, Other	Civilian Prop	Civilian Rotorcraft	Military Jet, Fighter	Military Jet, Other	Military Prop	Military Rotorcraft	Total
ATL	1	-	-	-	-	-	-	-	1
BDL	-	-	-	5	-	-	-	3	8
BIL	-	25	315	35	2	-	-	10	387
DSM	-	-	4	3	-	-	-	-	7
LAX	2	-	-	-	-	-	-	-	2
MIA	1	-	-	-	-	-	-	-	1
SEA	-	-	8	-	-	-	-	-	8
SJC	-	-	1	-	-	-	-	-	1
TUS	-	-	-	-	-	7	-	-	7

Table F-2. Modeled Annual Equivalent Flight Events for 2015, rounded

Airport ID	Comm'l Jet	Civilian Jet, Other	Civilian Prop	Civilian Rotorcraft	Military Jet, Fighter	Military Jet, Other	Military Prop	Military Rotorcraft	Total
ATL	1,622,489	8,429	16,588	-	16	633	611	-	1,648,766
BDL	200,618	15,499	17,459	4,782	5	1,166	631	1,414	241,574
BIL	32,262	5,462	119,657	2,691	7	131	287	59	160,556
DSM	106,008	17,776	28,359	1,018	86	598	570	347	154,762
LAX	1,609,336	34,970	73,871	-	-	-	-	-	1,718,177
MIA	886,132	30,333	26,497	-	3	1,228	793	-	944,986
SEA	678,454	5,278	214,701	-	-	-	-	-	898,433
SJC	206,905	28,655	44,516	-	-	42	280	-	280,398
TUS	98,869	14,832	70,265	25,127	20,273	1,372	3,764	751	235,253

Further analysis was performed on BIL to determine if the spatial distribution of flight tracks within each of the aircraft categories would cause a substantial increase at potential respondent locations disproportionally impacted by this distribution. The flight tracks for the missing operations within an aircraft category were assumed to have the same spatial distribution as the modeled aircraft in that category, and the impact of this category on potential respondent locations was increased proportionally. The adjusted impacts for each of the categories were combined at each of the potential respondent locations to determine if the overall impact showed a detectable difference with the additional operations accounted for. It was determined the excess exposure due to missed operations did not exceed a DNL of 0.1 dB at any of these locations; therefore the effect of the missing operations was determined not to be substantial.

F.1 Albuquerque Intl Sunport, ABQ

Airport: Albuquerque International Sunport Airport
City: Albuquerque, NM
Runways: 3
Helipads: 2
Elevation: 5,355 feet MSL

Local Operation Notes: Circuits modeled at 1,000 feet AFE and 2,500 feet AFE. Split military tracks counted as local operations as long as they went at least 7 nautical miles from the airport center. C130 and C130E tracks with a maximum altitude above 7,500 feet MSL were assigned the 2,500 feet AFE profile. All KC135R aircraft tracks were assigned the 2,500 feet AFE profile. All other local tracks used the 1,000 feet AFE profile. Military circuit tracks with a maximum range of greater than 25 nautical miles and non-military tracks with a maximum range greater than 4.3 nautical miles were removed from modeling. No maximum altitude was used to remove tracks.

Helicopter Notes: Many helicopter operations: 7 percent of all operations. About half are military and half general aviation or air taxi. Variety of INM types. None counted as local operations. Several thousand V22 Osprey operations.

F.1.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
03	35.022248	-106.63060	5,305	150	10,000	0	3
08	35.044353	-106.62159	5,312	150	13,793	1,000	2.95
12	35.043533	-106.62075	5,312	150	6,000	0	3
21	35.041741	-106.60707	5,316	150	10,000	0	3
26	35.044063	-106.57552	5,355	150	13,793	0	3
30	35.033195	-106.60515	5,314	150	6,000	0	3
H1	35.047455	-106.59743	5,328	n/a	n/a	n/a	n/a
H2	35.035069	-106.61950	5,314	n/a	n/a	n/a	n/a

F.1.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.1.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	58,138	29,681	27,087	16,322	4,571	6,917	142,716	365
ATADS for Data Days	56,647	28,829	26,313	15,848	4,403	6,757	138,797	353
Database	54,693	27,233	20,538	9,157	1,004	2,411	115,036	353
Scale Factor	103.6%	105.9%	128.1%	173.1%	438.5%	280.3%	120.7%	n/a

F.1.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	49,603	25,089	27,243	17,218	3,281	1,750	124,184	365
Database	54,693	27,233	20,538	9,157	1,004	2,411	115,036	353
Scale Factor	90.7%	92.1%	132.6%	188.0%	326.8%	72.6%	108.0%	n/a

F.1.3 Modeled Annual Average Daily Numbers of Flight Events and Operations

F.1.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	79.59	12.40	91.99	81.32	10.67	91.99	0.01	-	0.01	160.93	23.07	184.00
Civilian Jet, Other	6.32	0.40	6.72	6.37	0.36	6.73	0.15	-	0.15	12.99	0.76	13.75
Civilian Prop	50.42	4.51	54.93	46.79	8.14	54.93	5.62	0.46	6.08	108.45	13.57	122.02
Civilian Rotorcraft	3.45	1.25	4.70	3.44	1.26	4.70	-	-	-	6.89	2.51	9.40
Military Jet, Fighter	1.96	-	1.96	1.95	0.01	1.96	0.02	-	0.02	3.95	0.01	3.96
Military Jet, Other	0.53	0.03	0.56	0.52	0.04	0.56	0.67	-	0.67	2.39	0.07	2.46
Military Prop	5.12	2.93	8.05	7.32	0.73	8.05	4.91	3.97	8.88	22.26	11.60	33.86
Military Rotorcraft	9.53	2.35	11.88	11.46	0.42	11.88	-	-	-	20.99	2.77	23.76
TOTAL	**156.92**	**23.87**	**180.79**	**159.17**	**21.63**	**180.80**	**11.38**	**4.43**	**15.81**	**338.85**	**54.36**	**393.21**

Note: Each circuit operation counted as two operations in Total Operations

F.1.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	69.63	10.85	80.48	71.15	9.33	80.48	-	-	-	140.78	20.18	160.96
Civilian Jet, Other	6.55	0.42	6.97	6.59	0.37	6.96	0.12	-	0.12	13.26	0.79	14.05
Civilian Prop	48.50	4.12	52.62	44.96	7.66	52.62	4.18	0.34	4.52	97.64	12.12	109.76
Civilian Rotorcraft	3.21	1.10	4.31	3.21	1.11	4.32	-	-	-	6.42	2.21	8.63
Military Jet, Fighter	2.12	-	2.12	2.12	0.01	2.13	<0.01	-	-	4.24	0.01	4.25
Military Jet, Other	0.58	0.04	0.62	0.57	0.05	0.62	0.17	-	0.17	1.32	0.09	1.41
Military Prop	5.56	3.18	8.74	7.95	0.79	8.74	1.27	1.03	2.30	14.78	5.00	19.78
Military Rotorcraft	10.36	2.55	12.91	12.45	0.45	12.90	-	-	-	22.81	3.00	25.81
TOTAL	**146.51**	**22.26**	**168.77**	**149.00**	**19.77**	**168.77**	**5.74**	**1.37**	**7.11**	**301.25**	**43.40**	**344.65**

Note: Each circuit operation counted as two operations in Total Operations

F.1.4 Modeled Tracks

Area Navigation (RNAV) procedures:

- 5 Standard Terminal Arrival Route (STAR) RNAV procedures published Jan 2013, started using Feb 2013
- 6 RNAV Required Navigation Performance (RNP) procedures (one for each runway) published Jan 2013, started using Feb 2013
- 2 RNAV Global Positioning System (GPS) procedures (03 and 08) published Jan 2013, started using Feb 2013
- 9 RNAV Standard Instrument Departure (SID) procedures published Jan 2013, started using Feb 2013

Total Tracks:

Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	26,703	7,888	26,054	7,679	89	6
Non-Jets, fixed-wing	13,679	5,592	14,133	3,737	925	176
Total	40,382	13,480	40,187	11,416	1,014	182

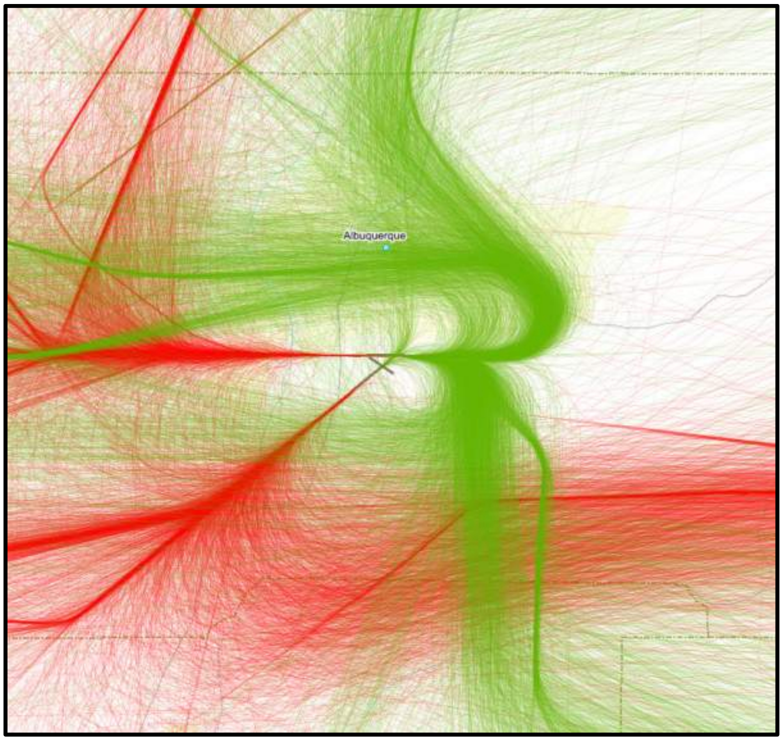
Aircraft Category	Arrivals	Departures	Locals
Helicopters*	3,555	3,624	-

Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	52,846	15,573	68,419	77%	23%
Non-Jets, fixed-wing	28,737	9,505	38,242	75%	25%
Helicopters*	n/a	n/a	7,179	n/a	n/a
Total	81,583	25,078	113,840	76%	24%

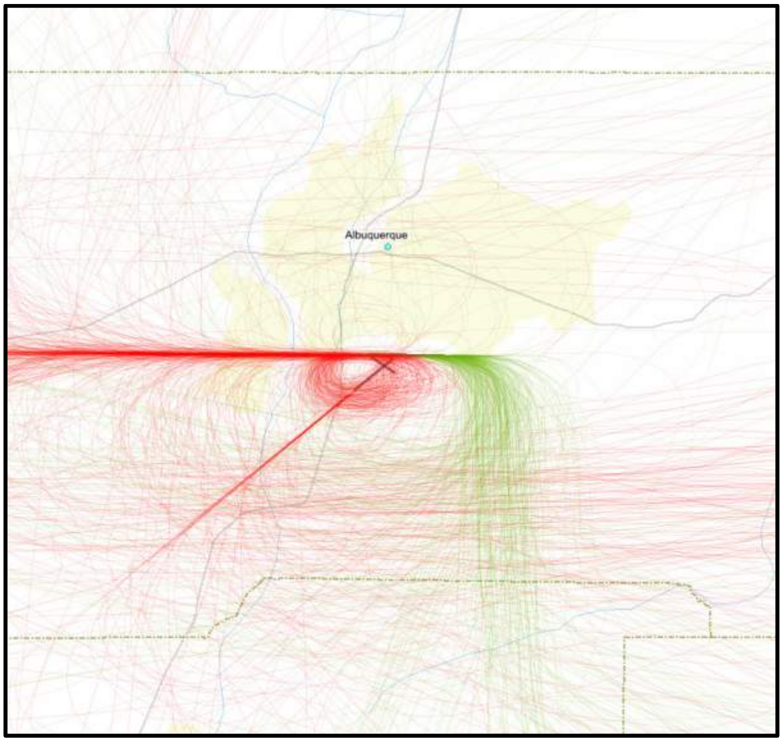
*V22 modeled as S65 are counted as Helicopters, those modeled as HS748A are counted as Non-Jets. The non-jet operations of the V22 are those when it operates with the propeller axis horizontal; the helicopter operations are when the propeller axis is vertical. If the radar flight track appeared to go to/from a helipad, that operation was assigned helicopter. If the radar flight track appeared to go to/from a runway end, the operation was assigned fixed-wing.

F.1.5 Representative Radar Flight Tracks

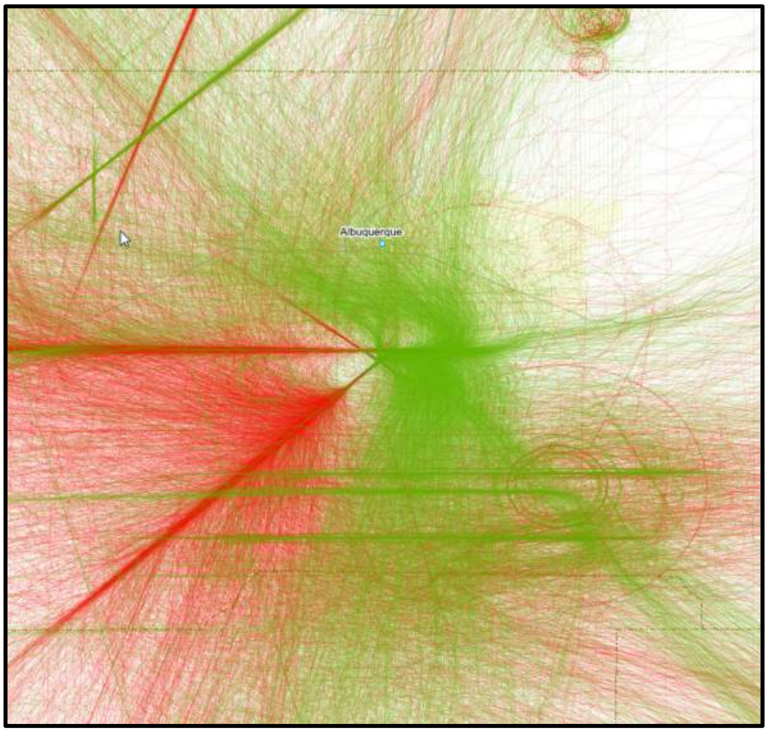
East Flow, Non-Military Jets – 33% Sample



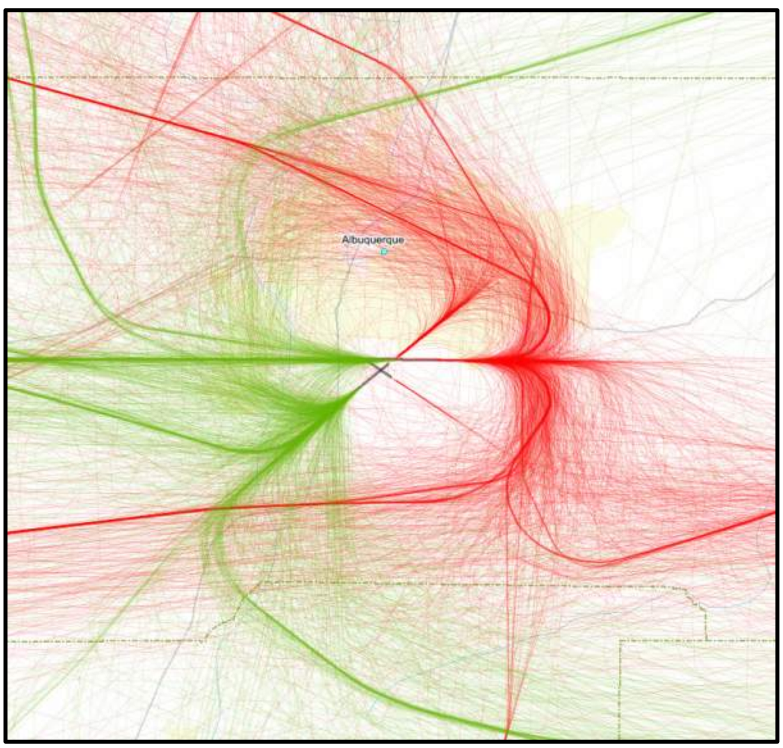
Military Jets – 33% Sample



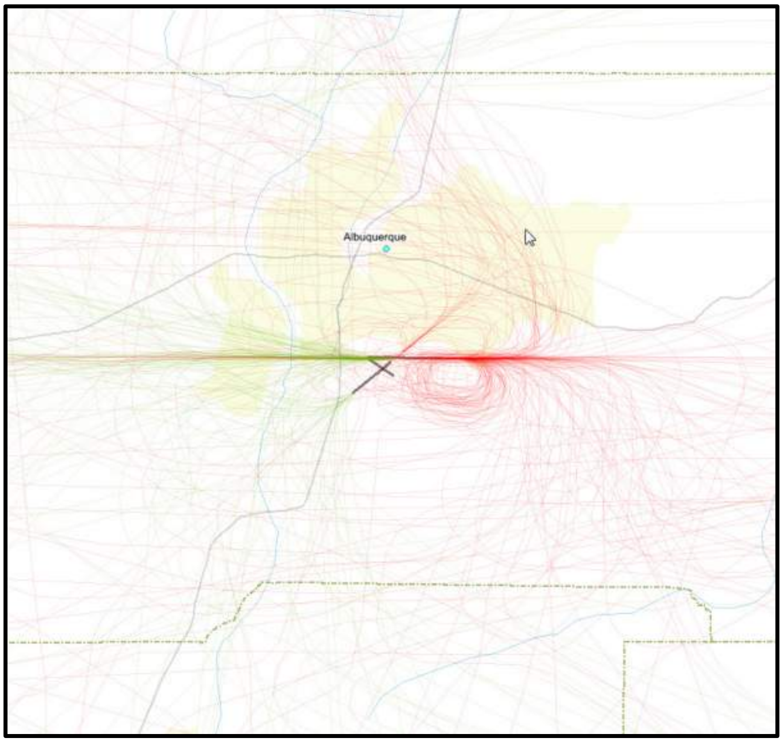
East Flow, Non-Jets – 33% Sample



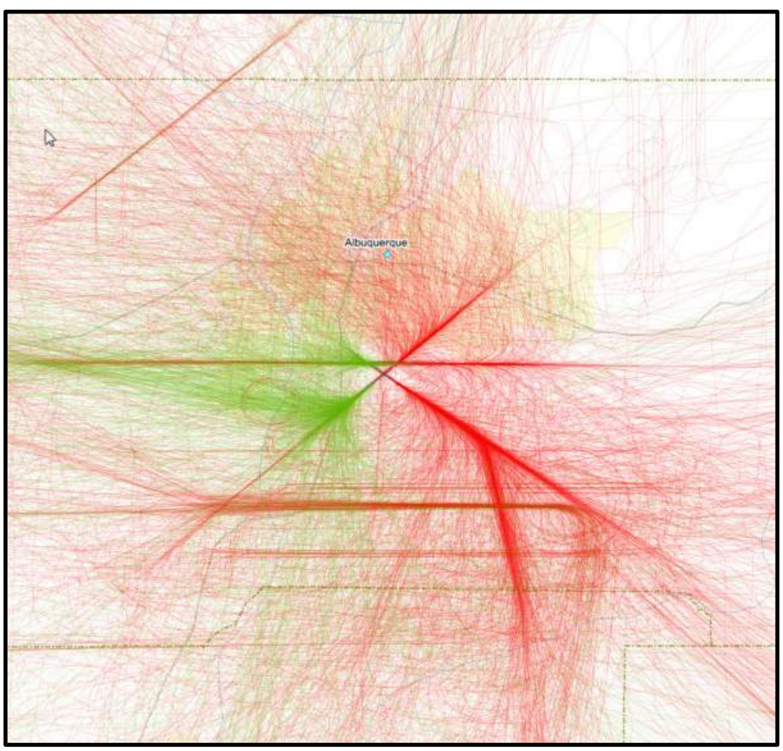
West Flow, Non-Military Jets – 33% Sample



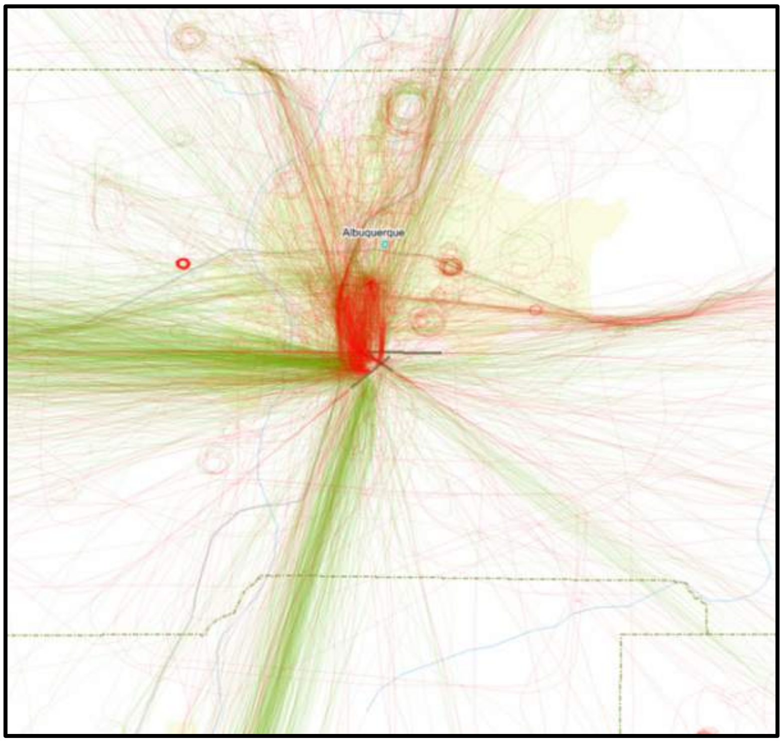
Military Jets - 33% Sample



West Flow, Non-Jets - 33% Sample

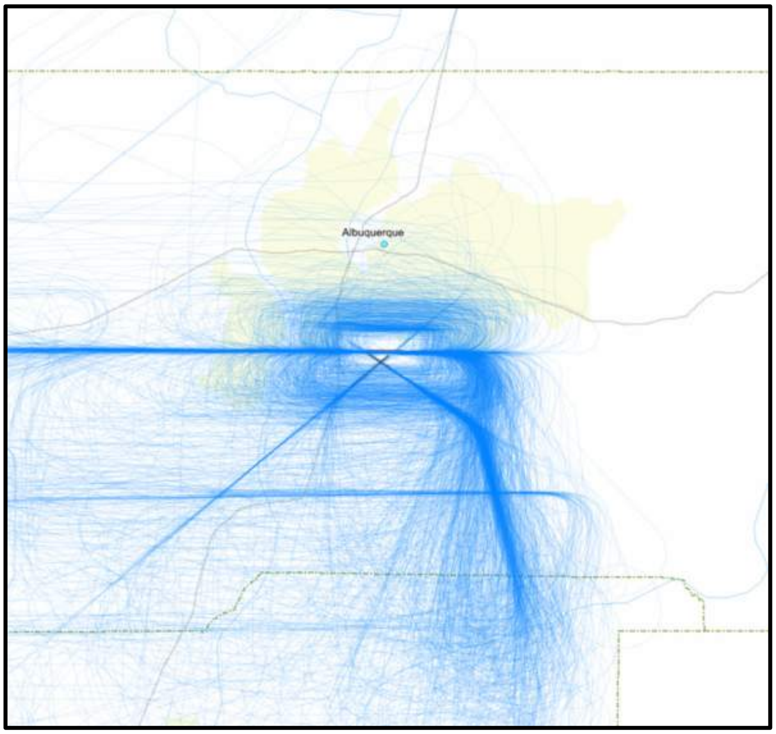


(all flows) Non-Military Helicopters – 100%

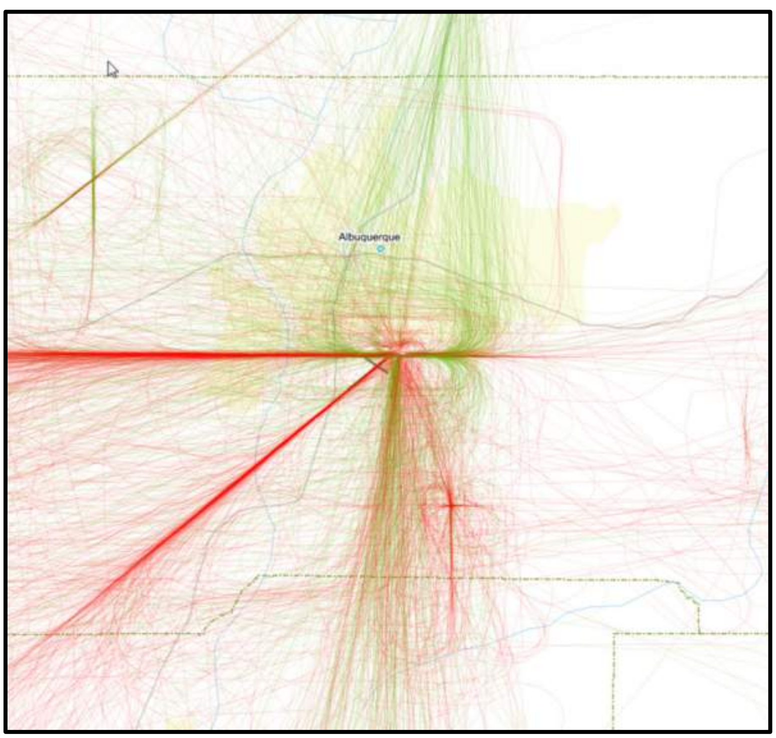


Military Helicopters – 100%

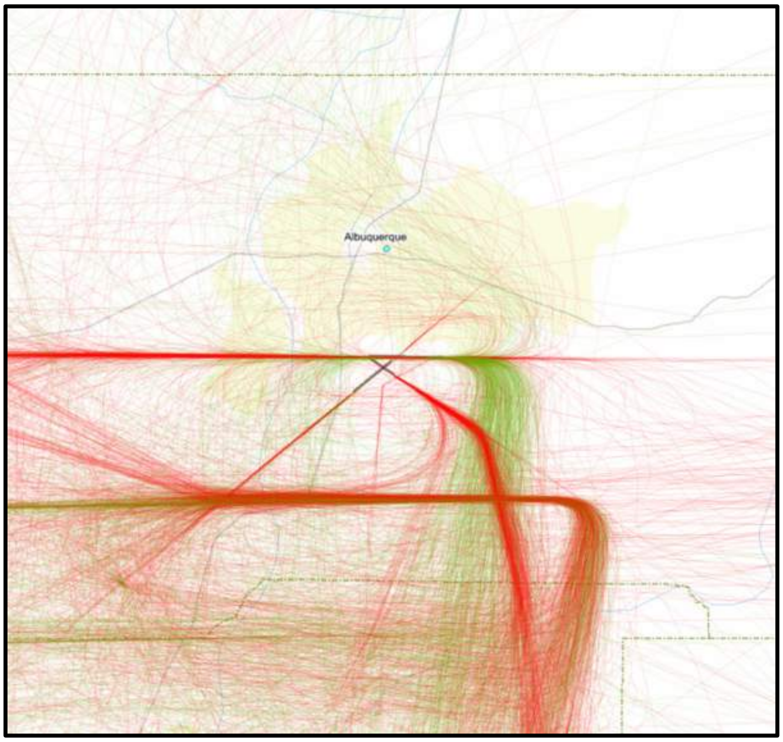
Local Operations – 100%



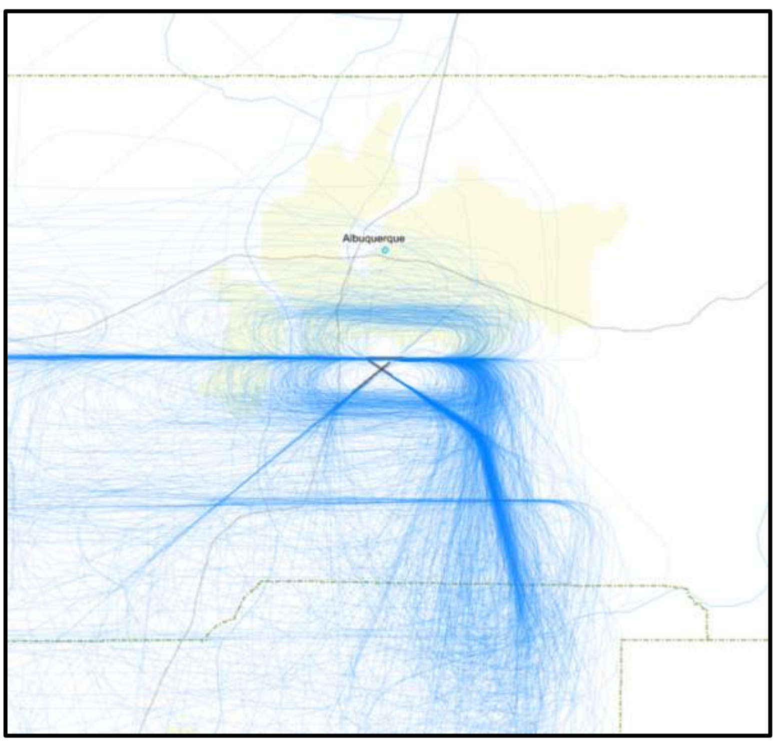
V22 Ospreys – 100%



C130 Arrivals and Departures – 100%



C130 Local Operations – 100%



F.1.6 Special KC135 Considerations

In INM, the KC135R has only one takeoff weight and it causes the aircraft to overrun ABQ's runway by thousands of feet. To avoid the overrun, the weight was reduced. As a KC135R is a derivative of a Boeing 707, the reduction in weight was based on INM's 707320 profile weights:

707320 - Max Take-off Weight= 334000

Stage 1 weight – 214000 (64.1% of Max TOW)
Stage 2 weight – 228000 (68.3% of Max TOW)
Stage 3 weight – 240000 (71.9% of Max TOW)
Stage 4 weight – 260000 (77.8% of Max TOW)

(There are stages 5, 6, and 7 but not needed for ABQ)

KC135R - Max Take-off Weight= 324000

Stage 1 weight – 208000 (64.2% of Max TOW)
Stage 2 weight – 221000 (68.2% of Max TOW)
Stage 3 weight – 233000 (71.9% of Max TOW)
Stage 4 weight – 252000 (77.8% of Max TOW)

Stage 1 weight was also used for circuit profile.

F.1.7 RNAV Procedures

RNAV STAR procedures:

COLTR ONE
KRKEE ONE
LOWBO ONE
LZZRD ONE
SNDIA ONE

RNAV Departure Procedures:

JEMEZ ONE
ADYOS ONE
ATOMK ONE
BOSQE ONE
DOOKK ONE
FYSTA ONE
GRZZZ ONE
JETOK ONE
MNZNO ONE
RDRNR ONE

RNAV RNP/GPS Procedures:

Y RWY 21

F.2 Albany Intl, ALB

Airport: Albany International Airport
City: Albany, NY
Runways: 2
Helipads: 2
Elevation: 285 feet MSL

Local Operation Notes: Circuits modeled at 1,500 feet AFE. Split tracks counted as local operations as long as they went at least 5 nautical miles from the airport center. Most of the split tracks were helicopters. Circuit tracks with a maximum altitude greater than 5,000 feet MSL were removed.

Helicopter Notes: Many operations, about 9 percent of daily operations. About half are military and half general aviation or air taxi. Variety of INM types. Some counted as local operations.

Other Notes: Some C130 activity at the airport.

F.2.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
01	42.737164	-73.804256	284	150	8,500	0	3
10	42.749150	-73.812091	276	150	7,200	0	3
19	42.760474	-73.805266	280	150	8,500	0	3
28	42.749777	-73.785302	276	150	7,200	1,202	3.35
HNG	42.744333	-73.802104	280	n/a	n/a	n/a	n/a
HGA	42.750989	-73.808866	285	n/a	n/a	n/a	n/a

F.2.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.2.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	22,527	26,065	13,716	3,194	7,327	1,778	74,607	365
ATADS for Data Days	22,434	25,940	13,700	3,187	7,297	1,764	74,322	363
Database	22,018	26,459	9,542	1,454	828	528	60,829	363
Scale Factor	101.9%	98.0%	143.6%	219.2%	881.3%	334.1%	122.2%	n/a

F.2.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	22,067	21,525	14,447	2,688	7,786	1,352	69,865	365
Database	22,018	26,459	9,542	1,454	828	528	60,829	363
Scale Factor	100.2%	81.4%	151.4%	184.9%	940.3%	256.1%	114.9%	n/a

F.2.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.2.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	32.87	12.41	45.28	36.06	9.26	45.32	0.02	-	0.02	68.97	21.67	90.64
Civilian Jet, Other	4.07	0.34	4.41	4.10	0.29	4.39	0.24	-	0.24	8.65	0.63	9.28
Civilian Prop	30.94	2.15	33.09	30.44	2.63	33.07	7.38	0.17	7.55	76.14	5.12	81.26
Civilian Rotorcraft	2.57	0.15	2.72	2.62	0.10	2.72	2.06	0.18	2.24	9.31	0.61	9.92
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	0.13	-	0.13	0.12	0.01	0.13	-	-	-	0.25	0.01	0.26
Military Prop	1.30	0.01	1.31	1.28	0.03	1.31	1.42	-	1.42	5.42	0.04	5.46
Military Rotorcraft	2.72	0.23	2.95	2.91	0.04	2.95	1.01	-	1.01	7.65	0.27	7.92
TOTAL	**74.60**	**15.29**	**89.89**	**77.53**	**12.36**	**89.89**	**12.13**	**0.35**	**12.48**	**176.39**	**28.35**	**204.74**

Note: Each circuit operation counted as two operations in Total Operations

F.2.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	30.21	11.90	42.11	33.49	8.61	42.10	0.03	-	0.03	63.73	20.51	84.24
Civilian Jet, Other	4.30	0.36	4.66	4.34	0.31	4.65	0.25	-	0.25	8.89	0.67	9.56
Civilian Prop	28.75	1.89	30.64	28.28	2.36	30.64	7.87	0.18	8.05	64.90	4.43	69.33
Civilian Rotorcraft	2.41	0.13	2.54	2.45	0.09	2.54	2.20	0.20	2.40	7.06	0.42	7.48
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	0.11	-	0.11	0.10	0.01	0.11	-	-	-	0.21	0.01	0.22
Military Prop	1.09	0.01	1.10	1.08	0.02	1.10	1.09	-	1.09	3.26	0.03	3.29
Military Rotorcraft	2.29	0.20	2.49	2.45	0.04	2.49	0.78	-	0.78	5.52	0.24	5.76
TOTAL	**69.16**	**14.49**	**83.65**	**72.19**	**11.44**	**83.63**	**12.22**	**0.38**	**12.60**	**153.57**	**26.31**	**179.88**

Note: Each circuit operation counted as two operations in Total Operations

F.2.4 Modeled Tracks

RNAV procedures:

- 0 STAR RNAV procedures
- 2 RNAV RNP procedures (01 and 19)
- 4 RNAV GPS procedures (one for each runway)
- 0 RNAV (SID) procedures

Total Tracks:

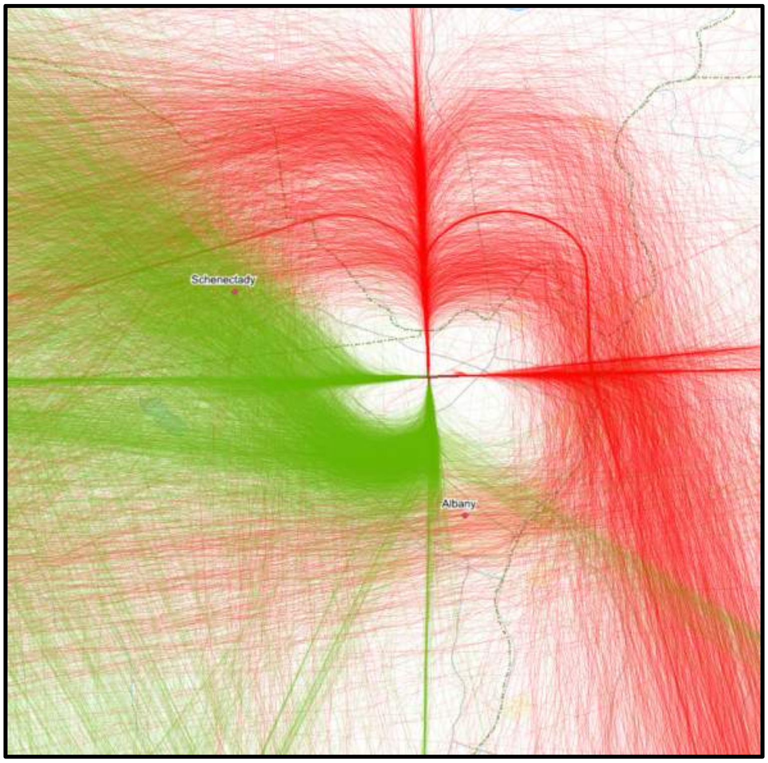
Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	9,652	7,971	9,482	7,986	8	3
Non-Jets, fixed-wing	4,765	6,376	5,238	5,500	62	386
Total	14,417	14,347	14,720	13,486	70	389

Aircraft Category	Arrivals	Departures	Locals
Helicopters	1,593	1,348	-

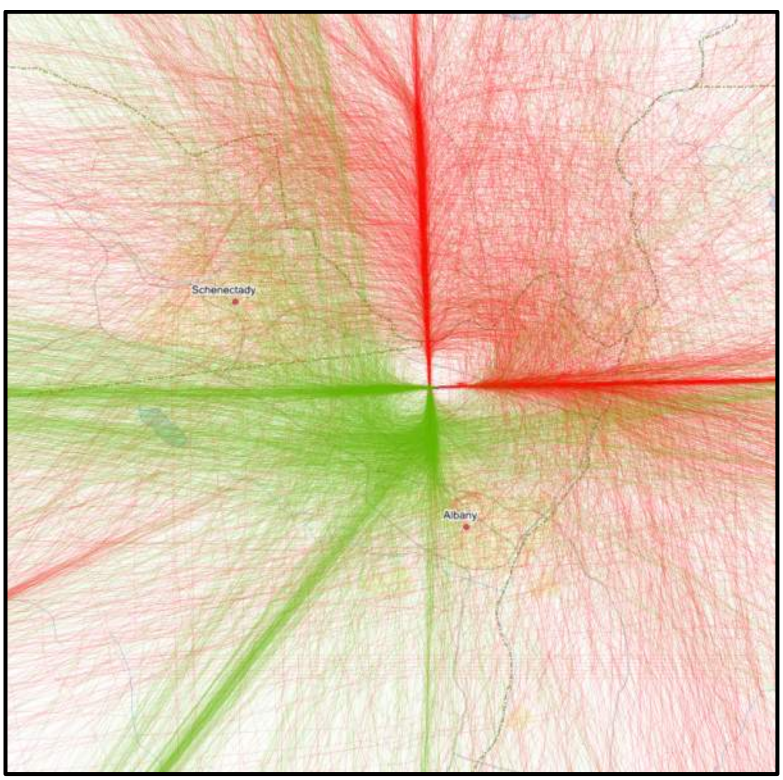
Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	19,142	15,960	35,102	55%	45%
Non-Jets, fixed-wing	10,065	12,262	22,327	45%	55%
Helicopters	n/a	n/a	2,941	n/a	n/a
Total	29,207	28,222	60,370	51%	49%

F.2.5 Representative Radar Flight Tracks

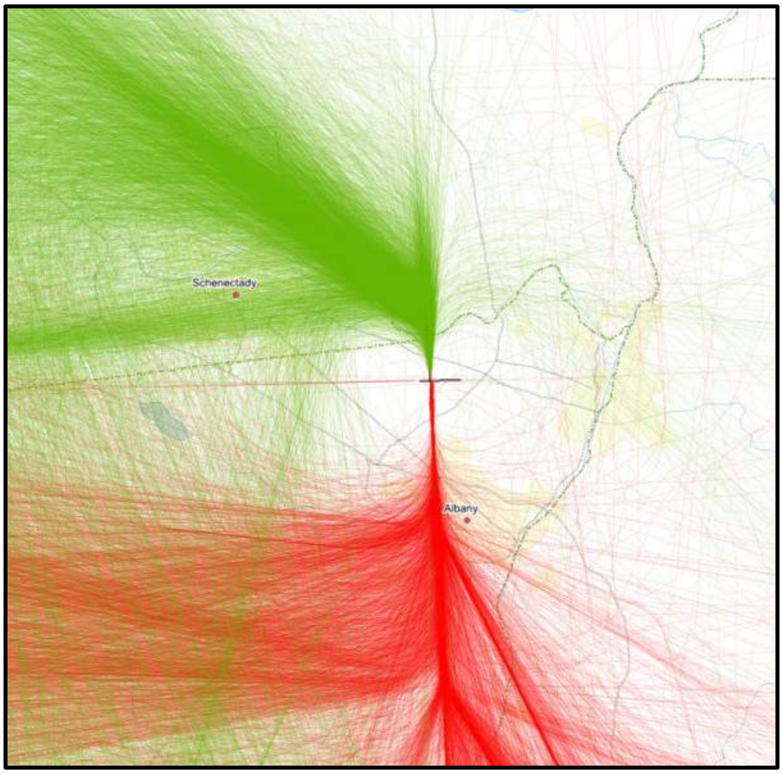
West Flow, Non-Military Jets – 50% Sample



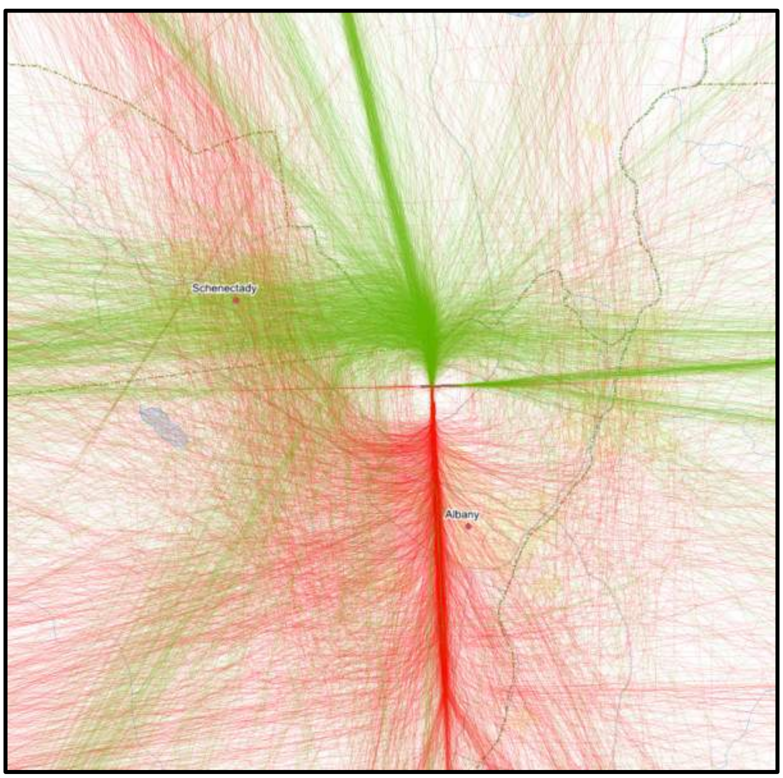
Non-Jets - 50% Sample



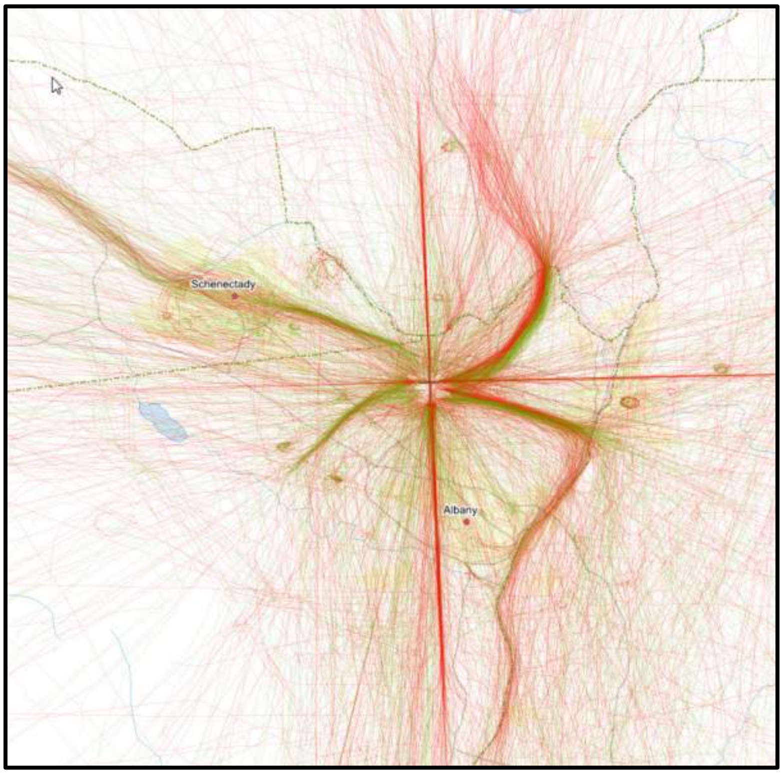
East Flow, Non-Military Jets – 50% Sample



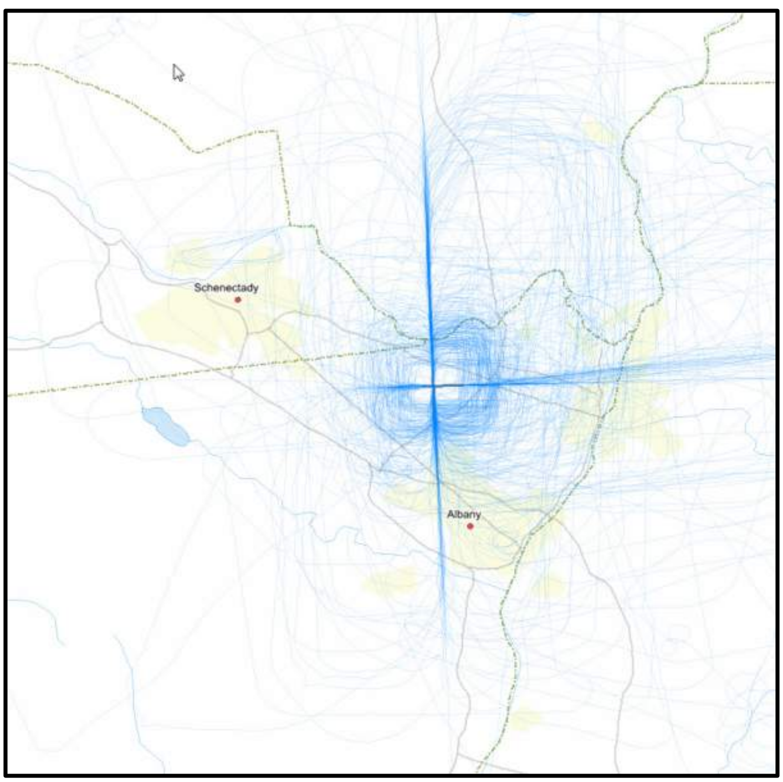
Non-Jets – 50% Sample



Helicopters – 100%



Local Operations – 100%



F.3 Hartsfield-Jackson Atlanta Intl, ATL

Airport: Hartsfield-Jackson Atlanta International Airport
City: Atlanta, GA
Runways: 5
Helipads: 0
Elevation: 1,027 feet MSL

Local Operation Notes: No local operations modeled.

Helicopter Notes: No Helicopters modeled.

Other Notes: Very busy airport with mostly commercial jet operations. One 2015 operation (of 882,497 total operations) was not modeled due to a processing error. This omission has no effect within the precision of the model.

F.3.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
08L	33.64953	-84.43900	1,015	150	9,000	0	3
08R	33.64679	-84.43840	1,024	150	10,000	0	3
09L	33.63470	-84.44800	1,019	150	12,390	0	3
09R	33.63181	-84.44800	1,026	150	9,000	0	3
10	33.62027	-84.44790	1,000	150	9,000	0	3
26R	33.64954	-84.40950	990	150	9,000	0	3
26L	33.64679	-84.40550	995	150	10,000	0	3
27R	33.63470	-84.40730	977	150	12,390	500	3
27L	33.63182	-84.41840	985	150	9,000	0	3
28	33.62028	-84.41830	998	150	9,000	0	3

F.3.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.3.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	734,894	178,130	7,753	300	0	0	921,077	365
ATADS (Data Days)	734,894	178,130	7,753	300	0	0	921,077	365
Database	731,581	176,109	5,199	79	0	0	912,968	365
Scale Factor	100.5%	101.1%	149.1%	379.7%	0	0	100.9%	n/a

F.3.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	780,326*	94,223	7,291	657	0	0	882,497	365
Database	731,581	176,109	5,199	79	0	0	912,968	365
Scale Factor	106.7%	53.5%	140.2%	831.6%	0	0	96.7%	n/a

*1 fewer operation was modeled due to processing error; Affected DNL by less than 0.1 dB (estimated).

F.3.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.3.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	1,134.91	104.70	1,239.61	1,109.53	130.08	1,239.61	-	-	-	2,244.44	234.78	2,479.22
Civilian Jet, Other	6.20	0.56	6.76	6.09	0.67	6.76	-	-	-	12.29	1.23	13.52
Civilian Prop	12.62	2.35	14.97	12.93	2.05	14.98	-	-	-	25.55	4.40	29.95
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	0.01	-	0.01	0.01	-	0.01	-	-	-	0.02	-	0.02
Military Jet, Other	0.25	0.01	0.26	0.24	0.02	0.26	-	-	-	0.49	0.03	0.52
Military Prop	0.11	0.03	0.14	0.12	0.02	0.14	-	-	-	0.23	0.05	0.28
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**1,154.10**	**107.65**	**1,261.75**	**1,128.92**	**132.84**	**1,261.76**	**-**	**-**	**-**	**2,283.02**	**240.49**	**2,523.51**

Note: Each circuit operation counted as two operations in Total Operations

F.3.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Day	Day	Night	Total	Day	Night	Total
Commercial Jet	1,091.06	101.06	1,192.12	1,064.20	127.93	1,192.13	-	-	-	2,155.26	228.99	2,384.25
Civilian Jet, Other	5.83	0.53	6.36	5.73	0.63	6.36	-	-	-	11.56	1.16	12.72
Civilian Prop	7.93	1.58	9.51	8.17	1.35	9.52	-	-	-	16.10	2.93	19.03
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	0.02	-	0.02	0.02	-	0.02	-	-	-	0.04	-	0.04
Military Jet, Other	0.55	0.02	0.57	0.53	0.04	0.57	-	-	-	1.08	0.06	1.14
Military Prop	0.23	0.08	0.31	0.26	0.04	0.30	-	-	-	0.49	0.12	0.61
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**1,105.62**	**103.27**	**1,208.89**	**1,078.91**	**129.99**	**1,208.90**	**-**	**-**	**-**	**2,184.53**	**233.26**	**2,417.79**

Note: Each circuit operation counted as two operations in Total Operations

F.3.4 Modeled Tracks

RNAV procedures:

- 7 STAR RNAV procedures.
- 10 RNAV GPS procedures (one for each runway).
- 16 RNAV (SID) procedures.

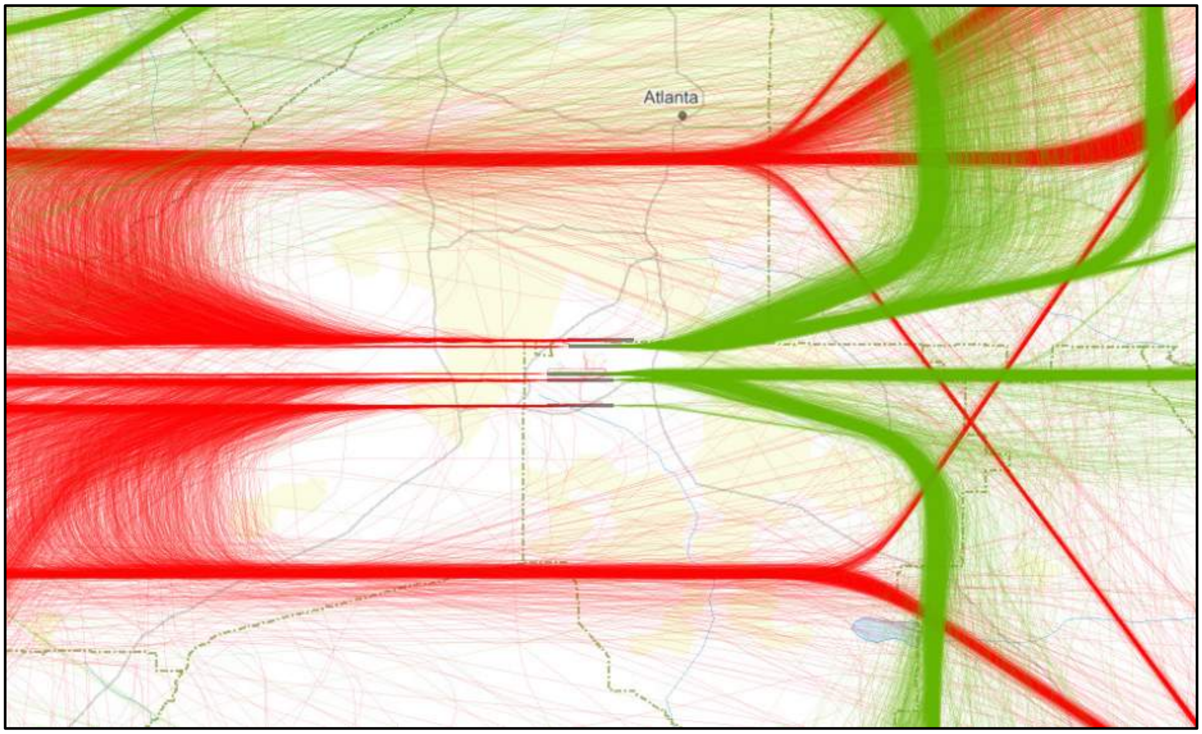
Total Tracks:

Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	180,787	271,671	180,158	270,791	-	-
Non-Jets, fixed-wing	1,993	2,967	1,826	2,774	-	-
Total	182,780	274,638	181,984	273,565	-	-

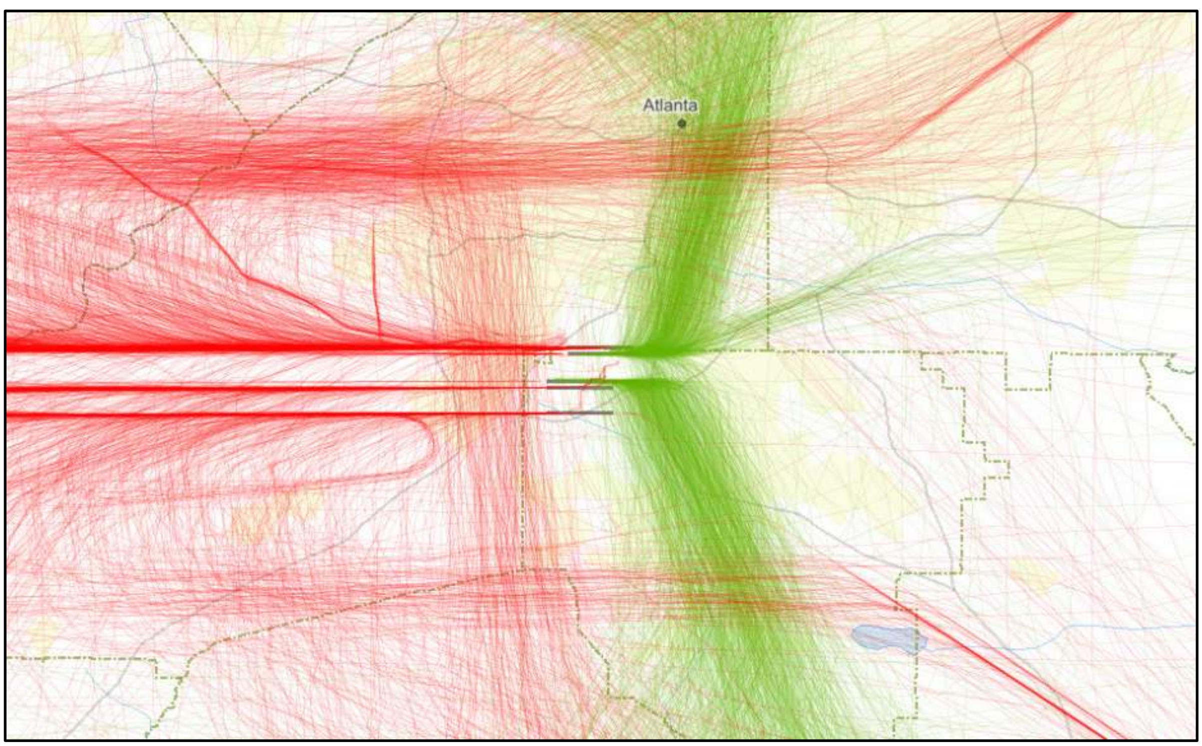
Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	360,945	542,462	903,407	40%	60%
Non-Jets, fixed-wing	3,819	5,741	9,560	40%	60%
Helicopters	n/a	n/a	-	n/a	n/a
Total	364,764	548,203	912,967	40%	60%

F.3.5 Representative Radar Flight Tracks

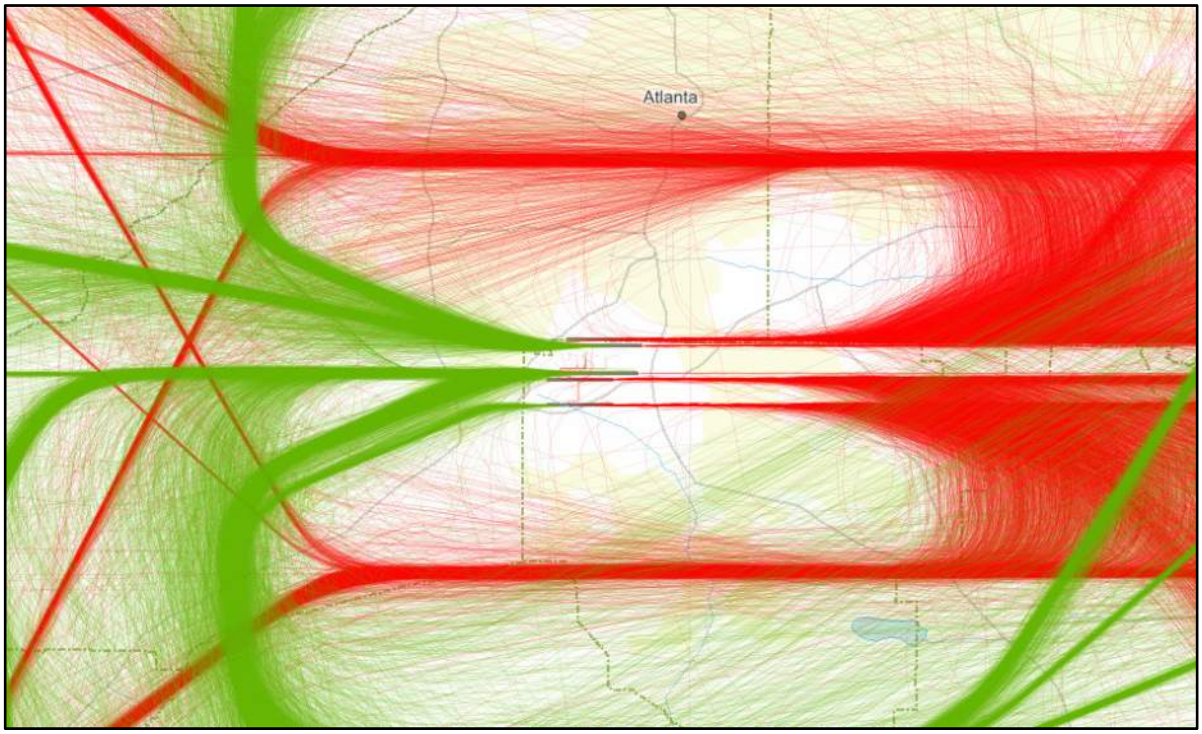
East Flow, Jets – 5% Sample



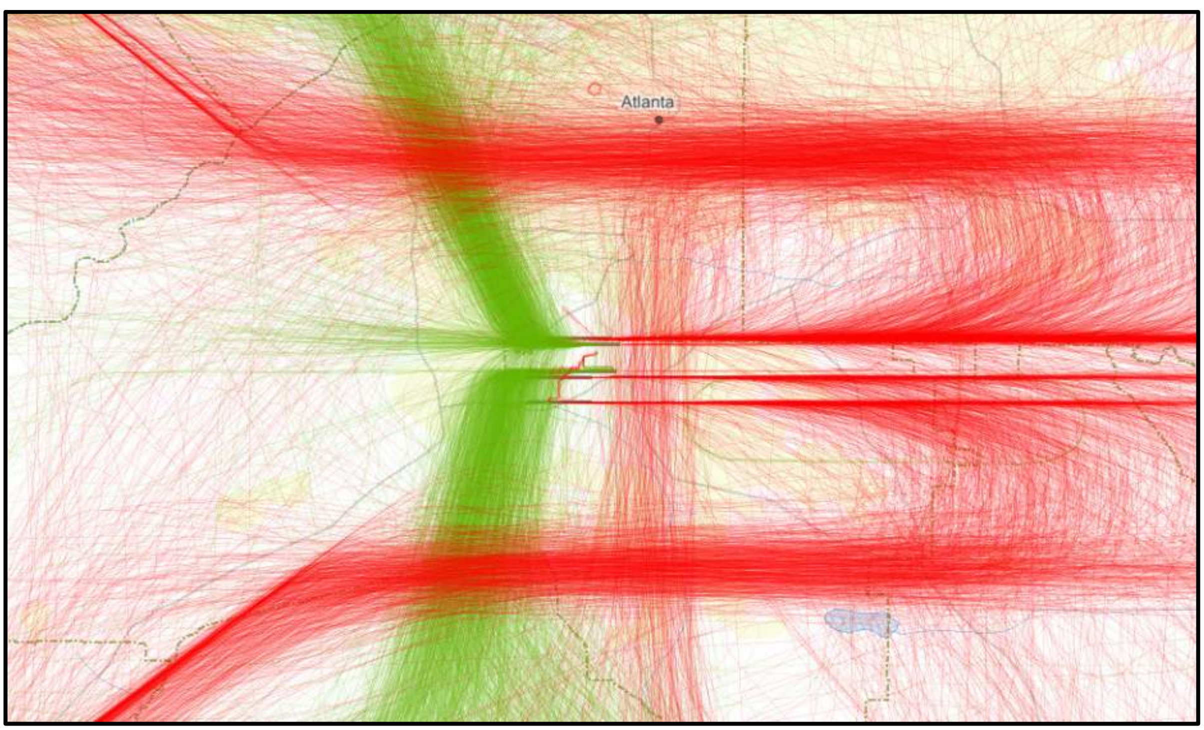
Non-Jets – 100% Sample



West Flow, Jets – 5% Sample



Non-Jets – 100% Sample



F.4 Austin-Bergstrom Intl, AUS

Airport: Austin-Bergstrom International Airport
City: Austin, TX
Runways: 2
Helipads: 3
Elevation: 544 feet MSL

Local Operation Notes: Circuits modeled at 1,000 feet AFE and 2,000 feet AFE. Split tracks counted as non-local operations as long as they went at least 7 nautical miles from the airport center. Circuit tracks that had a maximum altitude under 2,000 feet MSL used the 1,000 feet AFE profile. All other circuit operations used 2,000 feet AFE profile. Circuit tracks with a maximum range of greater than 25 nautical miles or a maximum altitude greater than 4,500 feet MSL were removed from modeling.

Helicopter Notes: About 3 percent of daily operations. About half are military and half general aviation or air taxi. Variety of INM types. None counted as local operations.

F.4.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
17L	30.203830	-97.657891	492	150	9,000	0	3
17R	30.213613	-97.679365	542	150	12,248	0	3
35L	30.179946	-97.678475	488	150	12,248	0	3
35R	30.179091	-97.657244	474	150	9,000	0	3
H1	30.202627	-97.655529	483	n/a	n/a	n/a	n/a
H2	30.187290	-97.661013	477	n/a	n/a	n/a	n/a
H3	30.179500	-97.673200	477	n/a	n/a	n/a	n/a

F.4.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.4.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	99,611	16,367	50,287	5,947	2,166	540	174,918	365
ATADS for Data Days	99,126	16,320	50,058	5,909	2,152	540	174,105	363
Database	96,439	16,706	40,171	2,437	1,468	48	157,269	363
Scale Factor	102.8%	97.7%	124.6%	242.5%	146.6%	1125.0%	110.7%	n/a

F.4.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	114,068	15,358	49,146	8,002	3,871	748	191,193	365
Database	96,439	16,706	40,171	2,437	1,468	48	157,269	363
Scale Factor	118.3%	91.9%	122.3%	328.4%	263.7%	1558.3%	121.6%	n/a

F.4.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.4.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	121.85	26.70	148.55	133.93	14.62	148.55	-	-	-	255.78	41.32	297.10
Civilian Jet, Other	22.24	1.42	23.66	22.31	1.35	23.66	0.09	-	0.09	44.73	2.77	47.50
Civilian Prop	47.76	4.28	52.04	47.51	4.53	52.04	2.82	0.05	2.87	100.91	8.91	109.82
Civilian Rotorcraft	2.72	0.99	3.71	2.95	0.77	3.72	-	-	-	5.67	1.76	7.43
Military Jet, Fighter	0.91	0.01	0.92	0.90	0.02	0.92	0.03	-	0.03	1.87	0.03	1.90
Military Jet, Other	0.55	-	0.55	0.55	-	0.55	-	-	-	1.10	-	1.10
Military Prop	3.41	0.15	3.56	3.49	0.07	3.56	0.71	-	0.71	8.32	0.22	8.54
Military Rotorcraft	2.81	0.31	3.12	3.04	0.08	3.12	-	-	-	5.85	0.39	6.24
TOTAL	**202.25**	**33.86**	**236.11**	**214.68**	**21.44**	**236.12**	**3.65**	**0.05**	**3.70**	**424.23**	**55.40**	**479.63**

Note: Each circuit operation counted as two operations in Total Operations

F.4.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	137.85	30.57	168.42	151.73	16.69	168.42	-	-	-	289.58	47.26	336.84
Civilian Jet, Other	21.84	1.39	23.23	21.90	1.33	23.23	0.17	-	0.17	43.91	2.72	46.63
Civilian Prop	46.63	4.12	50.75	46.41	4.34	50.75	5.08	0.09	5.17	98.12	8.55	106.67
Civilian Rotorcraft	2.63	0.94	3.57	2.84	0.73	3.57	-	-	-	5.47	1.67	7.14
Military Jet, Fighter	1.24	0.01	1.25	1.22	0.03	1.25	0.04	-	0.04	2.50	0.04	2.54
Military Jet, Other	0.74	-	0.74	0.74	-	0.74	-	-	-	1.48	-	1.48
Military Prop	4.62	0.20	4.82	4.73	0.09	4.82	0.99	-	0.99	10.34	0.29	10.63
Military Rotorcraft	3.80	0.41	4.21	4.11	0.10	4.21	-	-	-	7.91	0.51	8.42
TOTAL	**219.35**	**37.64**	**256.99**	**233.68**	**23.31**	**256.99**	**6.28**	**0.09**	**6.37**	**459.31**	**61.04**	**520.35**

Note: Each circuit operation counted as two operations in Total Operations

F.4.4 Modeled Tracks

RNAV procedures:

- 1 STAR (Arrival) RNAV procedure
- 0 RNAV RNP procedures
- 4 RNAV GPS procedures (one for each runway)
- 1 RNAV SID procedure (not used in May of 2013)

Total Tracks:

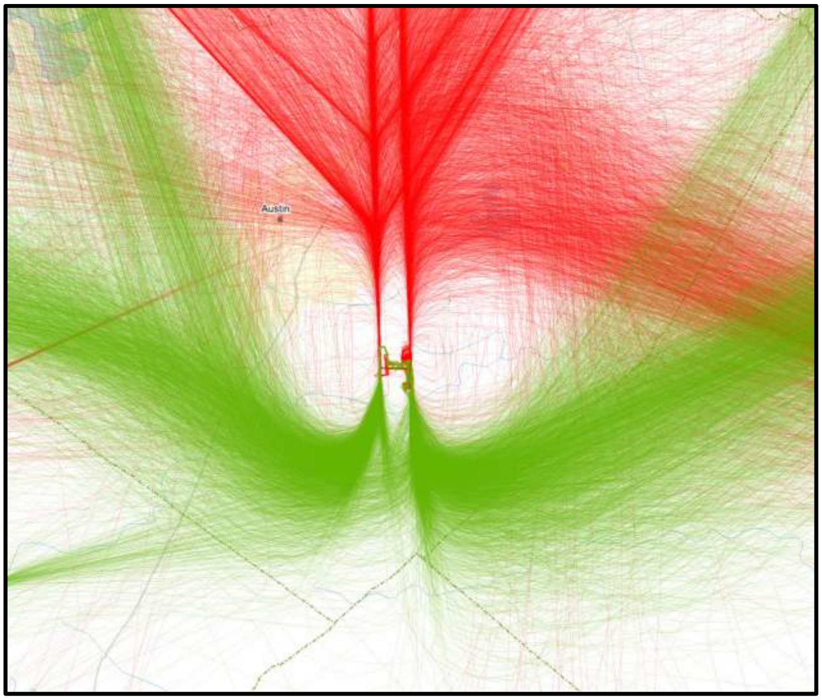
Aircraft Category	Arrivals		Departures		Locals	
	North	South	North	South	North	South
Jets	18,685	41,609	18,433	41,259	8	16
Non-Jets, fixed-wing	4,977	11,577	4,580	11,277	231	503
Total	23,662	53,186	23,013	52,536	239	519

Aircraft Category	Arrivals	Departures	Locals
Helicopters	1,643	1,713	-

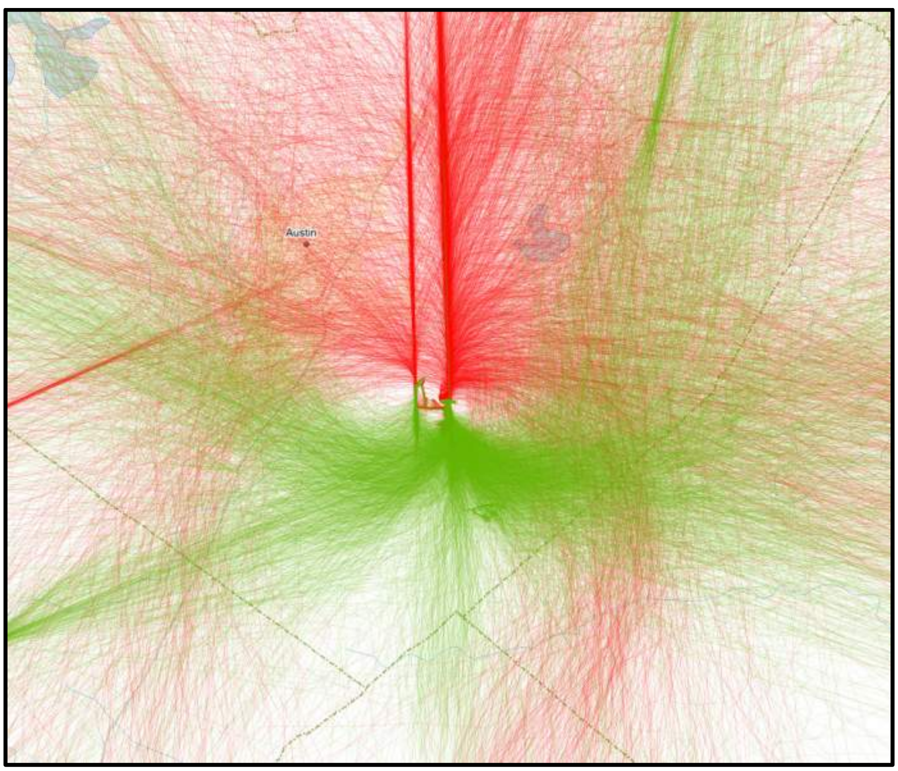
Aircraft Category	Total			Percent	
	North	South	Total	North	South
Jets	37,126	82,884	120,010	31%	69%
Non-Jets, fixed-wing	9,788	23,357	33,145	30%	70%
Helicopters	n/a	n/a	3,356	n/a	n/a
Total	46,914	106,241	156,511	31%	69%

F.4.5 Representative Radar Flight Tracks

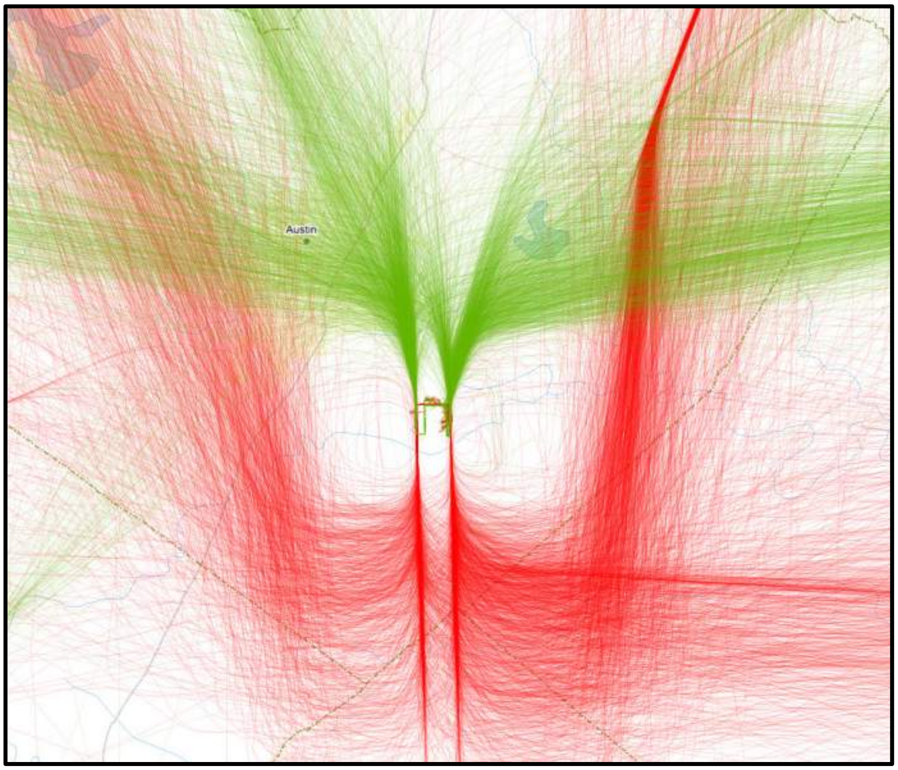
South Flow, Jets – 15% Sample



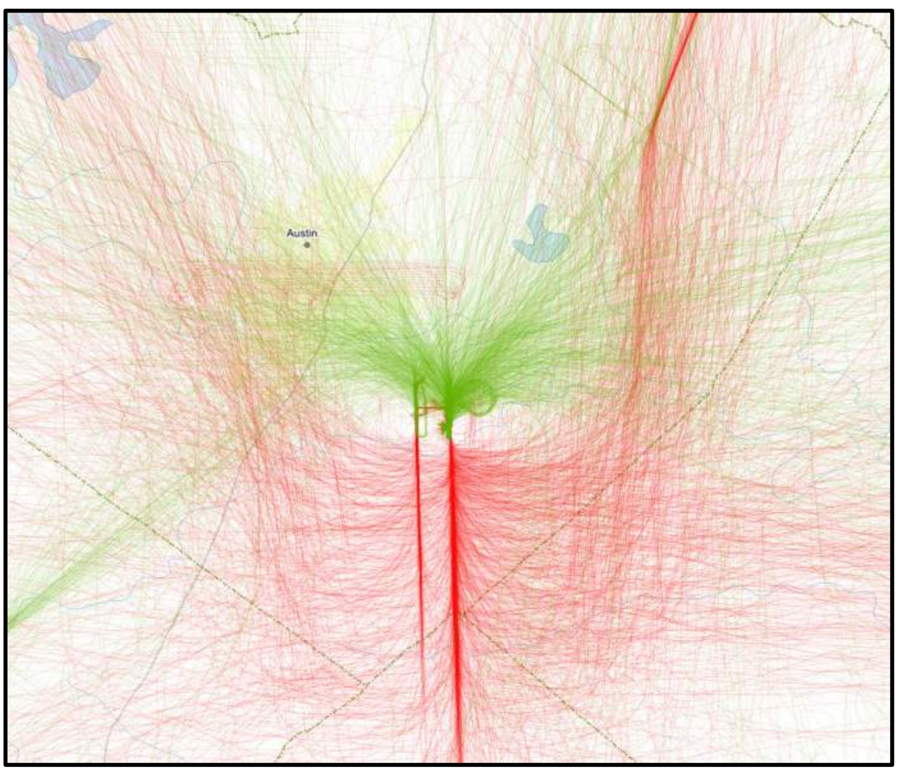
Non-Jets – 33% Sample



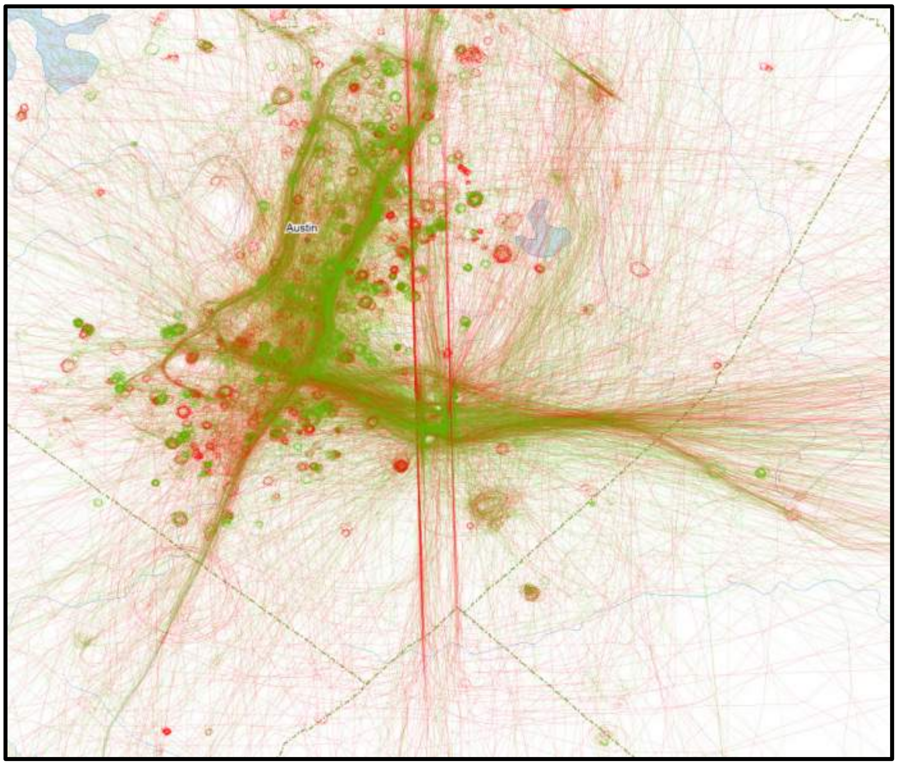
North Flow, Jets – 15% Sample



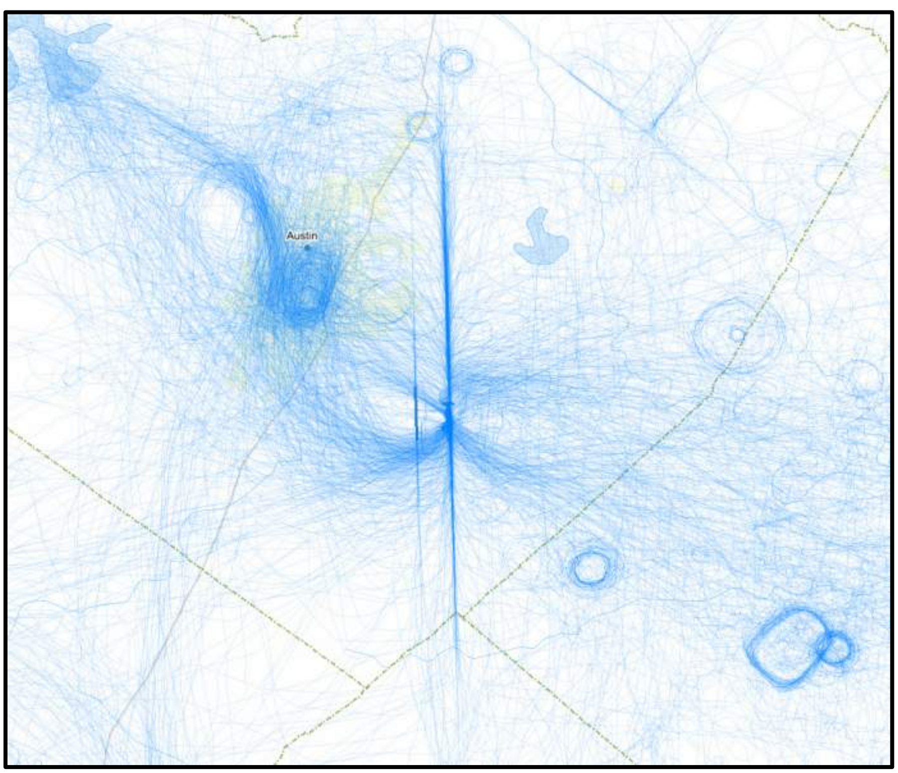
Non-Jets – 33% Sample



Helicopters – 100%



Local Operations – 100%



F.5 Bradley Intl, BDL

Airport: Bradley International Airport
City: Windsor Locks, CT
Runways: 3
Helipads: 3
Elevation: 173 feet MSL

Local Operation Notes: Circuits modeled at 1,700 feet AFE. Split tracks counted as non-local operations as long as they went at least 7 nautical miles from the airport center.

Helicopter Notes: About 4 percent of daily operations. About half are military and half general aviation or air taxi. Most operations are Sikorsky S70 or Sikorsky S76 aircraft. None counted as local operations.

Other Notes: Mostly commercial jet operations. Most local operations are jets. Eight 2015 operations (of 93,508 total operations) were not modeled due to a processing error. This omission has no effect within the precision of the model.

F.5.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
01	41.933725	-72.679620	171	100	4,268	475	3
06	41.932014	-72.696580	173	200	9,510	0	3
15	41.942397	-72.693253	169	150	6,847	0	3.5
19	41.945433	-72.679883	169	100	4,268	0	3
24	41.950664	-72.672133	161	200	9,510	0	3
33	41.929257	-72.675266	168	150	6,847	0	3
H1	41.944333	-72.676475	173	n/a	n/a	n/a	n/a
H2	41.938504	-72.693176	191	n/a	n/a	n/a	n/a
H3	41.936442	-72.674303	195	n/a	n/a	n/a	n/a

F.5.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.5.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	50,124	27,460	14,874	3,258	459	90	96,265	365
ATADS (Data Days)	49,897	27,353	14,854	3,249	459	90	95,902	363
Database	48,603	26,440	11,203	2,779	440	48	89,513	363
Scale Factor	102.7%	103.5%	132.6%	116.9%	104.3%	187.5%	107.1%	n/a

F.5.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	55,948	20,477	14,010	2,602	392	78	93,507	365
Database	48,603	26,440	11,203	2,779	440	48	89,513*	363
Scale Factor	115.1%	77.4%	125.1%	93.6%	89.1%	162.5%	104.5%	n/a

*5 fewer civilian rotorcraft and 3 fewer military rotorcraft ops modeled due to processing error; Affected DNL by less than 0.1 dB (est.)

F.5.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.5.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	75.08	20.96	96.04	79.22	16.82	96.04	-	-	-	154.30	37.78	192.08
Civilian Jet, Other	11.54	1.09	12.63	11.58	1.05	12.63	0.49	0.03	0.52	24.10	2.20	26.30
Civilian Prop	12.67	2.12	14.79	13.43	1.36	14.79	0.11	-	0.11	26.32	3.48	29.80
Civilian Rotorcraft	3.09	0.32	3.41	2.92	0.48	3.40	-	-	-	6.01	0.80	6.81
Military Jet, Fighter	0.01	-	0.01	0.01	-	0.01	-	-	-	0.02	-	0.02
Military Jet, Other	1.84	0.01	1.85	1.83	0.02	1.85	0.12	-	0.12	3.91	0.03	3.94
Military Prop	0.76	0.02	0.78	0.74	0.04	0.78	-	-	-	1.50	0.06	1.56
Military Rotorcraft	1.71	0.13	1.84	1.82	0.01	1.83	-	-	-	3.53	0.14	3.67
TOTAL	**106.70**	**24.65**	**131.35**	**111.55**	**19.78**	**131.33**	**0.72**	**0.03**	**0.75**	**219.69**	**44.49**	**264.18**

Note: Each circuit operation counted as two operations in Total Operations

F.5.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	75.17	22.34	97.51	80.11	17.40	97.51	-	-	-	155.28	39.74	195.02
Civilian Jet, Other	10.88	1.03	11.91	10.92	0.99	11.91	0.42	0.03	0.45	22.22	2.05	24.27
Civilian Prop	10.30	1.63	11.93	10.90	1.05	11.95	0.09	-	0.09	21.29	2.68	23.97
Civilian Rotorcraft	2.91	0.30	3.21	2.74	0.45	3.19	-	-	-	5.65	0.75	6.40
Military Jet, Fighter	0.01	-	0.01	0.01	-	0.01	-	-	-	0.02	-	0.02
Military Jet, Other	1.47	<0.01	1.47	1.47	0.01	1.48	0.11	-	0.11	3.05	0.01	3.06
Military Prop	0.61	0.02	0.63	0.60	0.03	0.63	-	-	-	1.21	0.05	1.26
Military Rotorcraft	1.37	0.10	1.47	1.45	0.01	1.46	-	-	-	2.82	0.11	2.93
TOTAL	**102.72**	**25.42**	**128.14**	**108.20**	**19.94**	**128.14**	**0.62**	**0.03**	**0.65**	**211.54**	**45.39**	**256.93**

Note: Each circuit operation counted as two operations in Total Operations

F.5.4 Modeled Tracks

RNAV procedures:

- 0 STAR RNAV procedure
- 3 RNAV RNP procedures (runways 06, 15, and 24)
- 4 RNAV GPS procedures (runways 06, 15, 24, and 33)
- 0 RNAV (SID) procedures

Total Tracks:

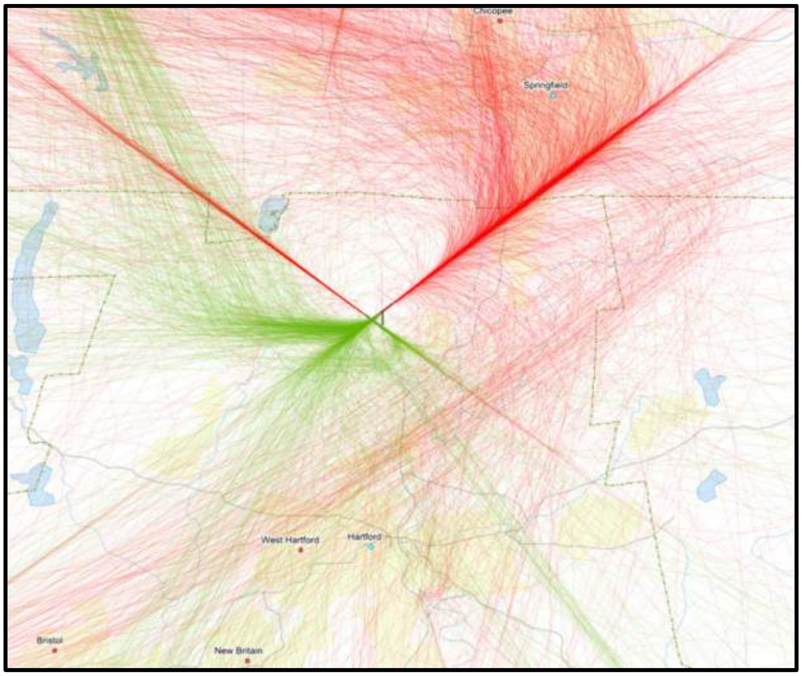
Aircraft Category	Arrivals		Departures		Locals	
	North	South	North	South	North	South
Jets	22,702	15,502	25,490	12,242	148	59
Non-Jets, fixed-wing	3,355	1,819	3,924	1,076	25	12
Total	26,057	17,321	29,414	13,318	173	71

Aircraft Category	Arrivals	Departures	Locals
Helicopters	1,526	1,382	-

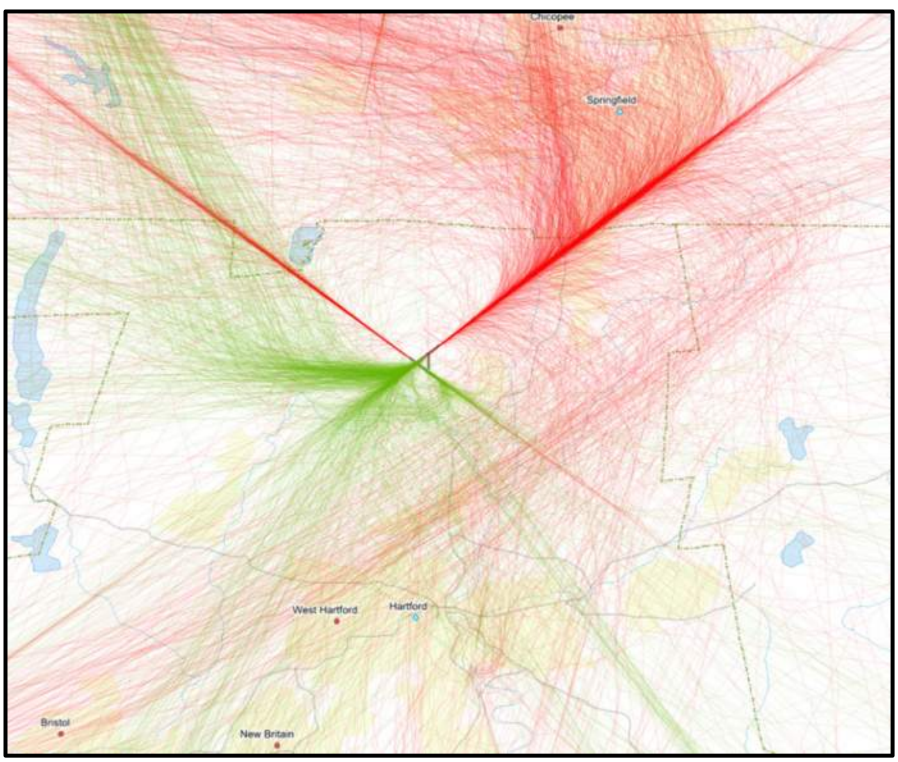
Aircraft Category	Total			Percent	
	North	South	Total	North	South
Jets	48,340	27,803	76,143	63%	37%
Non-Jets, fixed-wing	7,304	2,907	10,211	72%	28%
Helicopters	n/a	n/a	2,908	n/a	n/a
Total	55,644	30,710	89,262	64%	36%

F.5.5 Representative Radar Flight Tracks

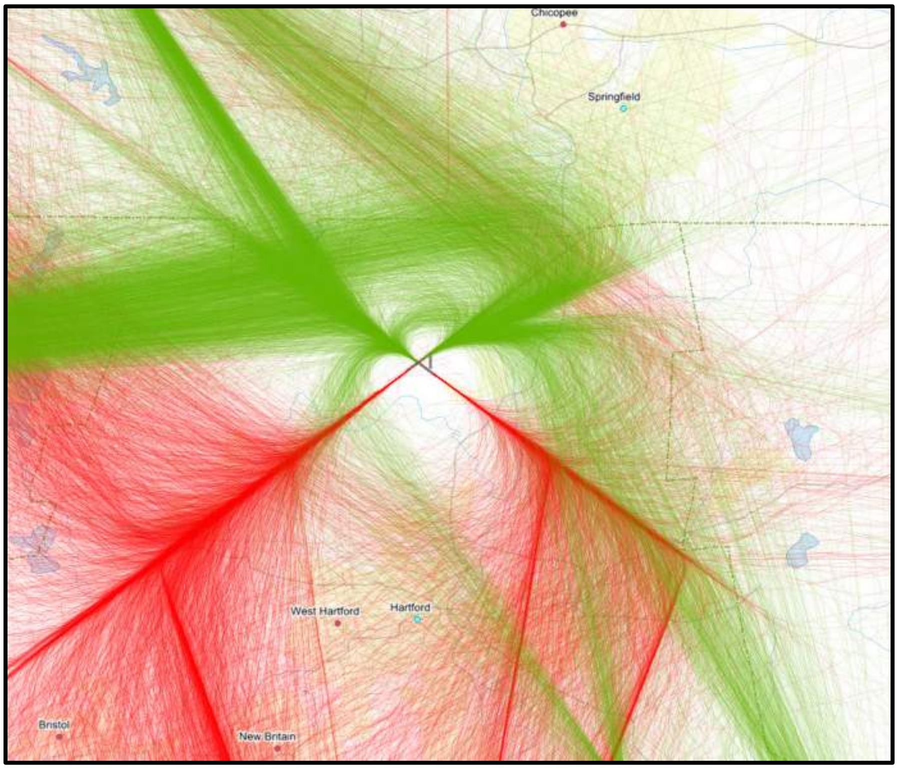
South Flow, Jets – 25% Sample



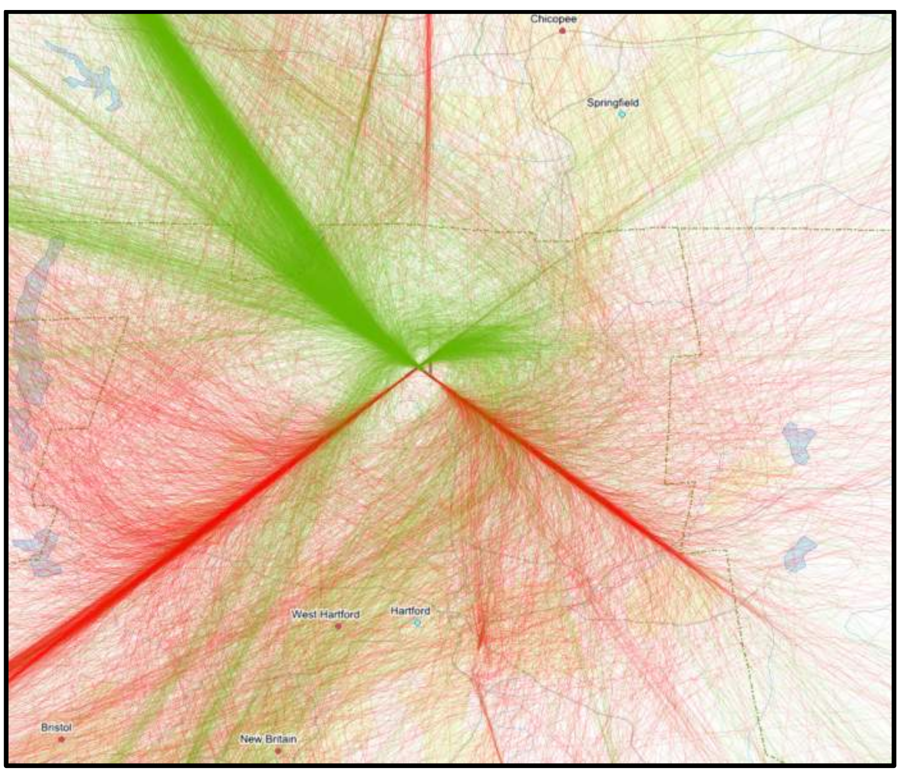
Non-Jets – 100%



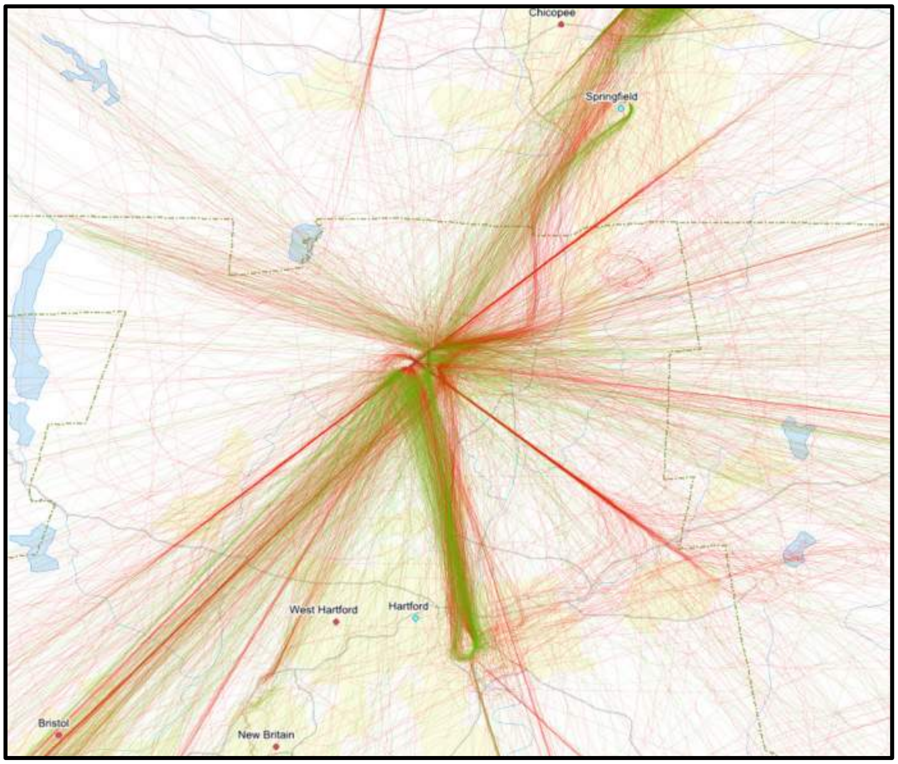
North Flow, Jets – 25% Sample



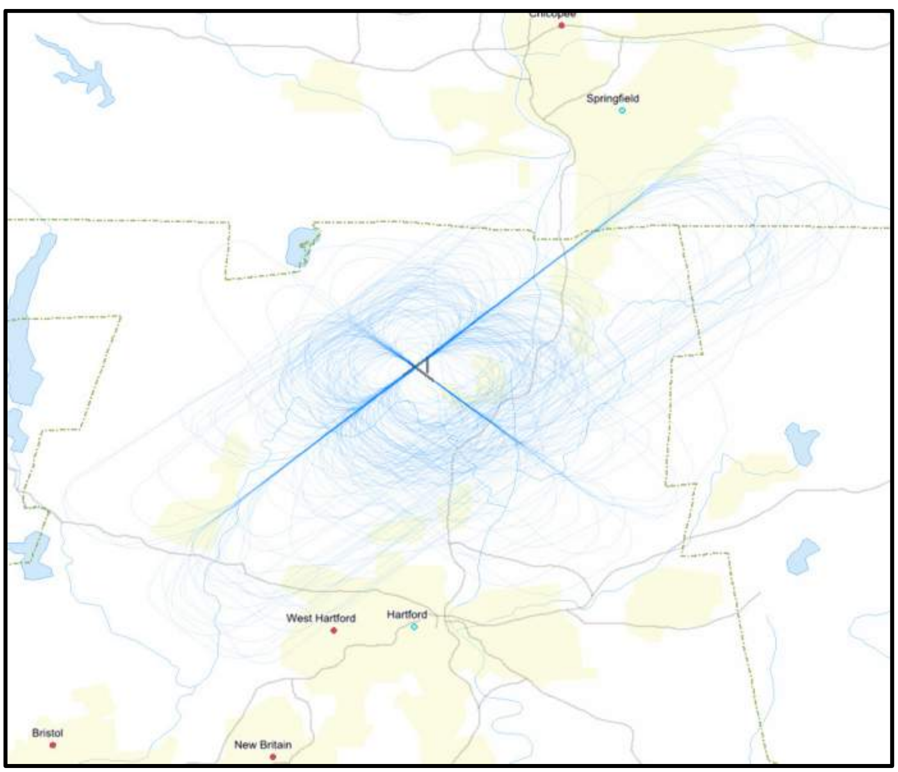
Non-Jets – 100%



Helicopters – 100%



Local Operations – 100%



F.6 Boeing Field / King County Intl, BFI

Airport: Boeing Field / King County International Airport
City: Seattle, WA
Runways: 2
Helipads: 0
Elevation: 21 feet MSL

Local Operation Notes: Circuits modeled at 979 feet AFE for runways 31L and 31R, and 779 feet AFE for runways 31R and 13L. Circuit tracks with a maximum range of greater than 3.5 nautical miles were removed from modeling.

Helicopter Notes: Very few operations modeled.

Other Notes: Mostly Non-Jet operations. Note that SEA operations were also modeled because those operations will add to the overall DNL exposures of survey subjects who live in some of the lower exposure areas produced by BFI operations. See Section F.7 for SEA-specific information. This section presents BFI information only. Local military operations were modeled as local civilian operations due to the low number of operations identified as military in the radar flight track data.

F.6.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
13L	47.538018	-122.30746	18	100	3,710	250	3
13R	47.540543	-122.31136	17	200	10,000	0	3
31L	47.516751	-122.29124	21	200	1,0000	880	3.1
31R	47.529193	-122.30000	17	100	3,710	375	3

F.6.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.6.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	9,001	35,240	94,596	668	47,138*	373*	187,016	365
ATADS for Data Days	9,001	35,240	94,596	668	47,511	0	187,016	365
Database	8,553	18,691	47,253	451	9,824	0	84,772	365
Scale Factor	105.2%	188.5%	200.2%	148.1%	483.6%	0	220.6%	n/a

*Local Military operations were modeled as Local Civil operations due to the low number of military tracks in the database.

F.6.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	10,896	28,809	84,280	1,056	39,770*	760*	165,571	365
Database	8,553	18,691	47,253	451	9,824	0	84,772	365
Scale Factor	127.4%	154.1%	178.4%	234.1%	412.6%	0	195.3%	n/a

*Local Military operations were modeled as Local Civil operations due to (only) 6 military tracks in the database.

F.6.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.6.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	22.18	4.19	26.37	23.28	3.09	26.37	-	-	-	45.46	7.28	52.74
Civilian Jet, Other	39.12	4.34	43.46	38.88	4.58	43.46	-	-	-	78.00	8.92	86.92
Civilian Prop	106.96	13.40	120.36	107.04	13.31	120.35	62.20	2.89	65.09	338.40	32.49	370.89
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	0.63	-	0.63	0.62	<0.01	0.62	-	-	-	1.25	-	1.25
Military Jet, Other	0.13	<0.01	0.13	0.14	-	0.14	-	-	-	0.27	-	0.27
Military Prop	0.15	<0.01	0.15	0.15	-	0.15	-	-	-	0.30	-	0.30
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**169.17**	**21.93**	**191.10**	**170.11**	**20.98**	**191.09**	**62.20**	**2.89**	**65.09**	**463.68**	**48.69**	**512.37**

Note: Each circuit operation counted as two operations in Total Operations

F.6.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	21.68	4.73	26.41	23.05	3.35	26.40	-	-	-	44.73	8.08	52.81
Civilian Jet, Other	34.85	3.87	38.72	34.64	4.08	38.72	-	-	-	69.49	7.95	77.44
Civilian Prop	93.37	11.35	104.72	93.40	11.31	104.71	53.06	2.46	55.52	239.83	25.12	264.95
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	0.99	-	0.99	0.99	0.01	1.00	-	-	-	1.98	0.01	1.99
Military Jet, Other	0.21	0.01	0.22	0.22	-	0.22	-	-	-	0.43	0.01	0.44
Military Prop	0.23	0.01	0.24	0.24	-	0.24	-	-	-	0.47	0.01	0.48
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**151.33**	**19.97**	**171.30**	**152.54**	**18.75**	**171.29**	**53.06**	**2.46**	**55.52**	**356.93**	**41.18**	**398.11**

Note: Each circuit operation counted as two operations in Total Operations

F.6.4 Modeled Tracks

Departures are green, Arrivals are red, Local operations are in blue.

RNAV procedures:

- 0 STAR (Arrival) RNAV procedure
- 1 RNAV RNP procedures (Runway 13R)
- 1 RNAV GPS procedures (Runway 13R)
- 0 RNAV SID procedures

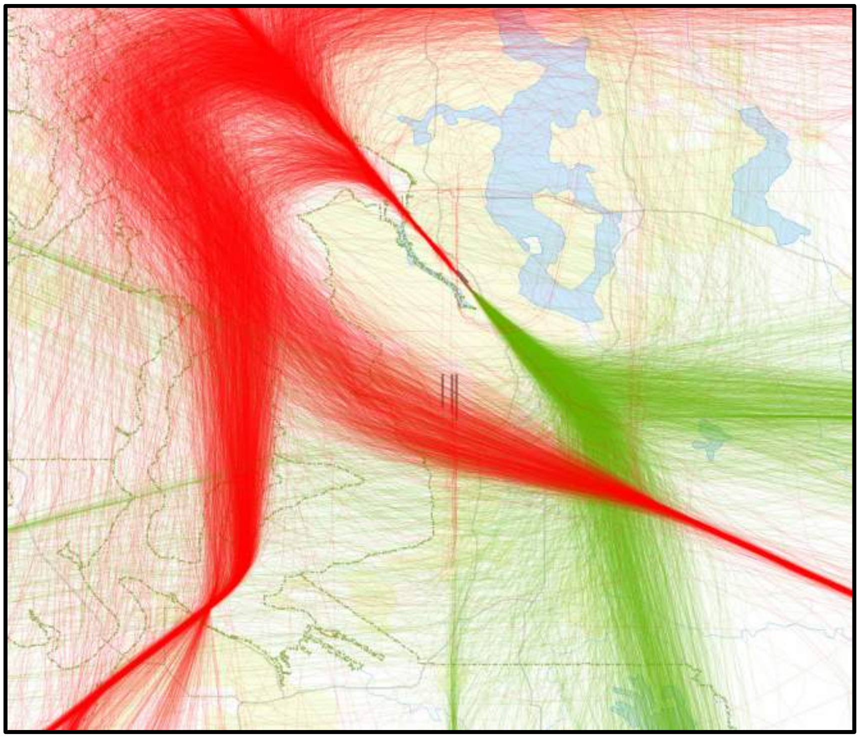
Total Tracks:

Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	11,395	4,206	11,135	4,264	-	-
Non-Jets, fixed-wing	15,311	7,812	12,192	8,633	3,500	1,412
Total	26,706	12,018	23,327	12,897	3,500	1,412

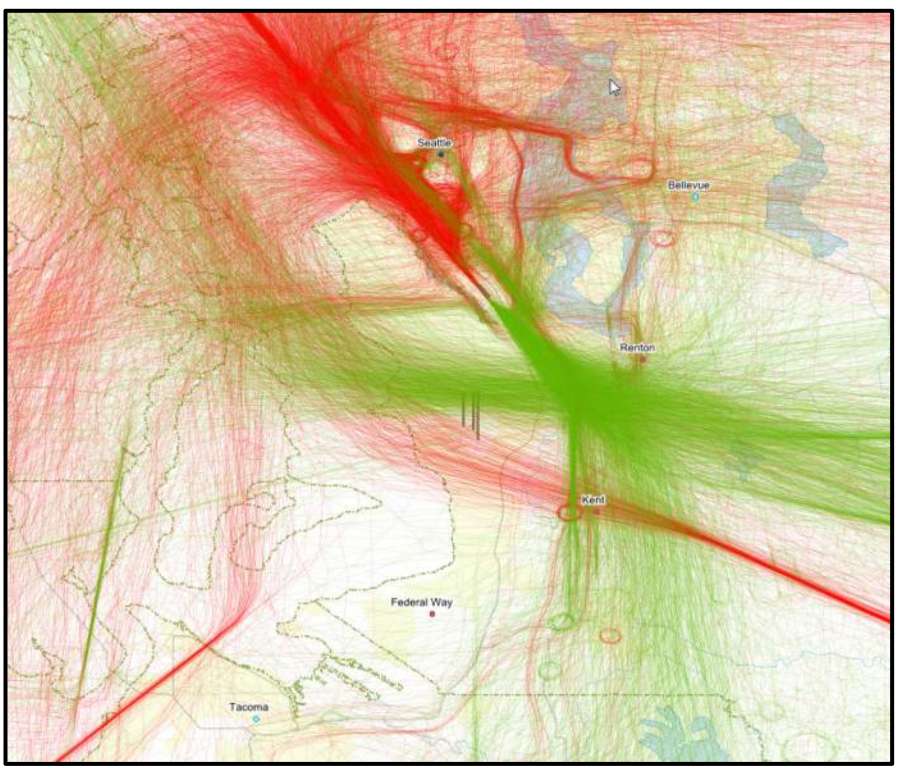
Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	22,530	8,470	31,000	73%	27%
Non-Jets, fixed-wing	31,003	17,857	48,860	63%	37%
Helicopters	n/a	n/a	-	n/a	n/a
Total	53,533	26,327	79,860	67%	33%

F.6.5 Representative Radar Flight Tracks

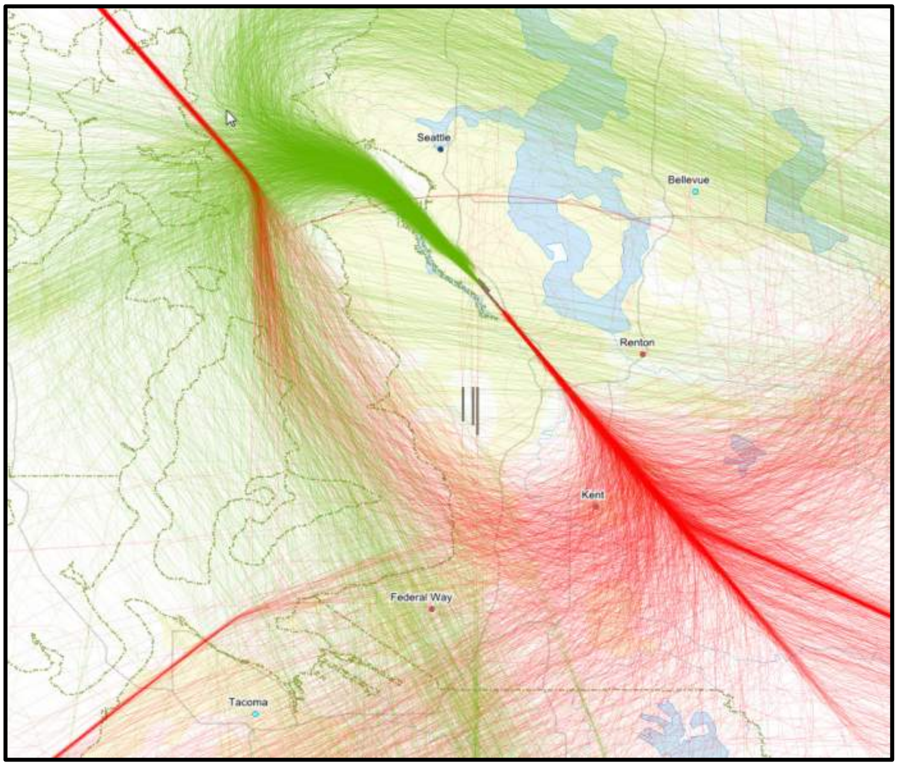
East Flow, Jets – 50% Sample



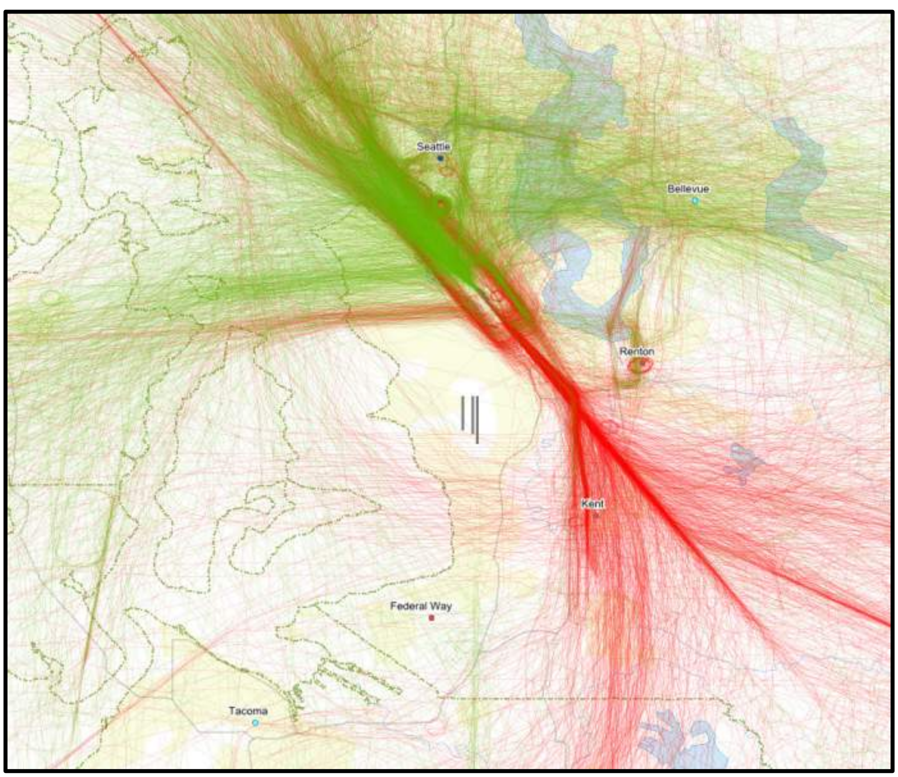
Non-Jets – 33% Sample



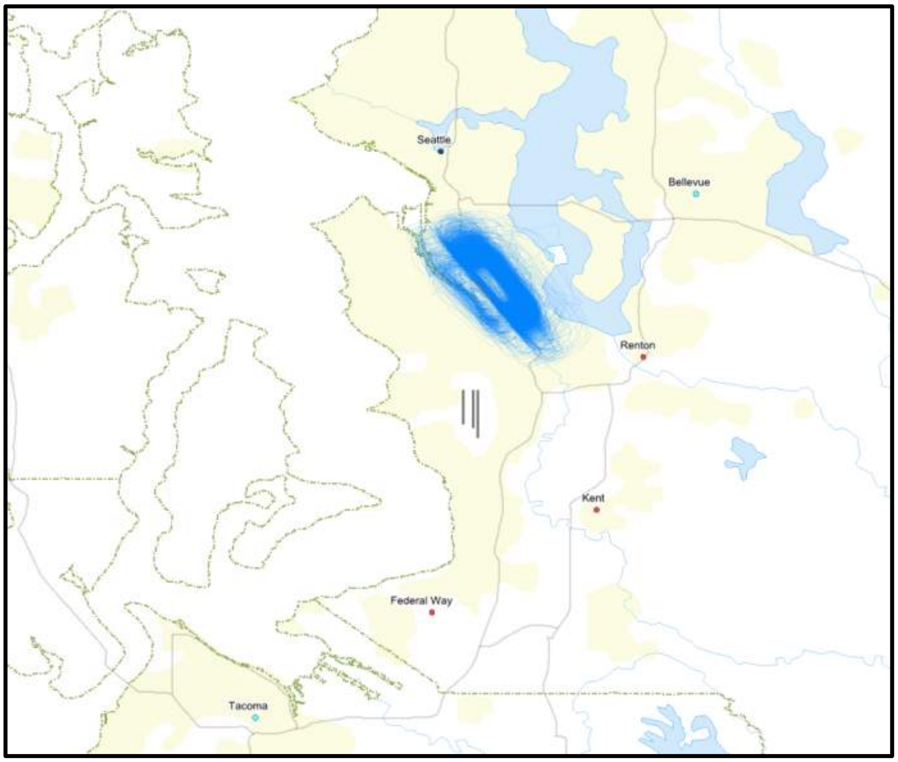
West Flow, Jets – 50% Sample



Non-Jets – 33% Sample



Local Operations – 100%



F.7 Seattle-Tacoma International Airport (SEA) Considerations

SEA is not one of the twenty airports selected for the survey. However, the residents near the BFI airport get several overflights from the nearby SEA airport. Therefore, SEA was modeled as an individual airport, but the results were added together with the BFI results. This was done because the combination of both airport operations were certain to affect annoyance, particularly in areas where overflights from both airports occur.

Local operations (circuits) at SEA were ignored and not modeled as they would not likely affect cumulative noise exposure at BFI.

Airport: Seattle-Tacoma International Airport
City: Seattle, WA
Runways: 3
Helipads: 0
Elevation: 432 feet MSL

Local Operation Notes: No local operations modeled

Helicopter Notes: No helicopter operations modeled

Other Notes: SEA has implemented new RNAV procedures since this modeling was done, although they are unlikely to cause a change of more than 1 dB DNL in the modeled contour levels. Eight 2015 operations (of 308,918 total operations) were not modeled due to a processing error. This omission has no effect within the precision of the model.

F.7.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
16C	47.463808	-122.310985	430.0	150	9,426	0	3
16L	47.463795	-122.307752	432.0	150	11,901	0	3
16R	47.463836	-122.317858	415.0	150	8,500	0	3
34C	47.437970	-122.311211	363.0	150	9,426	0	3
34L	47.440534	-122.318059	356.0	150	8,500	0	3
34R	47.431171	-122.308039	347.0	150	11,901	0	2.8

F.7.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.7.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	291,282	14,026	3,523*	87*	0	0	308,918	365
ATADS for Data Days	291,282	14,026	3,610	0	0	0	308,918	365
Database	288,687	13,743	1,363	0	0	0	303,793	365
Scale Factor	100.9%	102.1%	264.9%	0	0	0	101.7%	n/a

* Military operations were modeled as General Aviation due to the low number of military tracks in the database.

F.7.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	368,722	8,401	4,160	125 (1)	0	0	381,408	365
Database	288,687	13,743	1,363	0	0	0	303,793 (2)	365
Scale Factor	127.7%	61.1%	314.4%	0	0	0	125.5%	n/a

Notes:

1) 125 Military operations from ATADS were ignored due to no military tracks in the database.
2) 4 fewer civilian propeller operations modeled due to processing error; Affected overall DNL by less than 0.1 dB (estimated).

F.7.3 Modeled Average Annual Daily Number of Flight Events and Operations

F.7.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	247.25	48.36	295.61	245.94	49.67	295.61	-	-	-	493.19	98.03	591.22
Civilian Jet, Other	2.87	0.29	3.16	2.76	0.40	3.16	-	-	-	5.63	0.69	6.32
Civilian Prop	110.98	13.43	124.41	111.70	12.71	124.41	-	-	-	222.68	26.14	248.82
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	-	-	-	-	-	-	-	-	-	-	-	-
Military Prop	-	-	-	-	-	-	-	-	-	-	-	-
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**361.10**	**62.08**	**423.18**	**360.40**	**62.78**	**423.18**	**-**	**-**	**-**	**721.50**	**124.86**	**846.36**

Note: Each circuit operation counted as two operations in Total Operations

F.7.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	310.63	61.14	371.77	308.99	62.78	371.77	-	-	-	619.62	123.92	743.54
Civilian Jet, Other	3.31	0.33	3.64	3.18	0.46	3.64	-	-	-	6.49	0.79	7.28
Civilian Prop	129.93	16.96	146.89	131.14	15.76	146.90	-	-	-	261.07	32.72	293.79
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	-	-	-	-	-	-	-	-	-	-	-	-
Military Prop	-	-	-	-	-	-	-	-	-	-	-	-
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**443.87**	**78.43**	**522.30**	**443.31**	**79.00**	**522.31**	**-**	**-**	**-**	**887.18**	**157.43**	**1,044.61**

Note: Each circuit operation counted as two operations in Total Operations

F.7.4 Modeled Tracks

RNAV procedures:

- 2 STAR (Arrival) RNAV procedures
- 6 RNAV RNP procedures
- 6 RNAV GPS procedures
- 3 RNAV SID procedures

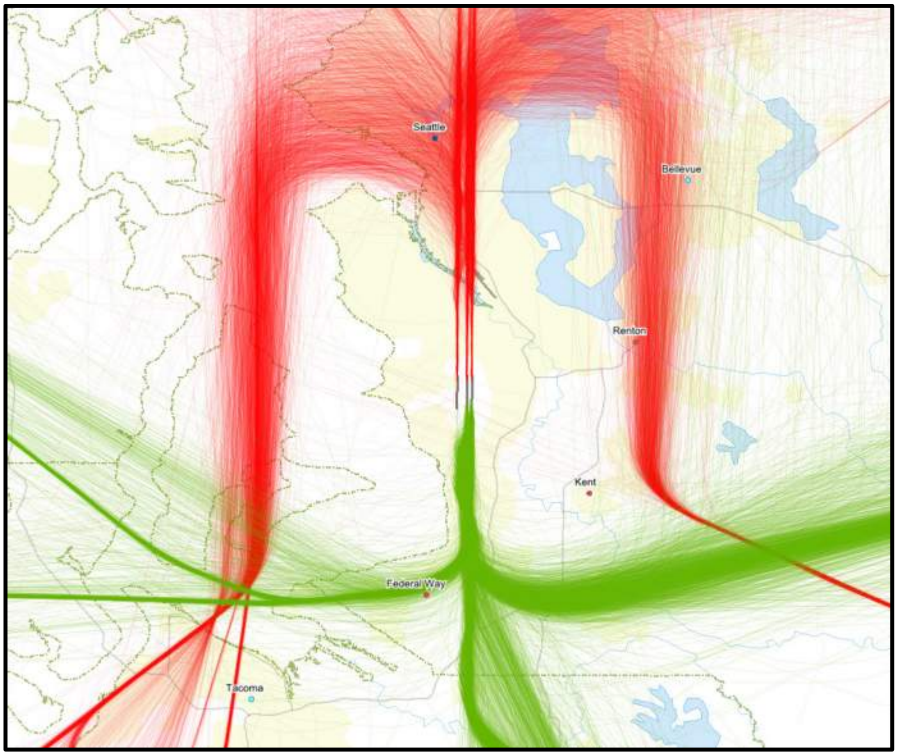
Total Tracks:

Aircraft Category	Arrivals		Departures		Locals	
	North	South	North	South	North	South
Jets	32,843	75,214	30,229	76,413	-	-
Non-Jets, fixed-wing	12,665	32,139	12,750	31,539	-	-
Total	45,508	107,353	42,979	107,952	-	-

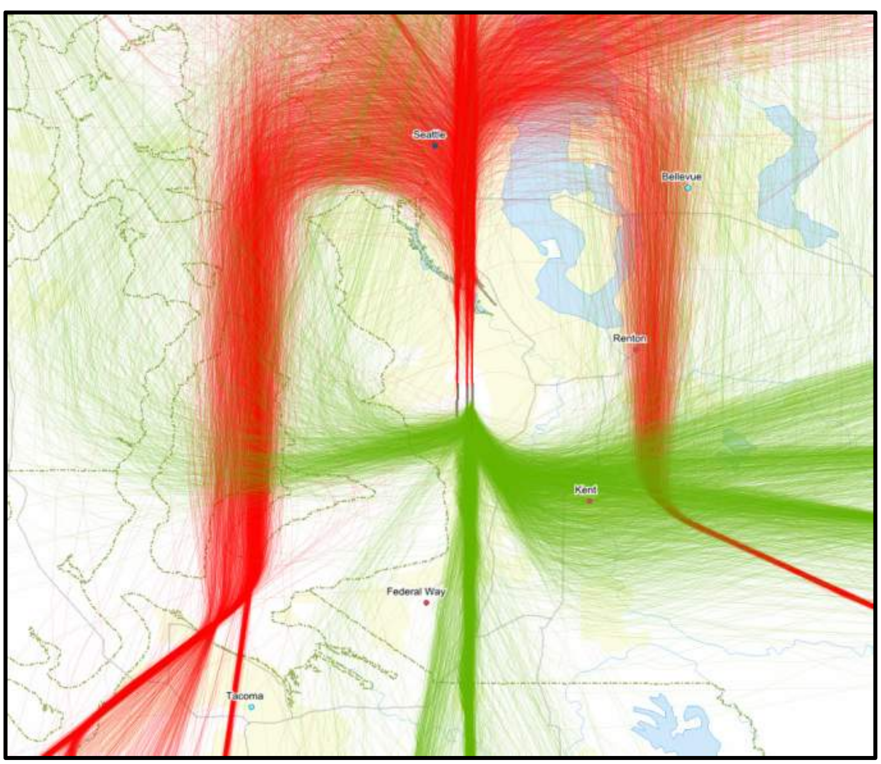
Aircraft Category	Total			Percent	
	North	South	Total	North	South
Jets	63,072	151,627	214,699	29%	71%
Non-Jets, fixed-wing	25,415	63,678	89,093	29%	71%
Helicopters	n/a	n/a	-	n/a	n/a
Total	88,487	215,305	303,792	29%	71%

F.7.5 Representative Radar Flight Tracks

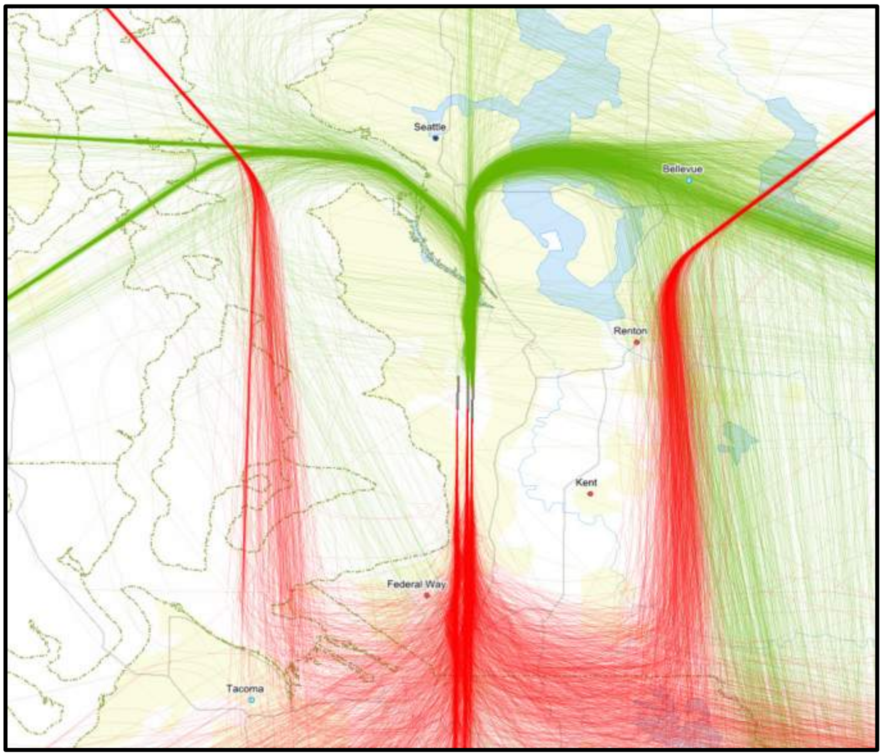
South Flow, Jets – 7% Sample



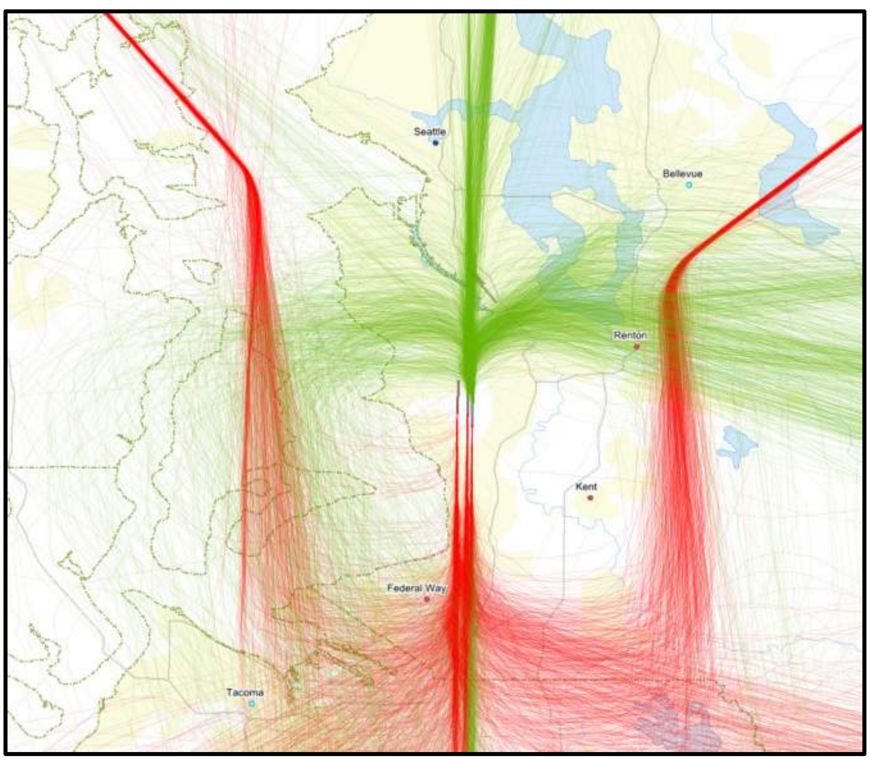
Non-Jets – 15% Sample



North Flow, Jets – 7% Sample



Non-Jets – 15% Sample



F.8 Billings Logan Intl, BIL

Airport: Billings Logan International Airport
City: Billings, MT
Runways: 3
Helipads: 1
Elevation: 3,652 feet MSL

Local Operation Notes: Circuits modeled at 1,000 feet AFE and 3,000 feet AFE. Split tracks counted as non-local operations. Local tracks that had a maximum range under 8 nautical miles used the 1,000 feet AFE profile. All other local operations used 3,000 feet AFE profile.

Helicopter Notes: Moderate number of helicopter operations, but about half of them were removed because the hospital is too close to the airport to model them in INM. None counted as local operations.

Other Notes: Mostly Non-Jet operations. There were 275 operations from 2015 (of 81,122 total operations) that were not modeled due to a processing error. This omission has no effect within the precision of the model.

F.8.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
07	45.807679	-108.55841	3,636	75	5,503	0	3
10L	45.812731	-108.55482	3,584	150	10,521	0	3
10R	45.809195	-108.56283	3,652	75	3,800	0	3
25	45.809255	-108.53694	3,534	75	5,503	0	3
28L	45.805338	-108.54898	3,607	75	3,800	0	3
28R	45.802049	-108.51651	3,488	150	10,521	0	3
H1	45.805147	-108.54373	3,597	n/a	n/a	n/a	n/a

F.8.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.8.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	10,203	26,096	25,541	480	18,732	70	81,122	365
ATADS (Data Days)	10,033	25,702	25,144	476	18,358	70	79,783	359
Database	9,086	22,553	14,884	324	6,082	24	52,953	359
Scale Factor	110.4%	114.0%	168.9%	146.9%	301.8%	291.7%	150.7%	n/a

F.8.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	10,036	26,516	26,303	385	17,674	126	81,040	365
Database	9,086	22,553	14,884	324	6,082	24	52,953*	359
Scale Factor	110.5%	117.6%	176.7%	118.8%	290.6%	525.0%	153.0%	n/a

*275 fewer operations modeled due to processing error; Consisted of 10 civilian (non-commercial jet), 218 civilian propeller, 35 civilian rotorcraft, 2 military jet fighter and 10 military rotorcraft operations; Affected overall DNL by less than 0.1 dB (estimated).

F.8.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.8.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	14.20	3.07	17.27	14.18	2.99	17.17	-	-	-	28.38	6.06	34.44
Civilian Jet, Other	4.48	0.26	4.74	4.52	0.24	4.76	0.27	0.03	0.30	9.54	0.56	10.10
Civilian Prop	51.41	9.22	60.63	51.28	9.44	60.72	24.13	1.14	25.27	150.95	20.94	171.89
Civilian Rotorcraft	2.03	0.12	2.15	1.93	0.22	2.15	-	-	-	3.96	0.34	4.30
Military Jet, Fighter	0.01	-	0.01	0.01	-	0.01	-	-	-	0.02	-	0.02
Military Jet, Other	0.10	0.01	0.11	0.10	-	0.10	0.08	-	0.08	0.36	0.01	0.37
Military Prop	0.46	-	0.46	0.46	<0.01	0.46	0.02	-	0.02	0.96	-	0.96
Military Rotorcraft	0.09	-	0.09	0.08	<0.01	0.08	-	-	-	0.17	-	0.17
TOTAL	**72.78**	**12.68**	**85.46**	**72.56**	**12.89**	**85.45**	**24.50**	**1.17**	**25.67**	**194.34**	**27.91**	**222.25**

Note: Each circuit operation counted as two operations in Total Operations

F.8.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	14.39	3.09	17.48	14.36	3.02	17.38	-	-	-	28.75	6.11	34.86
Civilian Jet, Other	4.69	0.27	4.96	4.72	0.26	4.98	0.26	0.02	0.28	9.67	0.55	10.22
Civilian Prop	53.36	9.50	62.86	53.32	9.74	63.06	23.23	1.10	24.33	129.91	20.34	150.25
Civilian Rotorcraft	2.12	0.12	2.24	1.90	0.23	2.13	-	-	-	4.02	0.35	4.37
Military Jet, Fighter	0.01	-	0.01	0.01	-	0.01	-	-	-	0.02	-	0.02
Military Jet, Other	0.08	0.01	0.09	0.08	-	0.08	0.15	-	0.15	0.31	0.01	0.32
Military Prop	0.37	-	0.37	0.37	<0.01	0.37	0.03	-	0.03	0.77	-	0.77
Military Rotorcraft	0.07	-	0.07	0.07	<0.01	0.07	-	-	-	0.14	-	0.14
TOTAL	**75.09**	**12.99**	**88.08**	**74.83**	**13.25**	**88.08**	**23.67**	**1.12**	**24.79**	**173.59**	**27.36**	**200.95**

Note: Each circuit operation counted as two operations in Total Operations

F.8.4 Modeled Tracks

RNAV procedures:

- 0 STAR RNAV procedure
- 0 RNAV RNP procedures
- 4 RNAV GPS procedures (runways 07, 10L, 25, and 28R)
- 0 RNAV (SID) procedures

Total Tracks:

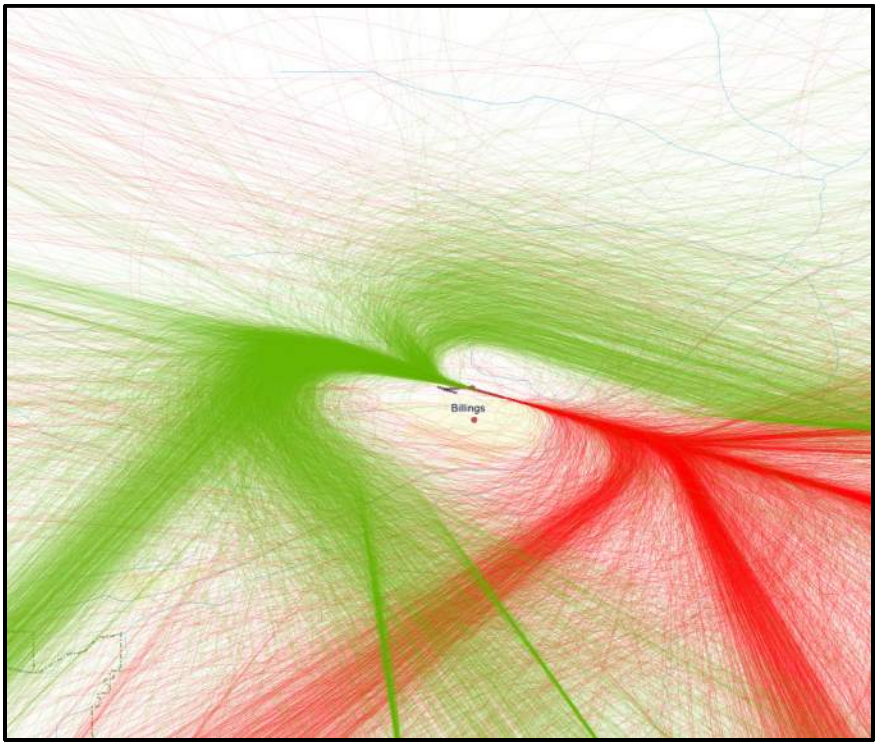
Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	1,693	4,868	1,570	5,114	12	33
Non-Jets, fixed-wing	5,495	11,055	3,319	12,711	563	2,445
Total	7,188	15,923	4,889	17,825	575	2,478

Aircraft Category	Arrivals	Departures	Locals
Helicopters	421	434	-

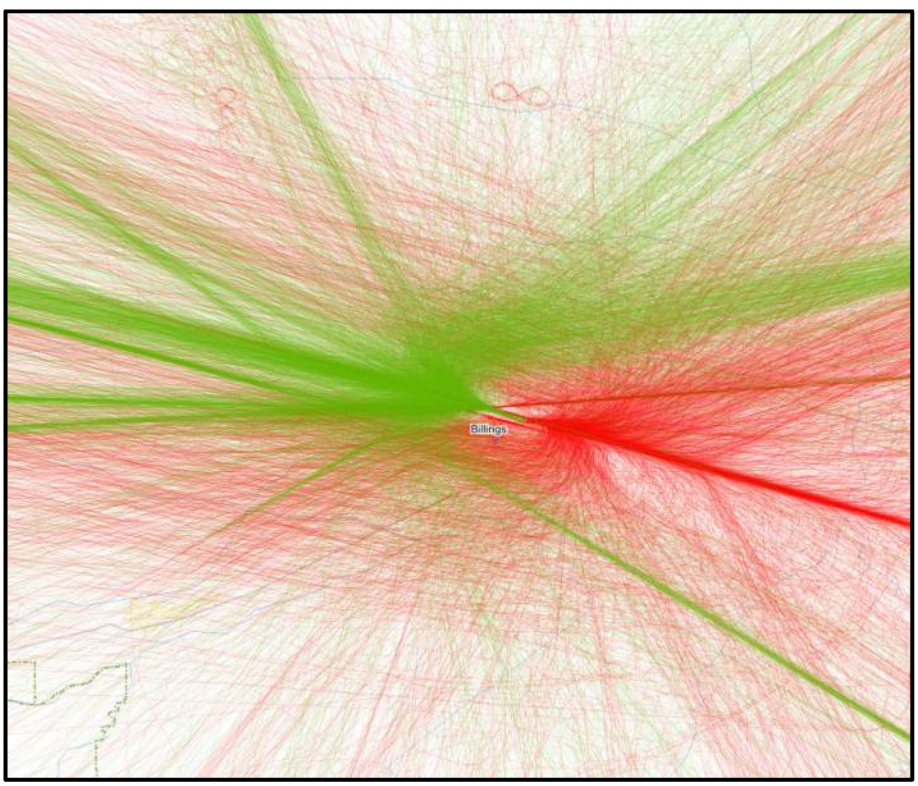
Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	3,275	10,015	13,290	25%	75%
Non-Jets, fixed-wing	9,377	26,211	35,588	26%	74%
Helicopters	n/a	n/a	855	n/a	n/a
Total	12,652	36,226	49,733	26%	74%

F.8.5 Representative Radar Flight Tracks

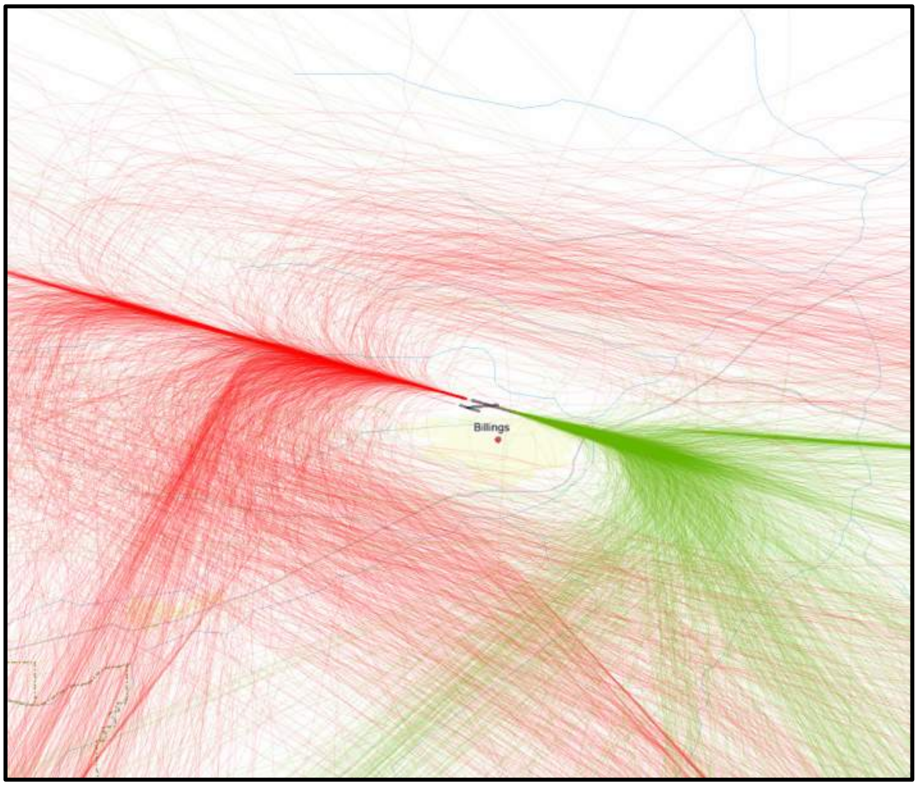
West Flow, Jets – 100%



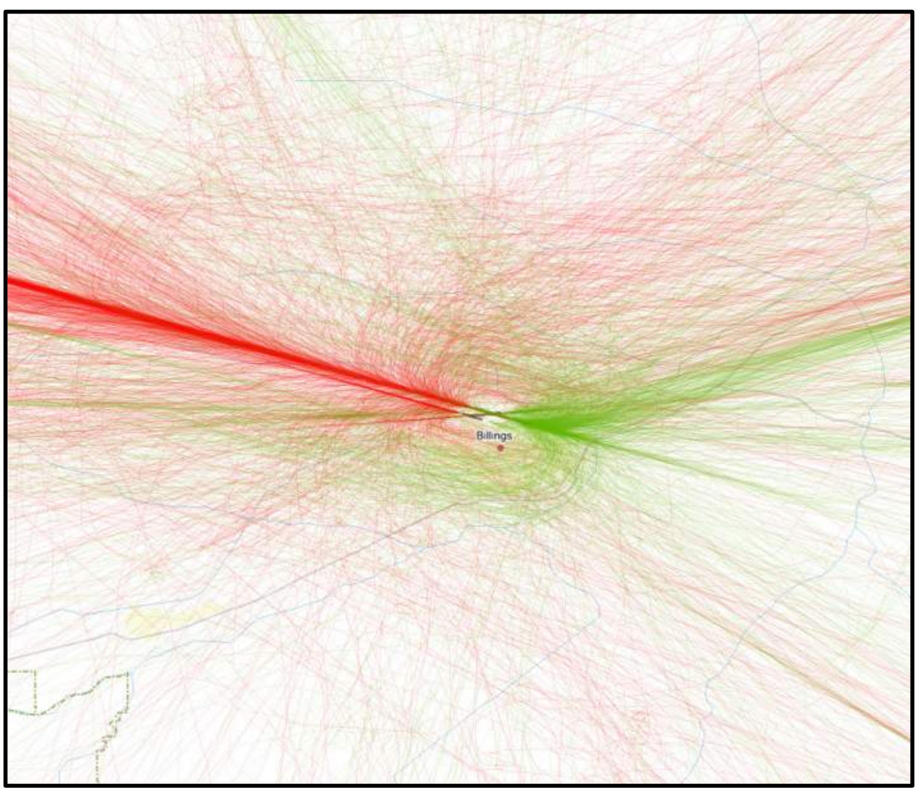
Non-Jets – 33% Sample



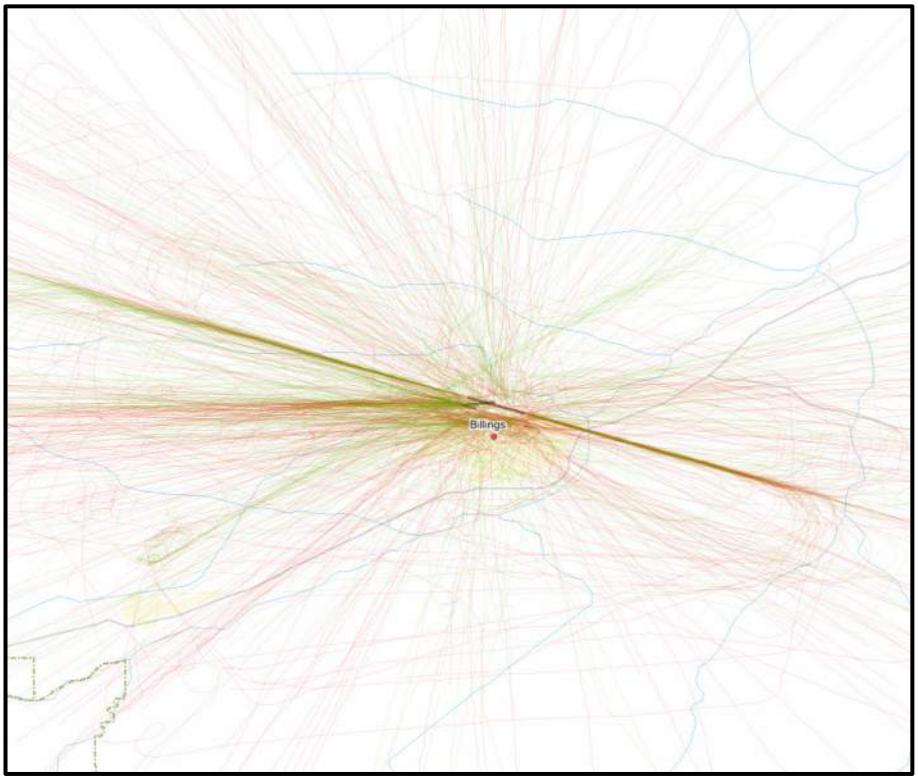
East Flow, Jets – 100%



Non-Jets – 33% Sample



Helicopters – 100%



F.9 Des Moines Intl, DSM

Airport: Des Moines International Airport
City: Des Moines, IA
Runways: 2
Helipads: 1
Elevation: 958 feet MSL

Local Operation Notes: Circuits modeled at 1,000 feet AFE and 2,000 feet AFE. Split tracks that went at least 7 nautical miles from the airport center were counted as non-local operations, the rest were counted as local operations. Circuit tracks that had a maximum range under 7 nautical miles used the 1,000 feet AFE profile. All other local operations used 2,000 feet AFE profile. Circuit tracks with a maximum range of greater than 35 nautical miles or a maximum altitude greater than 3,800 feet MSL were removed from modeling.

Helicopter Notes: Relatively small number of operations, less than one percent of daily operations. Mostly general aviation or air taxi. Variety of INM types. A few counted as local operations.

Other Notes: Mostly commercial jet operations. Relatively small number of total operations. Seven 2015 operations (of 77,647 total operations) were not modeled due to a processing error. This omission has no effect within the precision of the model.

F.9.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
05	41.523368	-93.677112	916	150	9,003	0	3
13	41.545606	-93.674454	912	150	9,002	0	3
23	41.537949	-93.650568	934	150	9,003	0	3
31	41.528967	-93.650153	958	150	9,002	0	3
H1	41.534179	-93.657656	930	n/a	n/a	n/a	n/a

F.9.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.9.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	20,323	22,875	24,974	2,377	5,605	1,493	77,647	365
ATADS (Data Days)	20,216	22,813	24,897	335	5,591	260	74,112	363
Database	19,787	21,474	20,056	247	765	48	62,377	363
Scale Factor	102.2%	106.2%	124.1%	135.6%	730.8%	541.7%	118.8%	n/a

Note: F-16s stopped flying at DSM, so ATADS scaled accordingly. See D.8.6.

F.9.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS[1]	28,354	11,402	23,900	1,069	4,175	487	69,387	365
Database	19,787	21,474	20,056	247	765	48	62,377 [2]	363
Scale Factor	143.3%	53.1%	119.2%	432.8%	545.8%	1014.6%	111.2%	n/a

Notes:

1) The F-16 adjustments used for 2012-2013 do not apply to the 2015 ATADS counts.
2) 4 fewer civilian propeller and 3 fewer civilian rotorcraft operations modeled due to processing error; Affected overall DNL by less than 0.1 dB (estimated).

F.9.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.9.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	47.11	9.36	56.47	46.63	9.85	56.48	-	-	-	93.74	19.21	112.95
Civilian Jet, Other	13.13	0.72	13.85	11.98	1.86	13.84	0.14	-	0.14	25.39	2.58	27.97
Civilian Prop	21.24	1.42	22.66	19.67	3.01	22.68	7.00	0.50	7.50	54.91	5.43	60.34
Civilian Rotorcraft	0.45	0.13	0.58	0.49	0.08	0.57	0.06	-	0.06	1.06	0.21	1.27
Military Jet, Fighter	0.04	-	0.04	0.04	-	0.04	-	-	-	0.08	-	0.08
Military Jet, Other	0.14	<0.01	0.14	0.13	0.01	0.14	0.24	-	0.24	0.75	0.01	0.76
Military Prop	0.19	<0.01	0.19	0.20	-	0.20	0.12	-	0.12	0.63	-	0.63
Military Rotorcraft	0.08	0.01	0.09	0.08	<0.01	0.08	-	-	-	0.16	0.01	0.17
TOTAL	**82.38**	**11.64**	**94.02**	**79.22**	**14.81**	**94.03**	**7.56**	**0.50**	**8.06**	**176.72**	**27.45**	**204.17**

Note: Each circuit operation counted as two operations in Total Operations

F.9.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	43.34	10.03	53.37	42.80	10.56	53.36	-	-	-	86.14	20.59	106.73
Civilian Jet, Other	12.60	0.69	13.29	11.50	1.79	13.29	0.10	-	0.10	24.20	2.48	26.68
Civilian Prop	19.51	0.98	20.49	18.37	2.14	20.51	5.23	0.37	5.60	43.11	3.49	46.60
Civilian Rotorcraft	0.41	0.12	0.53	0.45	0.07	0.52	0.04	-	0.04	0.90	0.19	1.09
Military Jet, Fighter	0.12	-	0.12	0.12	-	0.12	-	-	-	0.24	-	0.24
Military Jet, Other	0.44	0.01	0.45	0.43	0.02	0.45	0.45	-	0.45	1.32	0.03	1.35
Military Prop	0.61	0.01	0.62	0.62	-	0.62	0.22	-	0.22	1.45	0.01	1.46
Military Rotorcraft	0.25	0.03	0.28	0.27	0.01	0.28	-	-	-	0.52	0.04	0.56
TOTAL	**77.28**	**11.87**	**89.15**	**74.56**	**14.59**	**89.15**	**6.04**	**0.37**	**6.41**	**157.88**	**26.83**	**184.71**

Note: Each circuit operation counted as two operations in Total Operations

F.9.4 Modeled Tracks

RNAV procedures:

- 0 STAR RNAV procedure
- 0 RNAV RNP procedures
- 4 RNAV GPS procedures (one for each runway)
- 0 RNAV (SID) procedures

Total Tracks:

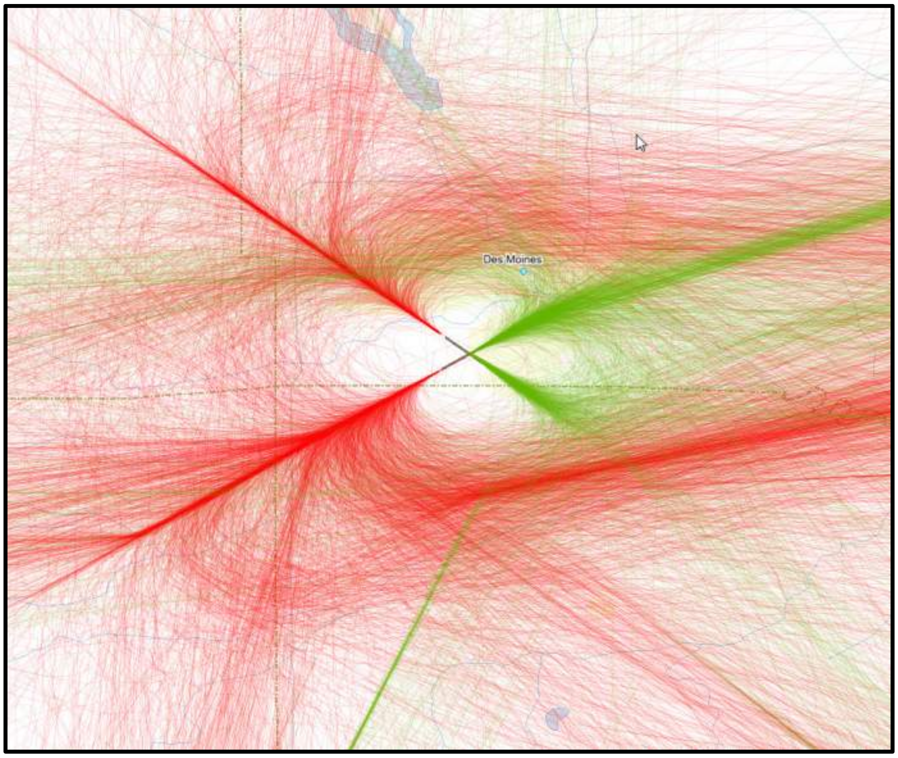
Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	11,537	12,421	4,930	18,809	6	14
Non-Jets, fixed-wing	2,725	4,256	1,447	5,223	121	186
Total	14,262	16,677	6,377	24,032	127	200

Aircraft Category	Arrivals	Departures	Locals
Helicopters	185	185	-

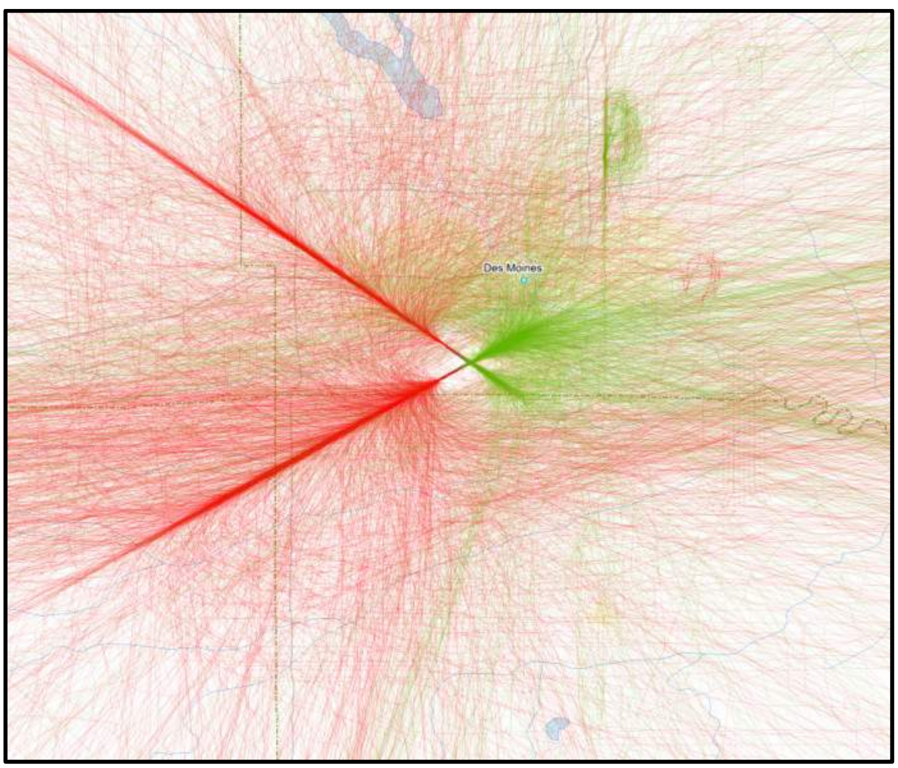
Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	16,473	31,244	47,717	35%	65%
Non-Jets, fixed-wing	4,293	9,665	13,958	31%	69%
Helicopters	n/a	n/a	370	n/a	n/a
Total	20,766	40,909	62,045	34%	66%

F.9.5 Representative Radar Flight Tracks

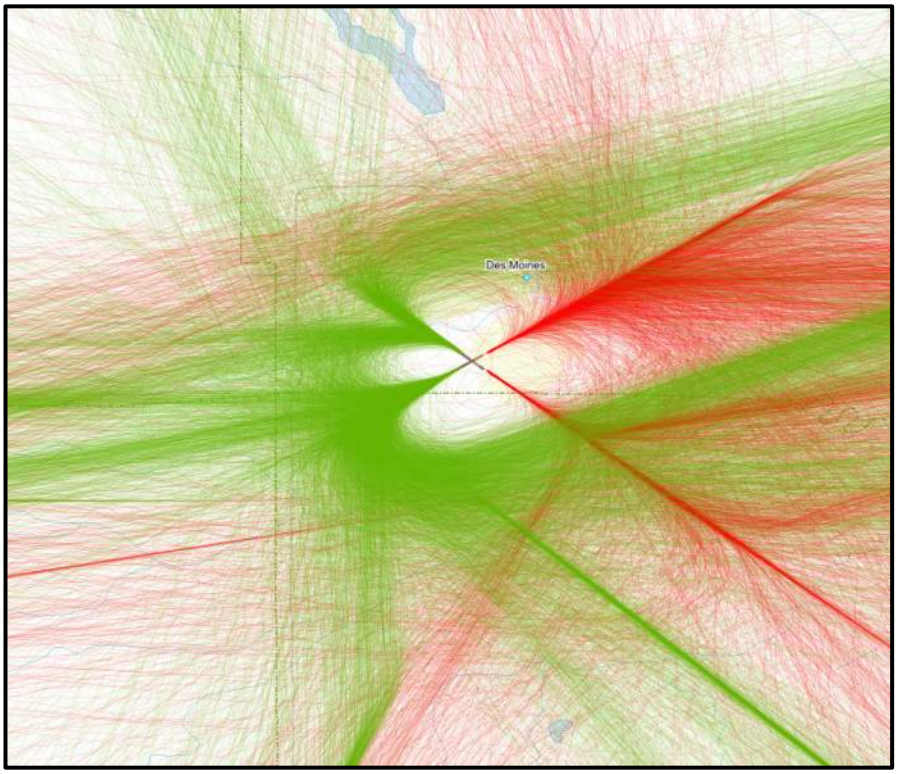
East Flow, Jets – 33% Sample



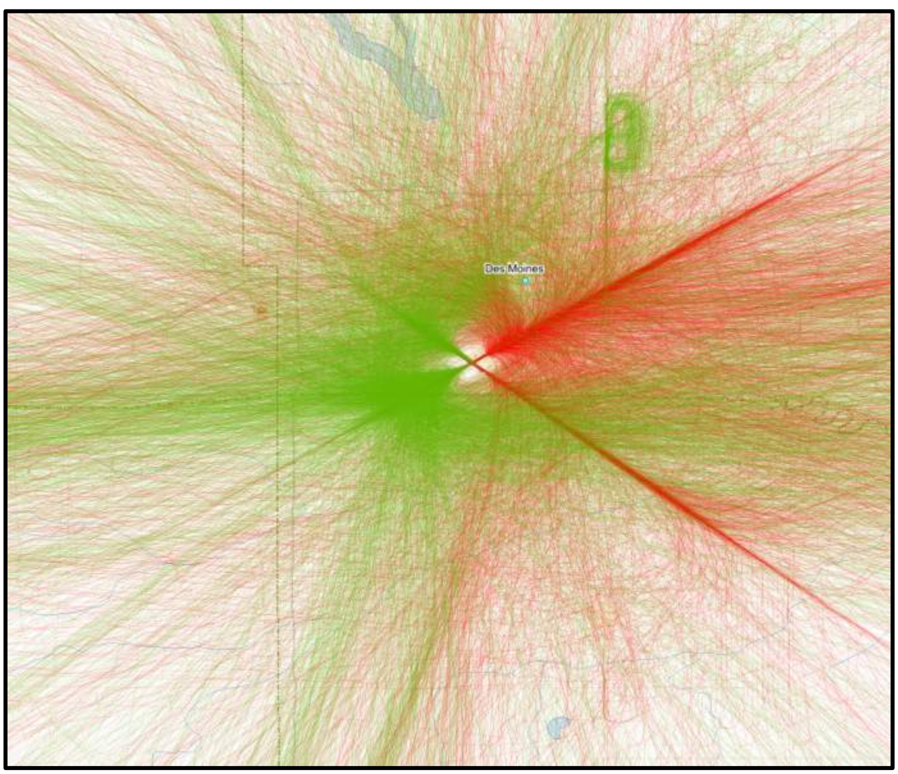
Non-Jets – 100%



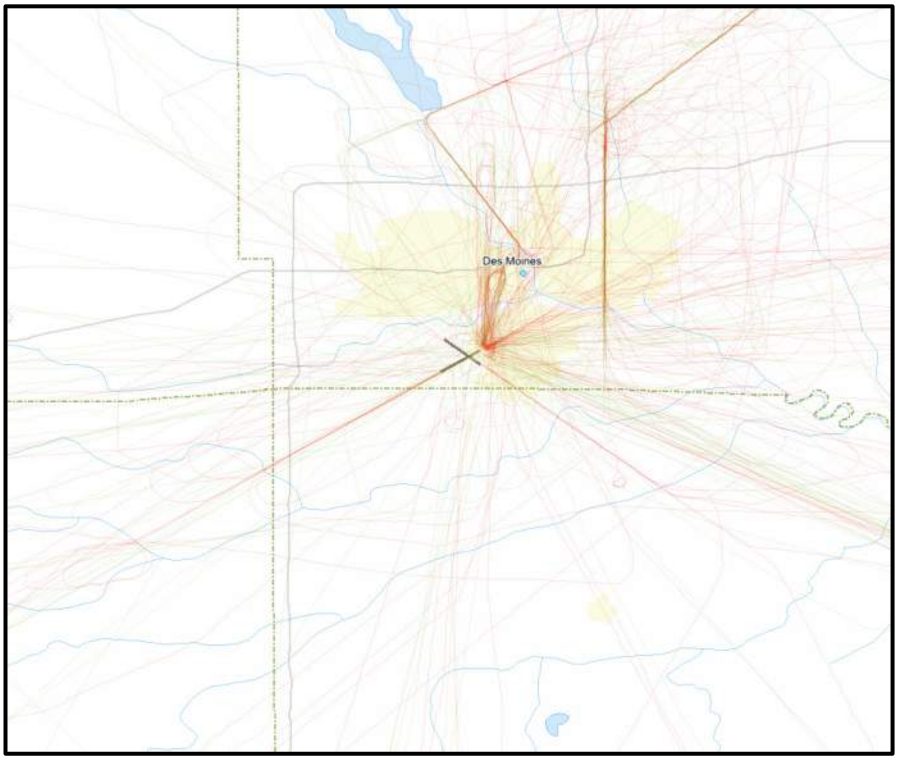
West Flow, Jets – 33% Sample



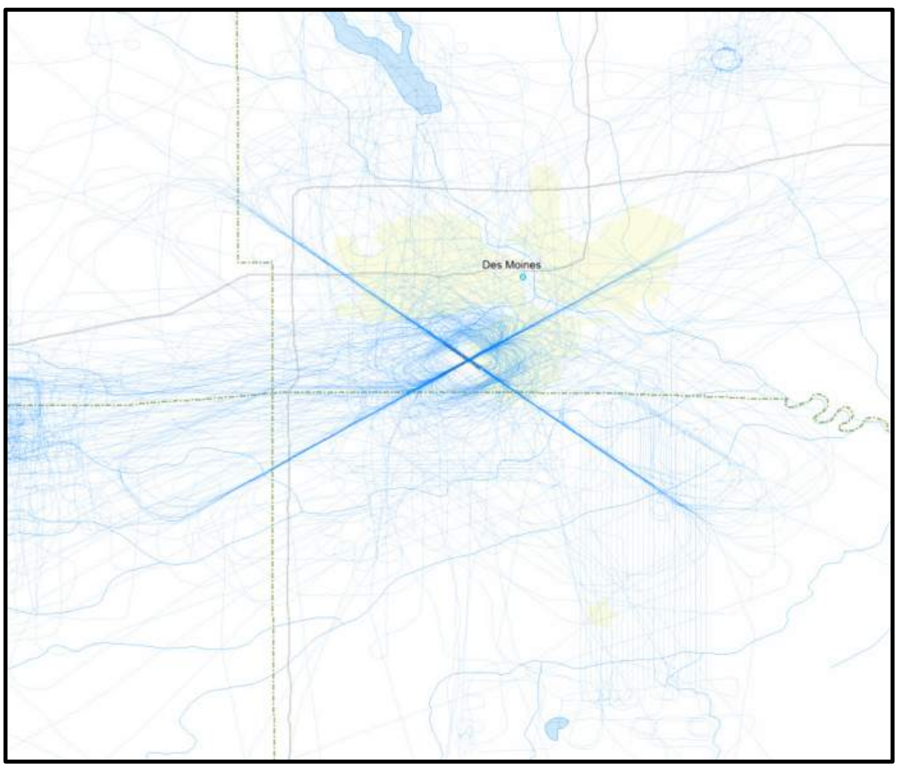
Non-Jets – 100%



Helicopters – 100%



Local Operations – 100%



F.9.6 F-16 Consideration

According to news articles online, the F16s at the airport discontinued service on September 8, 2013. Therefore, all the F16s were removed from the modeling. This decreased the number of military operations at the airport from 2,377 annual ops to 337 annual ops. This is close to the decrease seen in the ATADS after Sept 2013. For the period of June 2012 through Sept 8, 2013, ATADS shows 2,254 annual ops, whereas for the period Sept 9, 2013 through May 2014, it shows 636 annual ops.

For local military, this database had very few usable operations, so the operations were rescaled using data from ATADS. For the period of June 2012 through Sept 8, 2013, ATADS shows 1713 annual local ops, whereas for the period of October 2013 through Sept 9, 2013, it shows 130 annual local ops. The value of 130 was used as a rescaling factor for the local military ops.

F.10 Detroit Metropolitan Wayne County, DTW

Airport: Detroit Metropolitan Wayne County Airport
City: Detroit, MI
Runways: 6
Helipads: 0
Elevation: 646 feet MSL

Local Operation Notes: No local operations modeled.

Helicopter Notes: No helicopter operations modeled.

Other Notes: Mostly commercial jet operations.

F.10.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
03L	42.207835	-83.351219	636	200	8,501	0	3
03R	42.195615	-83.351802	633	150	10,001	0	3
04L	42.202173	-83.384000	645	150	10,000	0	3
04R	42.202324	-83.371268	637	200	12,003	0	3
09L	42.216967	-83.363168	639	150	8,708	0	3
09R	42.199015	-83.361729	636	150	8,500	0	3
21L	42.219682	-83.334070	632	150	10,001	0	3
21R	42.228293	-83.336143	632	200	8,501	0	3
22L	42.231213	-83.349991	636	200	12,003	0	3
22R	42.226245	-83.366281	642	150	10,000	0	3
27L	42.199538	-83.330369	629	150	8,500	0	3
27R	42.217506	-83.331032	635	150	8,708	0	3

F.10.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.10.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	228,862	189,154	5,889	188	0	0	424,093	365
ATADS for Data Days	228,862	189,154	5,889	188	0	0	424,093	365
Database	226,378	188,890	5,439	42	0	0	420,749	365
Scale Factor	101.1%	100.1%	108.3%	447.6%	0	0	100.8%	n/a

F.10.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	276,898	96,533	5,843	102	0	0	379,376	365
Database	226,378	188,890	5,439	42	0	0	420,749	365
Scale Factor	122.3%	51.1%	107.4%	242.9%	0	0	90.2%	n/a

F.10.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.10.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	521.85	46.61	568.46	524.45	44.01	568.46	-	-	-	1,046.30	90.62	1,136.92
Civilian Jet, Other	5.48	0.54	6.02	5.55	0.47	6.02	-	-	-	11.03	1.01	12.04
Civilian Prop	5.18	1.03	6.21	5.54	0.67	6.21	-	-	-	10.72	1.70	12.42
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	0.02	-	0.02	0.02	-	0.02	-	-	-	0.04	-	0.04
Military Jet, Other	0.14	0.01	0.15	0.14	0.01	0.15	-	-	-	0.28	0.02	0.30
Military Prop	0.07	0.01	0.08	0.07	0.01	0.08	-	-	-	0.14	0.02	0.16
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**532.74**	**48.20**	**580.94**	**535.77**	**45.17**	**580.94**	**-**	**-**	**-**	**1,068.51**	**93.37**	**1,161.88**

Note: Each circuit operation counted as two operations in Total Operations

F.10.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	460.21	49.21	509.42	466.82	42.60	509.42	-	-	-	927.03	91.81	1,018.84
Civilian Jet, Other	5.44	0.53	5.97	5.50	0.47	5.97	-	-	-	10.94	1.00	11.94
Civilian Prop	3.47	0.69	4.16	3.65	0.51	4.16	-	-	-	7.12	1.20	8.32
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	0.01	-	0.01	0.01	-	0.01	-	-	-	0.02	-	0.02
Military Jet, Other	0.08	0.01	0.09	0.08	0.01	0.09	-	-	-	0.16	0.02	0.18
Military Prop	0.04	0.01	0.05	0.04	0.01	0.05	-	-	-	0.08	0.02	0.10
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**469.25**	**50.45**	**519.70**	**476.10**	**43.60**	**519.70**	**-**	**-**	**-**	**945.35**	**94.05**	**1,039.40**

Note: Each circuit operation counted as two operations in Total Operations

F.10.4 Modeled Tracks

RNAV procedures:

- 0 STAR (Arrival) RNAV procedures
- 0 RNAV RNP procedures
- 8 RNAV GPS procedures (runways 03R, 04L, 04R, 21L, 22L, 22R, 27L, 27R)
- 0 RNAV SID (Departure) procedures

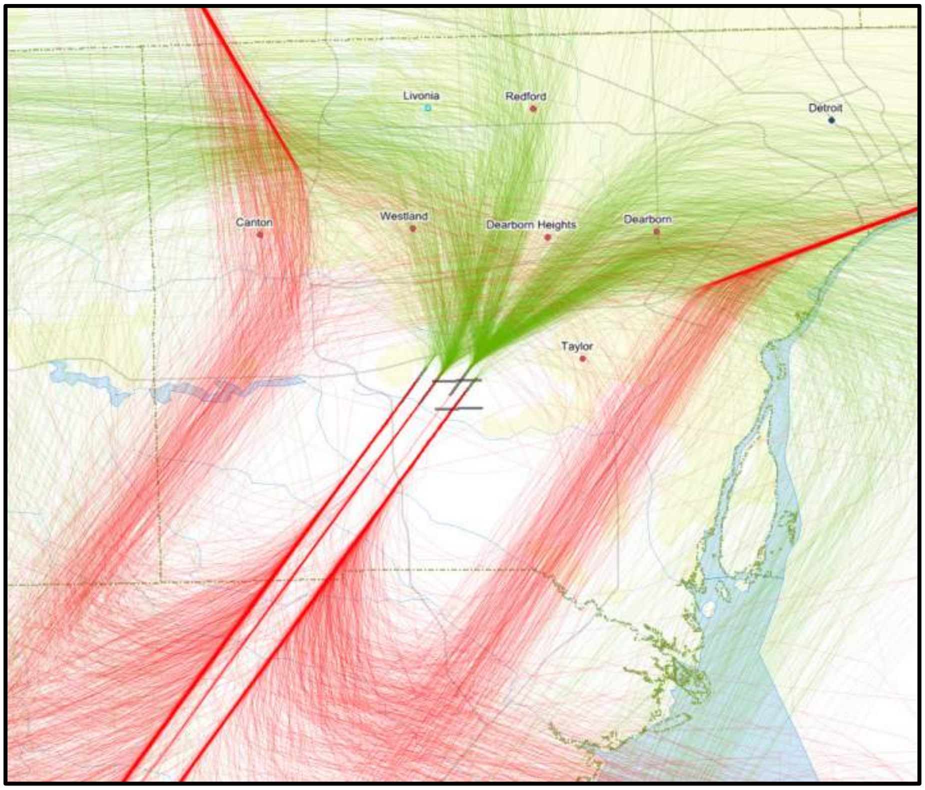
Total Tracks:

Aircraft Category	Arrivals North	Arrivals South	Departures North	Departures South	Locals North	Locals South
Jets	53,049	155,412	52,667	155,339	-	-
Non-Jets, fixed-wing	564	1,679	520	1,519	-	-
Total	53,613	157,091	53,187	156,858	-	-

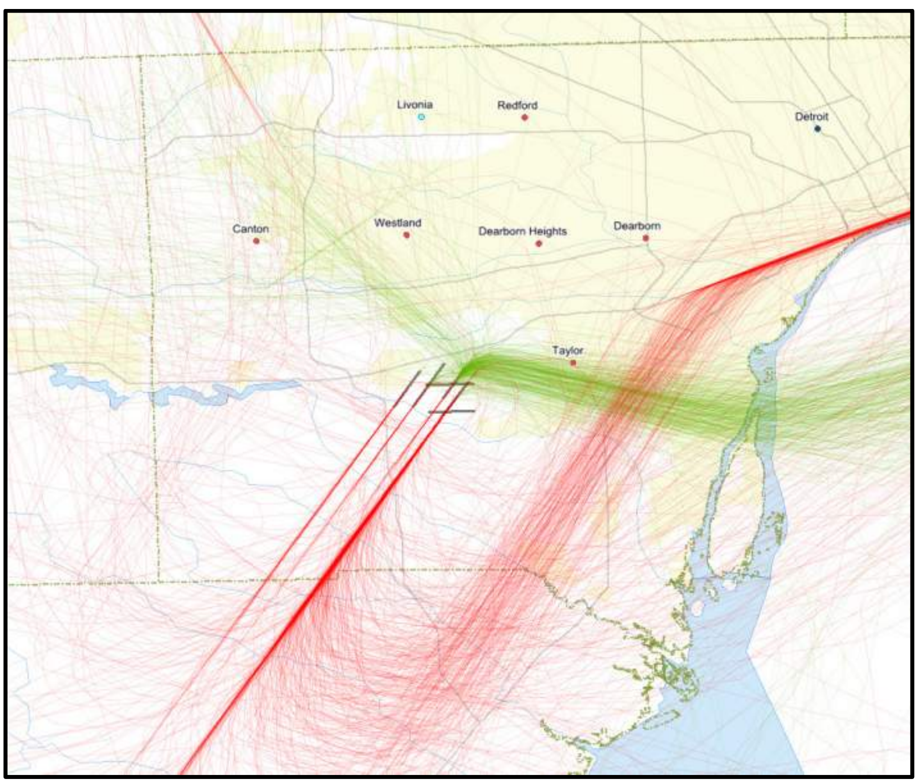
Aircraft Category	Total North	Total South	Total	Percent North	Percent South
Jets	105,716	310,751	416,467	25%	75%
Non-Jets, fixed-wing	1,084	3,198	4,282	25%	75%
Helicopters	n/a	n/a	-	n/a	n/a
Total	106,800	313,949	420,749	25%	75%

F.10.5 Representative Radar Flight Tracks

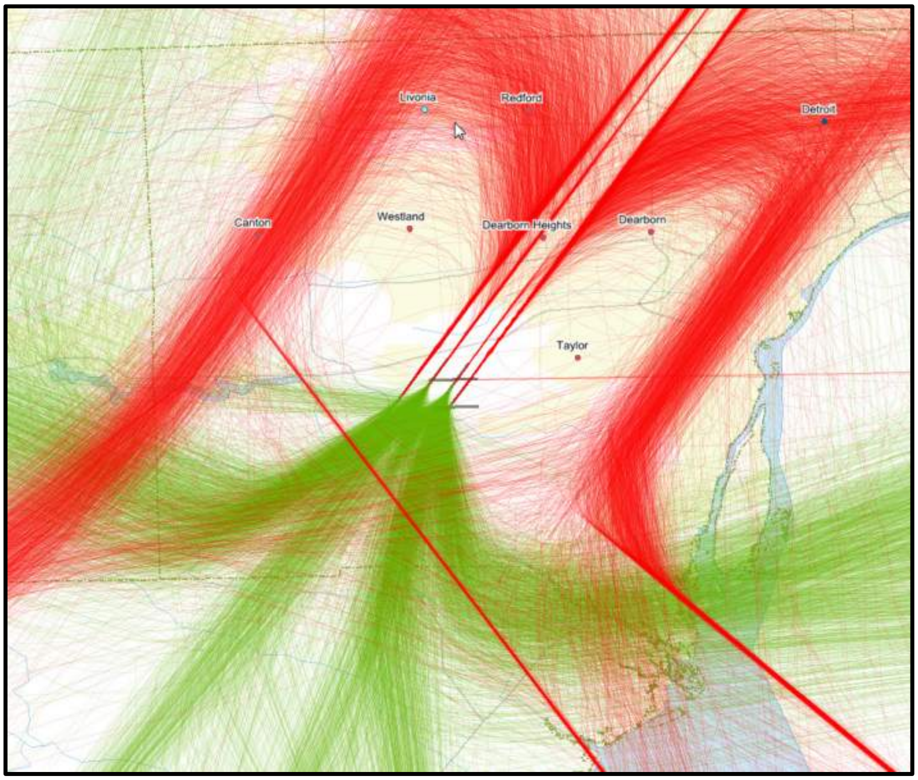
North Flow, Jets – 3% Sample



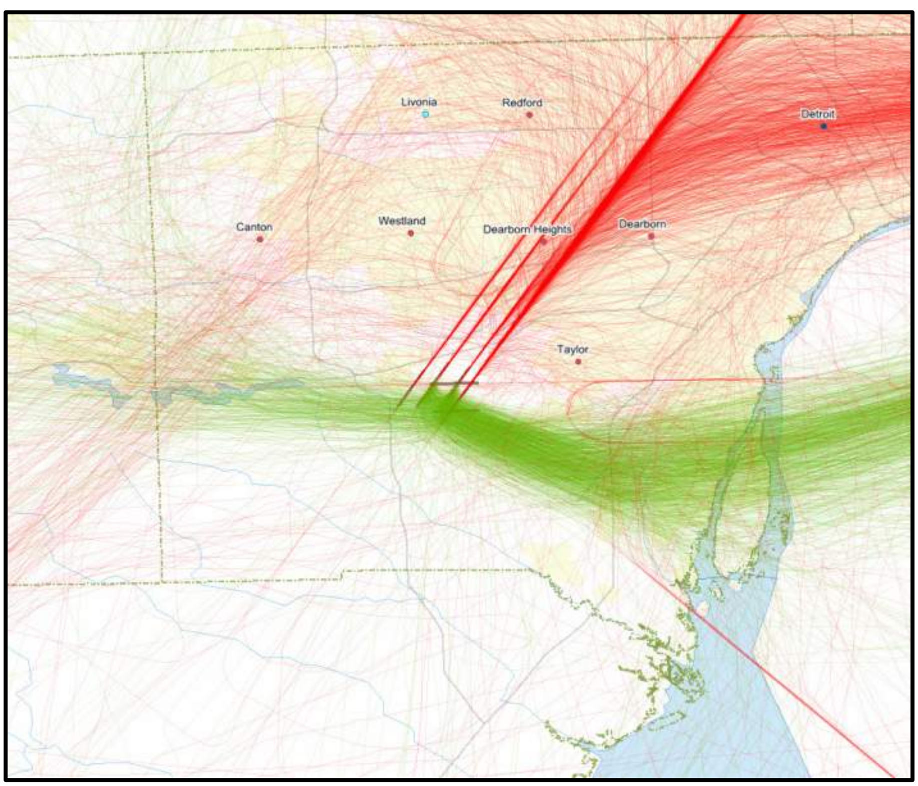
All Non-Jets – 100%



South Flow, Jets – 3% Sample



Non-Jets – 100%



F.11 McCarran Intl, LAS

Airport: McCarran International Airport
City: Las Vegas, NV
Runways: 4
Helipads: 0
Elevation: 2,181 feet MSL

Local Operation Notes: No local operations modeled.

Helicopter Notes: Large number of operations, about 21 percent of total daily operations. Mostly air tours along the strip or sightseeing to the east of the city. None are counted as local.

Other Notes: Mostly commercial operations.

F.11.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
01L	36.075333	-115.17036	2,181	150	8,985	584	3.4
01R	36.074244	-115.16749	2,176	150	9,775	491	3
07L	36.076367	-115.17019	2,179	150	14,510	2,139	3
07R	36.073627	-115.16143	2,157	150	10,526	0	3
19L	36.098591	-115.15355	2,078	150	9,775	878	3
19R	36.097712	-115.15755	2,089	150	8,985	0	3
25L	36.073657	-115.12582	2,048	150	10,526	0	3
25R	36.076407	-115.12110	2,033	150	14,510	1,397	3
H1	36.088301	-115.16612	2,144	n/a	n/a	n/a	n/a
H2	36.078883	-115.17135	2,179	n/a	n/a	n/a	n/a
H3	36.096150	-115.16168	2,107	n/a	n/a	n/a	n/a

F.11.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.11.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	340,088	135,940	45,507	1,249	0	0	522,784	365
ATADS for Data Days	340,088	135,940	45,507	1,249	0	0	522,784	365
Database	334,969	122,483	39,534	508	0	0	497,494	365
Scale Factor	101.5%	111.0%	115.1%	245.9%	0	0	105.1%	n/a

F.11.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	349,606	128,971	44,706	1,595	0	0	524,878	365
Database	334,969	122,483	39,534	508	0	0	497,494	365
Scale Factor	104.4%	105.3%	113.1%	314.0%	0	0	105.5%	n/a

F.11.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.11.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	432.86	56.14	489.00	416.04	72.96	489.00	-	-	-	848.90	129.10	978.00
Civilian Jet, Other	46.48	3.96	50.44	46.06	4.38	50.44	-	-	-	92.54	8.34	100.88
Civilian Prop	26.00	1.75	27.75	24.93	2.82	27.75	-	-	-	50.93	4.57	55.50
Civilian Rotorcraft	140.57	6.67	147.24	136.45	10.80	147.25	-	-	-	277.02	17.47	294.49
Military Jet, Fighter	0.51	-	0.51	0.51	-	0.51	-	-	-	1.02	-	1.02
Military Jet, Other	0.36	0.01	0.37	0.35	0.02	0.37	-	-	-	0.71	0.03	0.74
Military Prop	0.82	0.02	0.84	0.74	0.09	0.83	-	-	-	1.56	0.11	1.67
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**647.60**	**68.55**	**716.15**	**625.08**	**91.07**	**716.15**	**-**	**-**	**-**	**1,272.68**	**159.62**	**1,432.30**

Note: Each circuit operation counted as two operations in Total Operations

F.11.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	443.25	57.61	500.86	425.98	74.87	500.85	-	-	-	869.23	132.48	1,001.71
Civilian Jet, Other	45.66	3.89	49.55	45.25	4.30	49.55	-	-	-	90.91	8.19	99.10
Civilian Prop	25.03	1.69	26.72	23.99	2.73	26.72	-	-	-	49.02	4.42	53.44
Civilian Rotorcraft	133.37	6.33	139.70	129.46	10.24	139.70	-	-	-	262.83	16.57	279.40
Military Jet, Fighter	0.65	-	0.65	0.65	-	0.65	-	-	-	1.30	-	1.30
Military Jet, Other	0.45	0.02	0.47	0.44	0.03	0.47	-	-	-	0.89	0.05	0.94
Military Prop	1.05	0.02	1.07	0.95	0.12	1.07	-	-	-	2.00	0.14	2.14
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**649.46**	**69.56**	**719.02**	**626.72**	**92.29**	**719.01**	**-**	**-**	**-**	**1,276.18**	**161.85**	**1,438.03**

Note: Each circuit operation counted as two operations in Total Operations

F.11.4 Modeled Tracks

RNAV procedures:

- 0 RNAV RNP procedures
- 3 RNAV GPS procedures (runways 01R, 19L, 19R)
- 6 RNAV SID (Departure) procedures

Total Tracks:

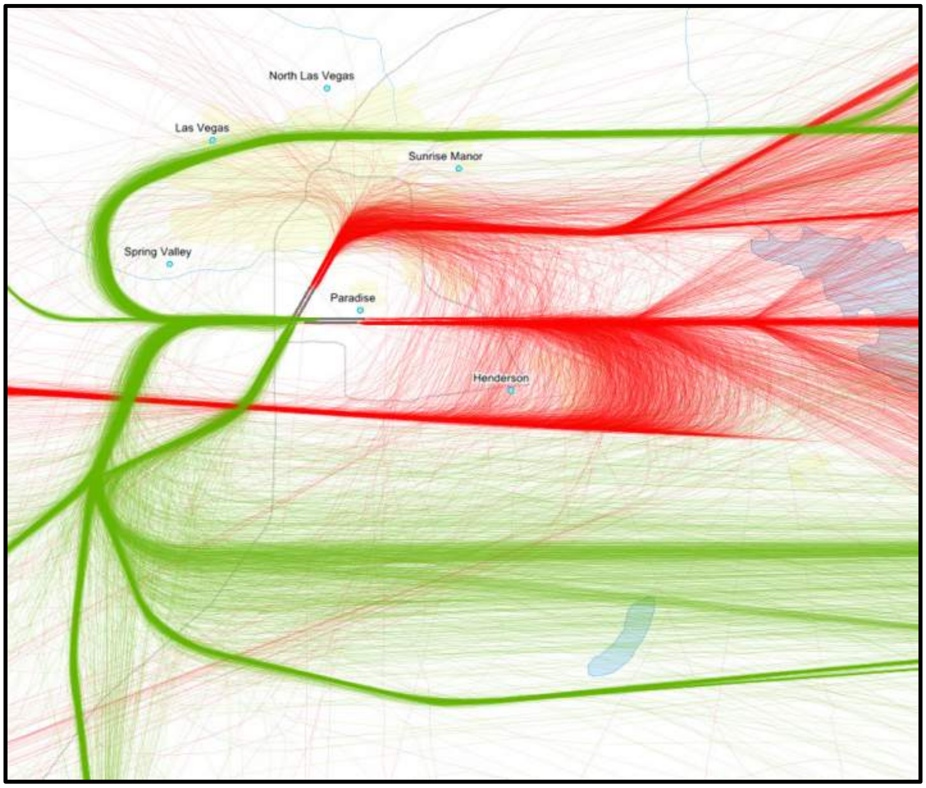
Aircraft Category	Arrivals		Departures		Locals	
	North	South	North	South	North	South
Jets	26,119	167,314	47,714	142,292	-	-
Non-Jets, fixed-wing	1,776	7,736	1,969	6,093	-	-
Total	27,895	175,050	49,683	148,385	-	-

Aircraft Category	Arrivals	Departures	Locals
Helicopters	45,818	50,663	-

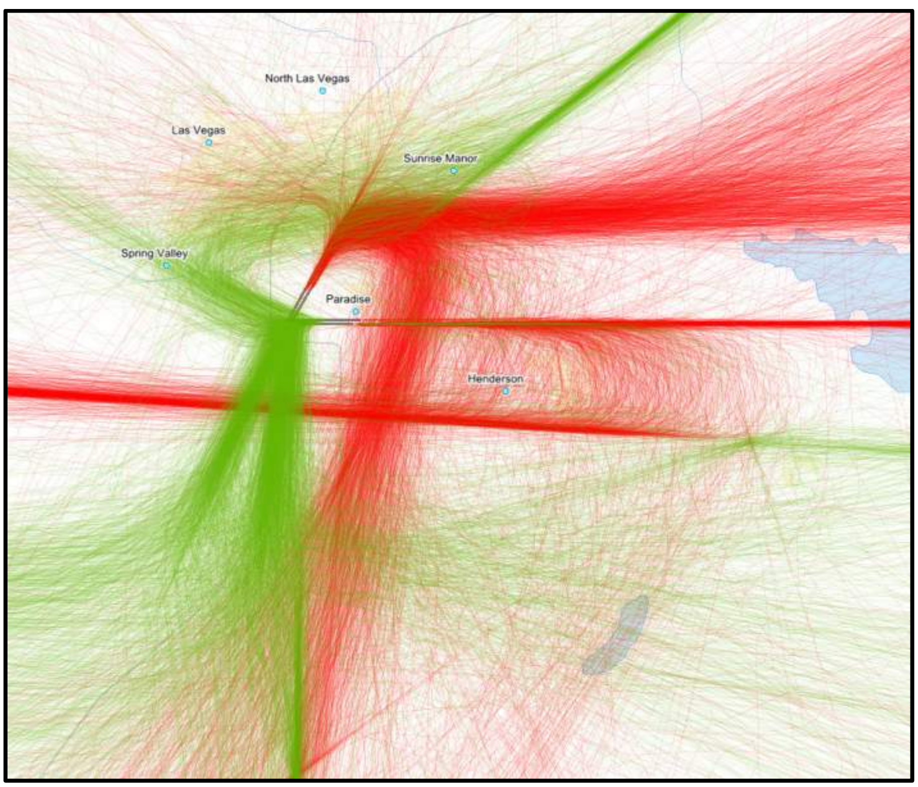
Aircraft Category	Total			Percent	
	North	South	Total	North	South
Jets	73,833	309,606	383,439	19%	81%
Non-Jets, fixed-wing	3,745	13,829	17,574	21%	79%
Helicopters	n/a	n/a	96,481	n/a	n/a
Total	77,578	323,435	497,494	19%	81%

F.11.5 Representative Radar Flight Track

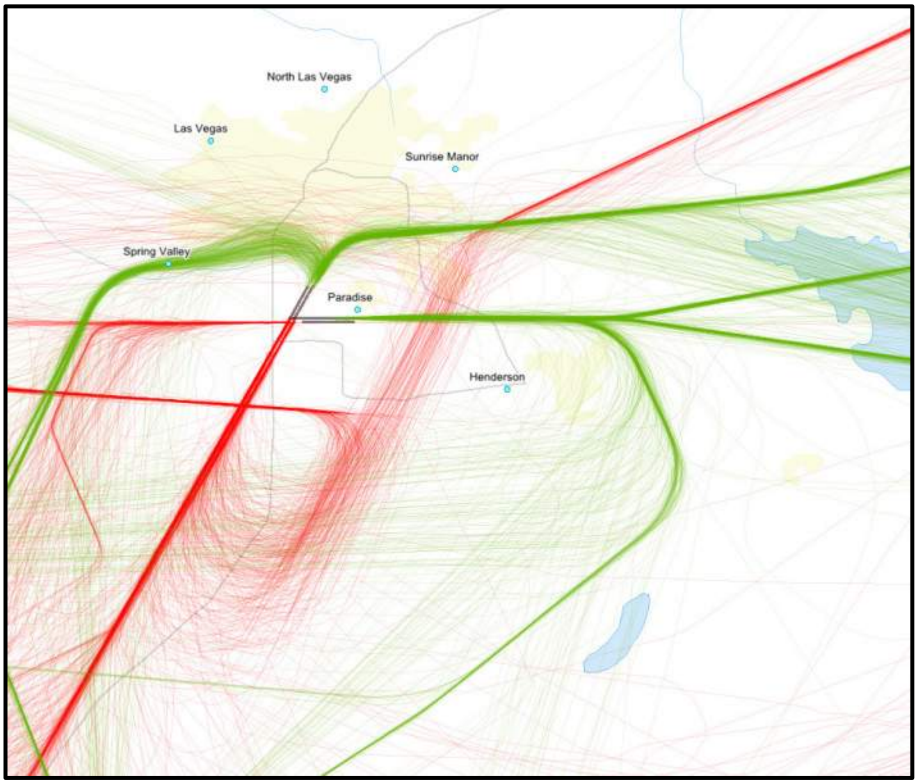
South Flow, Jets – 3% Sample



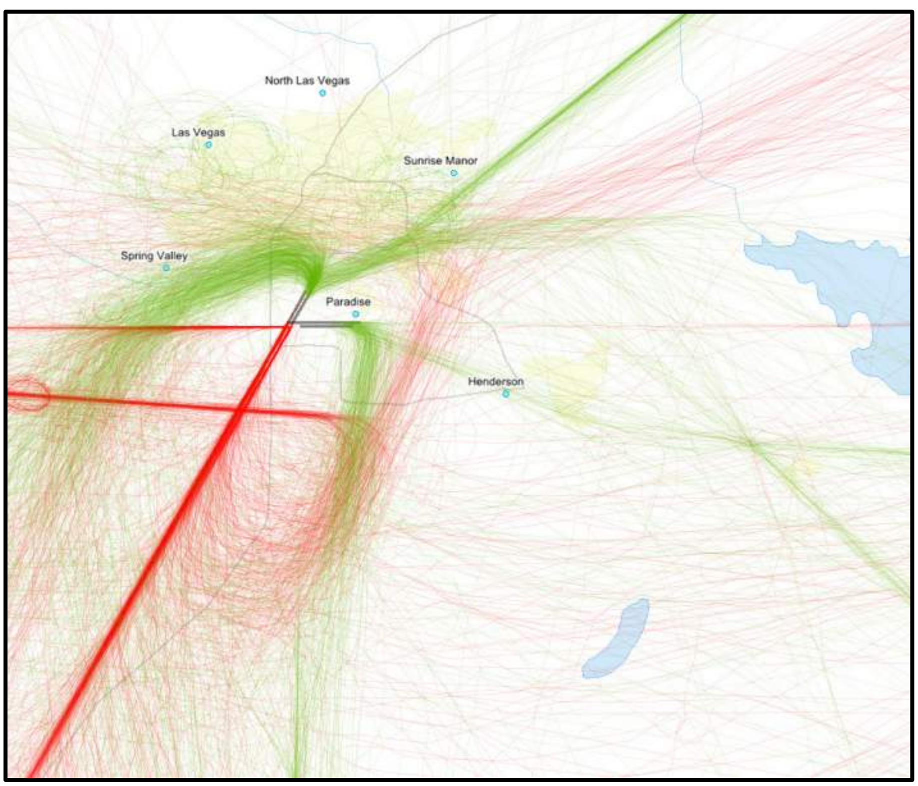
Non-Jets – 50% Sample



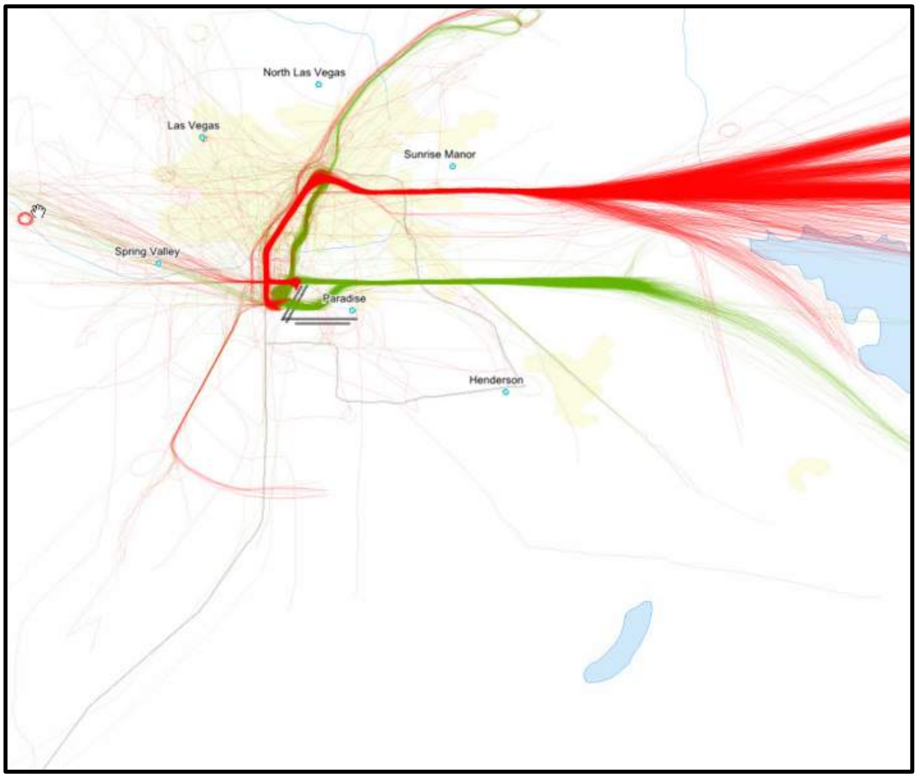
North Flow, Jets – 3% Sample



Non-Jets – 50% Sample



Helicopter operations – 8% Sample



F.12 Los Angeles Intl, LAX

Airport: Los Angeles International Airport
City: Los Angeles, CA
Runways: 4
Helipads: 0
Elevation: 125 feet MSL

Local Operation Notes: No local operations modeled.
Helicopter Notes: No helicopter operations modeled.
Other Notes: Mostly commercial operations. Two 2015 operations (of 654,501 total operations) were not modeled due to a processing error. This omission has no effect within the precision of the model. Military operations were modeled as general aviation operations due to the low number of operations identified as military in the radar flight track data.

F.12.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
06L	33.949108	-118.43115	112	150	8,925	0	3
06R	33.946743	-118.43532	108	150	10,285	331	3
07L	33.935826	-118.41934	118	150	12,091	0	3
07R	33.933644	-118.41901	119	200	11,095	0	3
24L	33.950190	-118.40166	111	150	10,285	0	3
24R	33.952100	-118.40194	117	150	8,925	0	3
25L	33.937358	-118.38271	98	200	11,095	0	3
25R	33.939873	-118.37977	92	150	12,091	957	3

F.12.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.12.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	483,251	96,002	18,192*	2,556*	0	0	600,001	365
ATADS (Data Days)	483,251	96,002	20,748	0	0	0	600,001	365
Database	478,707	96,147	18,211	0	0	0	593,065	365
Scale Factor	100.9%	99.8%	113.9%	0	0	0	101.2%	n/a

*Military operations modeled as General Aviation due to the low number of military tracks in the database.

F.12.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	570,445 (1)	61,681	20,344 (2)	2,023 (2)	8 (3)	0	654,501	365
Database	478,707	96,147	18,211	0	0	0	593,065	365
Scale Factor	119.2%	64.2%	122.8%	0	0	0	110.4%	n/a

Notes: 1) Two fewer air carrier operations modeled due to processing error.
2) Military operations modeled as General Aviation due to no military tracks in the database.
3) Ignored due to low ops.

F.12.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.12.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	615.63	114.37	730.00	576.35	153.65	730.00	-	-	-	1,191.98	268.02	1,460.00
Civilian Jet, Other	19.54	2.39	21.93	19.32	2.61	21.93	-	-	-	38.86	5.00	43.86
Civilian Prop	63.15	6.84	69.99	61.60	8.39	69.99	-	-	-	124.75	15.23	139.98
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	-	-	-	-	-	-	-	-	-	-	-	-
Military Prop	-	-	-	-	-	-	-	-	-	-	-	-
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**698.32**	**123.60**	**821.92**	**657.27**	**164.65**	**821.92**	**-**	**-**	**-**	**1,355.59**	**288.25**	**1,643.84**

Note: Each circuit operation counted as two operations in Total Operations

F.12.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	689.65	130.73	820.38	643.52	176.86	820.38	-	-	-	1,333.17	307.59	1,640.76
Civilian Jet, Other	21.06	2.58	23.64	20.83	2.81	23.64	-	-	-	41.89	5.39	47.28
Civilian Prop	47.96	4.58	52.54	46.31	6.23	52.54	-	-	-	94.27	10.81	105.08
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	-	-	-	-	-	-	-	-	-	-	-	-
Military Prop	-	-	-	-	-	-	-	-	-	-	-	-
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**758.67**	**137.89**	**896.56**	**710.66**	**185.90**	**896.56**	**-**	**-**	**-**	**1,469.33**	**323.79**	**1,793.12**

Note: Each circuit operation counted as two operations in Total Operations

F.12.4 Modeled Tracks

RNAV procedures:

- 3 STAR (Arrival) RNAV procedures
- 7 RNAV RNP procedures (All runways except 25R)
- 8 RNAV GPS procedures (All runways)
- 7 RNAV SID (Departure) procedures

Total Tracks*:

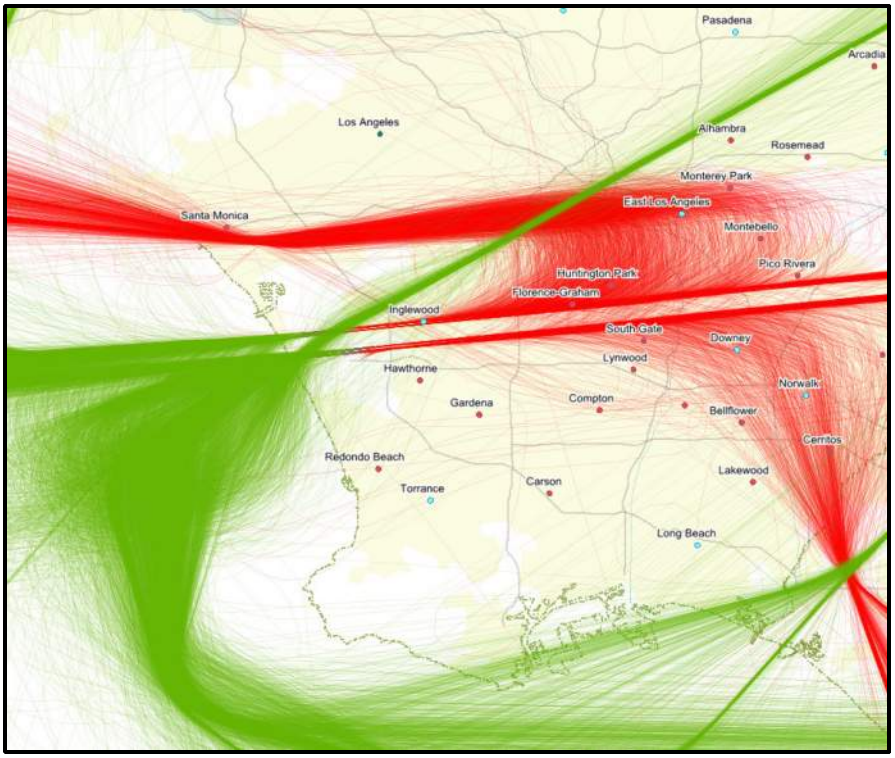
Aircraft Category	Arrivals East	Arrivals West	Departures East	Departures West	Locals East	Locals West
Jets	14,998	256,582	4,117	266,937	-	-
Non-Jets, fixed-wing	1,017	24,306	418	24,689	-	-
Total	16,015	280,888	4,535	291,626	-	-

Aircraft Category	Total East	Total West	Total	Percent East	Percent West
Jets	19,115	523,519	542,634	4%	96%
Non-Jets, fixed-wing	1,435	48,995	50,430	3%	97%
Helicopters	n/a	n/a	-	n/a	n/a
Total	20,550	572,514	593,064	3%	97%

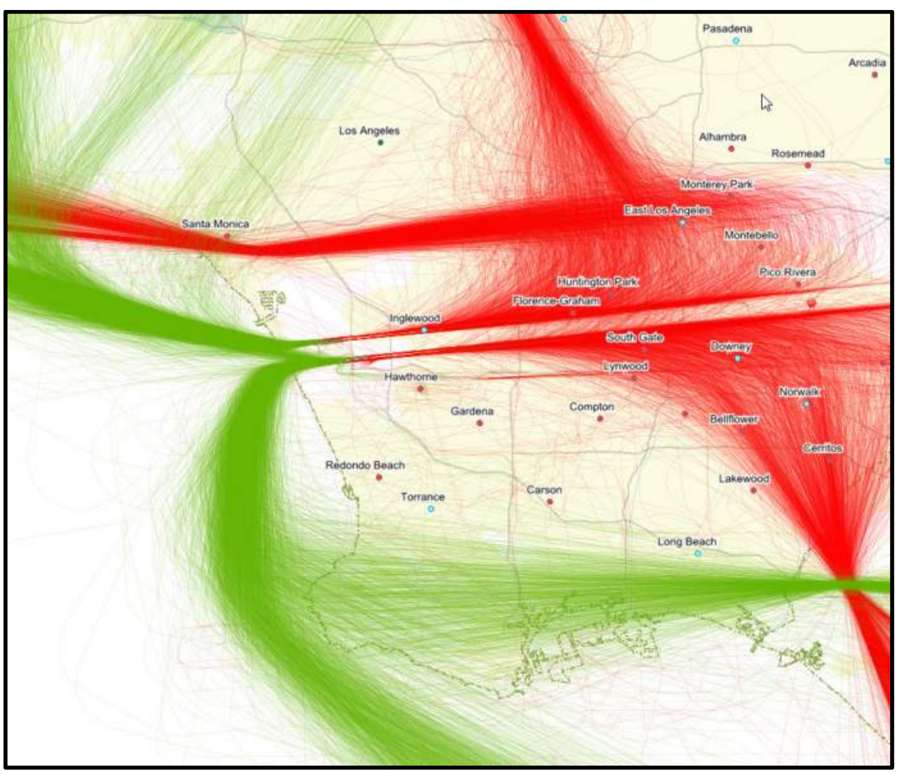
*LAX's nighttime "contra-flow", also known as its "over-ocean" condition, is included, via the tracks' runway assignment and operation type, in the east and west flow counts.

F.12.5 Representative Radar Flight Tracks

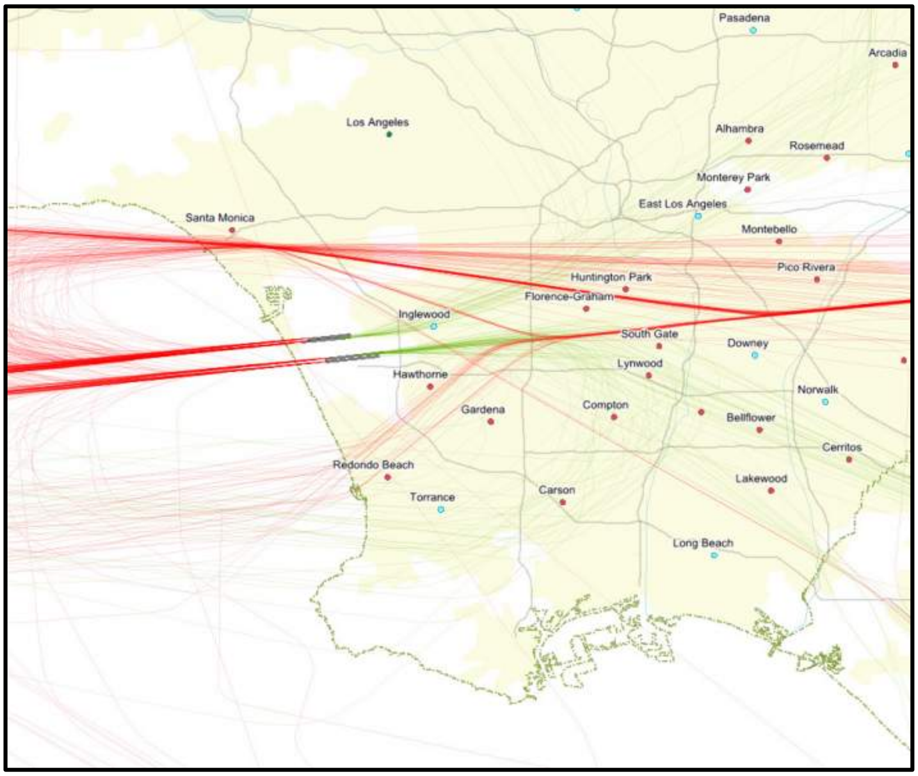
West Flow, Jets – 3% Sample



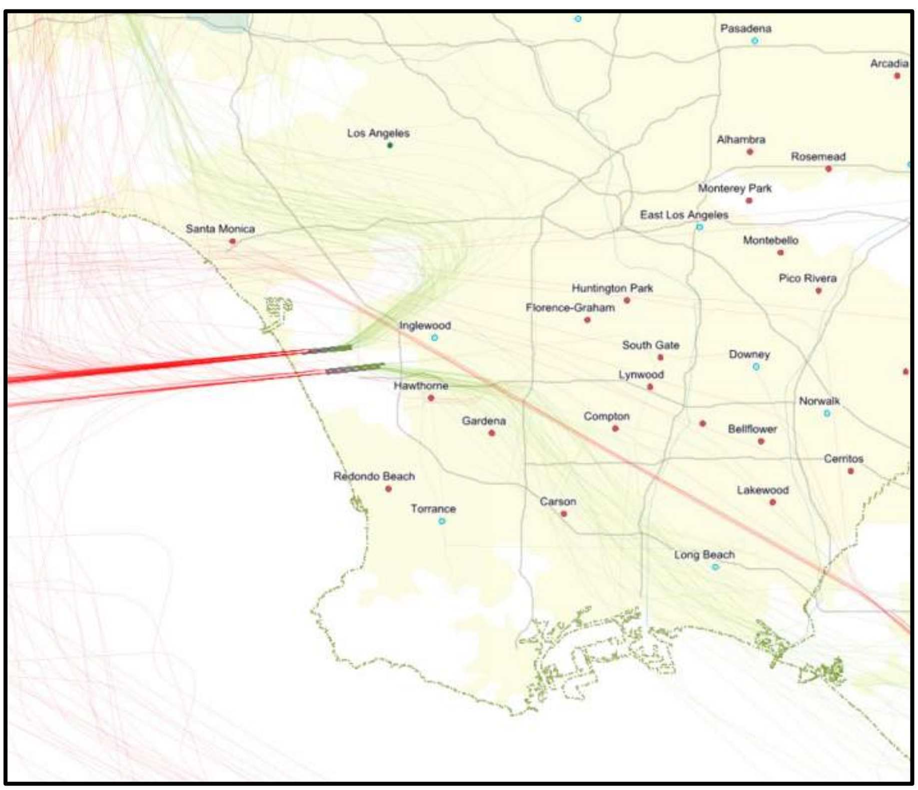
Non-Jets – 20% Sample



East Flow, Jets – 3%



Non-Jets – 20%



F.13 LaGuardia, LGA

Airport: LaGuardia Airport
City: New York, NY
Runways: 2
Helipads: 1
Elevation: 20 feet MSL

Local Operation Notes: No local operations modeled.

Helicopter Notes: A small number of helicopter operations modeled.

Other Notes: Mostly commercial operations. Military operations were modeled as general aviation operations due to the low number of operations identified as military in the radar flight track data.

F.13.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
04	40.769165	-73.884120	21	150	7,001	0	3
13	40.782297	-73.878522	12	150	7,003	0	3.1
22	40.785437	-73.870672	12	150	7,001	0	3
31	40.772071	-73.857112	7	150	7,003	0	3
H1	40.776008	-73.880967	19	60	60	0	3

F.13.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.13.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	291,723	73,223	6,876	302	0	0	372,124	365
ATADS for Data Days (preliminary)	291,723	73,223	6,873 (1)	294 (1)	0	0	372,113	362 (2)
ATADS for Data Days	291,723	73,223	7,167	0	0	0	372,113	362
Database	283,507	70,293	4,360	0	0	0	358,160	362
Scale Factor	102.9%	104.2%	164.4%	0	0	0	103.9%	n/a

Notes:
1) Military operations modeled as General Aviation due to the low number of military tracks in the database.
2) Three days (10/29/2012, 10/30/2012, 10/31/2012) have no operations in the database due to Superstorm Sandy, and thus were not counted.

F.13.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	307,548	54,211	6,178	425*	0	0	368,362	365
Database	283,507	70,293	4,360	0	0	0	358,160	362
Scale Factor	108.5%	77.1%	151.4%	0	0	0	102.8%	n/a

* Military operations modeled as General Aviation due to the no military tracks in the database.

F.13.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.13.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	452.14	45.75	497.89	452.96	44.92	497.88	-	-	-	905.10	90.67	995.77
Civilian Jet, Other	7.19	0.79	7.98	7.24	0.74	7.98	-	-	-	14.43	1.53	15.96
Civilian Prop	7.32	0.28	7.60	7.23	0.36	7.59	-	-	-	14.55	0.64	15.19
Civilian Rotorcraft	0.48	0.02	0.50	0.48	0.02	0.50	-	-	-	0.96	0.04	1.00
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	-	-	-	-	-	-	-	-	-	-	-	-
Military Prop	-	-	-	-	-	-	-	-	-	-	-	-
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**467.13**	**46.84**	**513.97**	**467.91**	**46.04**	**513.95**	**-**	**-**	**-**	**935.04**	**92.88**	**1,027.92**

Note: Each circuit operation counted as two operations in Total Operations

F.13.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	448.48	46.61	495.09	449.79	45.30	495.09	-	-	-	898.27	91.91	990.18
Civilian Jet, Other	6.63	0.73	7.36	6.67	0.68	7.35	-	-	-	13.30	1.41	14.71
Civilian Prop	5.64	0.24	5.88	5.59	0.29	5.88	-	-	-	11.23	0.53	11.76
Civilian Rotorcraft	0.45	0.02	0.47	0.44	0.02	0.46	-	-	-	0.89	0.04	0.93
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	-	-	-	-	-	-	-	-	-	-	-	-
Military Prop	-	-	-	-	-	-	-	-	-	-	-	-
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**461.20**	**47.60**	**508.80**	**462.49**	**46.29**	**508.78**	**-**	**-**	**-**	**923.69**	**93.89**	**1,017.58**

Note: Each circuit operation counted as two operations in Total Operations

F.13.4 Modeled Tracks

RNAV procedures:

- 0 STAR (Arrival) RNAV procedures
- 2 RNAV RNP procedures (runways 04 and 22)
- 4 RNAV GPS procedures (all runways)
- 5 RNAV SID (Departure) procedures

Total Tracks:

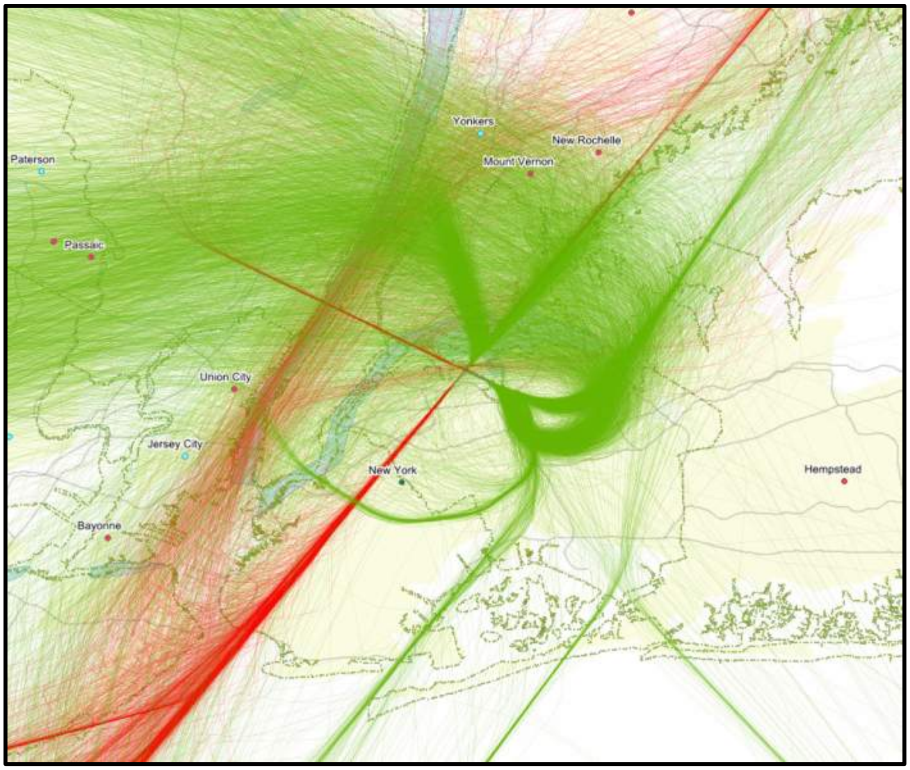
Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	38,633	141,357	128,821	44,354	-	-
Non-Jets, fixed-wing	537	1,980	1,819	497	-	-
Total	39,170	143,337	130,640	44,851	-	-

Aircraft Category	Arrivals	Departures	Locals
Helicopters	117	45	-

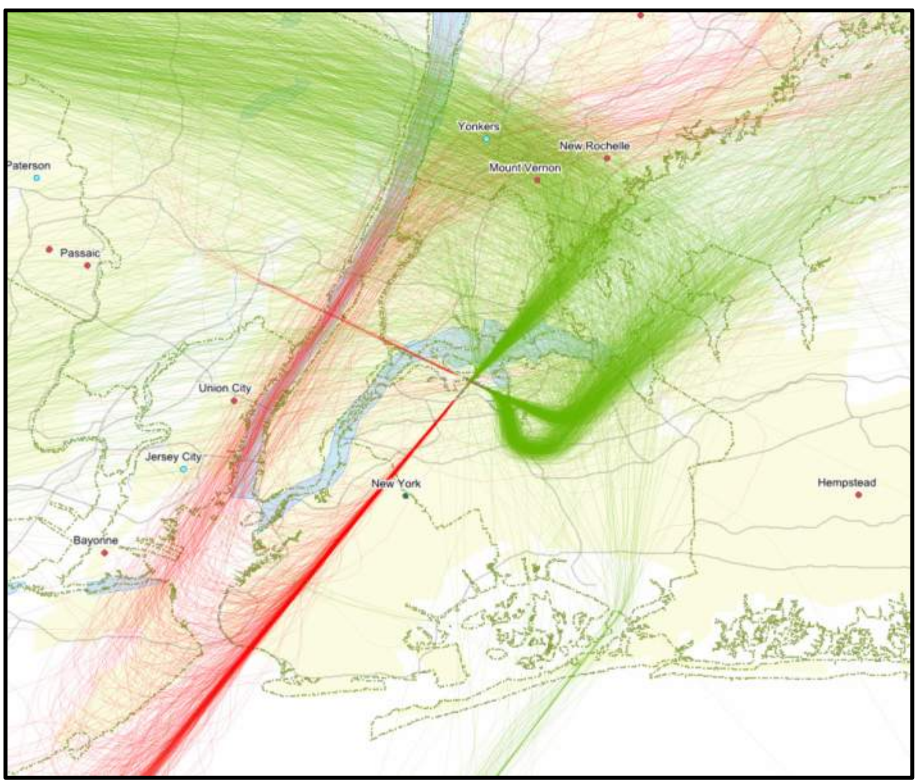
Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	167,454	185,711	353,165	47%	53%
Non-Jets, fixed-wing	2,356	2,477	4,833	49%	51%
Helicopters	n/a	n/a	162	n/a	n/a
Total	169,810	188,188	358,160	47%	53%

F.13.5 Representative Radar Flight Tracks

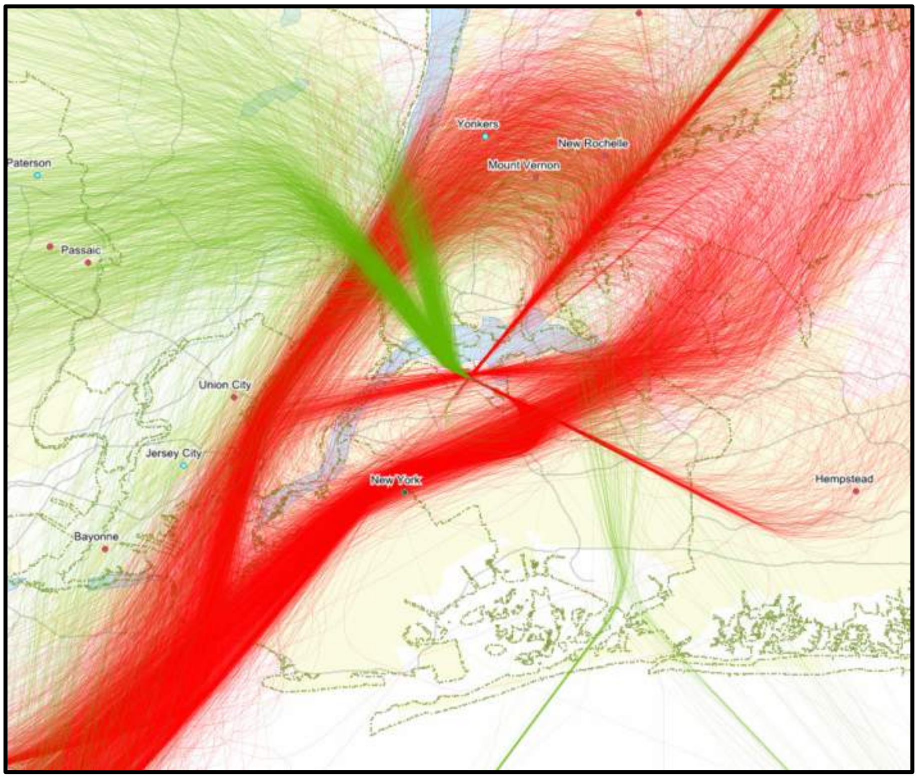
East Flow, Jets – 4% Sample



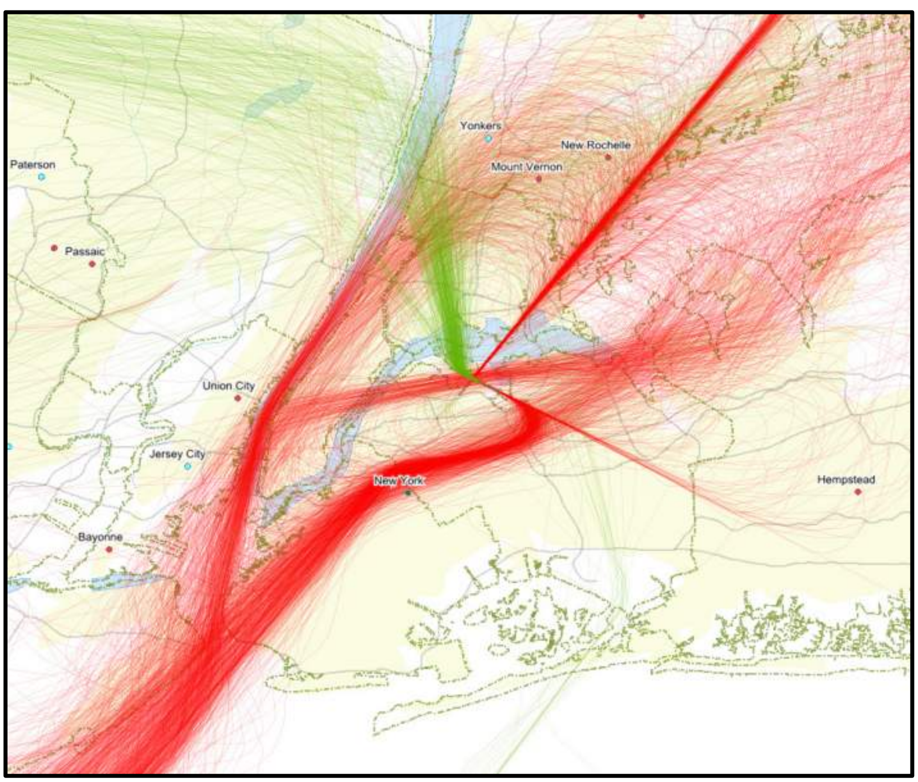
Non-Jets – 100%



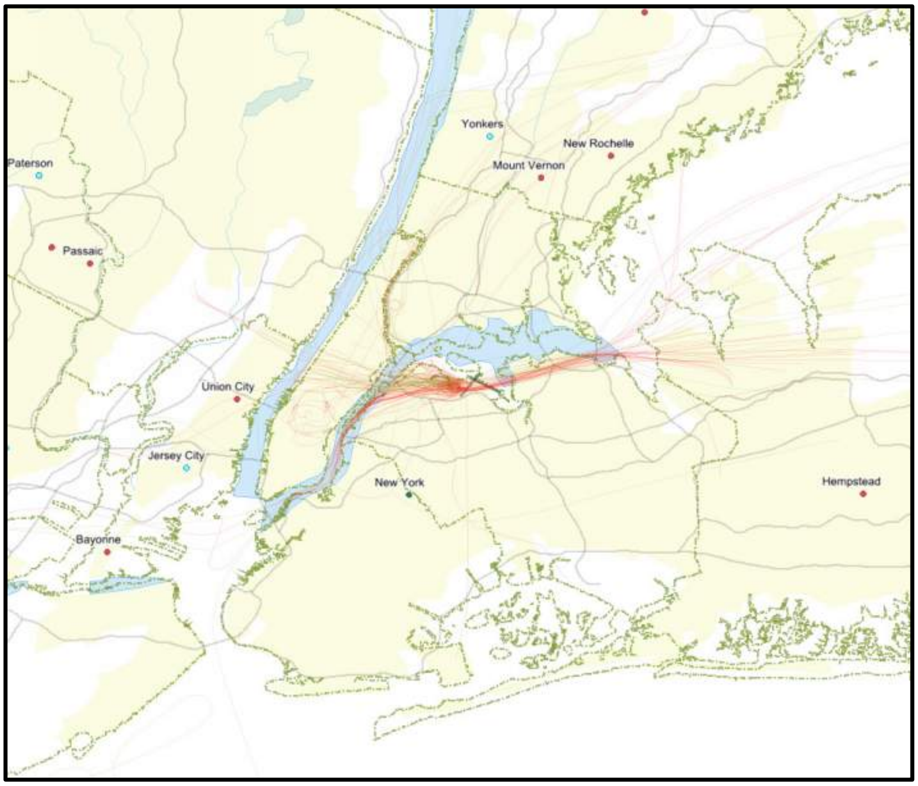
West Flow, Jets – 4% Sample



Non-Jets – 100%



Helicopters – 100%



F.14 Bill and Hillary Clinton National Airport / Adams Field, LIT

Airport: Bill and Hillary Clinton National Airport (also called Adams Field)
City: Little Rock, AR
Runways: 3
Helipads: 1
Elevation: 262 feet MSL

Local Operation Notes: Circuits modeled at 1,000 feet AFE and 2,000 feet AFE. Split tracks not counted as local operations. Circuit tracks with a maximum range of greater than 20 nautical miles or a maximum altitude of over 4,000 feet MSL were removed from modeling.

Helicopter Notes: Mostly general aviation and air taxi (to nearby hospital), about 4 percent of total daily operations. Variety of INM types. None counted as local operations.

Other Notes: Mostly commercial jet operations. Relatively large number of C130 circuit events. Military airfield ~10 nautical miles northeast of LIT.

F.14.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
06L	33.949108	-118.43115	112	150	8,925	0	3
06R	33.946743	-118.43532	108	150	10,285	331	3
07L	33.935826	-118.41934	118	150	12,091	0	3
07R	33.933644	-118.41901	119	200	11,095	0	3
24L	33.950190	-118.40166	111	150	10,285	0	3
24R	33.952100	-118.40194	117	150	8,925	0	3
25L	33.937358	-118.38271	98	200	11,095	0	3
25R	33.939873	-118.37977	92	150	12,091	957	3

F.14.2 ATADS and Radar Flight Track Data Operations Summary

F.14.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	19,860	24,555	40,373	8,337	4,538	7,761	105,424	365
ATADS for Data Days	19,762	24,462	40,249	8,307	4,536	7,761	105,077	363
Database	19,381	24,345	35,817	3,918	1,322	2,656	87,439	363
Scale Factor	102.0%	100.5%	112.4%	212.0%	343.1%	292.2%	120.2%	n/a

F.14.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	20,341	14,272	35,839	7,609	13,931	7,047	99,039	365
Database	19,381	24,345	35,817	3,918	1,322	2,656	87,439	363
Scale Factor	105.0%	58.6%	100.1%	194.2%	1053.8%	265.3%	113.3%	n/a

F.14.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.14.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	48.80	6.84	55.64	48.30	7.34	55.64	0.29	-	0.29	97.68	14.18	111.86
Civilian Jet, Other	15.51	0.97	16.48	15.36	1.13	16.49	1.01	0.03	1.04	32.89	2.16	35.05
Civilian Prop	37.93	2.00	39.93	37.34	2.59	39.93	4.58	0.35	4.93	84.43	5.29	89.72
Civilian Rotorcraft	3.36	0.94	4.30	3.35	0.95	4.30	-	-	-	6.71	1.89	8.60
Military Jet, Fighter	0.22	-	0.22	0.20	0.02	0.22	0.02	-	0.02	0.46	0.02	0.48
Military Jet, Other	3.12	0.02	3.14	3.14	-	3.14	0.81	-	0.81	7.88	0.02	7.90
Military Prop	6.53	0.70	7.23	6.65	0.59	7.24	9.15	0.71	9.86	31.48	2.71	34.19
Military Rotorcraft	0.85	<0.01	0.85	0.84	0.01	0.85	-	-	-	1.69	0.01	1.70
TOTAL	**116.32**	**11.47**	**127.79**	**115.18**	**12.63**	**127.81**	**15.86**	**1.09**	**16.95**	**263.22**	**26.28**	**289.50**

Note: Each circuit operation counted as two operations in Total Operations

F.14.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	38.62	5.90	44.52	38.17	6.35	44.52	0.89	-	0.89	77.68	12.25	89.93
Civilian Jet, Other	13.81	0.86	14.67	13.67	1.00	14.67	3.09	0.09	3.18	30.57	1.95	32.52
Civilian Prop	33.01	1.53	34.54	32.49	2.04	34.53	14.05	1.07	15.12	79.55	4.64	84.19
Civilian Rotorcraft	2.62	0.70	3.32	2.59	0.73	3.32	-	-	-	5.21	1.43	6.64
Military Jet, Fighter	0.20	-	0.20	0.19	0.01	0.20	0.01	-	0.01	0.40	0.01	0.41
Military Jet, Other	2.86	0.02	2.88	2.88	-	2.88	0.74	-	0.74	6.48	0.02	6.50
Military Prop	5.98	0.64	6.62	6.09	0.54	6.63	8.31	0.64	8.95	20.38	1.82	22.20
Military Rotorcraft	0.77	<0.01	0.77	0.77	0.01	0.78	-	-	-	1.54	0.01	1.55
TOTAL	**97.87**	**9.65**	**107.52**	**96.85**	**10.68**	**107.53**	**27.09**	**1.80**	**28.89**	**221.81**	**22.13**	**243.94**

Note: Each circuit operation counted as two operations in Total Operations

F.14.4 Modeled Tracks

RNAV procedures:

- 0 STAR RNAV procedures.
- 6 RNAV GPS procedures (one for each runway).
- 0 RNAV departure procedures.

Total Tracks:

Aircraft Category	Arrivals North	Arrivals South	Departures North	Departures South	Locals North	Locals South
Jets	10,492	15,712	10,262	15,543	70	174
Non-Jets, fixed-wing*	5,310	8,552	5,422	8,027	59	521
C130	347	495	192	110	380	789
Total	16,149	24,759	15,876	23,680	509	1,484

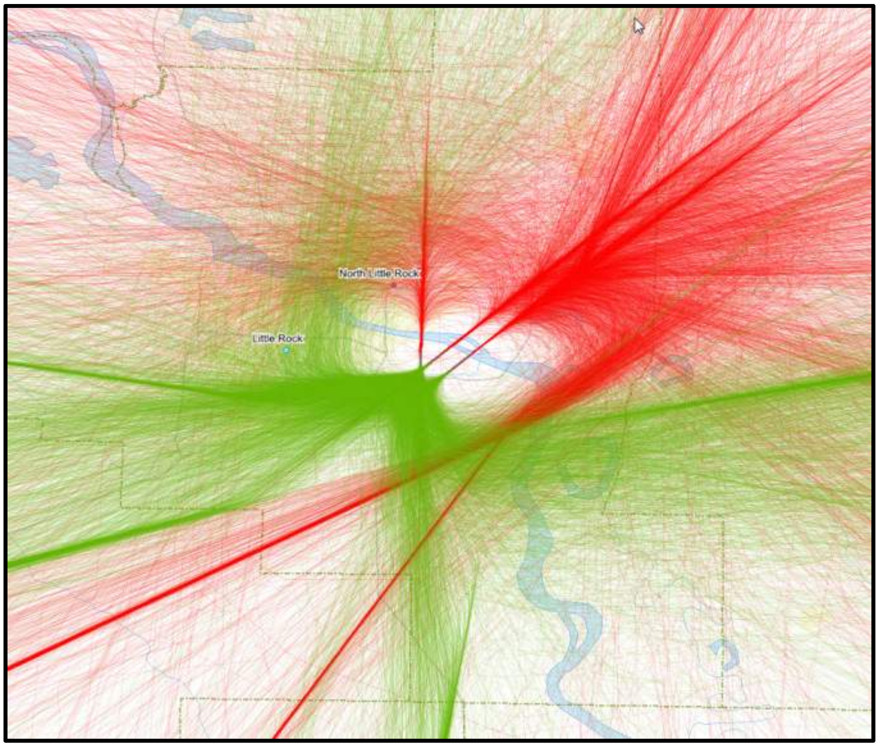
Aircraft Category	Arrivals	Departures	Locals
Helicopters	1,517	1,480	-

Aircraft Category	Total North	Total South	Total Total	Percent North	Percent South
Jets	20,824	31,429	52,253	40%	60%
Non-Jets, fixed-wing*	10,791	17,100	27,891	39%	61%
C130	919	1,394	2,313	40%	60%
Helicopters	n/a	n/a	2,997	n/a	n/a
Total	32,534	49,923	85,454	39%	61%

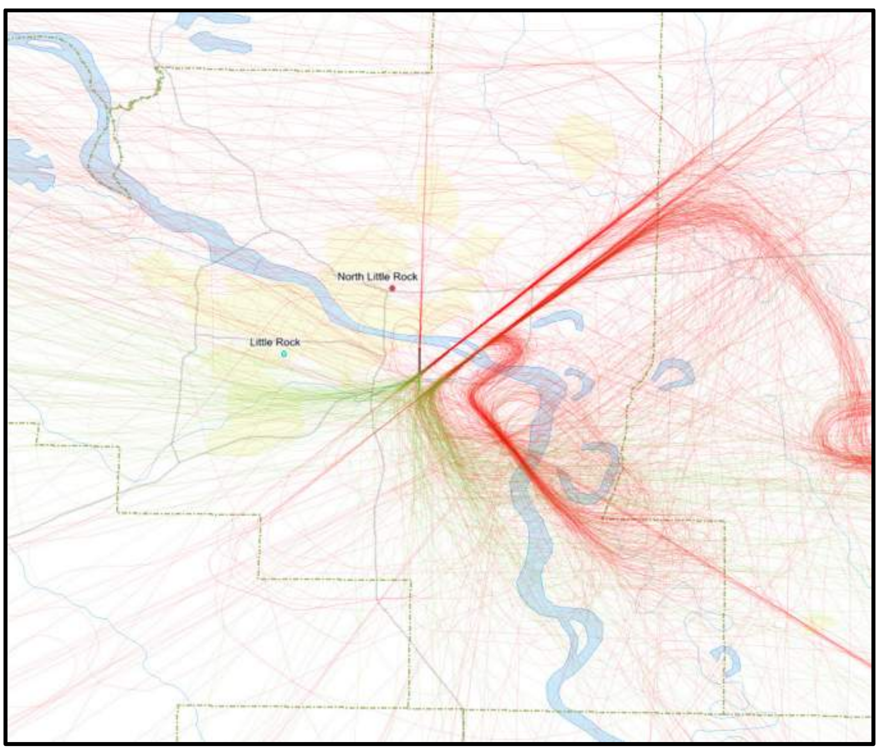
*Excludes C130 tracks and helicopters

F.14.5 Representative Radar Flight Tracks

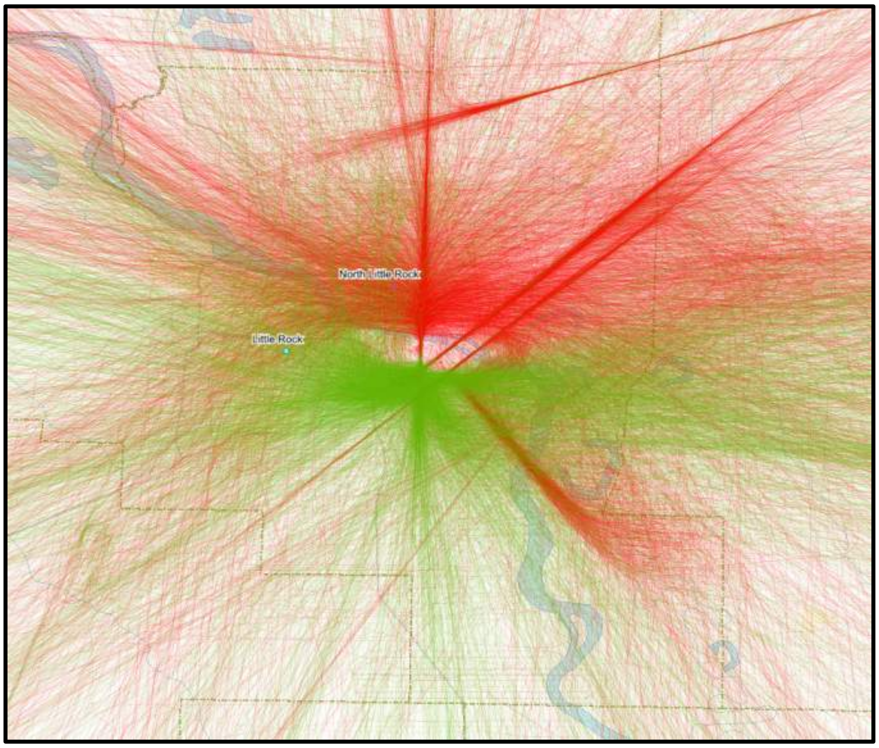
South Flow, Civil Jets – 33% Sample



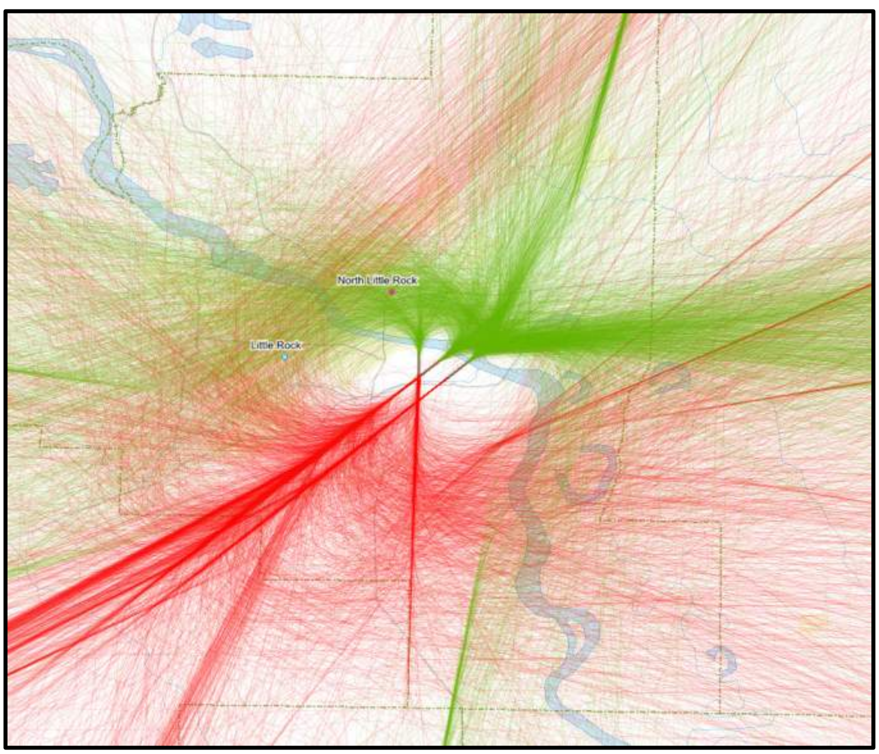
Military Jets – 100% Sample



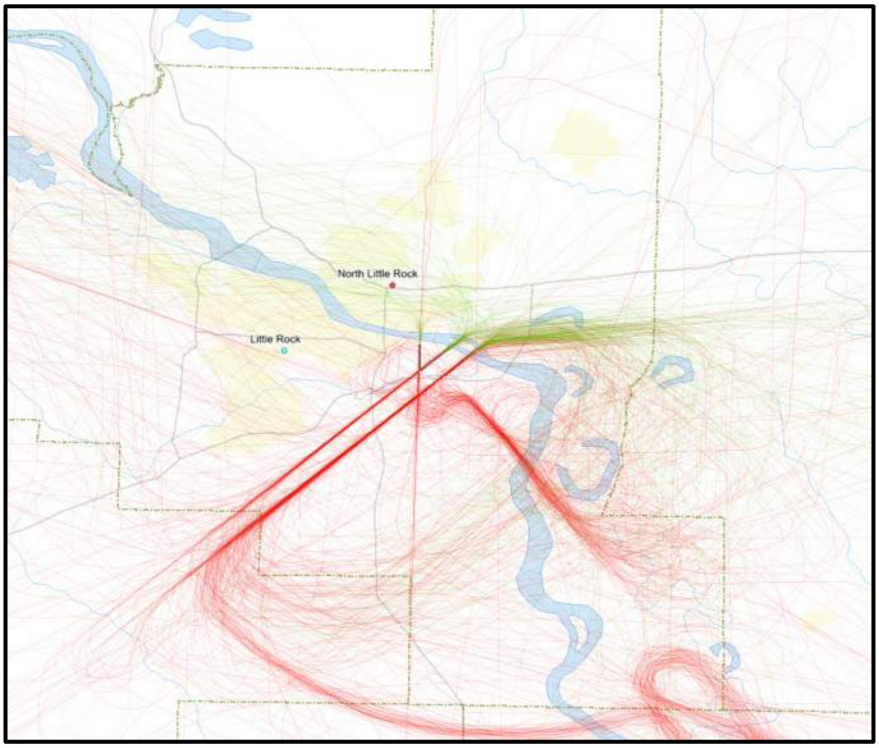
South Flow, Non-Jets – 50% Sample



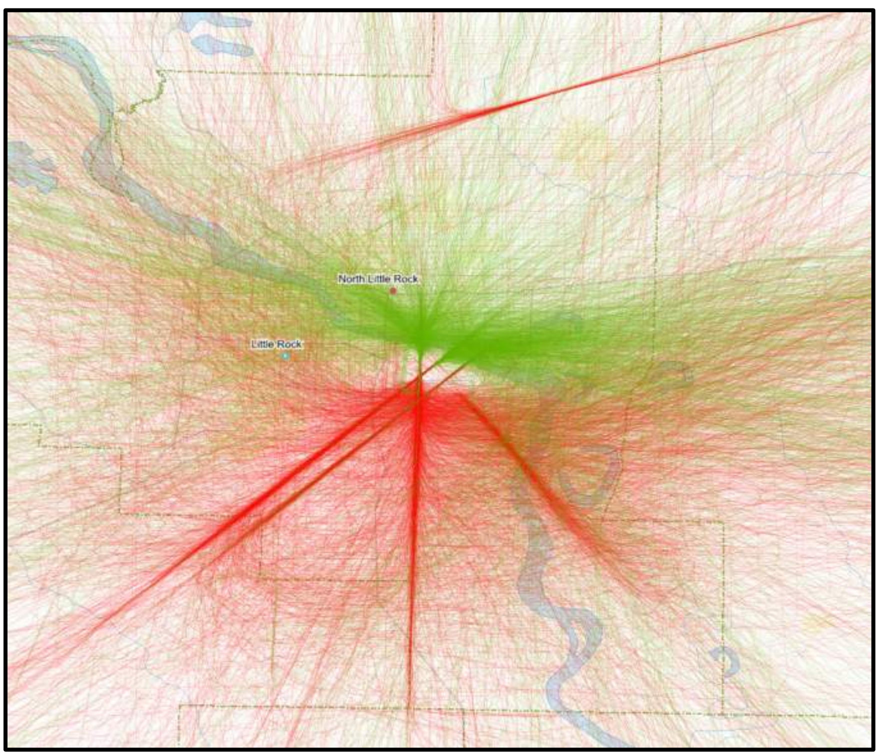
North Flow, Civil Jets – 33% Sample



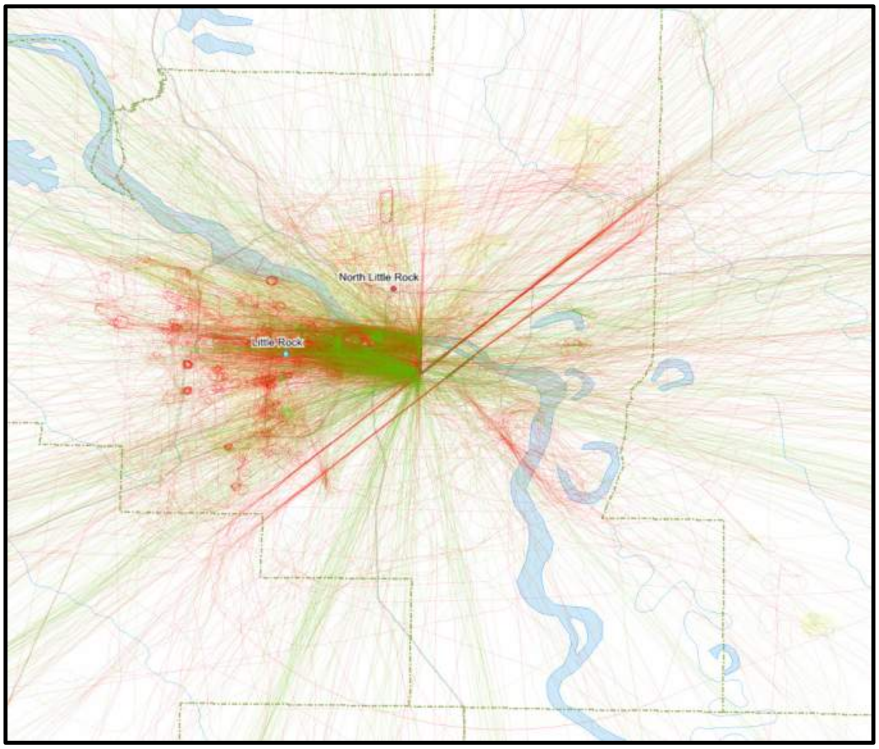
Military Jets – 100% Sample



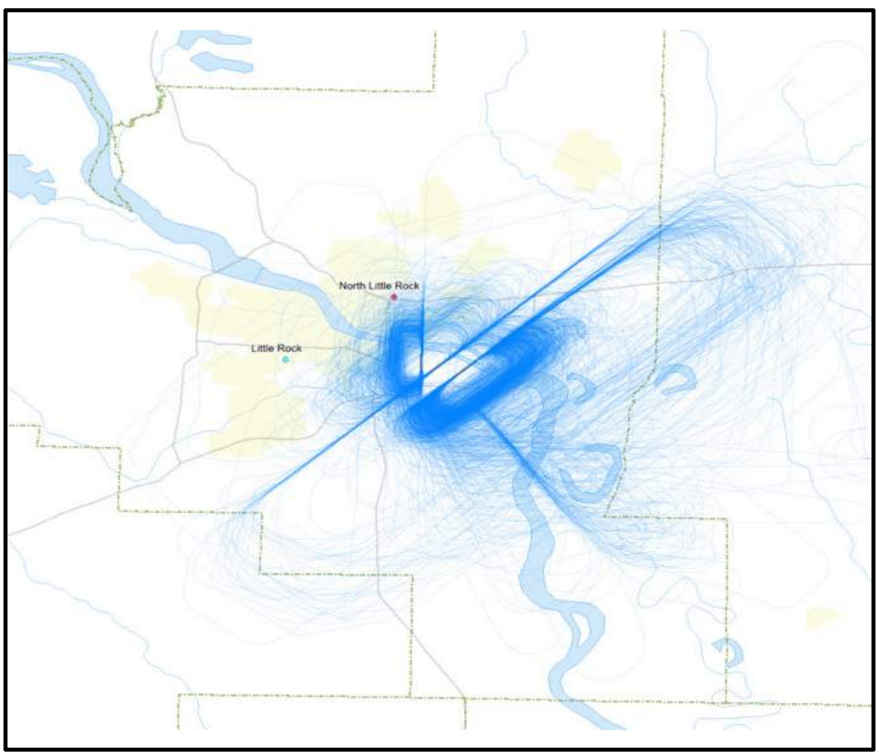
North Flow, Non-Jets – 50% Sample



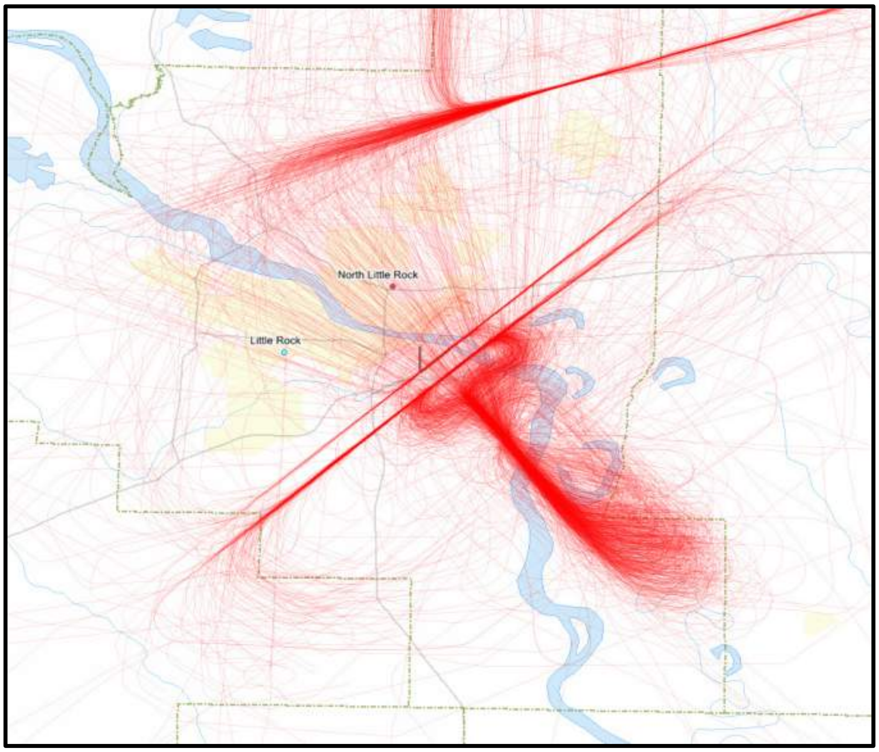
Helicopters – 100% Sample



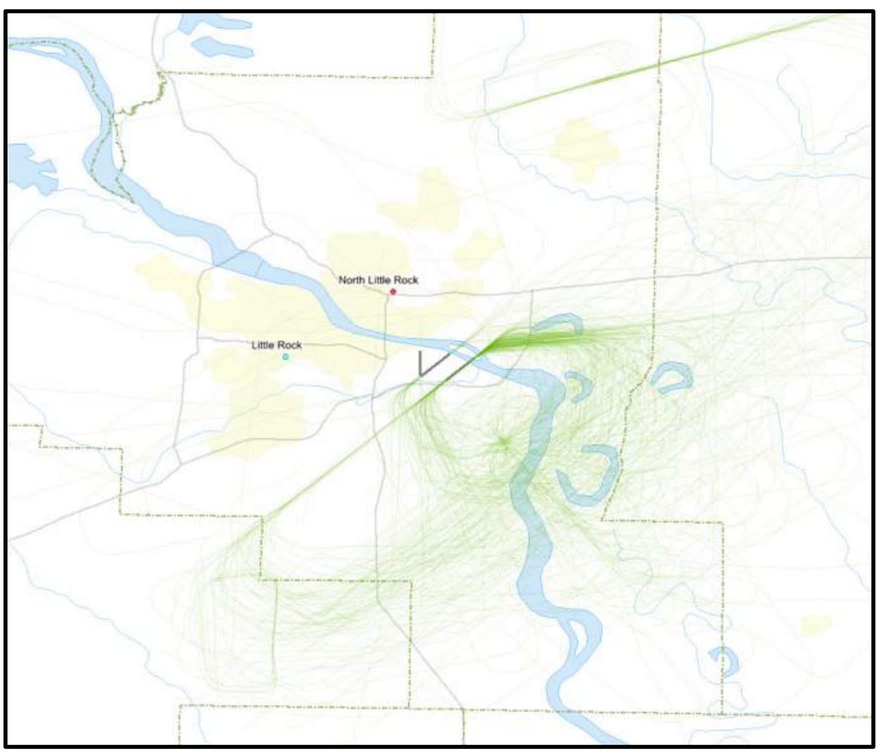
Local Operations – 100% Sample



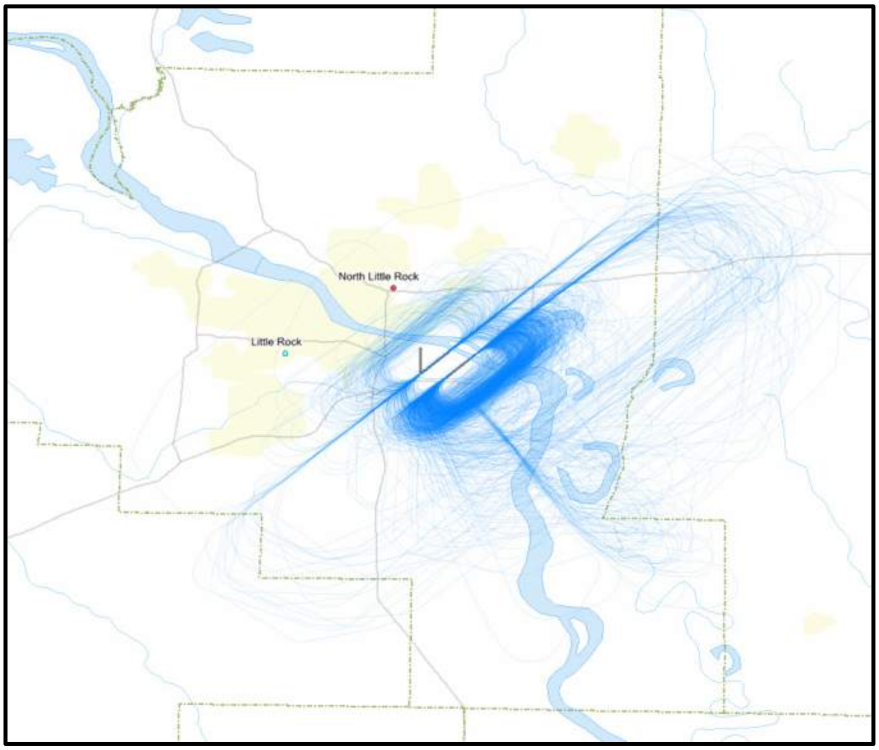
C130 Arrival Operations – 100%



C130 Departure Operations – 100%



C130 Local Operations – 100%



F.15 Memphis Intl, MEM

Airport: Memphis International Airport
City: Memphis, TN
Runways: 4
Helipads: 0
Elevation: 341 feet MSL

Local Operation Notes: No local operations modeled.

Helicopter Notes: No Helicopter operations modeled.

Other Notes: Mostly commercial operations.

F.15.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
09	35.058623	-89.985731	253	150	8,946	0	3
18C	35.054594	-89.976171	271	150	11,120	0	3
18L	35.048816	-89.972951	278	150	9,000	0	3
18R	35.049489	-89.987443	288	150	9,320	0	3
27	35.057781	-89.955856	292	150	8,946	0	3
36C	35.024050	-89.975526	341	150	11,120	0	3
36L	35.023885	-89.986893	321	150	9,320	0	3
36R	35.024094	-89.972432	335	150	9,000	0	3

F.15.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.15.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	167,944	64,899	19,183	1,323	73	42	253,464	365
ATADS (Data Days)	167,944	64,899	19,219	1,344	0	0	253,406	365
Database	165,603	63,561	18,279	686	0	0	248,129	365
Scale Factor	101.4%	102.1%	105.1%	195.9%	0	0	102.1%	n/a

Notes:

- Local Civil added to General Aviation due to the low number of Local Civil tracks in the database.
- Local Military added to Military due to low number of Local Military tracks in the database.

F.15.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	168,545	26,922	21,151 (1)	2,163 (2)	176 (1)	214 (2)	219,171	365
Database	165,603	63,561	18,279	686	0	0	248,129	365
Scale Factor	101.8%	42.4%	116.7%	346.5%	0	0	88.3%	n/a

Notes:

1) Local Civil added to General Aviation due to the low number of Local Civil tracks in the database.
2) Local Military added to Military due to the low number of Local Military tracks in the database.

F.15.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.15.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	196.45	110.78	307.23	199.95	107.27	307.22	-	-	-	396.40	218.05	614.45
Civilian Jet, Other	14.53	1.13	15.66	14.24	1.42	15.66	-	-	-	28.77	2.55	31.32
Civilian Prop	16.53	5.93	22.46	15.42	7.04	22.46	-	-	-	31.95	12.97	44.92
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	0.41	<0.01	0.41	0.42	-	0.42	-	-	-	0.83	-	0.83
Military Jet, Other	0.63	0.05	0.68	0.67	0.01	0.68	-	-	-	1.30	0.06	1.36
Military Prop	0.75	0.02	0.77	0.75	0.02	0.77	-	-	-	1.50	0.04	1.54
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**229.30**	**117.91**	**347.21**	**231.45**	**115.76**	**347.21**	**-**	**-**	**-**	**460.75**	**233.67**	**694.42**

Note: Each circuit operation counted as two operations in Total Operations

F.15.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	153.36	108.74	262.10	156.86	105.24	262.10	-	-	-	310.22	213.98	524.20
Civilian Jet, Other	16.10	1.25	17.35	15.77	1.57	17.34	-	-	-	31.87	2.82	34.69
Civilian Prop	13.93	3.60	17.53	13.21	4.32	17.53	-	-	-	27.14	7.92	35.06
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	0.72	0.01	0.73	0.73	-	0.73	-	-	-	1.45	0.01	1.46
Military Jet, Other	1.10	0.08	1.18	1.18	0.01	1.19	-	-	-	2.28	0.09	2.37
Military Prop	1.30	0.04	1.34	1.30	0.04	1.34	-	-	-	2.60	0.08	2.68
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**186.51**	**113.72**	**300.23**	**189.05**	**111.18**	**300.23**	**-**	**-**	**-**	**375.56**	**224.90**	**600.46**

Note: Each circuit operation counted as two operations in Total Operations

F.15.4 Modeled Tracks

RNAV procedures:

- 7 STAR (Arrival) RNAV procedures
- 5 RNAV RNP procedures (runway 08L, 08C, and 08R)
- 8 RNAV GPS procedures (all runways)
- 18 RNAV SID (Departure) procedures

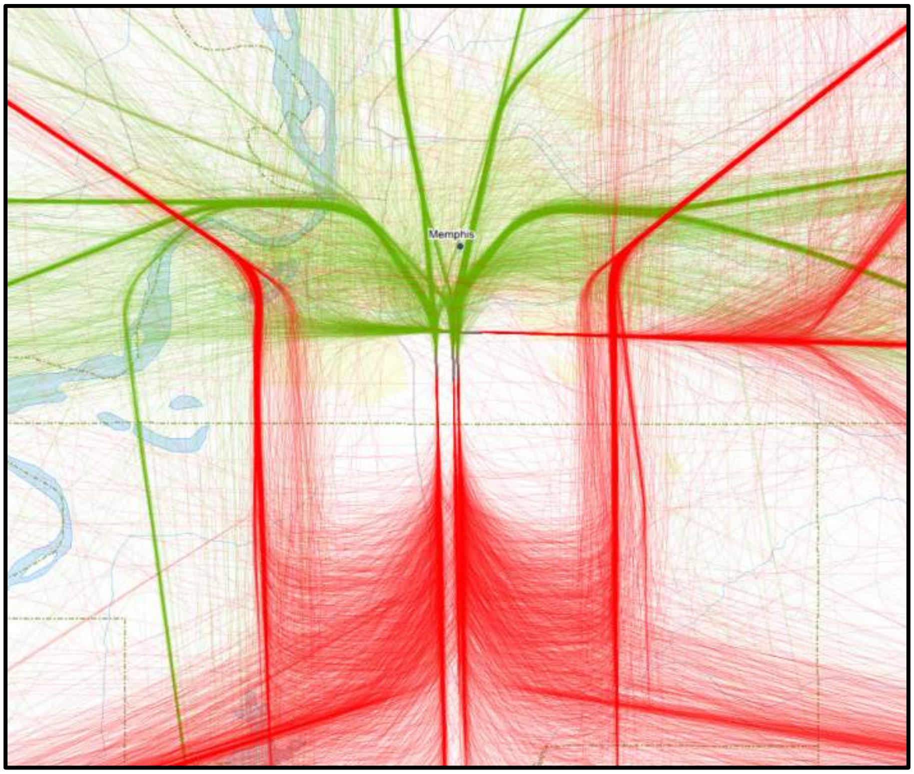
Total Tracks:

	Arrivals		Departures		Locals	
Aircraft Category	South	North	South	North	South	North
Jets	62,468	54,419	39,311	76,100	-	-
Non-Jets, fixed-wing	3,100	5,000	1,918	5,813	-	-
Total	65,568	59,419	41,229	81,913	-	-

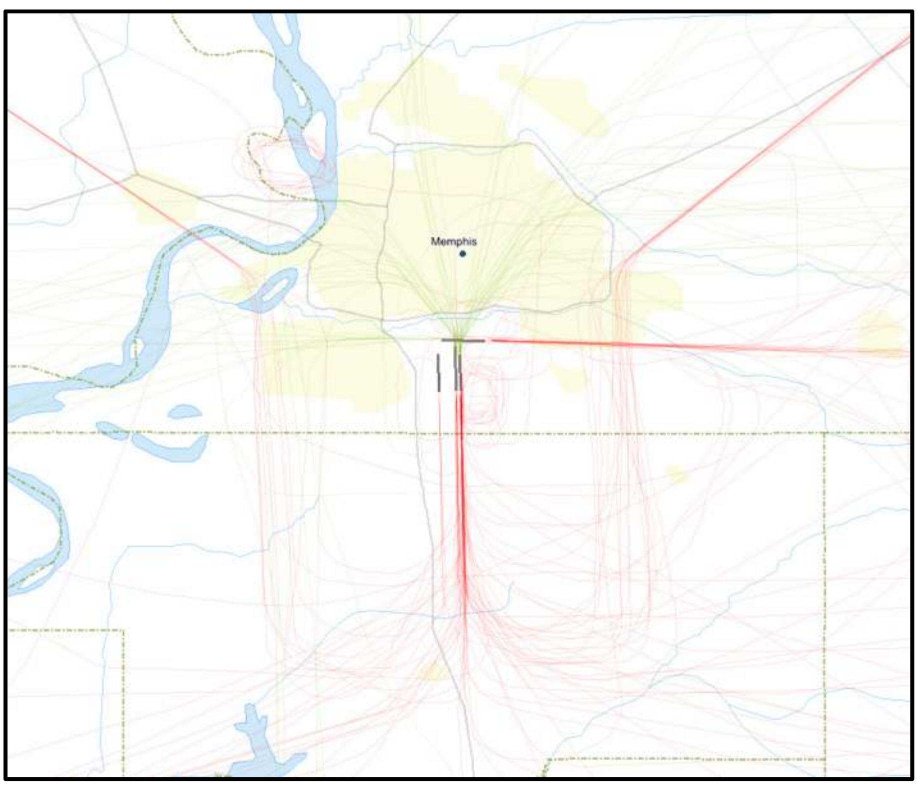
	Total			Percent	
Aircraft Category	South	North	Total	South	North
Jets	101,779	130,519	232,298	44%	56%
Non-Jets, fixed-wing	5,018	10,813	15,831	32%	68%
Helicopters	n/a	n/a	-	n/a	n/a
Total	106,797	141,332	248,129	43%	57%

F.15.5 Representative Radar Flight Tracks

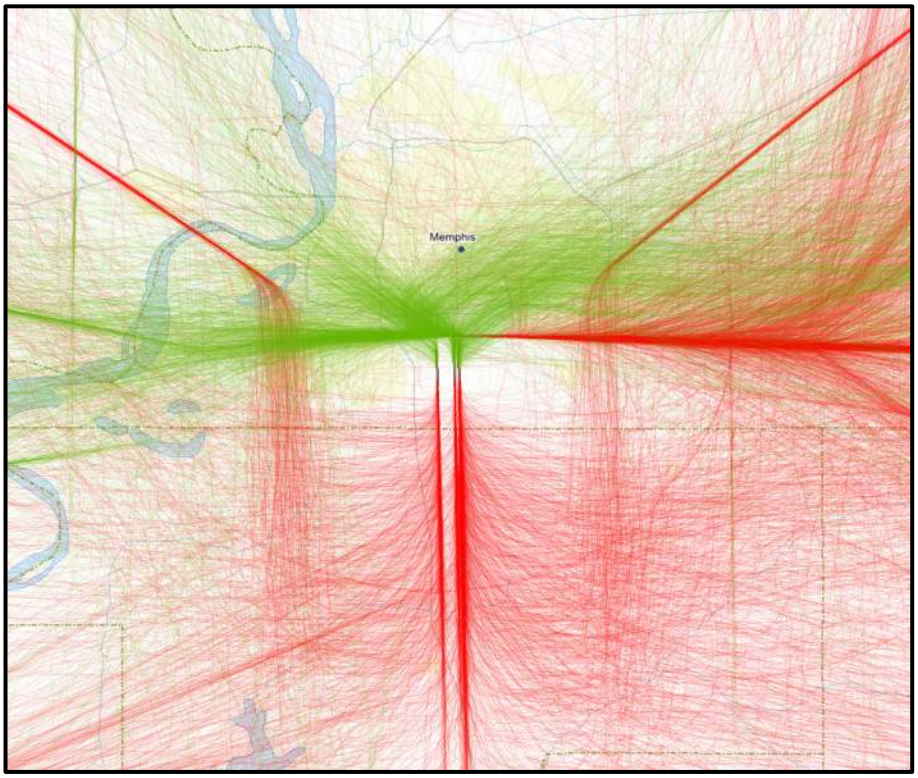
North Flow, Non-military Jets – 7% Sample



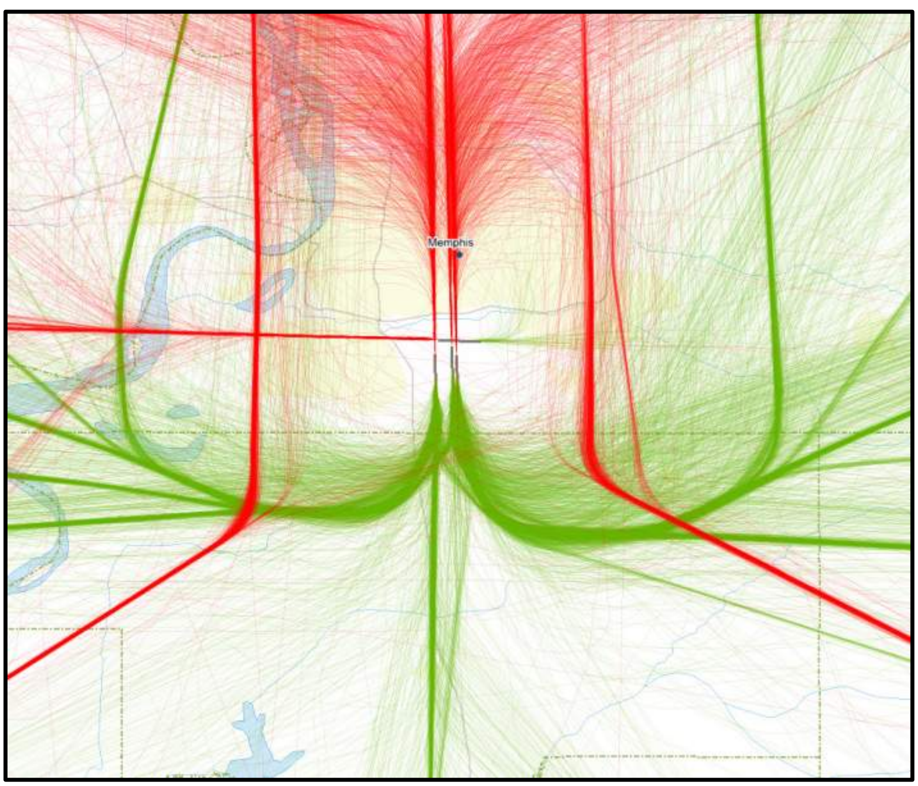
Military Jets – 100% Sample



North Flow, Non-Jets – 50% Sample



South Flow, Non-military Jets – 7% Sample



Military Jets – 100% Sample

South Flow, Non-Jets – 50% Sample

F.16 Miami Intl, MIA

Airport: Miami International Airport
City: Miami, FL
Runways: 4
Helipads: 0
Elevation: 8 feet MSL

Local Operation Notes: No local operations modeled.

Helicopter Notes: No helicopter operations modeled.

Other Notes: Mostly commercial operations. One 2015 operation (412,915 total operations) was not modeled due to a processing error. This omission has no effect within the precision of the model.

F.16.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
08L	25.802898	-80.301542	8	150	8,600	0	3
08R	25.800699	-80.301434	8	200	10,506	0	3
09	25.786095	-80.314838	7	150	13,016	1,358	3
12	25.799285	-80.302290	8	150	9,355	0	3
26L	25.802019	-80.269536	8	200	10,506	0	3
26R	25.803978	-80.275430	8	150	8,600	0	3
27	25.787731	-80.275326	8	150	1,3016	261	3
30	25.786625	-80.277537	8	150	9,355	940	3

F.16.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.16.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	309,780	63,546	18,616	952	0	0	392,894	365
ATADS for Data Days	309,780	63,546	18,616	952	0	0	392,894	365
Database	305,654	61,543	18,670	687	0	0	386,554	365
Scale Factor	101.3%	103.3%	99.7%	138.6%	0	0	101.6%	n/a

F.16.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	359,554*	33,914	18,224	1,223	0	0	412,915	365
Database	305,654	61,543	18,670	687	0	0	386,554	365
Scale Factor	117.6%	55.1%	97.6%	178.0%	0	0	106.8%	n/a

* One fewer air carrier operation modeled due to processing error.

F.16.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.16.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	413.80	71.64	485.44	420.35	65.08	485.43	-	-	-	834.15	136.72	970.87
Civilian Jet, Other	16.59	2.80	19.39	17.08	2.32	19.40	-	-	-	33.67	5.12	38.79
Civilian Prop	30.65	1.42	32.07	30.66	1.42	32.08	-	-	-	61.31	2.84	64.15
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	<0.01	-	-	<0.01	-	-	-	-	-	-	-	-
Military Jet, Other	0.59	0.05	0.64	0.55	0.09	0.64	-	-	-	1.14	0.14	1.28
Military Prop	0.63	0.02	0.65	0.63	0.02	0.65	-	-	-	1.26	0.04	1.30
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**462.26**	**75.93**	**538.19**	**469.27**	**68.93**	**538.20**	**-**	**-**	**-**	**931.53**	**144.86**	**1,076.39**

Note: Each circuit operation counted as two operations in Total Operations

F.16.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	437.86	81.55	519.41	446.64	72.77	519.41	-	-	-	884.50	154.32	1,038.82
Civilian Jet, Other	16.24	2.75	18.99	16.72	2.27	18.99	-	-	-	32.96	5.02	37.98
Civilian Prop	24.40	1.16	25.56	24.33	1.23	25.56	-	-	-	48.73	2.39	51.12
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	<0.01	-	-	<0.01	-	-	-	-	-	-	-	-
Military Jet, Other	0.76	0.07	0.83	0.71	0.12	0.83	-	-	-	1.47	0.19	1.66
Military Prop	0.82	0.02	0.84	0.81	0.03	0.84	-	-	-	1.63	0.05	1.68
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**480.08**	**85.55**	**565.63**	**489.21**	**76.42**	**565.63**	**-**	**-**	**-**	**969.29**	**161.97**	**1,131.26**

Note: Each circuit operation counted as two operations in Total Operations

F.16.4 Modeled Tracks

RNAV procedures:

- 4 STAR (Arrival) RNAV procedures
- 5 RNAV RNP procedures (runway 08R, 12, 26L, 27, 30)
- 8 RNAV GPS procedures (All runways)
- 11 RNAV SID (Departure) procedures

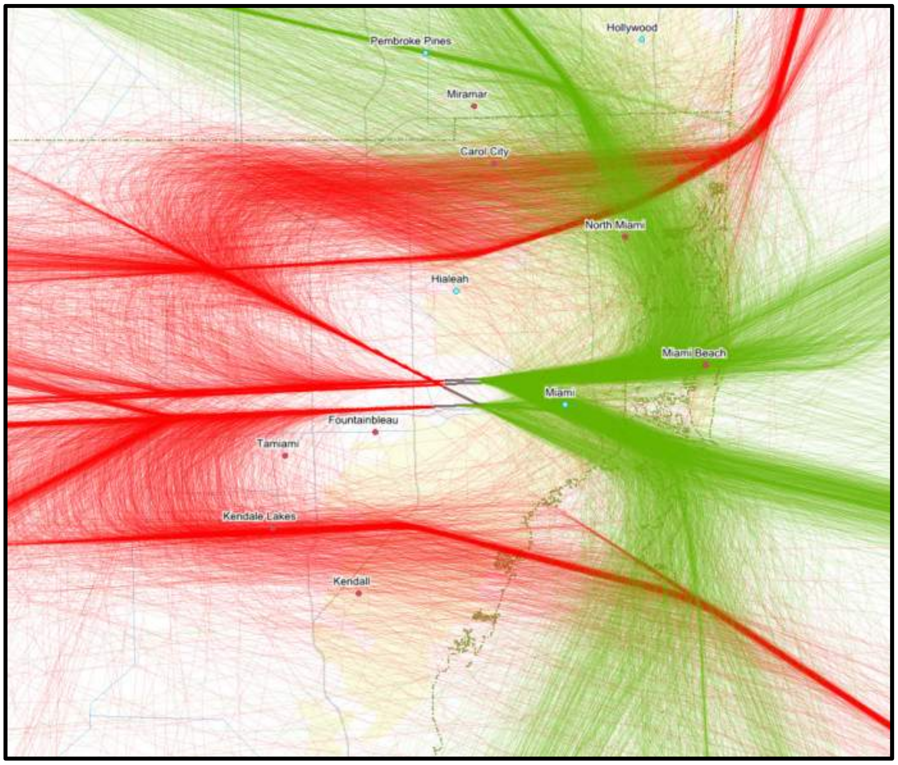
Total Tracks:

Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	136,114	46,234	136,115	45,196	-	-
Non-Jets, fixed-wing	8,885	2,899	8,291	2,820	-	-
Total	144,999	49,133	144,406	48,016	-	-

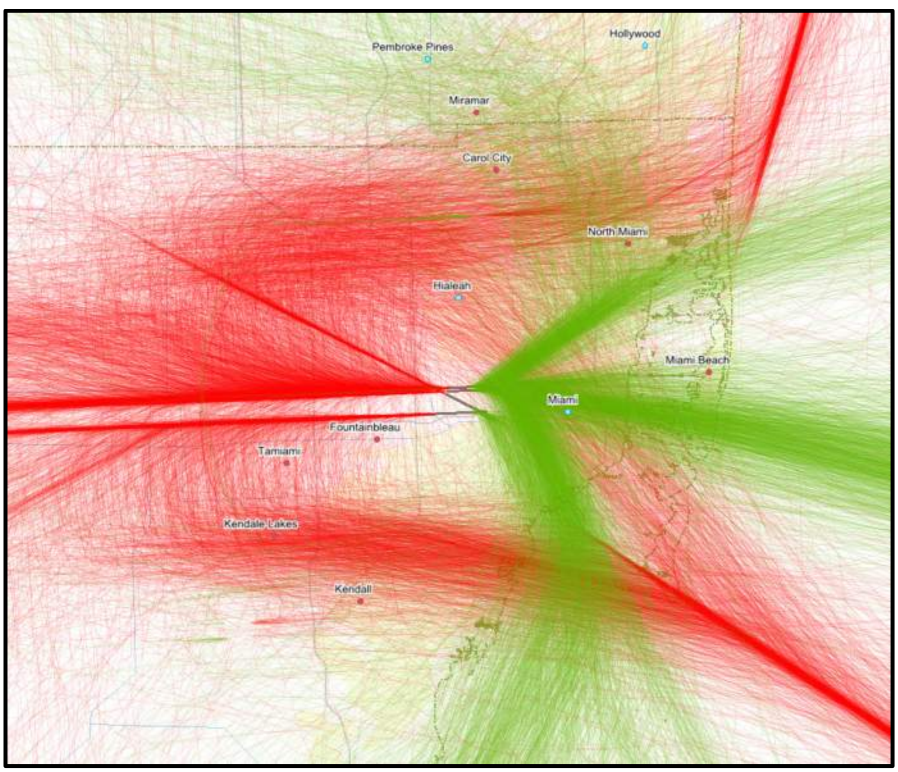
Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	136,114	46,234	136,115	45,196	-	-
Non-Jets, fixed-wing	8,885	2,899	8,291	2,820	-	-
Helicopters	n/a	n/a	n/a	n/a	n/a	n/a
Total	144,999	49,133	144,406	48,016	-	-

F.16.5 Representative Radar Flight Tracks

East Flow, Jets – 4% Sample

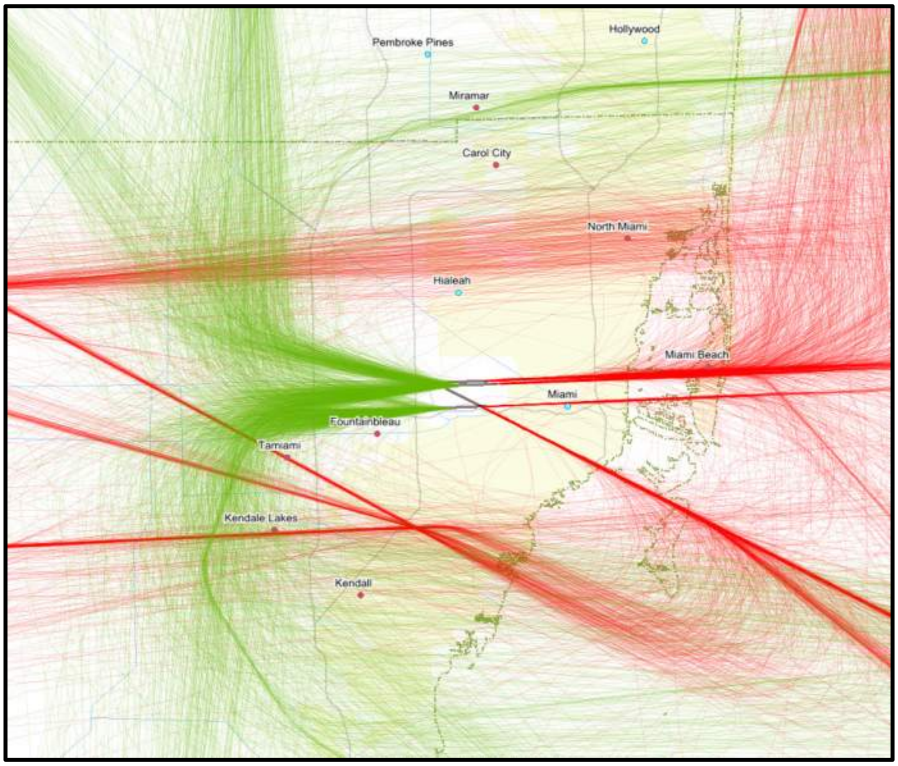


Non-Jets – 50% Sample

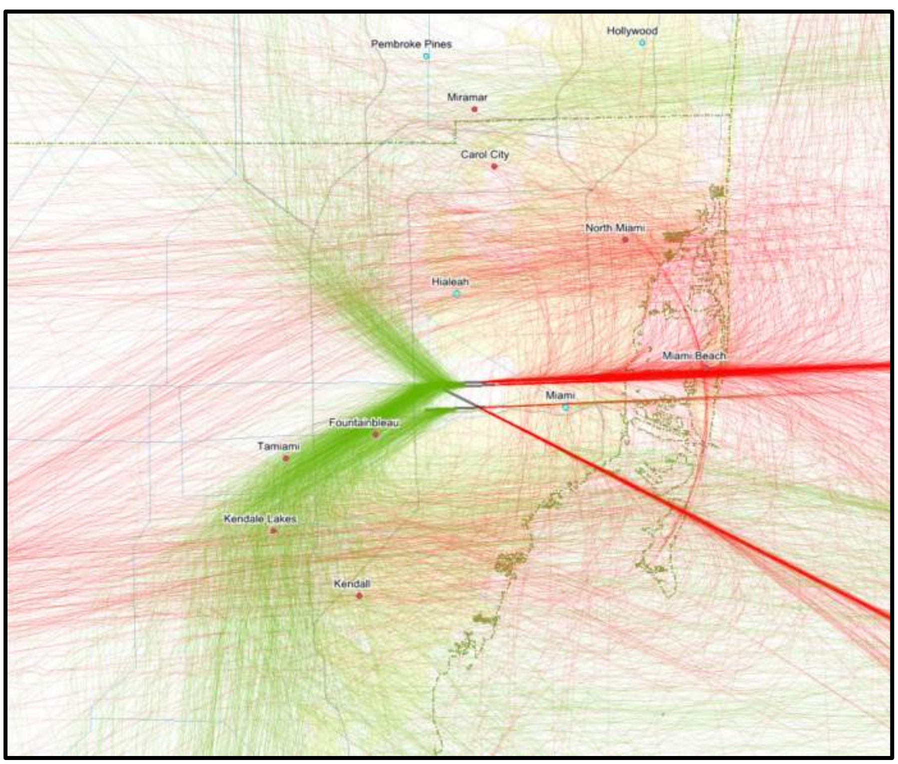


West Flow

Jets – 4% Sample



Non-Jets – 50% Sample



F.17 Chicago O'Hare Intl, ORD

Airport: Chicago O'Hare International Airport
City: Chicago, IL
Runways: 8
Helipads: 1
Elevation: 668 feet MSL

Local Operation Notes: No local operations modeled.

Helicopter Notes: No helicopter operations were modeled.

Other Notes: Very busy commercial airport.

F.17.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
04L	41.981655	-87.913918	656	150	7,500	0	3
04R	41.953327	-87.899418	661	150	8,075	0	3
09L	42.002832	-87.926676	668	150	7,500	0	3
09R	41.983898	-87.918352	660	150	7,967	0	3
10C	41.965701	-87.931522	669	200	10,801	0	3
10L	41.968995	-87.931532	672	150	13,001	0	3
14L	42.002435	-87.915368	653	150	10,005	1,998	3
14R	41.990435	-87.933140	666	200	9,685	0	3
22L	41.969922	-87.879743	654	150	8,075	0	3
22R	41.997537	-87.896371	648	150	7,500	0	3
27L	41.983900	-87.889051	650	150	7,967	0	3
27R	42.002831	-87.899084	664	150	7,500	0	3
28R	41.969070	-87.883729	651	150	13,001	0	3
28C	41.965766	-87.891810	650	200	10,801	0	3
32L	41.970083	-87.910233	654	200	9,685	0	3
32R	41.981405	-87.891713	648	150	10,005	0	3

F.17.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.17.2.1 2013-2014

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	539,542	331,524	7,302	193	0	0	878,561	365
ATADS for Data Days	533,913	327,945	7,243	193	0	0	869,294	361
Database	515,374	317,902	5,754	43	0	0	839,073	361
Scale Factor	103.6%	103.2%	125.9%	448.8%	0	0	103.6%	n/a

F.17.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	597,750	270,110	7,141	135	0	0	875,136	365
Database	515,374	317,902	5,754	43	0	0	839,073	361
Scale Factor	116.0%	85.0%	124.1%	314.0%	0	0	104.3%	n/a

F.17.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.17.3.1 2013-2014

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	1,063.03	125.53	1,188.56	1,077.37	111.20	1,188.57	-	-	-	2,140.40	236.73	2,377.13
Civilian Jet, Other	7.19	0.40	7.59	7.12	0.47	7.59	-	-	-	14.31	0.87	15.18
Civilian Prop	6.97	0.62	7.59	7.20	0.40	7.60	-	-	-	14.17	1.02	15.19
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	0.23	0.01	0.24	0.22	0.03	0.25	-	-	-	0.45	0.04	0.49
Military Prop	0.02	-	0.02	0.02	-	0.02	-	-	-	0.04	-	0.04
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**1,077.44**	**126.56**	**1,204.00**	**1,091.93**	**112.10**	**1,204.03**	**-**	**-**	**-**	**2,169.37**	**238.66**	**2,408.03**

Note: Each circuit operation counted as two operations in Total Operations

F.17.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	1,080.47	117.31	1,197.78	1,081.63	116.15	1,197.78	-	-	-	2,162.10	233.46	2,395.56
Civilian Jet, Other	6.75	0.72	7.47	6.79	0.68	7.47	-	-	-	13.54	1.40	14.94
Civilian Prop	5.99	0.67	6.66	6.01	0.65	6.66	-	-	-	12.00	1.32	13.32
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	0.17	0.01	0.18	0.16	0.02	0.18	-	-	-	0.33	0.03	0.36
Military Prop	0.01	-	0.01	0.01	-	0.01	-	-	-	0.02	-	0.02
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**1,093.39**	**118.71**	**1,212.10**	**1,094.60**	**117.50**	**1,212.10**	**-**	**-**	**-**	**2,187.99**	**236.21**	**2,424.20**

Note: Each circuit operation counted as two operations in Total Operations

F.17.4 Modeled Tracks

RNAV procedures:

- 5 STAR (Arrival) RNAV procedures
- 0 RNAV RNP procedures
- 13 RNAV GPS procedures (All runways except 32L)
- 6 RNAV SID (Departure) procedures

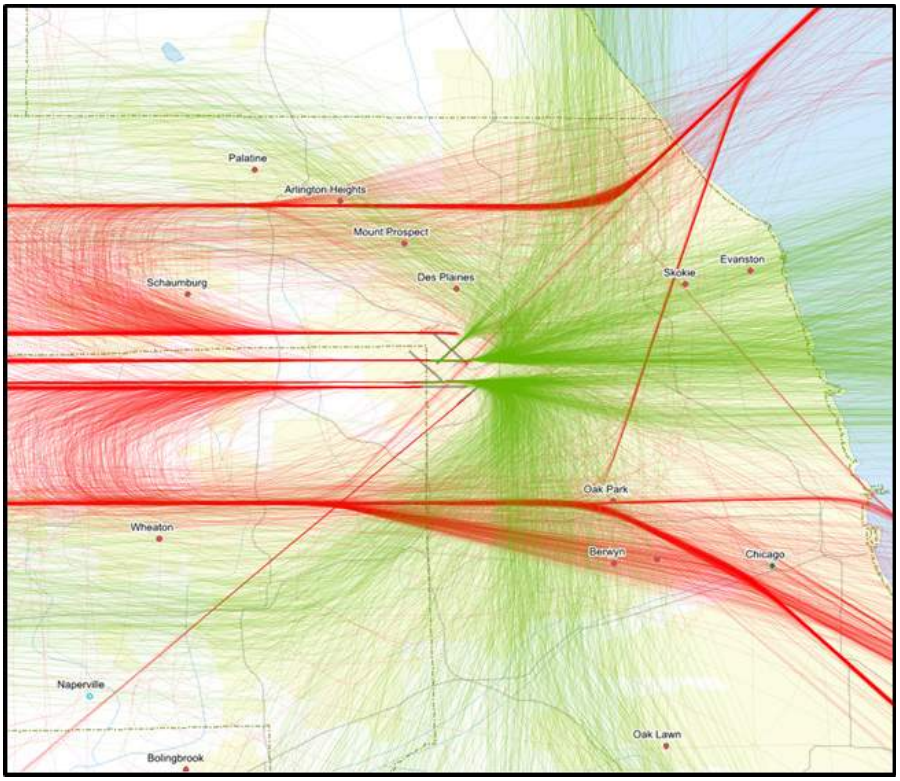
Total Tracks:

Aircraft Category	Arrivals East	Arrivals West	Departures East	Departures West	Locals East	Locals West
Jets	102,371	315,870	94,806	321,027	-	-
Non-Jets, fixed-wing	534	1,960	527	1,978	-	-
Total	102,905	317,830	95,333	323,005	-	-

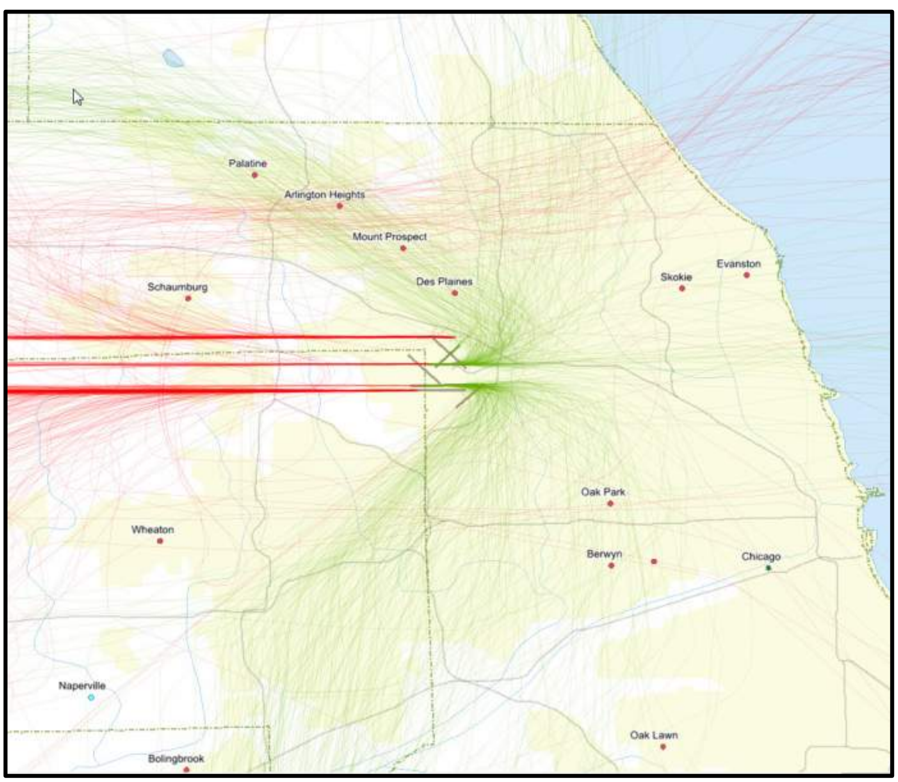
Aircraft Category	Total East	Total West	Total Total	Percent East	Percent West
Jets	197,177	636,897	834,074	24%	76%
Non-Jets, fixed-wing	1,061	3,938	4,999	21%	79%
Helicopters	n/a	n/a	-	n/a	n/a
Total	198,238	640,835	839,073	24%	76%

F.17.5 Representative Radar Flight Tracks

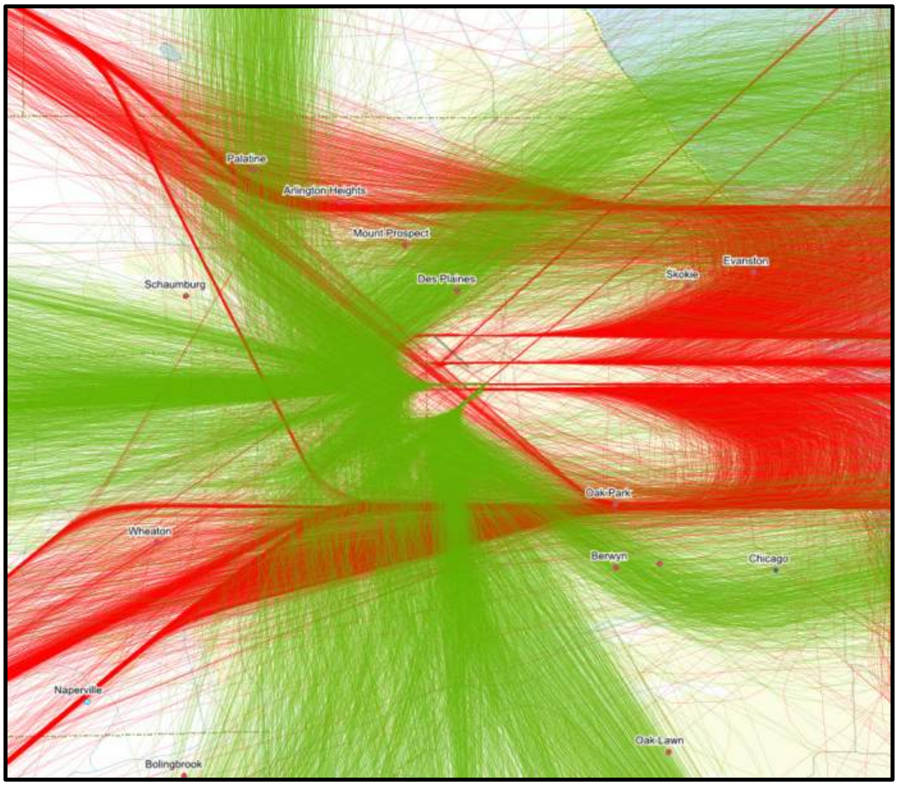
East Flow, Jets – 3% Sample



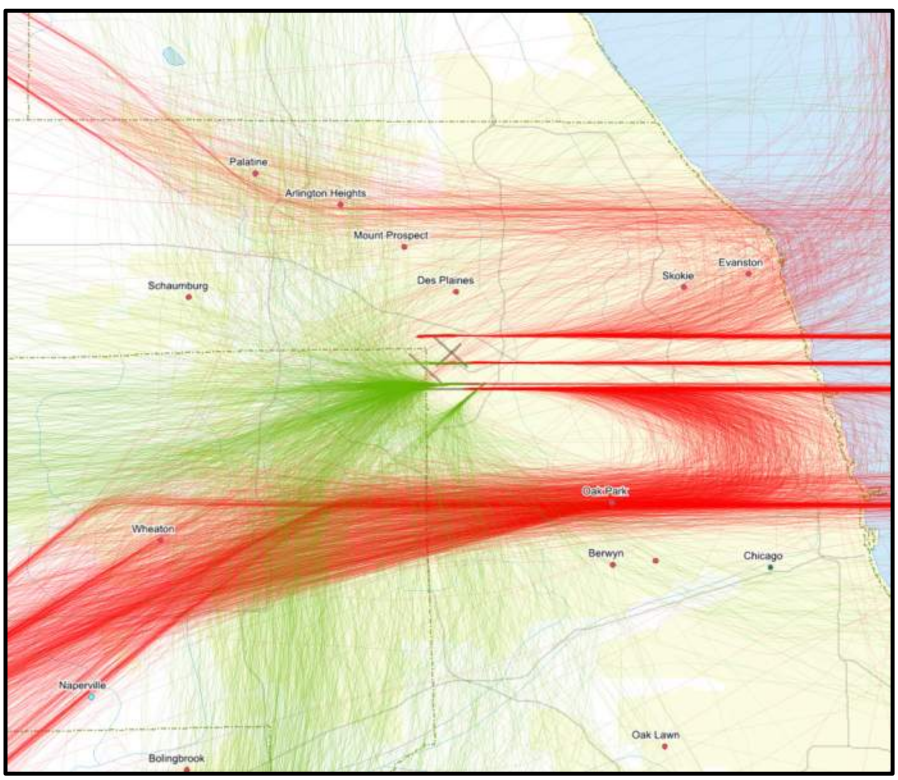
Non-Jets – 100% Sample



West Flow, Jets – 3% Sample



Non-Jets – 100% Sample



F.18 Savannah/Hilton Head Intl, SAV

Airport: Savannah/Hilton Head International Airport
City: Savannah, GA
Runways: 2
Helipads: 3
Elevation: 50 feet MSL

Local Operation Notes: Circuits modeled at 2,000 feet AFE. Split tracks counted as local operations and make up the majority of the local operations. Local tracks were not removed from modeling based on maximum range or maximum altitude.

Helicopter Notes: A moderate number of operations, about 3 percent of total daily operations. Variety of INM types. Split tracks counted as local operations. MD600N not modeled (26 annual operations).

Other Notes: Relatively large number of military jet operations and C-130 aircraft operations.

F.18.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
01	32.116571	-81.199991	29	150	7,002	0	3
10	32.128754	-81.218792	17	150	9,351	0	3
19	32.135816	-81.200138	42	150	7,002	0	3
28	32.128475	-81.188589	46	150	9,351	0	3
H1	32.116622	-81.197215	25	n/a	n/a	n/a	n/a
H2	32.122858	-81.197436	33	n/a	n/a	n/a	n/a
H3	32.125799	-81.205562	18	n/a	n/a	n/a	n/a

F.18.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.18.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	14,728	21,477	30,734	6,460	13,952	1,691	89,042	365
ATADS for Data Days	14,654	21,397	30,545	6,404	13,898	1,669	88,567	363
Database	14,624	19,409	24,388	3,283	5,418	980	68,102	363
Scale Factor	100.2%	110.2%	125.2%	195.1%	256.5%	170.3%	130.1%	n/a

F.18.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	20,094	19,151	31,895	7,535	8,701	1,556	88,932	365
Database	14,624	19,409	24,388	3,283	5,418	980	68,102	363
Scale Factor	137.4%	98.7%	130.8%	229.5%	160.6%	158.8%	130.6%	n/a

F.18.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.18.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	38.36	5.88	44.24	40.08	4.16	44.24	-	-	-	78.44	10.04	88.48
Civilian Jet, Other	13.25	0.70	13.95	13.34	0.62	13.96	7.58	0.06	7.64	41.75	1.44	43.19
Civilian Prop	30.46	1.66	32.12	30.06	2.06	32.12	9.94	0.07	10.01	80.40	3.86	84.26
Civilian Rotorcraft	1.36	0.06	1.42	1.35	0.08	1.43	1.31	0.18	1.49	5.33	0.50	5.83
Military Jet, Fighter	3.07	0.02	3.09	3.04	0.04	3.08	1.53	0.01	1.54	9.17	0.08	9.25
Military Jet, Other	1.31	0.03	1.34	1.31	0.03	1.34	0.15	0.01	0.16	2.92	0.08	3.00
Military Prop	3.42	0.08	3.50	3.49	0.02	3.51	0.57	0.01	0.58	8.05	0.12	8.17
Military Rotorcraft	0.88	0.02	0.90	0.90	-	0.90	0.02	-	0.02	1.82	0.02	1.84
TOTAL	**92.11**	**8.45**	**100.56**	**93.57**	**7.01**	**100.58**	**21.10**	**0.34**	**21.44**	**227.88**	**16.14**	**244.02**

Note: Each circuit operation counted as two operations in Total Operations

F.18.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	42.42	6.79	49.21	44.43	4.78	49.21	-	-	-	86.85	11.57	98.42
Civilian Jet, Other	13.84	0.73	14.57	13.92	0.64	14.56	4.75	0.04	4.79	32.51	1.41	33.92
Civilian Prop	31.21	1.58	32.79	30.80	1.99	32.79	6.22	0.05	6.27	68.23	3.62	71.85
Civilian Rotorcraft	1.36	0.06	1.42	1.34	0.08	1.42	0.82	0.11	0.93	3.52	0.25	3.77
Military Jet, Fighter	3.61	0.02	3.63	3.58	0.05	3.63	1.42	0.01	1.43	8.61	0.08	8.69
Military Jet, Other	1.54	0.03	1.57	1.54	0.04	1.58	0.14	0.01	0.15	3.22	0.08	3.30
Military Prop	4.03	0.10	4.13	4.10	0.02	4.12	0.54	0.01	0.55	8.67	0.13	8.80
Military Rotorcraft	1.03	0.02	1.05	1.06	-	1.06	0.02	-	0.02	2.11	0.02	2.13
TOTAL	**99.04**	**9.33**	**108.37**	**100.77**	**7.60**	**108.37**	**13.91**	**0.23**	**14.14**	**213.72**	**17.16**	**230.88**

Note: Each circuit operation counted as two operations in Total Operations

F.18.4 Modeled Tracks

RNAV procedures:

- 0 STAR (Arrival) RNAV procedures
- 1 RNAV RNP procedures (runway 28)
- 4 RNAV GPS procedures (one for each runway)
- 0 RNAV SID (Departure) procedures

Total Tracks:

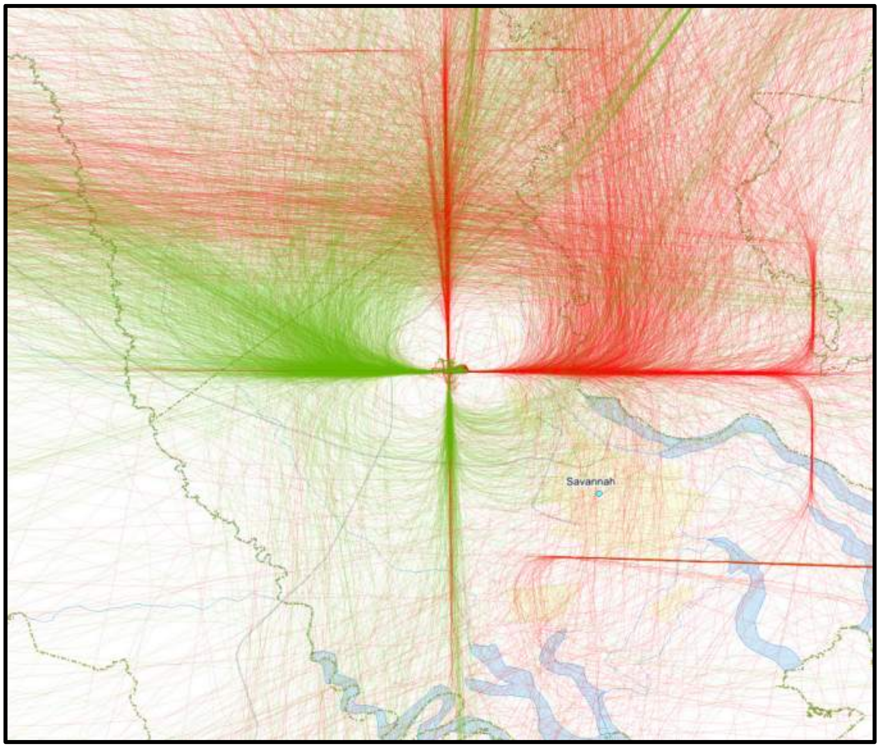
Aircraft Category	Arrivals		Departures		Locals	
	North	South	North	South	North	South
Jets	7,558	14,107	9,163	11,987	71	59
Non-Jets, fixed-wing	4,801	6,634	7,463	3,984	274	36
Total	12,359	20,741	16,626	15,971	345	95

Aircraft Category	Arrivals	Departures	Locals
Helicopters	803	722	-

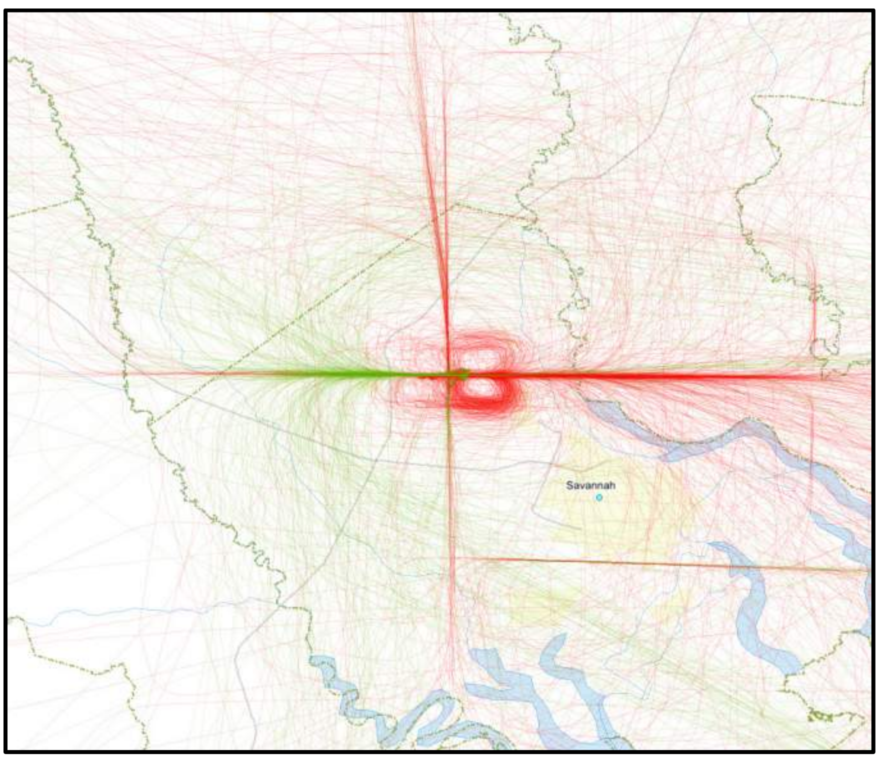
Aircraft Category	Total			Percent	
	North	South	Total	North	South
Jets	16,792	26,153	42,945	39%	61%
Non-Jets, fixed-wing	12,538	10,654	23,192	54%	46%
Helicopters	n/a	n/a	1,525	n/a	n/a
Total	29,330	36,807	67,662	44%	56%

F.18.5 Representative Radar Flight Tracks

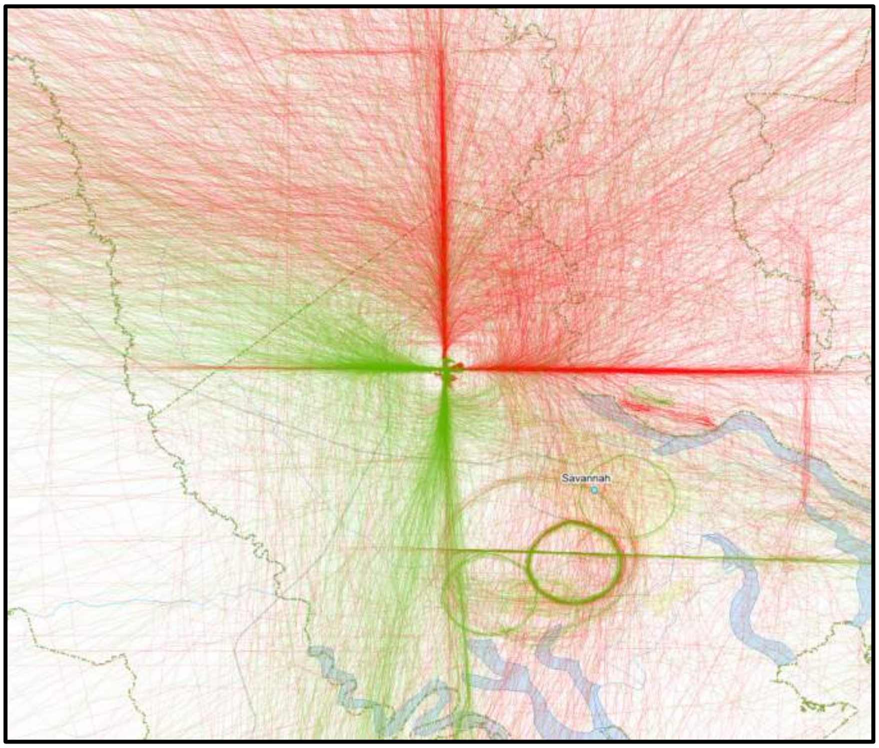
South Flow, Non-Military Jets – 33% Sample



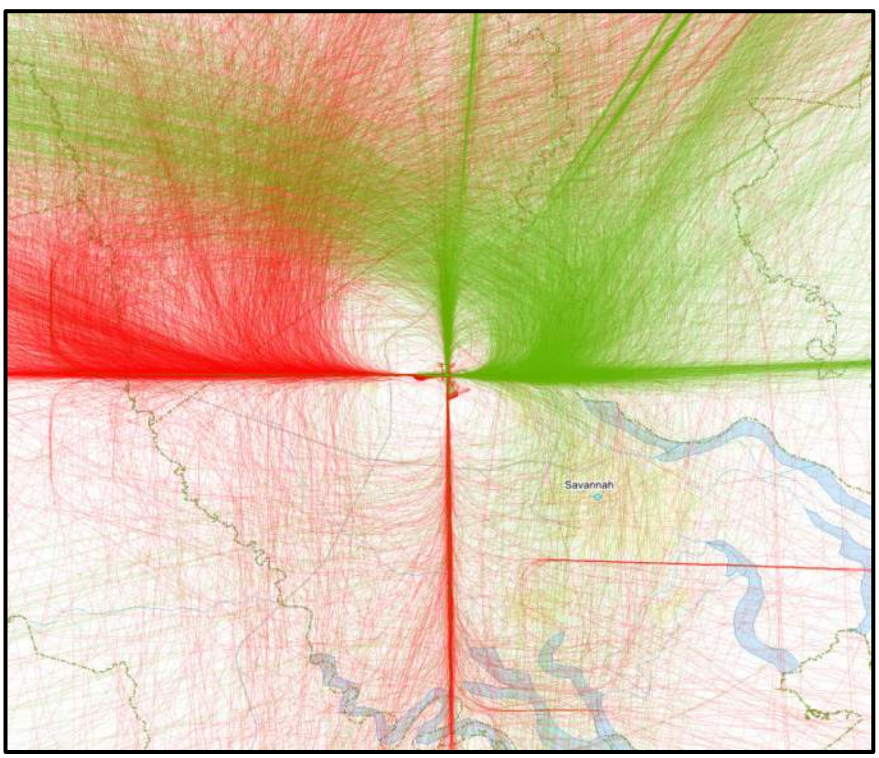
Military Jets – 100% Sample



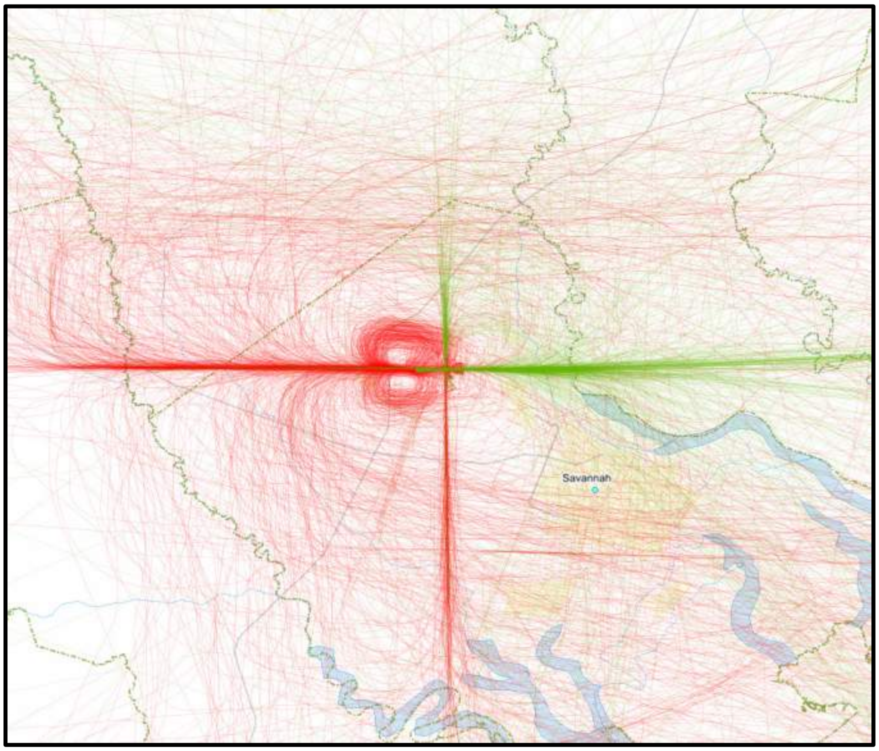
South Flow, Non-Jets – 50% Sample



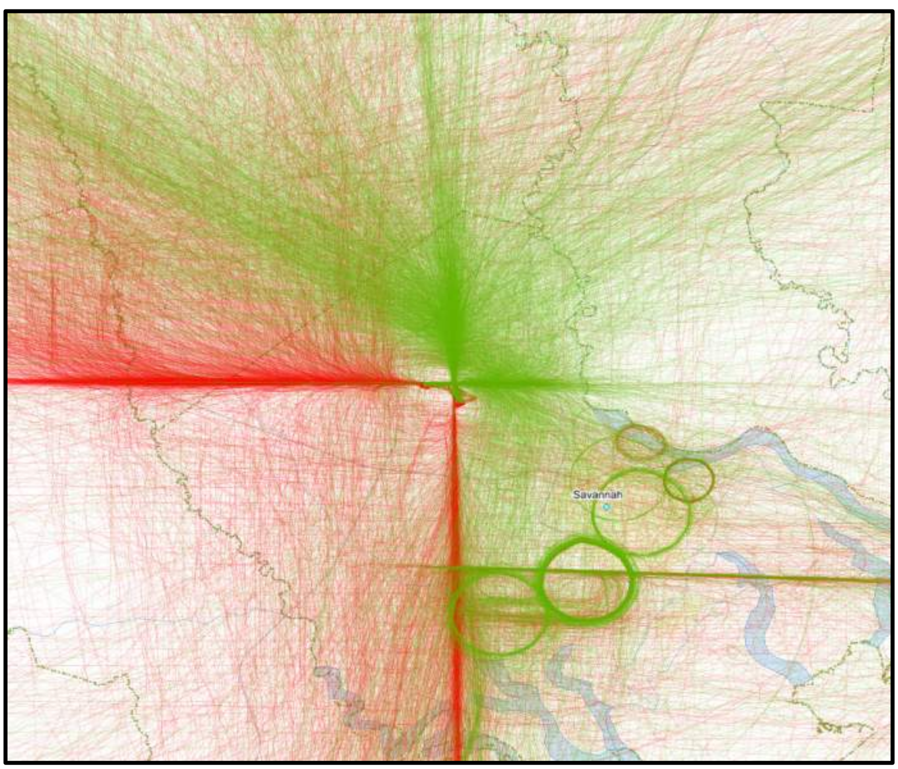
North Flow, Non-Military Jets – 33% Sample



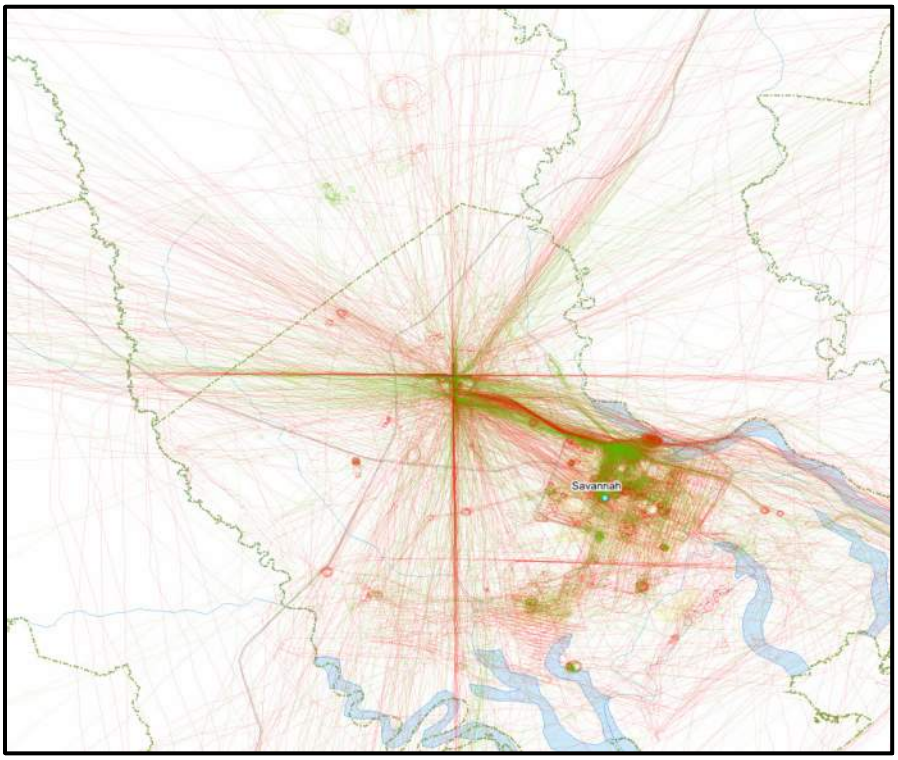
Military Jets – 100% Sample



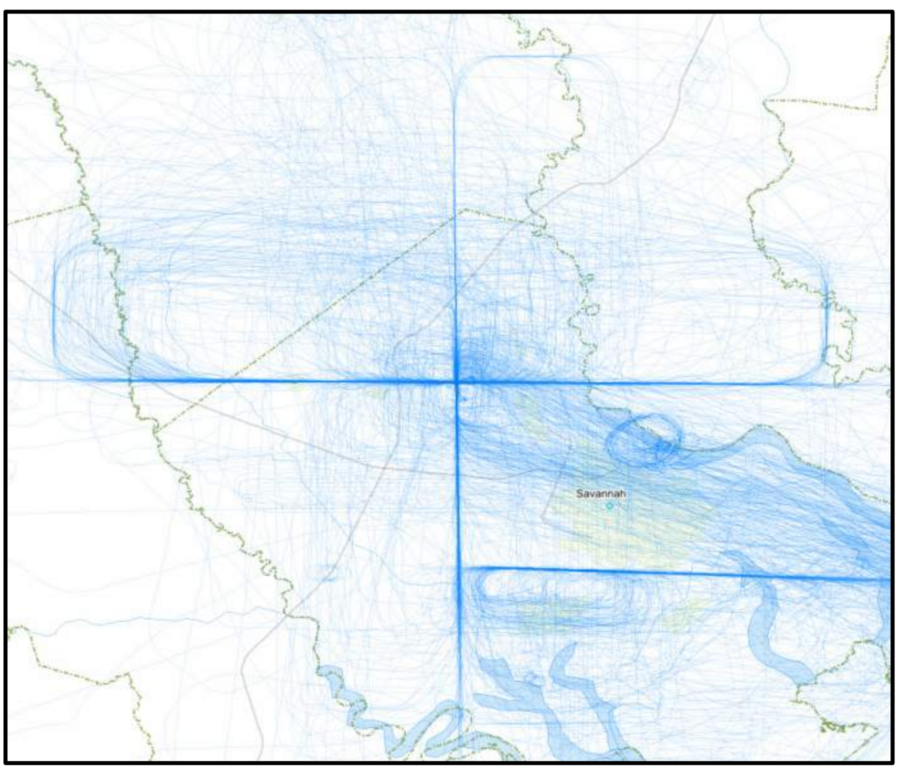
North Flow, Non-Jets – 50% Sample



Helicopters 100% Sample



Local 100% Sample



F.19 Norman Y. Mineta San Jose Intl, SJC

Airport: Norman Y. Mineta San Jose International Airport
City: San Jose, CA
Runways: 3
Helipads: 0
Elevation: 62 feet MSL

Local Operation Notes: Circuits modeled at 1,442 feet AFE. There were no split tracks. Circuit tracks that had a maximum altitude greater than 2,200 feet MSL were removed from modeling.

Helicopter Notes: No helicopter operations modeled.

Other Notes: Mostly commercial jet operations. One 2015 operation (148,669 total operations) was not modeled due to a processing error. This omission has no effect within the precision of the model.

F.19.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
11	37.365892	-121.93660	42	100	4,599	0	3
12L	37.374993	-121.94018	38	150	11,000	1,307	3
12R	37.373728	-121.94199	38	150	1,1000	1,297	3
29	37.356391	-121.92618	52	100	4,599	0	3.6
30L	37.350992	-121.91707	62	150	11,000	2,537	3
30R	37.352257	-121.91525	61	150	11,000	2,537	3

F.19.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.19.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	82,280	20,445	27,034	217	4,863	114	134,953	365
ATADS for Data Days	82,280	20,445	27,034	217	4,863	114	134,953	365
Database	81,750	19,849	26,200	188	2,906	56	130,949	365
Scale Factor	100.6%	103.0%	103.2%	115.4%	167.3%	203.6%	103.1%	n/a

F.19.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	91,134	23,183	29,715	237	4,338	62	148,669	365
Database	81,750	19,849	26,200	188	2,906	56	130,949*	365
Scale Factor	111.5%	116.8%	113.4%	126.1%	149.3%	110.7%	113.5%	n/a

* 1 fewer civilian propeller operation modeled due to processing error; Affected overall DNL by less than 0.1 dB (estimated).

F.19.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.19.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	118.67	12.03	130.70	115.14	15.56	130.70	-	-	-	233.81	27.59	261.40
Civilian Jet, Other	20.68	1.47	22.15	20.64	1.51	22.15	0.17	0.02	0.19	41.66	3.02	44.68
Civilian Prop	21.84	3.07	24.91	22.19	2.72	24.91	6.02	0.46	6.48	56.07	6.71	62.78
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	0.05	-	0.05	0.05	-	0.05	0.02	-	0.02	0.14	-	0.14
Military Prop	0.25	<0.01	0.25	0.25	<0.01	0.25	0.12	0.02	0.14	0.74	0.04	0.78
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**161.49**	**16.57**	**178.06**	**158.27**	**19.79**	**178.06**	**6.33**	**0.50**	**6.83**	**332.42**	**37.36**	**369.78**

Note: Each circuit operation counted as two operations in Total Operations

F.19.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	132.10	13.37	145.47	128.19	17.28	145.47	-	-	-	260.29	30.65	290.94
Civilian Jet, Other	22.73	1.61	24.34	22.68	1.66	24.34	0.16	0.02	0.18	45.57	3.29	48.86
Civilian Prop	24.10	3.39	27.49	24.48	3.00	27.48	5.36	0.41	5.77	53.94	6.80	60.74
Civilian Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Fighter	-	-	-	-	-	-	-	-	-	-	-	-
Military Jet, Other	0.05	-	0.05	0.05	-	0.05	0.01	-	0.01	0.11	-	0.11
Military Prop	0.27	<0.01	0.27	0.27	<0.01	0.27	0.07	0.01	0.08	0.61	0.01	0.62
Military Rotorcraft	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**179.25**	**18.37**	**197.62**	**175.67**	**21.94**	**197.61**	**5.60**	**0.44**	**6.04**	**360.52**	**40.75**	**401.27**

Note: Each circuit operation counted as two operations in Total Operations

F.19.4 Modeled Tracks

RNAV procedures:

- 0 STAR (Arrival) RNAV procedures
- 4 RNAV RNP procedures (runways 12L, 12R, 30L, and 30R)
- 6 RNAV GPS procedures (All runways)
- 0 RNAV SID (Departure) procedures

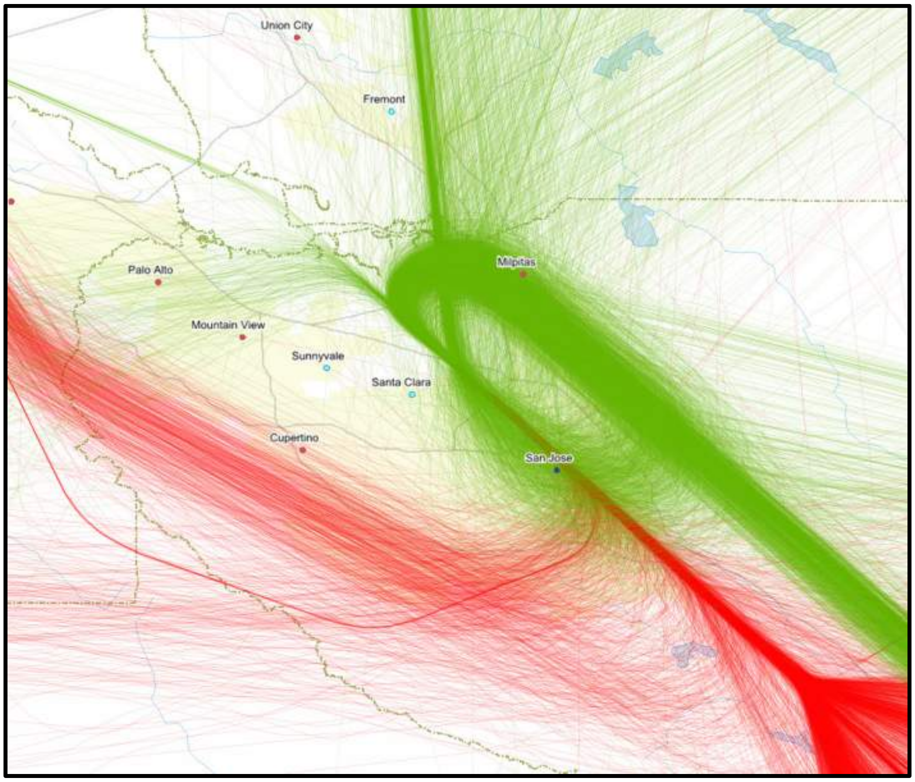
Total Tracks:

Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	5,926	49,577	6,369	48,393	8	38
Non-Jets, fixed-wing	897	7,881	814	8,130	172	1,262
Total	6,823	57,458	7,183	56,523	180	1,300

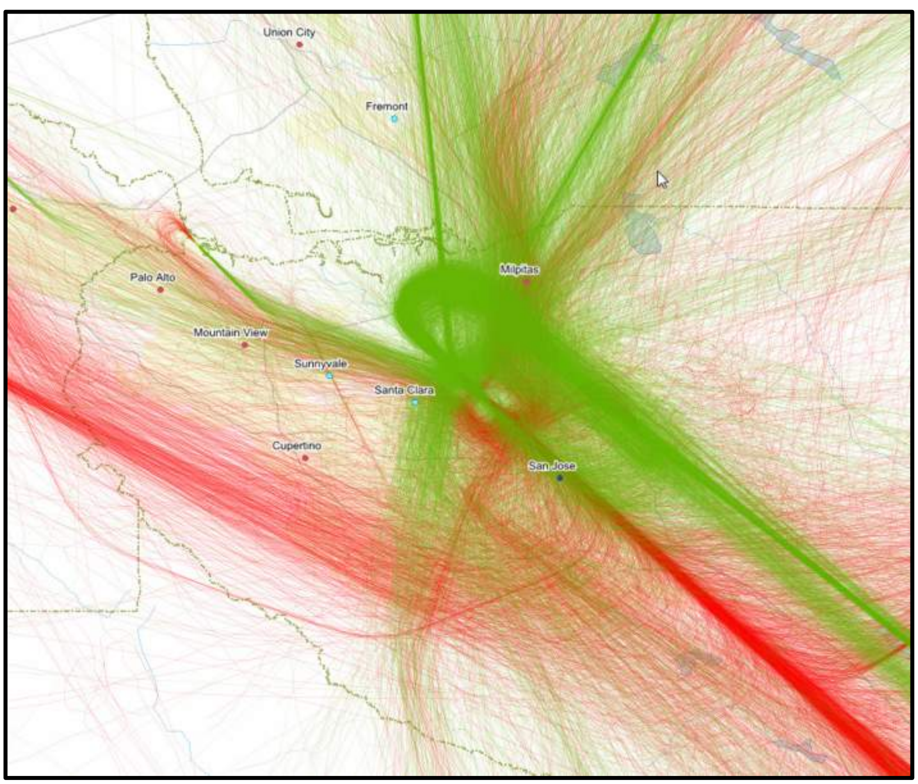
Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	12,303	98,008	110,311	11%	89%
Non-Jets, fixed-wing	1,883	17,273	19,156	10%	90%
Helicopters	n/a	n/a	-	n/a	n/a
Total	14,186	115,281	129,467	11%	89%

F.19.5 Representative Radar Flight Tracks

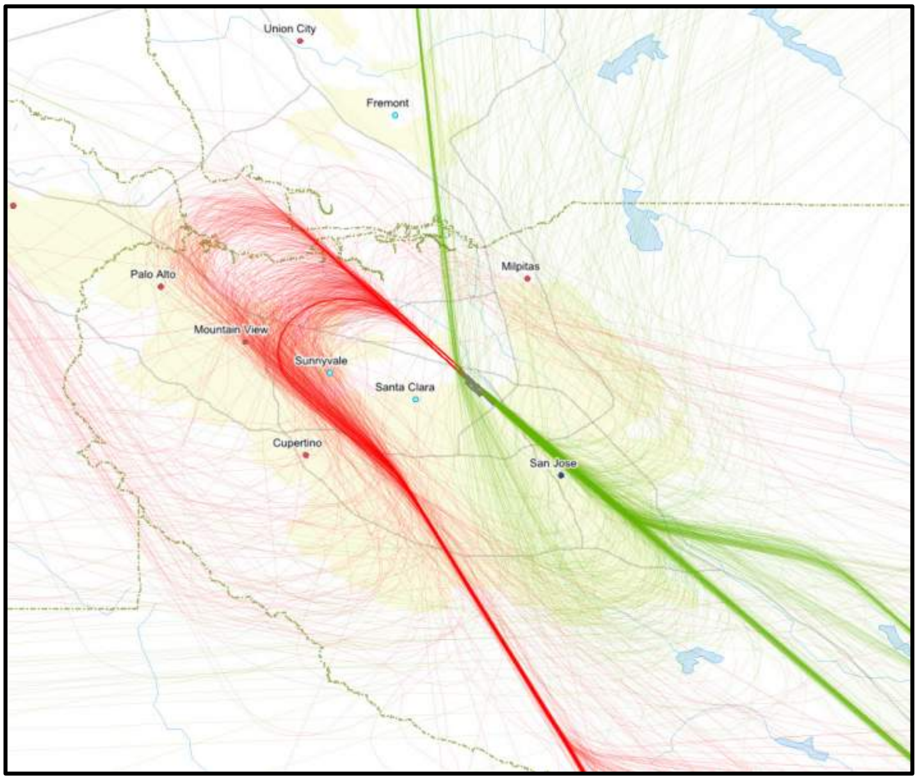
West Flow, Jets – 10% Sample



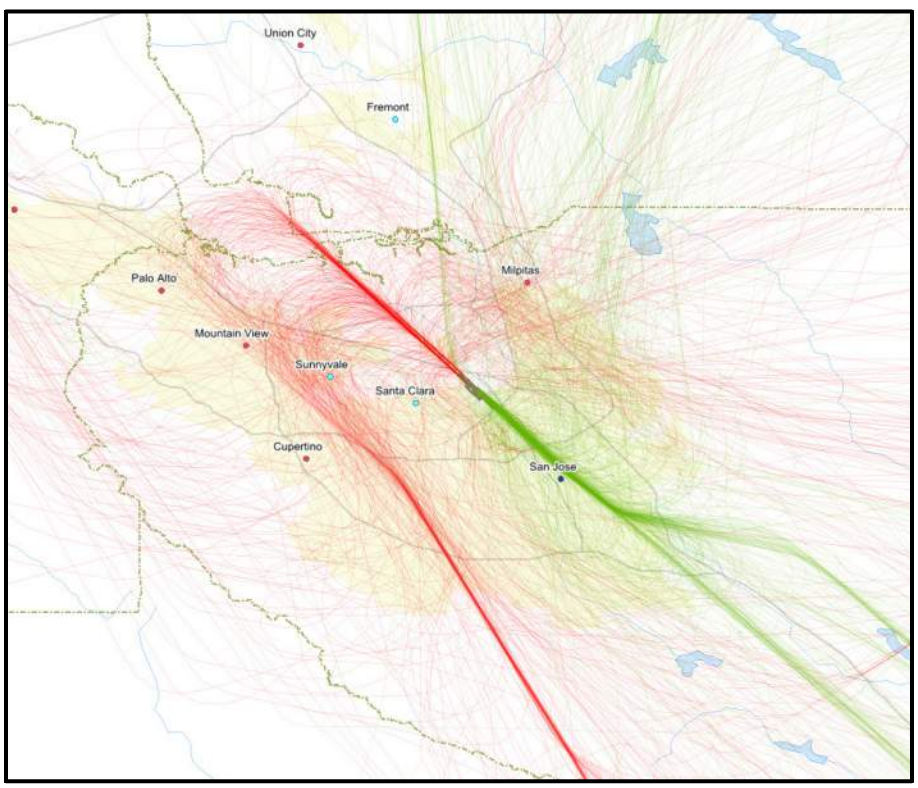
Non-Jets – 60% Sample



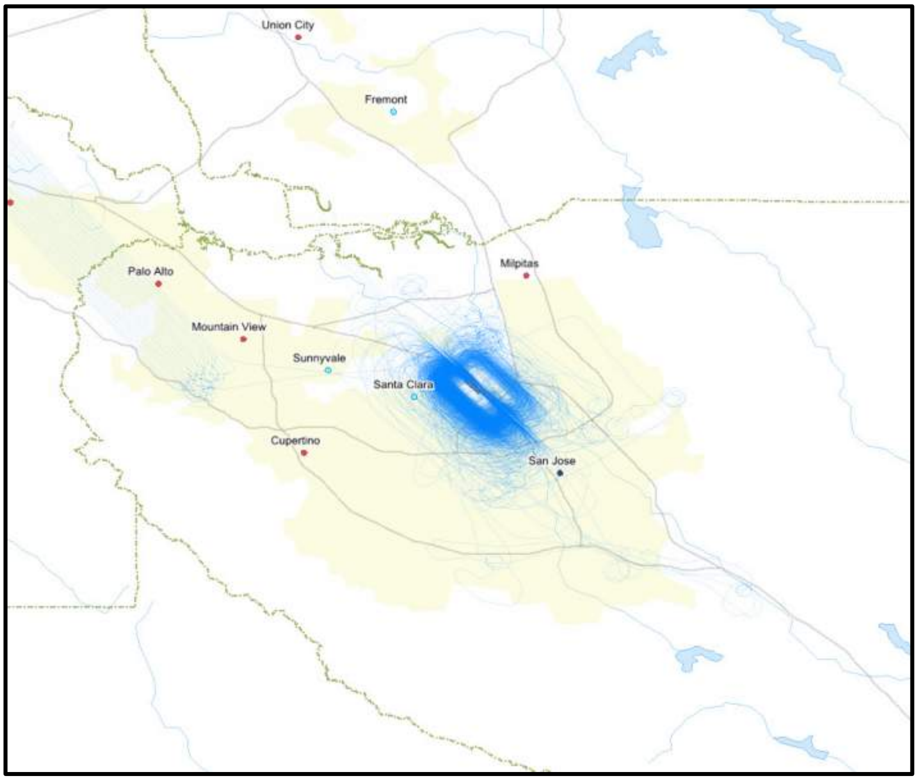
East Flow, Jets – 10% Sample



Non-Jets – 60% Sample



Local operations – 100% Sample



F.20 Syracuse Hancock Intl, SYR

Airport: Syracuse Hancock International Airport
City: Syracuse, NY
Runways: 2
Helipads: 1
Elevation: 421 feet MSL

Local Operation Notes: Circuits modeled at 1,000 feet AFE and 2,600 feet AFE. Split tracks were mostly helicopters and counted as non-local operations. Local tracks with their longest level segment at 2,100 feet MSL or below used the 1,000 feet AFE profile. All other circuit operations used the 2,600 feet AFE profile. Circuit tracks with a maximum range of greater than 25 nautical miles or a maximum altitude greater than 4,200 feet MSL were removed from modeling.

Helicopter Notes: A moderate number of operations, about 3 percent of total daily operations. Mostly general aviation or air taxi. Variety of INM types. None counted as local operations.

Other Notes: Mostly commercial jet operations.

F.20.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
10	43.108200	-76.126153	419	150	9,003	0	3
15	43.121227	-76.112834	415	150	7,500	0	3
28	43.109308	-76.092475	400	150	9,003	0	3
33	43.106975	-76.092577	402	150	7,500	0	3
H1	43.107803	-76.111619	414	n/a	n/a	n/a	n/a

F.20.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.20.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	18,605	27,762	12,989	1,039	5,532	322	66,249	365
ATADS for Data Days	18,513	27,646	12,938	1,034	5,532	322	65,985	363
Database	17,696	26,875	9,673	294	966	252	55,756	363
Scale Factor	104.6%	102.9%	133.8%	351.7%	572.7%	127.8%	118.3%	n/a

F.20.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	20,635	22,464	13,239	1,061	3,487	341	61,227	365
Database	17,696	26,875	9,673	294	966	252	55,756	363
Scale Factor	116.6%	83.6%	136.9%	360.9%	361.0%	135.3%	109.8%	n/a

F.20.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.20.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	34.13	10.94	45.07	37.51	7.56	45.07	0.06	-	0.06	71.76	18.50	90.26
Civilian Jet, Other	3.66	0.34	4.00	3.73	0.28	4.01	0.25	-	0.25	7.89	0.62	8.51
Civilian Prop	25.68	4.61	30.29	26.46	3.83	30.29	6.88	0.43	7.31	65.90	9.30	75.20
Civilian Rotorcraft	1.86	0.18	2.04	1.89	0.15	2.04	-	-	-	3.75	0.33	4.08
Military Jet, Fighter	0.03	0.01	0.04	0.04	-	0.04	-	-	-	0.07	0.01	0.08
Military Jet, Other	0.24	-	0.24	0.21	0.03	0.24	0.25	0.07	0.32	0.95	0.17	1.12
Military Prop	0.59	0.02	0.61	0.60	0.01	0.61	0.12	0.01	0.13	1.43	0.05	1.48
Military Rotorcraft	0.53	0.02	0.55	0.49	0.05	0.54	-	-	-	1.02	0.07	1.09
TOTAL	**66.72**	**16.12**	**82.84**	**70.93**	**11.91**	**82.84**	**7.56**	**0.51**	**8.07**	**152.77**	**29.05**	**181.82**

Note: Each circuit operation counted as two operations in Total Operations

F.20.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	32.44	11.57	44.01	36.18	7.82	44.00	0.07	-	0.07	68.69	19.39	88.08
Civilian Jet, Other	3.75	0.35	4.10	3.81	0.29	4.10	0.10	-	0.10	7.66	0.64	8.30
Civilian Prop	23.63	3.91	27.54	24.24	3.30	27.54	4.37	0.27	4.64	52.24	7.48	59.72
Civilian Rotorcraft	1.78	0.17	1.95	1.80	0.15	1.95	-	-	-	3.58	0.32	3.90
Military Jet, Fighter	0.03	0.01	0.04	0.04	-	0.04	-	-	-	0.07	0.01	0.08
Military Jet, Other	0.24	-	0.24	0.21	0.03	0.24	0.09	0.03	0.12	0.54	0.06	0.60
Military Prop	0.60	0.02	0.62	0.61	0.01	0.62	0.30	0.05	0.35	1.51	0.08	1.59
Military Rotorcraft	0.54	0.02	0.56	0.51	0.05	0.56	-	-	-	1.05	0.07	1.12
TOTAL	**63.01**	**16.05**	**79.06**	**67.40**	**11.65**	**79.05**	**4.93**	**0.35**	**5.28**	**135.34**	**28.05**	**163.39**

Note: Each circuit operation counted as two operations in Total Operations

F.20.4 Modeled Tracks

RNAV procedures:

- 0 STAR (Arrival) RNAV procedure
- 0 RNAV RNP procedures
- 4 RNAV GPS procedures (one for each runway)
- 0 RNAV SID (Departure) procedures

Total Tracks:

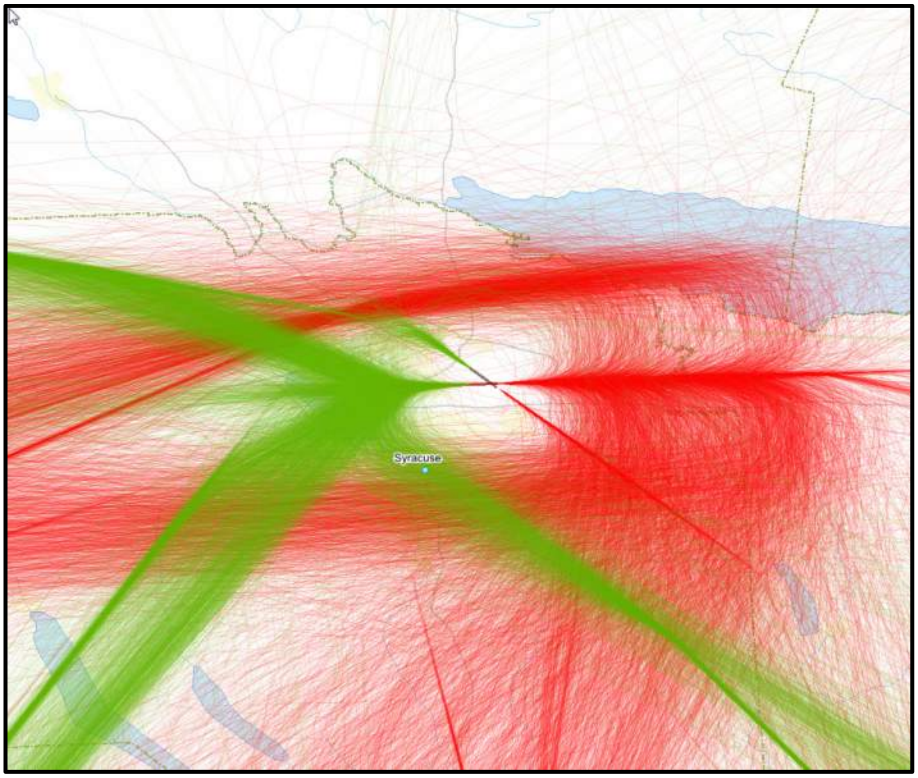
Aircraft Category	Arrivals		Departures		Locals	
	East	West	East	West	East	West
Jets	6,519	10,530	6,666	10,228	23	88
Non-Jets, fixed-wing	3,523	6,222	3,916	5,742	170	329
Total	10,042	16,752	10,582	15,970	193	417

Aircraft Category	Arrivals	Departures	Locals
Helicopters	609	583	-

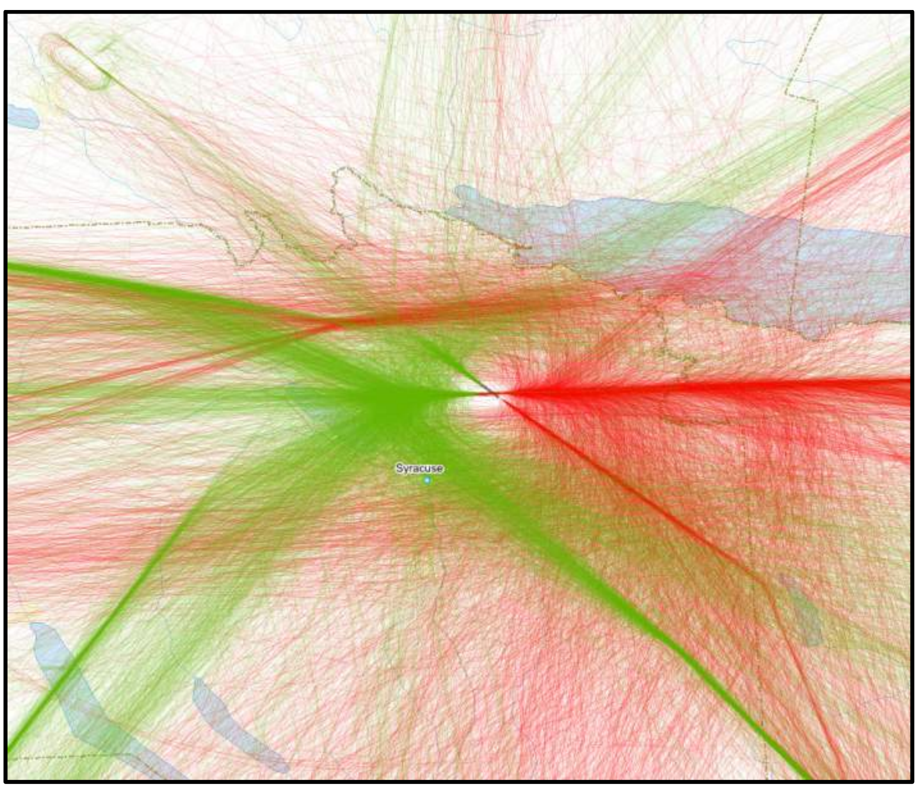
Aircraft Category	Total			Percent	
	East	West	Total	East	West
Jets	13,208	20,846	34,054	39%	61%
Non-Jets, fixed-wing	7,609	12,293	19,902	38%	62%
Helicopters	n/a	n/a	1,192	n/a	n/a
Total	20,817	33,139	55,148	39%	61%

F.20.5 Representative Radar Flight Tracks

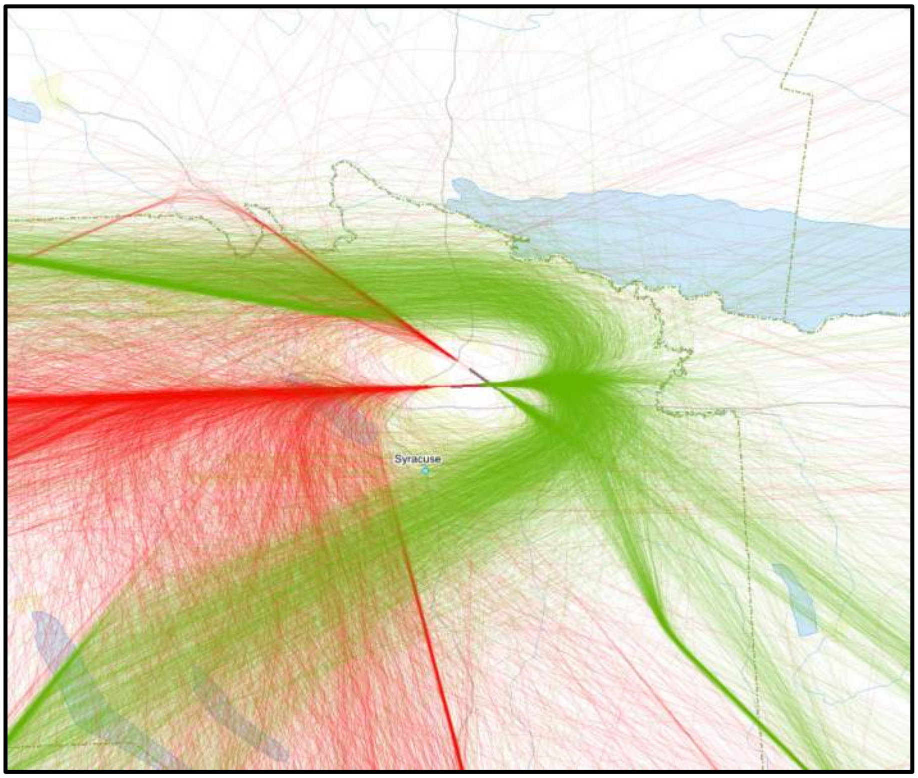
West Flow, Jets – 50% Sample



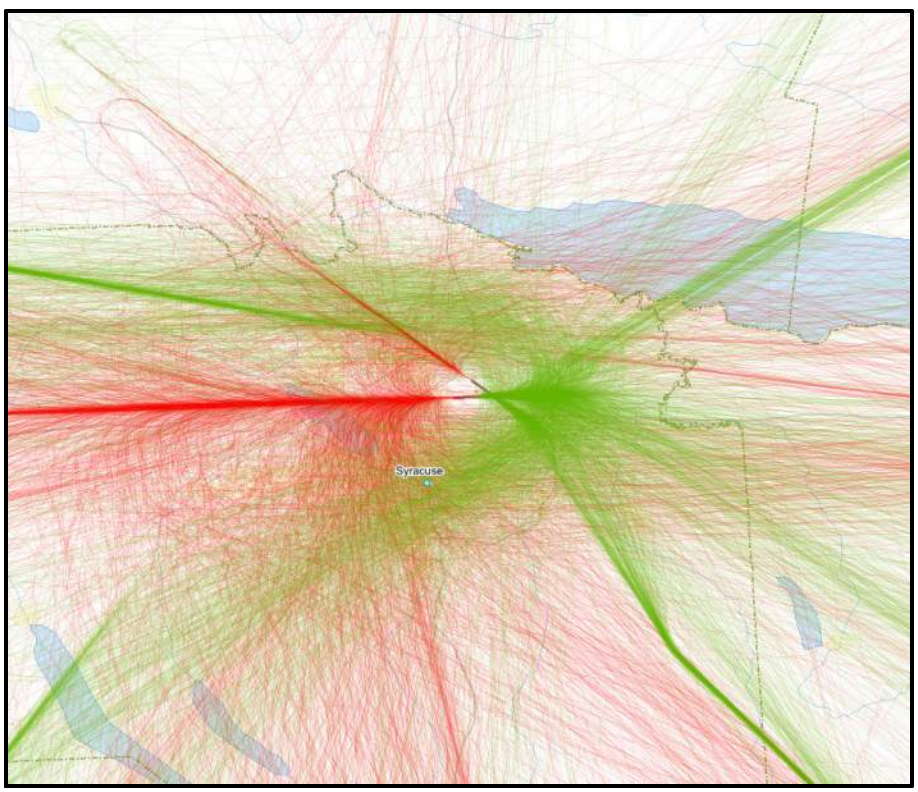
Non-Jets – 75% Sample



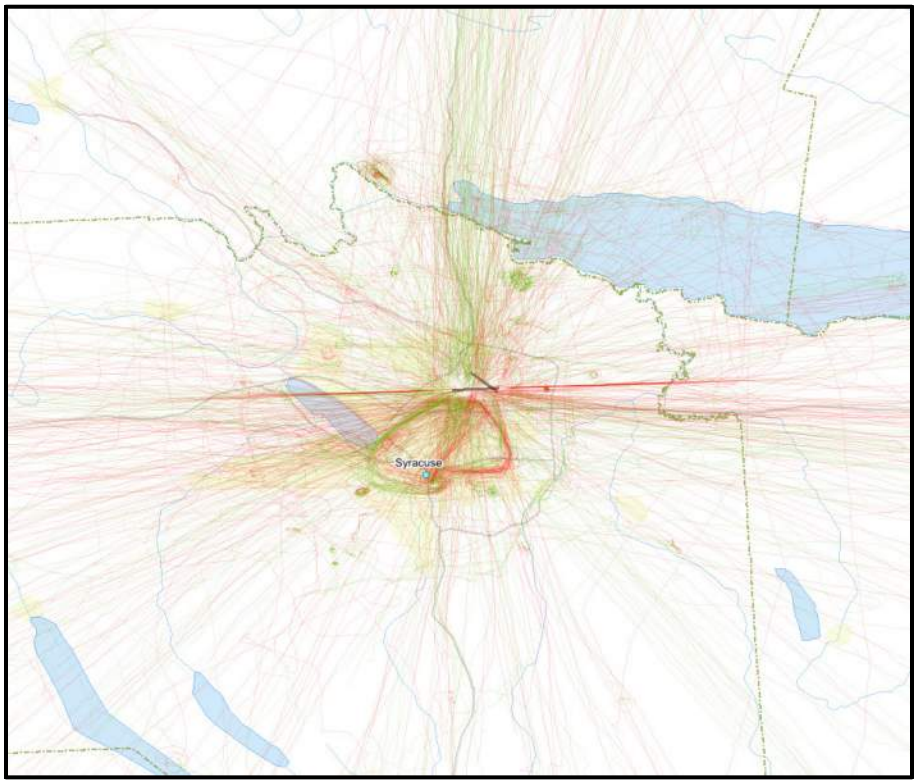
East Flow, Jets – 50% Sample



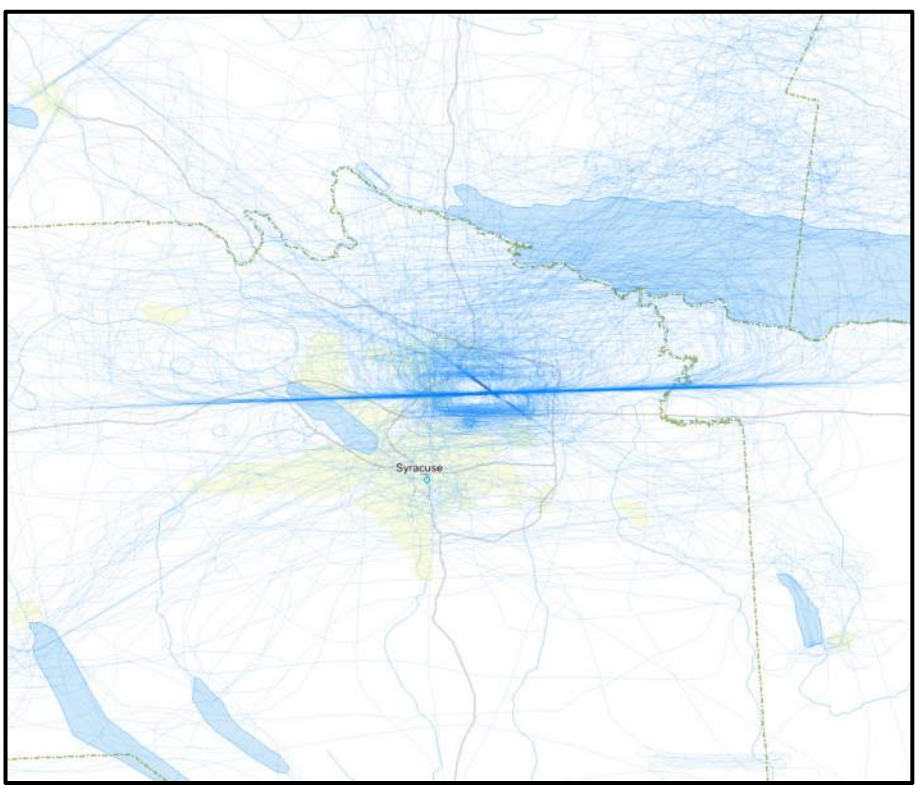
Non-Jets – 33% Sample



Helicopters 100% Sample



Local 100% Sample



F.21 Tucson Intl, TUS

Airport: Tucson International Airport
City: Tucson, AZ
Runways: 3
Helipads: 1
Elevation: 2,643 feet MSL

Local Operation Notes: Circuits modeled at 1,400 feet AFE. Local tracks with their longest level segment at or above 5,000 feet MSL were removed from the modeling. Split military tracks counted as local operations. Other split tracks counted as itinerant operations as long as their maximum range was at least 7 nautical miles from the airport center. There were a large number of military fighters split tracks counted as local.

Helicopter Notes: A large number of operations, about 5 percent of total daily operations. Mostly small non-military operations. None counted as local operations.

Other Notes: Relatively high number of non-jet operations. Very high number of military fighter operations.

F.21.1 Runway Coordinates

Runway Or Pad	Latitude (Degrees)	Longitude (Degrees)	Elevation (feet MSL)	Width (feet)	Length (feet)	Displaced Threshold (feet)	Glide Slope (degrees)
03	32.117167	-110.95904	2561	150	7,000	850	3
11L	32.123370	-110.94791	2578	150	10,996	0	3
11R	32.122103	-110.94965	2574	75	8,408	1,410	3
21	32.130761	-110.94304	2569	150	7,000	0	3
29L	32.105756	-110.93046	2629	75	8,408	0	3
29R	32.101990	-110.92282	2643	150	10,996	0	3
H1	32.130655	-110.94074	2571	n/a	n/a	n/a	n/a

F.21.2 ATADS and Radar Flight Track Data Operations (Annual) Summary

F.21.2.1 2012-2013

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	32,219	20,314	40,820	14,928	22,861	9,514	140,656	365
ATADS for Data Days	31,814	20,079	40,233	14,867	22,507	9,508	139,008	360
Database	31,278	20,148	26,335	9,407	9,900	1,253	98,321	360
Scale Factor	101.7%	99.7%	152.8%	158.0%	227.3%	758.8%	141.4%	n/a

F.21.2.2 2015

Data Parameter	Air Carrier	Air Taxi	General Aviation	Military	Local Civil	Local Military	Total Ops	Days of Data
ATADS	28,979	19,936	39,282	18,552	26,926	9,760	143,435	365
Database	31,278	20,148	26,335	9,407	9,900	1,253	98,321*	360
Scale Factor	92.6%	98.9%	149.2%	197.2%	272.0%	778.9%	145.9%	n/a

* 7 fewer military jet (non-fighter) operations modeled due to processing error; Affected overall DNL by less than 0.0005 dB (estimated).

F.21.3 Modeled Annual Average Daily Number of Flight Events and Operations

F.21.3.1 2012-2013

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	51.76	9.49	61.25	51.57	9.68	61.25	0.08	0.01	0.09	103.49	19.19	122.68
Civilian Jet, Other	13.60	0.68	14.28	13.49	0.79	14.28	0.21	0.01	0.22	27.51	1.49	29.00
Civilian Prop	40.98	1.97	42.95	39.82	3.12	42.94	28.24	2.72	30.96	137.28	10.53	147.81
Civilian Rotorcraft	6.58	2.90	9.48	6.66	2.82	9.48	-	-	-	13.24	5.72	18.96
Military Jet, Fighter	18.12	0.07	18.19	18.18	-	18.18	9.92	-	9.92	56.14	0.07	56.21
Military Jet, Other	0.52	<0.01	0.52	0.53	-	0.53	2.38	-	2.38	5.81	-	5.81
Military Prop	1.18	0.20	1.38	1.15	0.23	1.38	0.76	0.15	0.91	3.85	0.73	4.58
Military Rotorcraft	0.51	0.05	0.56	0.56	0.01	0.57	-	-	-	1.07	0.06	1.13
TOTAL	**133.25**	**15.36**	**148.61**	**131.96**	**16.65**	**148.61**	**41.59**	**2.89**	**44.48**	**348.39**	**37.79**	**386.18**

Note: Each circuit operation counted as two operations in Total Operations

F.21.3.2 2015

Aircraft Group	Arrivals			Departures			Circuits			Total Operations		
	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Commercial Jet	48.42	8.77	57.19	48.18	9.02	57.20	0.09	0.01	0.10	96.69	17.80	114.49
Civilian Jet, Other	13.28	0.66	13.94	13.17	0.77	13.94	0.25	0.02	0.27	26.70	1.45	28.15
Civilian Prop	40.06	1.93	41.99	38.93	3.05	41.98	33.77	3.26	37.03	112.76	8.24	121.00
Civilian Rotorcraft	6.50	2.88	9.38	6.58	2.80	9.38	-	-	-	13.08	5.68	18.76
Military Jet, Fighter	22.61	0.08	22.69	22.69	-	22.69	10.18	-	10.18	55.48	0.08	55.56
Military Jet, Other	0.65	<0.01	0.65	0.66	-	0.66	2.45	-	2.45	3.76	-	3.76
Military Prop	1.47	0.24	1.71	1.43	0.28	1.71	0.78	0.15	0.93	3.68	0.67	4.35
Military Rotorcraft	0.64	0.06	0.70	0.69	0.01	0.70	-	-	-	1.33	0.07	1.40
TOTAL	**133.63**	**14.62**	**148.25**	**132.33**	**15.93**	**148.26**	**47.52**	**3.44**	**50.96**	**313.48**	**33.99**	**347.47**

Note: Each circuit operation counted as two operations in Total Operations

F.21.4 Special KC135 Considerations

In INM, the KC135R has only one takeoff weight and it causes the aircraft to overrun TUS's runway by thousands of feet. To avoid the overrun, the weight was reduced. As a KC135R is a derivative of a Boeing 707, the reduction in weight was based on INM's 707320 profile weights:

707320 - Max Take-off Weight= 334000

Stage 1 weight – 214000 (64.1% of Max TOW)
Stage 2 weight – 228000 (68.3% of Max TOW)
Stage 3 weight – 240000 (71.9% of Max TOW)
Stage 4 weight – 260000 (77.8% of Max TOW)

(There are stages 5, 6, and 7 but not needed for ABQ)

KC135R- Max Take-off Weight= 324000

Stage 1 weight – 208000 (64.2% of Max TOW)
Stage 2 weight – 221000 (68.2% of Max TOW)
Stage 3 weight – 233000 (71.9% of Max TOW)
Stage 4 weight – 252000 (77.8% of Max TOW)

Stage 1 weight was also used for circuit profile.

F.21.5 Modeled Tracks

RNAV procedures:

- 1 STAR (Arrival) RNAV procedure
- 2 RNAV RNP procedures (runways 11L and 29R)
- 6 RNAV GPS procedures (all runways)
- 2 RNAV SID (Departure) procedures

Total Tracks:

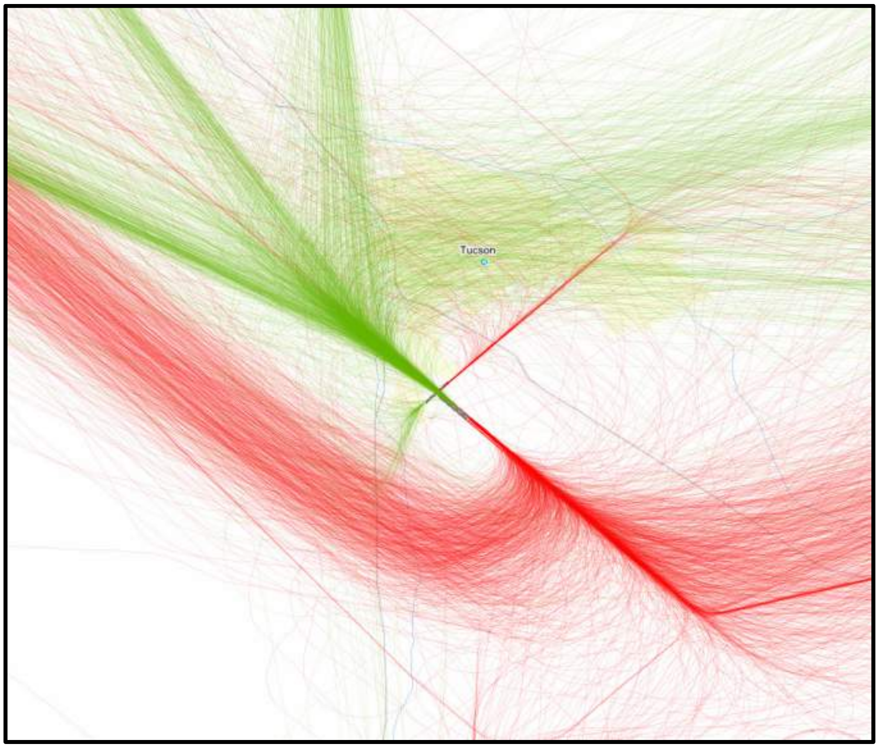
	Arrivals		Departures		Locals	
Aircraft Category	East	West	East	West	East	West
Jets	22,385	8,503	23,087	6,583	58	16
Non-Jets, fixed-wing	7,943	3,823	6,283	4,266	3,818	615
Total	30,328	12,326	29,370	10,849	3,876	631

Aircraft Category	Arrivals	Departures	Locals
Helicopters	3,138	3,256	-

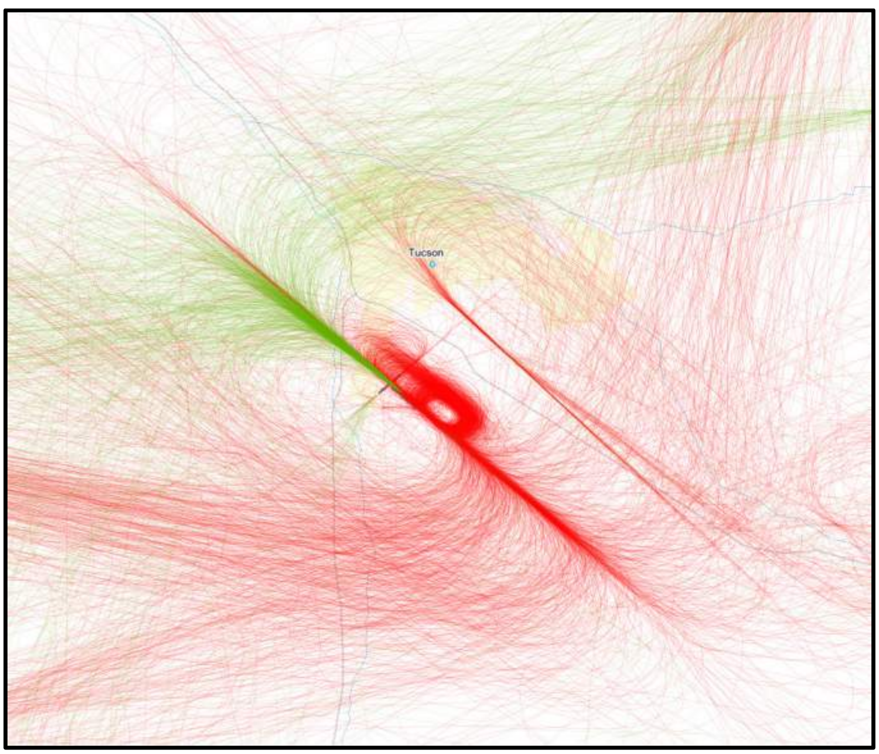
	Total			Percent	
Aircraft Category	East	West	Total	East	West
Jets	45,530	15,102	60,632	75%	25%
Non-Jets, fixed-wing	18,044	8,704	26,748	67%	33%
Helicopters	n/a	n/a	6,394	n/a	n/a
Total	63,574	23,806	93,774	73%	27%

F.21.6 Representative Radar Flight Tracks

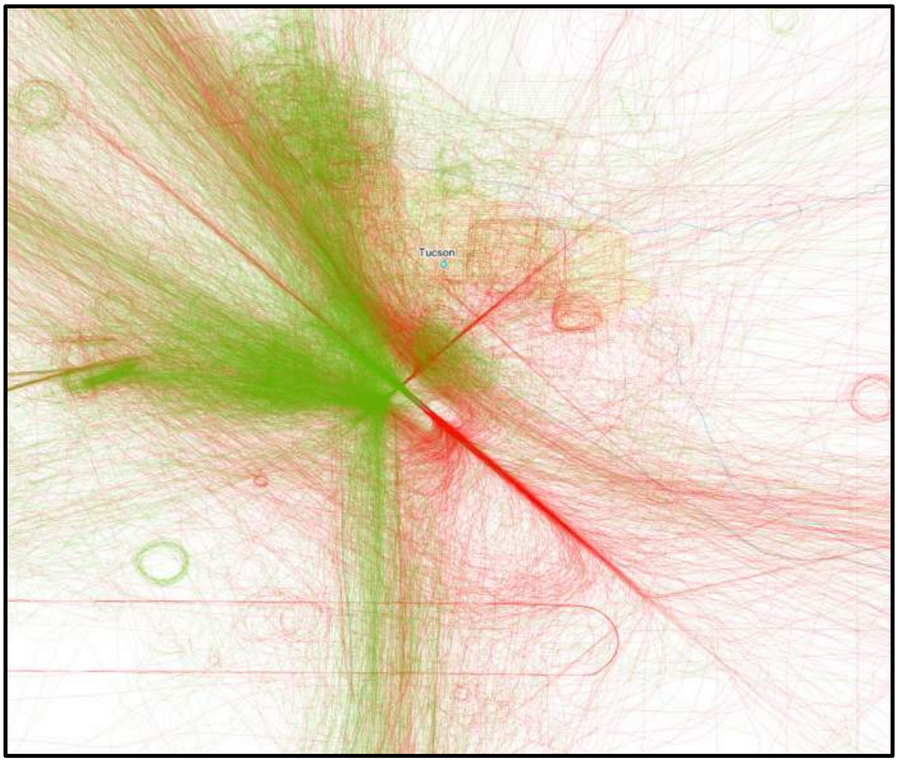
West Flow, Non-Military Jets – 25% Sample



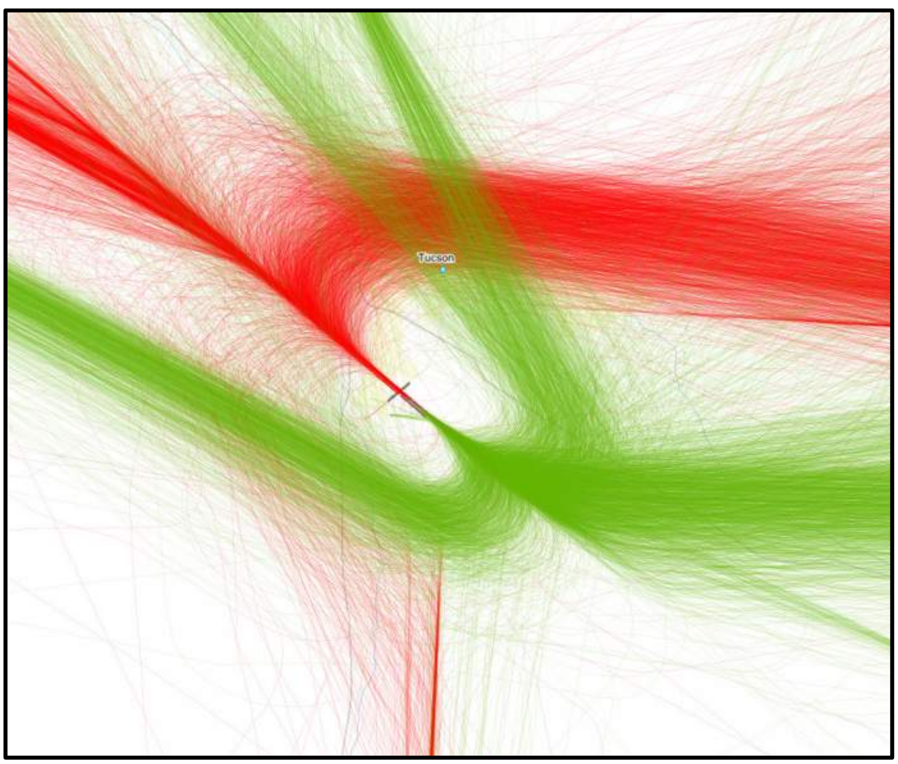
Military Jets – 100% Sample



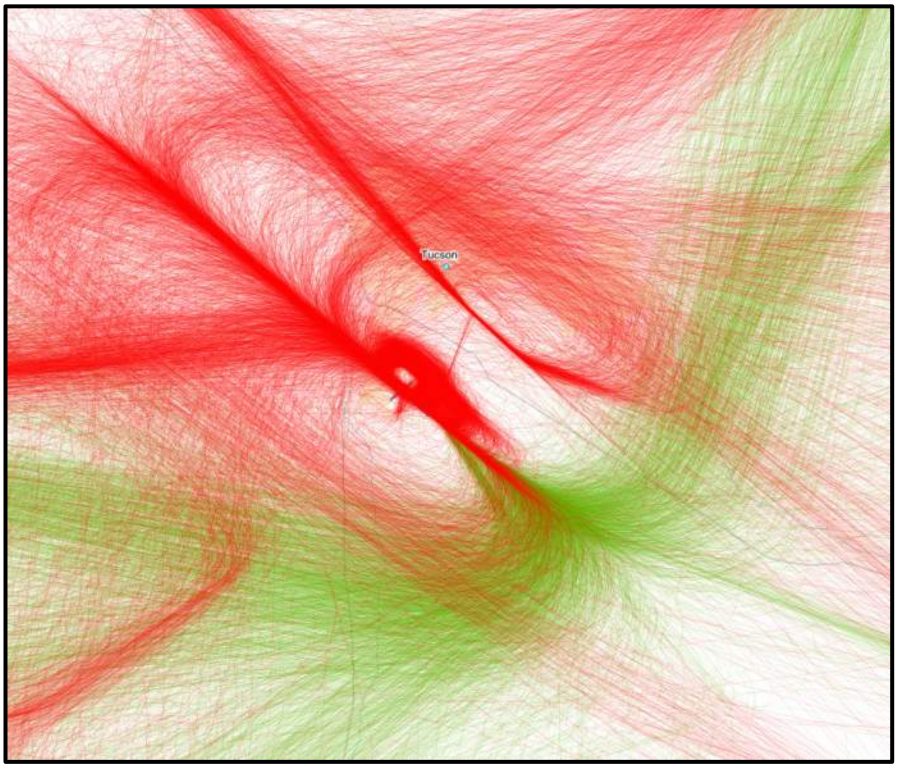
West Flow, Non-Jets – 50% Sample



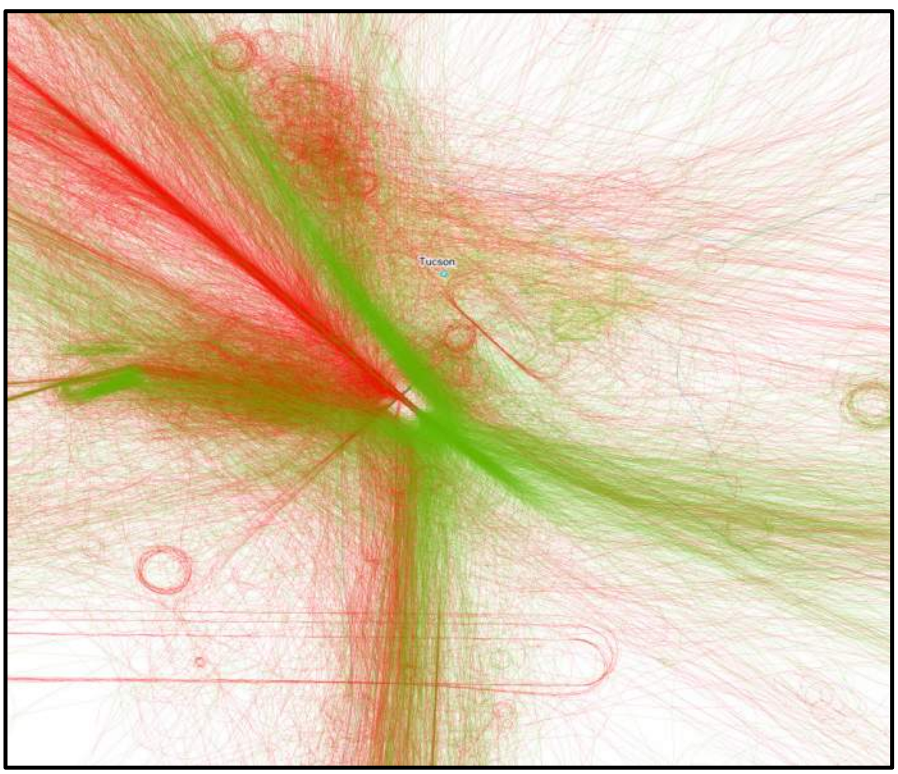
East Flow, Non-Military Jets – 25% Sample



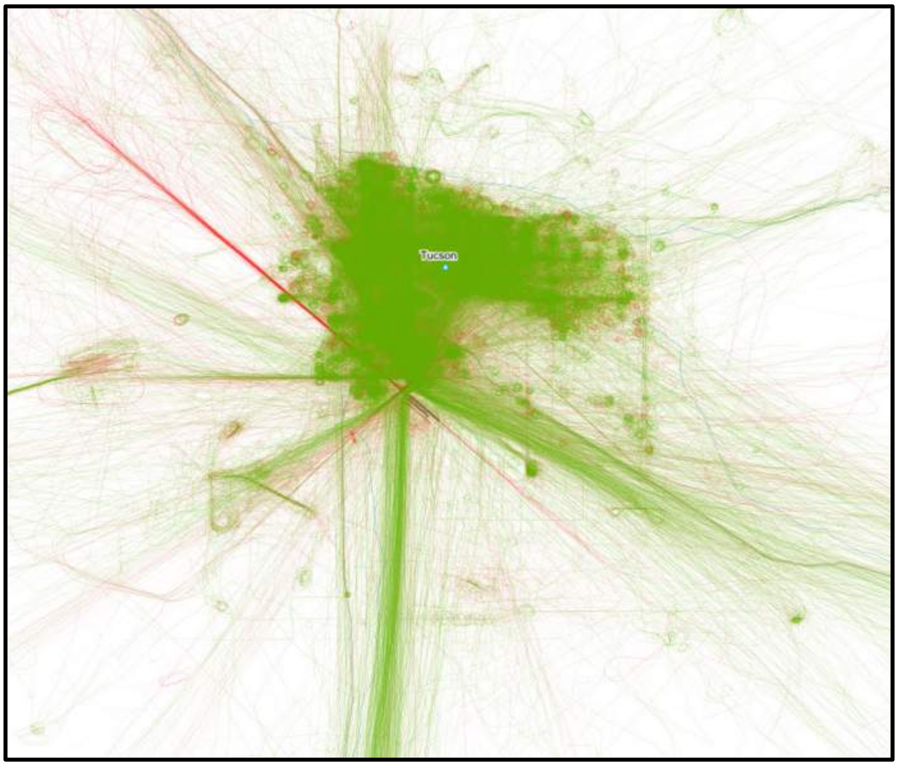
Military Jets – 100% Sample



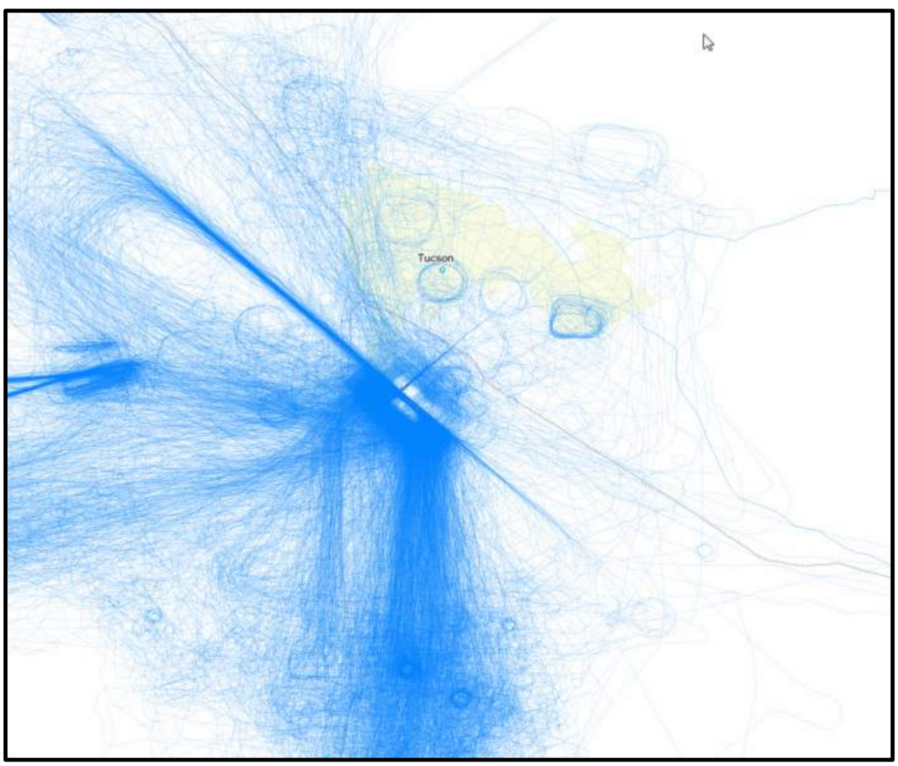
East Flow, Non-Jets – 50% Sample



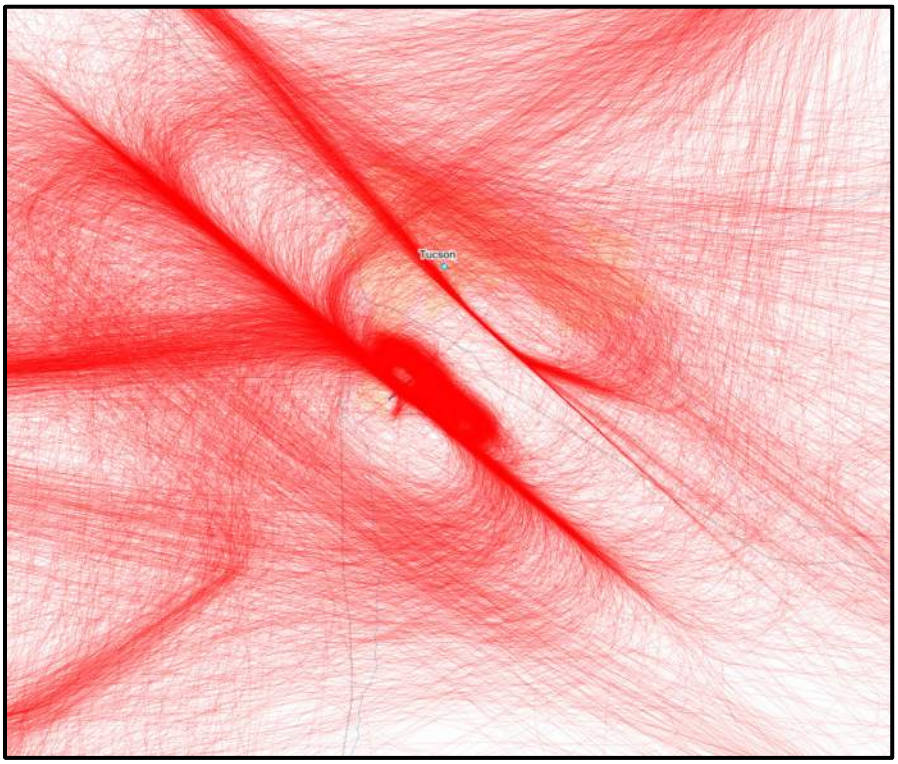
Helicopters 100% Sample



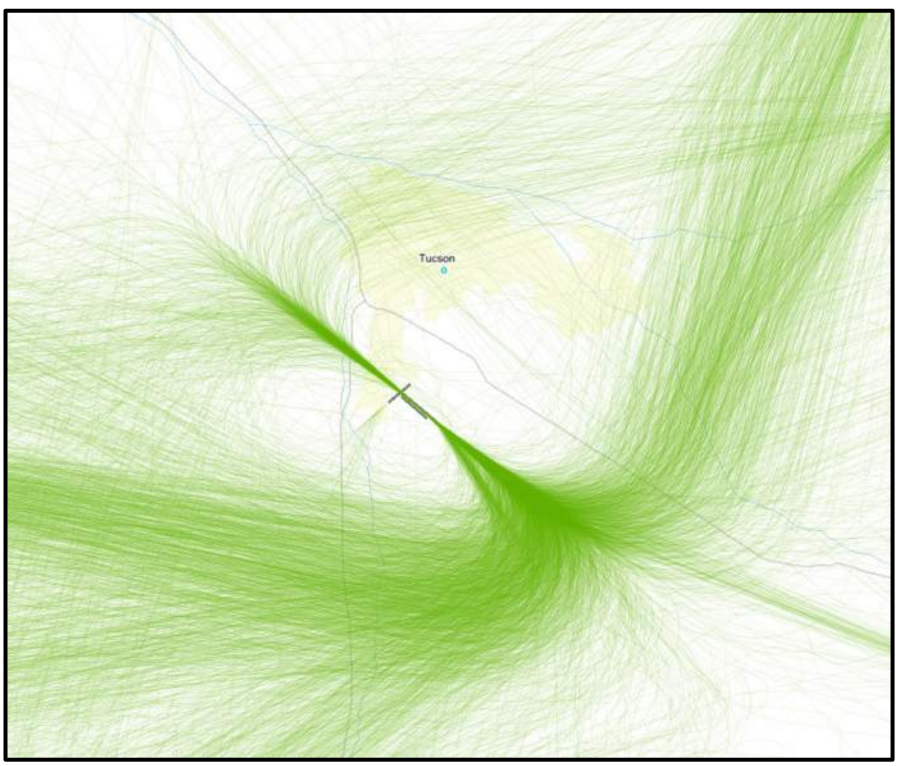
Local 100% Sample



F16 Aircraft – 100% Sample - Arrivals



F16 Aircraft – 100% Sample - Departures



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Analysis of the Neighborhood Environmental Survey

Volume 4 of 4: Appendices G through J

Contracts DTFACT-15-D-00008 and DTFACT-15-D-00007

HMMH Report No. 308520.004.001

January 2021

Prepared for:

Federal Aviation Administration
William J. Hughes Technical Center
4th Floor, M26
Atlantic City International Airport
Atlantic City, NJ 08405

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Appendix G Sensitivity Analyses for Regression Models

The confidence bands for each dose-response curve are computed from the estimated covariance matrix of the estimated slope and intercept, under the following assumptions:

A. The form of the two-parameter logistic model described in Equation (8.1) and Appendix H accurately describes the relationship between DNL and the probability of being highly annoyed. The model in Equation (8.1), with a positive slope, forces the predicted percent HA to increase as DNL increases. This assumption would be violated if the actual curve had a different form, for example, if the percent HA increased with DNL up to DNL 65 dB and decreased thereafter.

B. The curve and variability measures are calculated using the respondents to the survey. The confidence bands are computed under the assumption that respondents and nonrespondents have the same relationship between noise exposure and annoyance, and do not account for possible differences between respondents and nonrespondents to the survey.

C. Observations within the same airport are sampled independently. This assumption is met through the sampling design.

D. The values of HA and DNL for each respondent are accurate measures. These assumptions require external validation and cannot be assessed from the survey data alone. The validity of the questionnaire for determining the annoyance of the respondent was established through in the ACRP pilot study 02-35 (Miller, et al. 2014a), as discussed in Chapter 2. The validity of the DNL values depend on the quality procedures for the noise calculations and could be assessed by an independent confirmation of the DNL values at the geolocations of the survey respondents.

This appendix contains the results of the sensitivity analyses that were performed to assess assumptions (A) and (B). The first two sections fit expanded models that include the model in Equation (8.1) as a special case in order to assess the appropriateness of the model in Equation (8.1). Appendix E presents the results of a nonresponse bias analysis; Section G.3 repeats the model-fitting using a set of nonresponse-adjusted weights, and it is found that these nonresponse adjustments do not change the national curve. Finally, Section G.4 fits an alternative model from Fidell et al. (2011) to the data, as requested by the FAA.

G.1 Assessing Model Fit for the Individual Airport Dose-Response Curves

The sensitivity analyses for assessing the fit of the two-parameter logistic regression curve to individual airports included fitting expanded models that contained the model in Equation (8.1) as a special case and conducting hypothesis tests for lack of fit. The sensitivity analyses showed that the model in Equation (8.1) fits most of the individual airports well, although there are indications that BFI, LAS, LIT, and ORD may have some features in specific noise exposure ranges that deviate from the sigmoidal shape of the logistic regression function. As with the national curve, there were few, if any, observations for most airports above DNL 70 dB, and caution should be used when predicting percent HA from the curves in higher noise ranges.

One standard statistical approach for assessing the fit of a model is to embed it in a larger model and then perform a statistical test of whether the additional terms in the larger model equal zero. The logistic regression model in Equations (H.1) and (H.2) assumes that annoyance always increases with higher noise exposures. It is possible, however, that in an individual airport annoyance might be lower in the 70-75 dB range of DNL than in the 65-70 dB range: A larger model that allows assessment of whether the two-parameter logistic model adequately describes the relationship between DNL and HA includes additional quadratic and cubic terms[1] in the regression model. The cubic polynomial model is expressed using the form of the model in Equation (H.2):

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 DNL + \beta_2 DNL^2 + \beta_3 DNL^3, \quad (G.1)$$

When the coefficients β_2 and β_3 equal zero, the model in Equation (G.1) reduces to that in Equation (H.2).

Table G-1 presents the Wald chi-squared test statistic and p-value for the test of the null hypothesis that β_2 = β_3 = 0. For this test, a small p-value (less than 0.05) means that at least one of the coefficients β_2 or β_3 is statistically significantly different from zero. A large p-value means that there is no reason to doubt the adequacy of the two-parameter model in Equation (8.1). Table G-1 also presents the Hosmer-Lemeshow (2000) goodness-of-fit test statistic and p-value for each airport. For the Hosmer-Lemeshow test, a small p-value indicates statistically significant lack of fit; a large p-value gives no reason to doubt the adequacy of the model in Equation (8.1).

Table G-1. Statistical tests for quadratic and cubic terms, and for lack of fit, in individual airport models.

Airport Identifier	Wald Chi-squared Test Statistic	Wald Test p-value	Hosmer-Lemeshow Test Statistic	Hosmer-Lemeshow p-value
ABQ	0.1397	0.9325	4.5655	0.8028
ALB	0.7226	0.6968	10.9874	0.2024
ATL	1.6731	0.4332	8.8591	0.3543
AUS	0.1038	0.9494	2.6546	0.9541
BDL	3.5830	0.1667	11.2858	0.1860
BFI	9.0648	0.0108	8.4722	0.3888
BIL	0.0286	0.9858	3.2748	0.9159
DSM	3.6523	0.1610	9.3598	0.3129
DTW	2.3961	0.3018	4.5570	0.8037
LAS	12.6859	0.0018	10.5022	0.2315
LAX	1.6698	0.4339	6.8362	0.5544
LGA	1.1608	0.5597	9.6040	0.2939
LIT	6.3360	0.0421	6.2035	0.6245
MEM	4.0553	0.1316	8.8276	0.3570
MIA	0.9185	0.6318	8.3593	0.3992
ORD	10.2131	0.0061	25.9661	0.0011
SAV	4.4465	0.1083	10.1340	0.2557
SJC	2.0093	0.3662	17.5246	0.0251
SYR	5.2414	0.0728	9.6472	0.2907
TUS	3.1695	0.2050	13.0720	0.1094

Four airports (BFI, LAS, LIT, and ORD) had values for the quadratic and/or cubic terms in Equation (G.1) that were statistically significantly different from zero.[2] These results are consistent with the data plots in Appendix I.1, in which the scatter from the data points indicated that there may be a downturn in percent HA for those airports at higher noise exposures. In addition, ORD and SJC exhibited statistically significant lack of fit from the Hosmer-Lemeshow test. For SJC, note the data points in Figure I-18 are evenly scattered but not as tightly clustered about the line as for the other airports, giving rise to the large Hosmer-Lemeshow test statistic for that airport.

[1] The Stone-Weierstrass theorem (Rudin 1964, p. 150) states that any smooth curve can be well approximated by a polynomial of sufficiently large degree. Higher-order polynomial terms (beyond cubic) did not improve the model fit.
[2] Note that no adjustments for multiple testing were performed for the statistical tests presented in this section. In general, if all 20 null hypotheses for the individual airports were true, one would expect one of the tests to be declared statistically significant by chance. A Bonferroni adjustment can be performed for the tests in Table J.1, if desired, by multiplying each p-value by 20.

G.2 Assessing Model Fit for the National Dose-Response Curve

To assess assumption (A), models that were generalizations of the model in Equation (8.1) were fit to the data. The first alternative model included extra quadratic and cubic terms in the model, and fit the model from Equation (G.1) to the data from all airports combined. The jackknife (see Appendix H, Section H.3) was used to compute the covariance matrix and standard errors of the coefficients. Table G-2 gives the estimated coefficients for the cubic polynomial model.

Table G-2. Coefficients for cubic polynomial model, all airports

Coefficient	Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Intercept, β_0	-4.2752	23.8340	-54.1717	45.6213
DNL, β_1	-0.2964	1.1835	-2.7735	2.1807
DNL^2, β_2	0.01125	0.0195	-0.0295	0.0520
DNL^3, β_3	-0.00009	0.0001	-0.0003	0.0001

Note that the coefficients of the intercept and slope differ greatly from those in Table 8-2 because of the multicollinearity of the variables; the multicollinearity also results in much larger standard errors for all coefficients. This is a common occurrence when the independent variables in a regression model are highly correlated. The Wald test statistic for the null hypothesis $H_0: \beta_2 = \beta_3 = 0$ is Q = 27 with p-value < 0.001, indicating that the quadratic and cubic terms improve the fit of the model. This significance of the quadratic and cubic terms occurs largely because of the observations above DNL 70 dB.

An additional check of model adequacy was run by fitting a cubic spline model to the data (Eilers and Marx 1996; Breidt, Claeskens and Opsomer 2005; Breidt and Opsomer 2009; SAS Institute 2014, p. 8077). A cubic spline model divides the horizontal axis into segments, and fits a cubic regression model as in Equation (G.1) to each segment. It thus allows the data to determine the shape of the curve in each segment, and provides a method of checking assumptions about model form. When the data set is sufficiently large for the model to be fit, a cubic spline model provides a more accurate picture of the underlying curve than a cubic polynomial because the spline model is completely data-driven while the cubic polynomial model must follow that functional form. The spline model can be thought of as a smoothed method of "connecting the dots" of the data points. A cubic spline model was fit with 3 internal knots (leading to 5 segments) at equal percentiles of DNL.

Figure G-1 shows the national curve with coefficients in Table 8-2 along with the 95 percent confidence bands for that curve. It is displayed alongside the curve from Equation (G.1) with quadratic and cubic terms in DNL, and the spline model. Although the higher-order polynomial terms in the cubic polynomial model are statistically significant, for values of DNL between 50 and 70 dB, the curves fit using the two expanded models produced predictions of percent HA that were close to the predictions from the model from Equation (8.1); the curves were entirely contained within the confidence bands shown for the national curve in Figure 8-2. Above 70 dB, the two expanded models produced predictions of percent HA that were lower than the curve using the model from Equation (8.1). We recommend caution when using the national curve to predict percent HA for values of DNL above 70 dB.

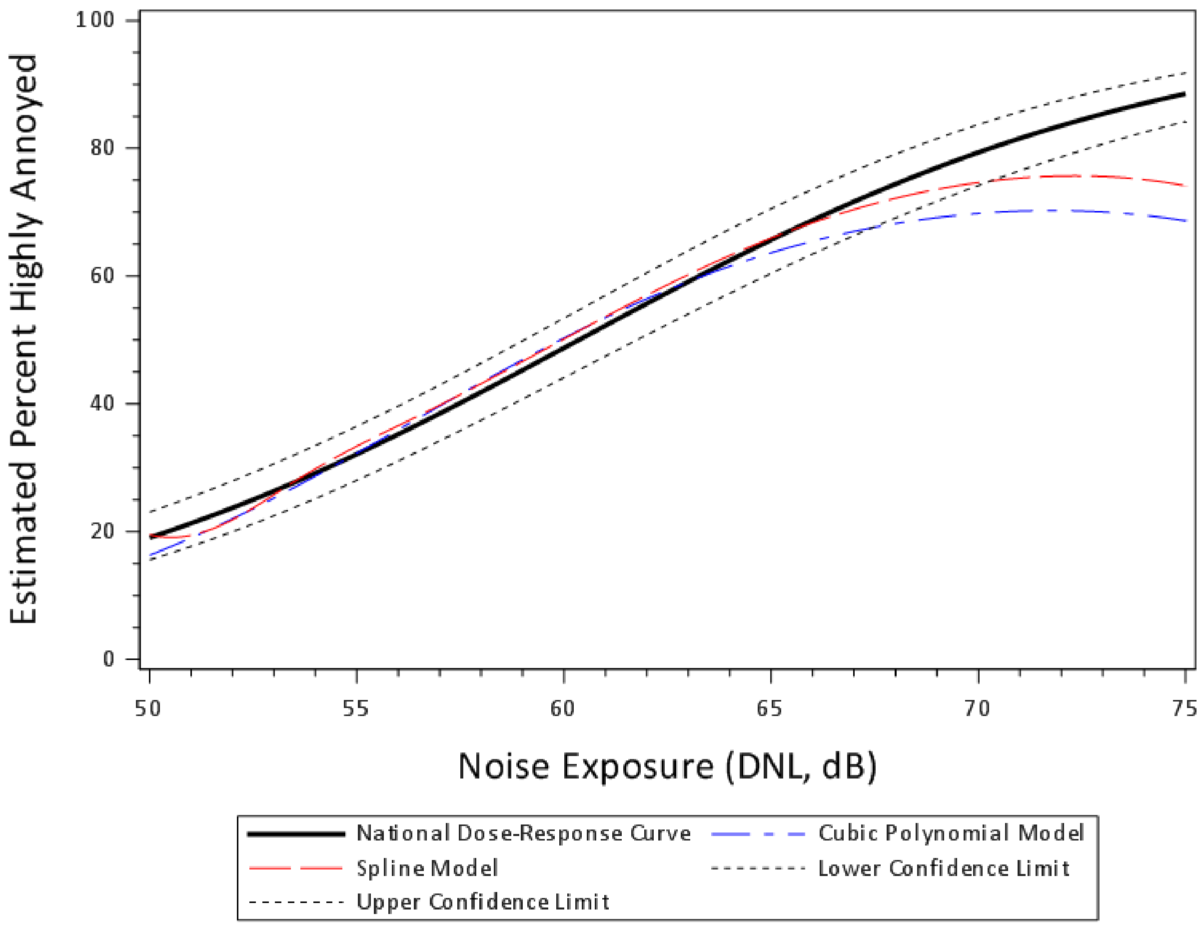

Figure G-1. Alternative Models Fit to All Airports

G.3 Fitting the Curves using Nonresponse-Adjusted Weights

For the NES, the overall response rate for the mail questionnaire was 40.3 percent. Nonresponse bias would occur if respondents and nonrespondents at the same noise exposure have different levels of annoyance. Appendix E contains the results of nonresponse bias analyses that evaluated whether the response propensity differed by characteristics known for all sampled units.

As argued in Appendix H.1, a weight of one can be used for each respondent when fitting the dose-response curves. However, there is nonresponse to the survey and it is possible that the nonresponse is related to the outcome variable (annoyance to aircraft noise). It is therefore desired to explore the effect of nonresponse-adjusted weights on the estimated dose-response.

To do an additional check on Assumption (B), weights were constructed that adjust for nonresponse (Brick 2013). Computation of nonresponse-adjusted weights started with an initial weight of one for each respondent. Separately for each airport, regression tree models (Hothorn, Hornik & Zeilus 2006; Lohr, Hsu & Montaquila 2015; Earp, Toth & Oslund 2016) were fit to the observations in the selected sample. The models predicted whether each eligible sampled address was a respondent based on information known for both respondents and nonrespondents, using the variables in Table D-1. The predicted probability of responding to the survey was calculated from the model for each respondent and the nonresponse-adjusted weight for each respondent was the reciprocal of its predicted probability to respond to the survey. In this way, the weights of respondents were increased so they also represented nonrespondents with similar characteristics. The weights were scaled to sum to 500 for each airport.

Both the individual airport curves and the national curve were refit using the nonresponse-adjusted weights. Table G-3 shows the model coefficients without and with the weights for the individual airport curves. The first two columns of the table repeat the coefficients given in Table 8-1 for the twenty airports. The weights had no meaningful impact on the predicted percent highly annoyed. For all airports except BFI, BIL, and ORD, the maximum difference between predicted percent highly annoyed from the model with weights and the model without weights was less than 2.5 percentage points (and for most airports, the differences were smaller than that). For BFI, BIL, and ORD, the maximum difference was less than 4 percentage points.

Table G-3. Coefficients of Model in Equation (8.1), unweighted and weighted

Airport Identifier	β_0, no weights	β_1, no weights	β_0, nonresponse-adjusted weights	β_1, nonresponse-adjusted weights
ABQ	-6.1563	0.1093	-6.3547	0.1115
ALB	-8.2847	0.1355	-8.2697	0.1355
ATL	-8.3554	0.1379	-8.3852	0.1369
AUS	-11.4847	0.1903	-12.0232	0.1998
BDL	-6.9470	0.1124	-6.9953	0.1131
BFI	-6.5752	0.1031	-6.0274	0.0935
BIL	-13.8302	0.2395	-14.1638	0.2473
DSM	-8.6299	0.1387	-8.2164	0.1315
DTW	-5.9880	0.1059	-5.6359	0.0995
LAS	-6.6325	0.1025	-6.7051	0.1033
LAX	-5.7330	0.0930	-6.1811	0.1002
LGA	-13.1473	0.2125	-13.2178	0.2127
LIT	-8.0593	0.1395	-7.8990	0.1365
MEM	-8.9629	0.1388	-8.7980	0.1354
MIA	-12.6290	0.2005	-12.3167	0.1953
ORD	-10.5999	0.1840	-10.4877	0.1793
SAV	-9.1981	0.1566	-9.5121	0.1627
SJC	-10.7487	0.1782	-11.3460	0.1877
SYR	-3.4425	0.0489	-3.5687	0.0505
TUS	-7.3388	0.1399	-7.3821	0.1409
National curve	-8.4304	0.1397	-8.4459	0.1396

The last row in Table G-3 shows the coefficients of the national curve without weights (columns 1 and 2) and with weights (columns 3 and 4). The two curves, with and without weights, are shown in Figure G-2 and are virtually identical at all values of DNL between 50 and 75. The maximum difference between the predicted percent HA for the curve without weights and the curve fit with nonresponse-adjusted weights is less than one-half of one percentage point.

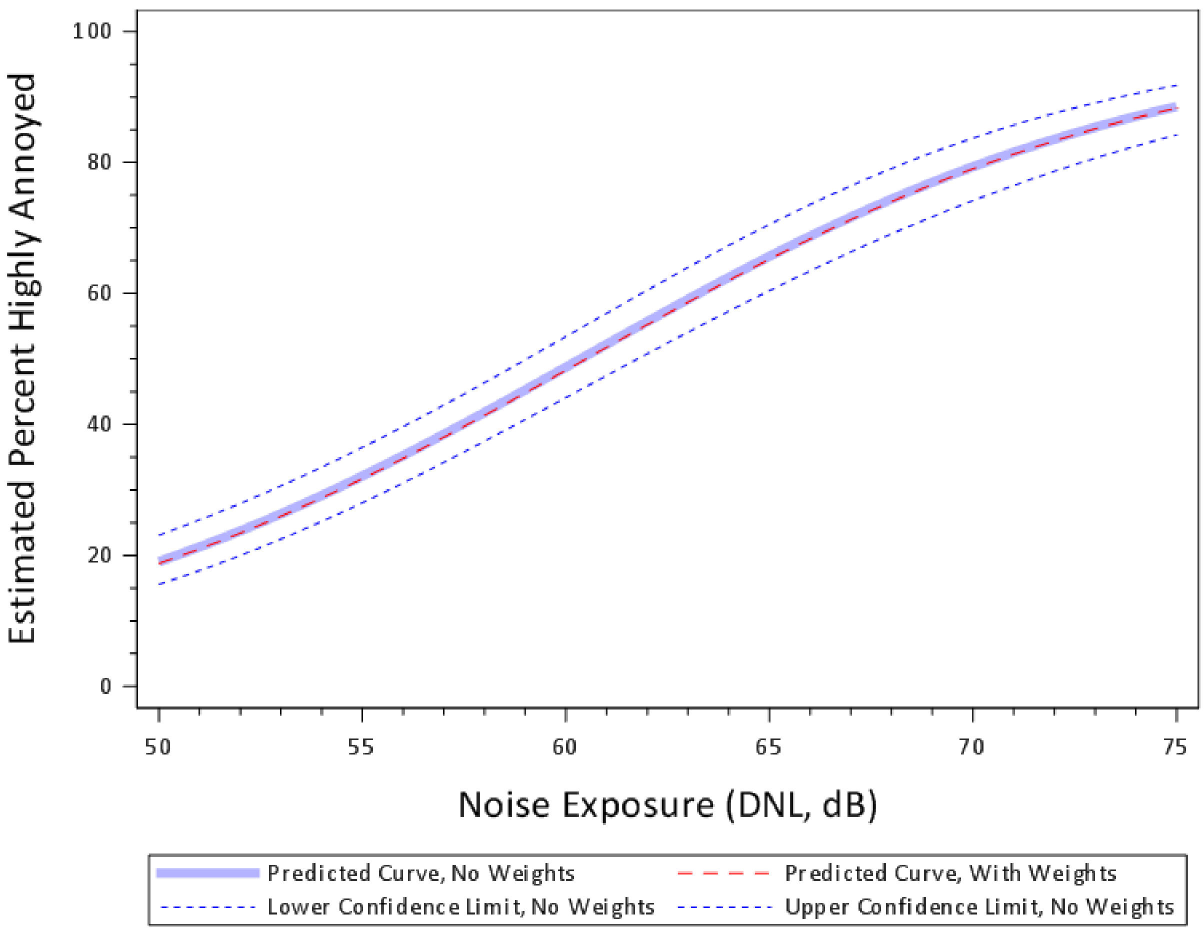

Figure G-2. National Curve and Curve Fit with Nonresponse-Adjusted Weights

The analyses in this section were conducted to provide a further investigation of potential nonresponse bias. Evidence of potential nonresponse bias potentially correctable by using the weights would exist, if the curves fit with nonresponse-adjusted weights differed greatly from the curves fit without weights. The results of these analyses show that the individual airport curves and national curve are little changed when nonresponse-adjusted weights are used, and therefore, the simpler unweighted models are used. This analysis detected no nonresponse bias in the national curve reported in Chapter 8 using the information available on the sampling frame.

G.4 Fitting the Community Tolerance Level Curve from Fidell et al. (2011)

Fidell et al. (2011) proposed an alternative model for the relationship between noise exposure and annoyance. This model hypothesized that the annoyance with noise "should increase at the same rate as the duration-adjusted loudness of exposure" (Fidell et al. 2011, p. 793). The estimated noise dose is given by $m = \left[10^{DNL/10}\right]^{0.3}$. The model predicts the probability of being highly annoyed, P(HA), as

$$P(HA) = p = \exp\left(-\frac{A}{m}\right), \tag{G.2}$$

where A is the parameter to be estimated.

For fitting the model in Equation (G.2), it is convenient to express it in a form that is structurally similar to the logistic regression model used in Chapter 8. By substituting $\left[10^{DNL/10}\right]^{0.3}$ for *m*, taking the natural logarithm of both sides of the equation, and performing some algebra, the model in Equation (G.2) can be written in an algebraically equivalent form as:

$$-ln[-ln(p)] = -\ln(A) + [0.03][\ln(10)](DNL). \tag{G.3}$$

Equation (G.3) is of the form

$$-ln[-ln(p)] = \beta_0 + \beta_1\,(DNL), \tag{G.4}$$

and thus has similar structure to the FICON (1992) model in Equation (H.2), with an intercept β_0 and slope β_1.

The difference between Equation (H.2) and Equation (G.4) is that Equation (H.2) uses a logit link function, $\ln\left(\frac{p}{1-p}\right)$, while Equation (G.4) uses a log-log link function, $-ln[-ln(p)]$. The relationships specified by the two functions (logit and log-log) are slightly different, but both transform *p*, which is between 0 and 1, to a number in the range $(-\infty, +\infty)$. Both models specify that the predicted P(HA) increases with DNL. The logit function is symmetric about $p = 0.5$, because $\ln\left(\frac{p}{1-p}\right) = -\ln\left(\frac{1-p}{p}\right)$. That is, with logistic regression one could model P(not highly annoyed) instead of modeling P(highly annoyed) and obtain the same results. The log-log link function is not symmetric; it approaches a probability of 0 more steeply and approaches a probability of 1 more slowly than the logistic function, although the differences in fit are usually small for the middle of the probability range.

The specific formulation of the model in Fidell et al. (2011), in Equation (G.3), sets the intercept in Equation (G.4) equal to $-\ln(A)$, and this parameter is estimated from the data. The model fixes the slope in Equation (G.4) to be $[0.03][\ln(10)] \approx 0.069$. The slope in the Fidell et al. (2011) model is forced to equal 0.069 for all airports and is not estimated from the data.

The model in Equation (G.3) was fit to the individual airports from the NES, and to all airports together. Table G-4 gives the coefficients and standard errors for the individual airport curves and the national curve using this model, as well as the estimate of the parameter A from Equation (G.2) and the estimated value of the Community Tolerance Level (CTL) arising from this model. The CTL is defined to be the value of DNL for which half of the community is predicted to be highly annoyed, according to the model in Equation (G.2). These values are calculated as:

$$A = \exp(-\beta_0) \tag{G.5}$$

and

$$CTL = \{-ln[-ln(0.5)] - \beta_0\}/\{[0.03][\ln(10)]\}. \tag{G.6}$$

Table G-4. Estimated Coefficients for Model in Equation (G.3), with Lower and Upper Confidence Limits (CLs)

Airport Identifier	β_0			A			CTL		
	Estimate	Lower CL	Upper CL	Estimate	Lower CL	Upper CL	Estimate	Lower CL	Upper CL
ABQ	-3.54	-3.66	-3.42	34.51	30.69	38.81	56.57	54.87	58.27
ALB	-3.95	-4.07	-3.84	52.06	46.47	58.32	62.52	60.88	64.17
ATL	-3.84	-3.96	-3.71	46.50	41.04	52.67	60.89	59.08	62.69
AUS	-4.04	-4.15	-3.92	56.60	50.60	63.31	63.73	62.11	65.36
BDL	-3.92	-4.04	-3.81	50.62	45.17	56.72	62.12	60.47	63.76
BFI	-4.03	-4.14	-3.91	56.14	50.00	63.04	63.62	61.94	65.29
BIL	-3.90	-4.01	-3.79	49.49	44.23	55.38	61.79	60.16	63.42
DSM	-4.04	-4.15	-3.92	56.58	50.61	63.26	63.73	62.11	65.34
DTW	-3.53	-3.66	-3.40	34.06	29.97	38.71	56.38	54.53	58.23
LAS	-4.08	-4.19	-3.96	59.01	52.61	66.19	64.34	62.67	66.00
LAX	-3.86	-3.99	-3.73	47.52	41.74	54.10	61.20	59.32	63.08
LGA	-4.06	-4.18	-3.94	57.93	51.54	65.10	64.07	62.38	65.76
LIT	-3.69	-3.81	-3.58	40.10	35.74	44.99	58.74	57.08	60.41
MEM	-4.14	-4.26	-4.02	62.91	55.76	70.98	65.26	63.52	67.01
MIA	-4.11	-4.22	-3.99	60.72	54.01	68.27	64.75	63.05	66.45
ORD	-3.48	-3.63	-3.34	32.61	28.21	37.69	55.75	53.65	57.85
SAV	-3.82	-3.93	-3.71	45.68	40.83	51.10	60.63	59.01	62.25
SJC	-3.94	-4.05	-3.82	51.20	45.52	57.60	62.28	60.58	63.99
SYR	-3.95	-4.07	-3.84	52.17	46.63	58.37	62.55	60.93	64.18
TUS	-3.09	-3.24	-2.95	22.05	19.01	25.56	50.08	47.94	52.22
National Curve	-3.85	-3.97	-3.73	47.05	41.79	52.97	61.06	59.34	62.77

The last row of Table G-4 shows the estimated coefficient from the model in Equation (G.3) for all airports together. This was calculated using a random intercept regression model.

The model in Equation (G.4), in which the slope as well as the intercept is estimated from the data, allows one to check the implicit assumption in Fidell et al. (2011) that the slope is 0.069, which is equivalent to assuming that the exponent α in the function $m = \left[10^{DNL/10}\right]^{\alpha}$ is $\alpha =$ 0.3. This is done by fitting the two-parameter model in Equation (G.4) and then testing the null hypothesis H_0: $\beta_1 = 0.069$. Table G-5 gives the estimated slope and intercept for the model in Equation (G.4) for each airport. The value of the exponent in Table G-5 is calculated as $\alpha = 10\ \beta_1/\ln(10)$. The test for whether the slope β_1 is equal to (0.03) ln(10) ≈ 0.069 was carried out by forming the test statistic

$$T = [\text{estimate of } \beta_1 - (0.03)\ln(10)]/(\text{Standard error of estimate of } \beta_1) \qquad \text{(G.7)}$$

and comparing the value of T to a t distribution with (number of observations – 2) degrees of freedom. This also serves as a statistical test for the null hypothesis that the exponent α equals 0.3.

Table G-5. Estimated Slopes and Intercepts from Model in Equation (G.4) for Each Airport

Airport Identifier	β_0 Estimate	β_0 Lower CL	β_0 Upper CL	β_1 Estimate	β_1 Lower CL	β_1 Upper CL	Estimate of exponent, α	Test statistic for $H_0: \beta_1 = 0.069$	p-value for $H_0: \beta_1 = 0.069$
ABQ	-3.682	-6.432	-0.933	0.072	0.020	0.124	0.312	0.101	0.920
ALB	-4.541	-6.334	-2.747	0.080	0.047	0.112	0.346	0.645	0.519
ATL	-5.382	-6.768	-3.995	0.095	0.072	0.119	0.415	2.183	0.029
AUS	-6.439	-8.339	-4.539	0.112	0.078	0.147	0.488	2.482	0.013
BDL	-4.230	-5.908	-2.552	0.075	0.045	0.104	0.324	0.358	0.720
BFI	-4.073	-5.545	-2.600	0.070	0.045	0.095	0.303	0.060	0.952
BIL	-7.694	-10.134	-5.254	0.139	0.094	0.184	0.604	3.048	0.002
DSM	-5.094	-6.865	-3.324	0.088	0.057	0.119	0.381	1.175	0.241
DTW	-3.991	-5.885	-2.097	0.077	0.044	0.111	0.336	0.481	0.631
LAS	-3.945	-5.169	-2.721	0.067	0.046	0.088	0.290	-0.214	0.830
LAX	-3.823	-4.997	-2.648	0.068	0.049	0.088	0.297	-0.065	0.948
LGA	-7.702	-9.121	-6.283	0.131	0.107	0.156	0.570	5.018	0.000
LIT	-5.127	-7.055	-3.199	0.095	0.060	0.131	0.414	1.462	0.144
MEM	-5.469	-6.654	-4.283	0.091	0.071	0.111	0.395	2.200	0.028
MIA	-7.261	-8.617	-5.905	0.122	0.099	0.145	0.530	4.548	0.000
ORD	-7.924	-9.471	-6.376	0.145	0.118	0.172	0.629	5.558	0.000
SAV	-5.561	-7.943	-3.178	0.101	0.057	0.144	0.438	1.433	0.152
SJC	-6.397	-8.043	-4.751	0.112	0.083	0.142	0.488	2.931	0.004
SYR	-1.849	-3.471	-0.227	0.031	0.002	0.060	0.136	-2.566	0.011
TUS	-5.456	-7.565	-3.347	0.111	0.073	0.149	0.482	2.194	0.029
National	-5.225	-5.971	-4.478	0.093	0.080	0.106	0.405	3.817	0.001

From Table G-5, 10 of the 20 airports have slopes that are statistically significantly different from the hypothesized value of 0.069 (i.e., the exponents α are statistically significantly different from 0.3).

The last row of Table G-5 shows the estimated coefficients for the national curve for the model in Equation (G.4). This was fit using a random coefficients regression model, where each airport had its own intercept β_{0i} and slope β_{1i} for the model

$$-ln[-ln(P[HA, \text{airport } i])] = \beta_{0i} + \beta_{1i}\,(DNL),$$

and the different intercepts and slopes are related through the model in Equation (H.4). The one-parameter model in Fidell et al. (2011), reported in Table G-4, exhibits statistically significant lack of fit for the data for the national curve. The maximum likelihood estimate of the exponent α, from the two-parameter model reported in Table G-5, is 0.405, which is significantly higher than the assumed value of 0.3.

Figure G-3 displays the national curve from Table 8-2, the curve fit using the model in Fidell et al. (2011), and a curve fit using the two-parameter log-log link model in Equation (G.4). The two-parameter log-log link model fits the data well, and may in fact provide a better fit above DNL 70 dB than the logistic model that was requested for the national curve. The one-parameter model from Fidell et al. (2011), however, does not fit the data well. It overestimates the annoyance at low noise exposures and underestimates the annoyance at higher noise exposure by fixing the slope at 0.069.

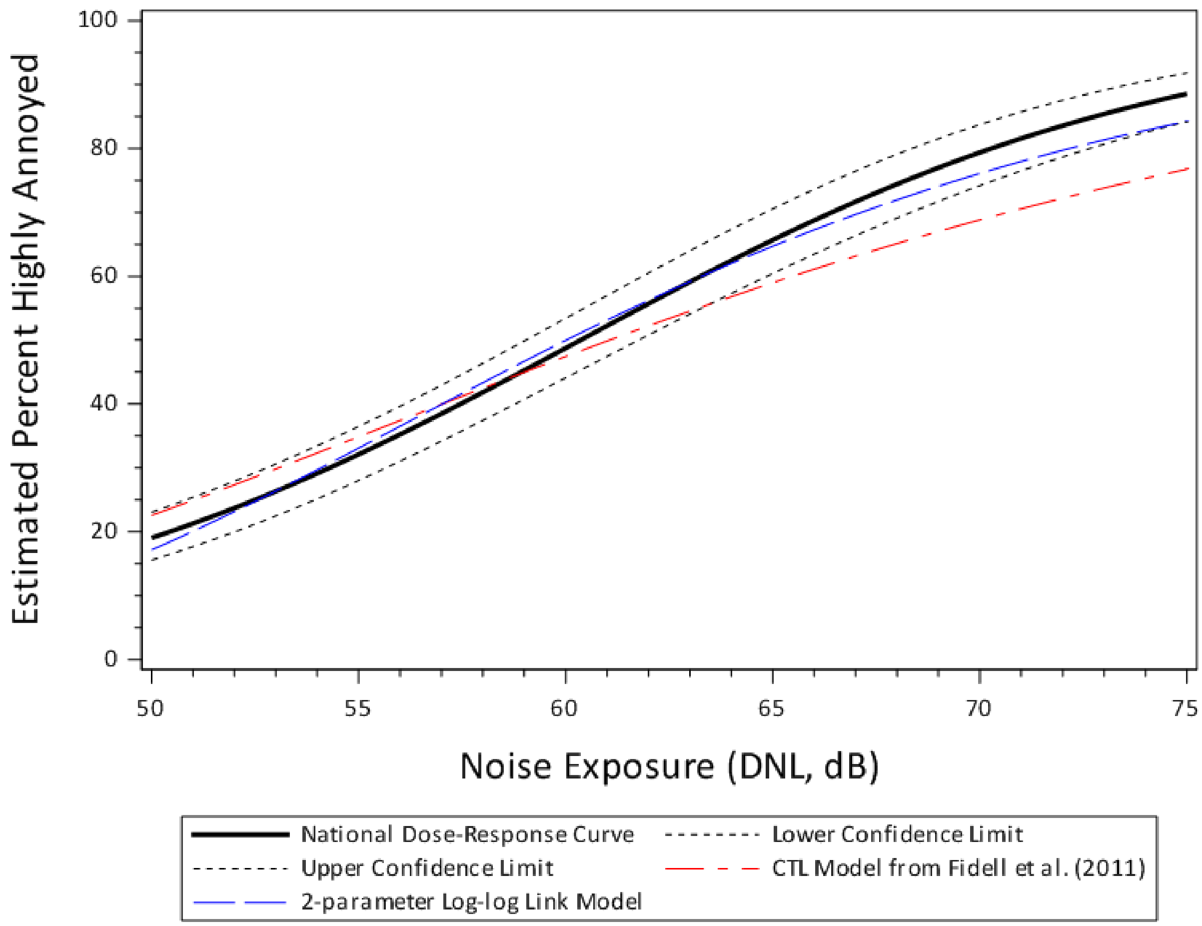

Figure G-3. National Curve, along with Curves Fit using Fidell et al. (2011) Model and Two-parameter Log-log Link Model

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Appendix H Regression Model Formulas and Computations

H.1 Model for Individual Airport Dose-Response Curves

Equations (8.1) and (H.1) give the logistic regression model, from FICON (1992), used to fit dose-response curves for the individual airports. It is:

$$\text{Percent } HA = \frac{100\ \exp(\beta_0 + \beta_1 DNL)}{1 + \exp(\beta_0 + \beta_1 DNL)}. \quad \text{(H.1)}$$

This logistic regression model can be expressed in algebraically equivalent form as:

$$\ln\left(\frac{p}{1-p}\right) = \text{logit}(p) = \beta_0 + \beta_1 DNL, \quad \text{(H.2)}$$

where $p = P(HA)$ is the probability of being highly annoyed if exposed to noise at the DNL value in the right-hand side of the equation. The slope β_1 in the logistic regression model may be interpreted as the expected change in the log odds ratio $\ln\left(\frac{p}{1-p}\right)$ associated with a change of one dB in DNL. Alternatively, the exponentiated value of the coefficient gives the change in the odds ratio $p/(1-p)$ associated with a one-dB change in DNL. Thus, the parameters in the FICON (1992) curve ($\beta_0 = -11.13$ and $\beta_1 = 0.141$) can be interpreted as follows: if address A has a value of DNL that is one dB greater than the DNL value for address B, then the log odds ratio for being highly annoyed is expected to be 0.141 higher for address A than for address B, and the odds ratio is expected to be exp(0.141) = 1.15 greater for address A than for address B. The difference in P(HA) at values of DNL that differ by one dB depends on the particular values of DNL because of the nonlinear relationship between P(HA) and DNL in the logistic regression.

The LOGISTIC procedure of SAS® software (SAS Institute, Inc., 2014), version 9.4, was used to fit the model predicting HA from DNL for each airport. The profile likelihood method was used to construct confidence intervals.

Sampling weights were not used when fitting the dose-response curves. The NES was designed for estimating the logistic regression function in Equation (8.1) with high statistical efficiency. The sampling design specified higher inclusion probabilities for addresses in higher noise strata than in lower noise strata to obtain sufficiently high numbers of respondents with higher noise exposure — this ensured that the sample from each airport would include respondents with a large range of noise exposures. The noise exposure was the only variable used in the stratification at each airport. Because regression analyses are performed conditionally on the independent (x) variable (here, DNL), weights are not needed for the analysis. Pfeffermann and Sverchkov (1999) and Pfeffermann (2011) provide a theoretical justification for conditioning on the weights in the analysis of the data. In their approach, modified "q weights" are calculated that divide the design weight (the inverse of the inclusion probability) by the conditional expected value of the design weight given x. Because the inclusion probabilities in the NES are functions of x, the "q weight" for each unit is one. Therefore, the national curve can be estimated using a logistic regression with each observation having weight one.[3]

[3] It would be possible to fit a regression model using the sampling weights, but the model would have low precision for estimating the dose-response curve. Because the sampling fractions were so much higher in the high noise exposure strata, the sampling weights are low for high noise exposure households and high for low noise exposure households. An airport curve fit using the weights would be determined almost exclusively by the sampled households with DNL between 50 and 55 dB, with almost no influence from households with higher DNL.

H.2 Model for National Dose-Response Curve

The national curve was fit using a random coefficients logistic regression model, which includes individual airport intercepts and slopes as random effects (McCulloch and Neuhaus 2001; Demidenko 2004; Allison 2012). The full model is expressed in two stages. First, the model for percent HA at each airport is assumed to have its own intercept β_{0i} and slope β_{1i}, according to the model in Equation (H.1):

$$\%\, HA, airport\ i = \frac{100\ \exp(\beta_{0\mathrm{i}} + \beta_{1\mathrm{i}} DNL)}{1 + \exp(\beta_{0\mathrm{i}} + \beta_{1\mathrm{i}} DNL)}. \tag{H.3}$$

The coefficients for the individual airports are assumed to be related through a multivariate normal model, where

$$\begin{bmatrix} \beta_{0\mathrm{i}} \\ \beta_{1\mathrm{i}} \end{bmatrix} \sim N\left(\begin{bmatrix} \beta_0 \\ \beta_1 \end{bmatrix}, \begin{bmatrix} V_{11} & V_{12} \\ V_{12} & V_{22} \end{bmatrix} \right). \tag{H.4}$$

In essence, the model given by Equations (H.3) and (H.4) fits separate dose-response curves for each individual airport and then combines them to produce the national curve. It allows each airport to have its own intercept, as in the probit model of Groothuis-Oodshourn and Miedema (2006). The model also allows each airport to have its own slope, as suggested by Groothuis-Oodshourn and Miedema (2006) as an extension of their model. The random slope term allows the confidence interval bands about the dose-response curve to account for airport-to-airport variability of the slopes.

The estimated dose-response curve resulting from this model is virtually identical to the curve that results from fitting the individual airport logistic regression curves using the model in Section H.1 and then computing the slope as the average of the 20 airport model slopes and the intercept as the average of the 20 airport model intercepts.[4] The advantage of using the form of the model in Equations (H.3) and (H.4) is that it creates a single model that includes all of the airport information, and allows the calculation of the standard errors of the parameter estimates and the confidence bands about the curve. This structure also facilitates the investigation of other factors that might be associated with annoyance to aircraft noise, as discussed in Section H.3.

The precision for the estimated national dose-response curve depends on:

1. The slope and intercept of the “true” population curve,
2. The variability in the dose-response relationship among different airports in the sample,
3. The number of airports in the sample,
4. The number of households sampled per airport, and
5. The distribution of noise exposure among the sampled households.

The variability among airports (item 2) and the number of airports in the sample (item 3) are typically the main factors determining the precision of the estimated slope and intercept in a random coefficient regression model. If different airports have vastly different curves, then more sampled airports are needed to be able to estimate the national relationship with high precision. Item (4) contributes to the precision of the national curve, but the main purpose of sampling 500 addresses per airport was to obtain high precision for the individual airport dose-response curves; the national curve was expected to have almost as much precision if 300 addresses were sampled per airport as if 500 addresses were sampled, because the primary determinant of the precision of the national curve is the variability among airports (Lohr 2014). The sampling

[4] The average of the 20 airport intercepts is -8.64; the average of the 20 airport slopes is 0.143. These values are similar to the coefficients in Table 8.2.

design specified taking a high fraction of high-noise-exposure addresses to increase the precision associated with item (5).

The confidence bands presented for the national curve reflect the sampling error for estimating the national curve, including both the variability among the dose-response curves at different airports and the variability from fitting each individual airport dose-response curve. The confidence bands in Figure 8-2 reflect the uncertainty about the mean of the slopes and intercepts of the individual airport curves. These are distinguished from other types of error bands that might describe the uncertainty about the expected dose-response relationship of a randomly selected new airport, or the uncertainty about the probability that a randomly selected individual at an airport would report being highly annoyed at a specific value of DNL (Groothuis-Oodshourn and Miedema, 2006).

The GLIMMIX procedure of SAS® software (SAS Institute, Inc., 2016), version 9.4, was used to fit the model in Equations (H.3) and (H.4). Adaptive Gauss-Hermite quadrature was used to calculate the maximum likelihood estimates of the slope and intercept.

H.3 Models Used for Additional Analyses in Chapter 9

The goal of the analyses in Chapter 9 was to determine the extent to which the factors listed in Table 9-1 contribute to the prediction of the probability of being highly annoyed, after accounting for the effects of DNL.

For all factors in Table 9-1 except for DEGREEDAYS, two sets of analyses were performed. The first fit a logistic regression model separately for each airport. The form of this model, where FACTOR represents each of the factors in Table 9-1 except for DEGREEDAYS, is

$$\ln\left(\frac{p}{1-p}\right) = \text{logit}(p) = \beta_0 + \beta_1 DNL + \beta_2 FACTOR + \beta_3 DNL \times FACTOR. \quad \text{(H.5)}$$

The extra coefficients β_2 and β_3, relative to the model in Equation (H.2), provide information about how the relationship between DNL and P(HA) is modified when FACTOR is included in the model. The coefficient β_2 describes the change in the intercept when the value of FACTOR is increased by one, and the coefficient β_3 describes the change in the slope for DNL when the value of FACTOR is increased by one, assuming that the value of DNL is held constant. The model in Equation (H.5) contains the model in Equation (H.2) as a special case that occurs if the coefficients β_2 and β_3 are equal to zero. If the additional terms β_2 and β_3 are both zero, then, after controlling for DNL, FACTOR is not related to the overall level of annoyance and it does not moderate the relationship between P(HA) and DNL.

To assess the role of FACTOR in the individual airports, a hypothesis test was performed for the compound null hypothesis $H_0: \beta_2 = \beta_3 = 0$. The compound test is needed, rather than simply examining the significance of the separate coefficients, because the estimates of β_2 and β_3 may be correlated. This test examines whether FACTOR and the FACTOR-by-DNL interaction explain any additional variability in HA after accounting for the effect of DNL by itself. A Wald test statistic was used, calculated with the TEST statement in PROC LOGISTIC. Under the null hypothesis, the test statistic asymptotically follows a chi-squared distribution with 2 degrees of freedom.

For testing the significance of the additional factors with the national curve, however, a different approach was needed because the values of FACTOR may be correlated within airports.[5] To account for that dependence, the jackknife method was used (Shao and Tu 1995). Twenty analyses were performed using the model in Equation (H.5), where each analysis omitted one of the airports. The variability among the coefficients among the 20 analyses was used to find the standard errors of the regression coefficients and to test the null hypothesis $H_0: \beta_2 = \beta_3 = 0$.

The test of the compound null hypothesis $H_0: \beta_2 = \beta_3 = 0$ was carried out by calculating the estimated covariance matrix, V, of the vector of estimated coefficients $[\hat{\beta}_2, \hat{\beta}_3]'$. Then the test statistic

$$Q = [\hat{\beta}_2, \hat{\beta}_3]\, V^{-1}\, [\hat{\beta}_2, \hat{\beta}_3]' \quad \text{(H.6)}$$

was compared to a chi-squared distribution with 2 degrees of freedom.[6]

The factor DEGREEDAYS is an airport-level characteristic, having the same value for all respondents at an individual airport. It therefore was analyzed using a different model than the other factors in Table 9-1. The

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[5] For the national airport curve, that correlation was accounted for by allowing both intercept and slope to be random effects.

[6] The Wald test statistic Q asymptotically follows a chi-squared distribution if the variance matrix is known rather than estimated. Thomas and Rao (1987) found in empirical studies that for studies with a small number of clusters, an alternative test compares F = Q/2 to an F distribution with appropriate degrees of freedom.

interest was in determining whether airports with different values of DEGREEDAYS had different predicted values of P(HA) at fixed values of DNL. For DEGREEDAYS, the model fit was:

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 DNL + \beta_2 DEGREEDAYS. \tag{H.7}$$

A test of the null hypothesis $H_0: \beta_2 = 0$ was performed by comparing the test statistic $T = \hat{\beta}_2 / SE(\hat{\beta}_2)$ to a t distribution with 19 degrees of freedom.

Care must be taken when interpreting statistical tests. Because of the large sample size of the NES, a very small difference between curves at different levels of the FACTOR variable can be deemed to be statistically significant. The decision whether a statistically significant difference is practically important depends on scientific considerations.

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Appendix I Dose-Response Analyses for Individual Airports

Figure 8-1 displayed the individual dose-response curves for all 20 airports on the same plot. In this appendix, the curves are graphed separately for each airport, along with 95 percent confidence bands for the estimated curves. In each graph, the solid line represents the dose-response curve for the airport and the dashed lines represent the 95 percent confidence bands. The data points displayed on the plots were computed using grouped data from each airport, as described in footnote 43 of Chapter 8. To protect the confidentiality of the respondents, the curves for each airport are displayed to the end of the largest noise exposure stratum that has at least 20 respondents, as described in footnote 42 of Chapter 8.

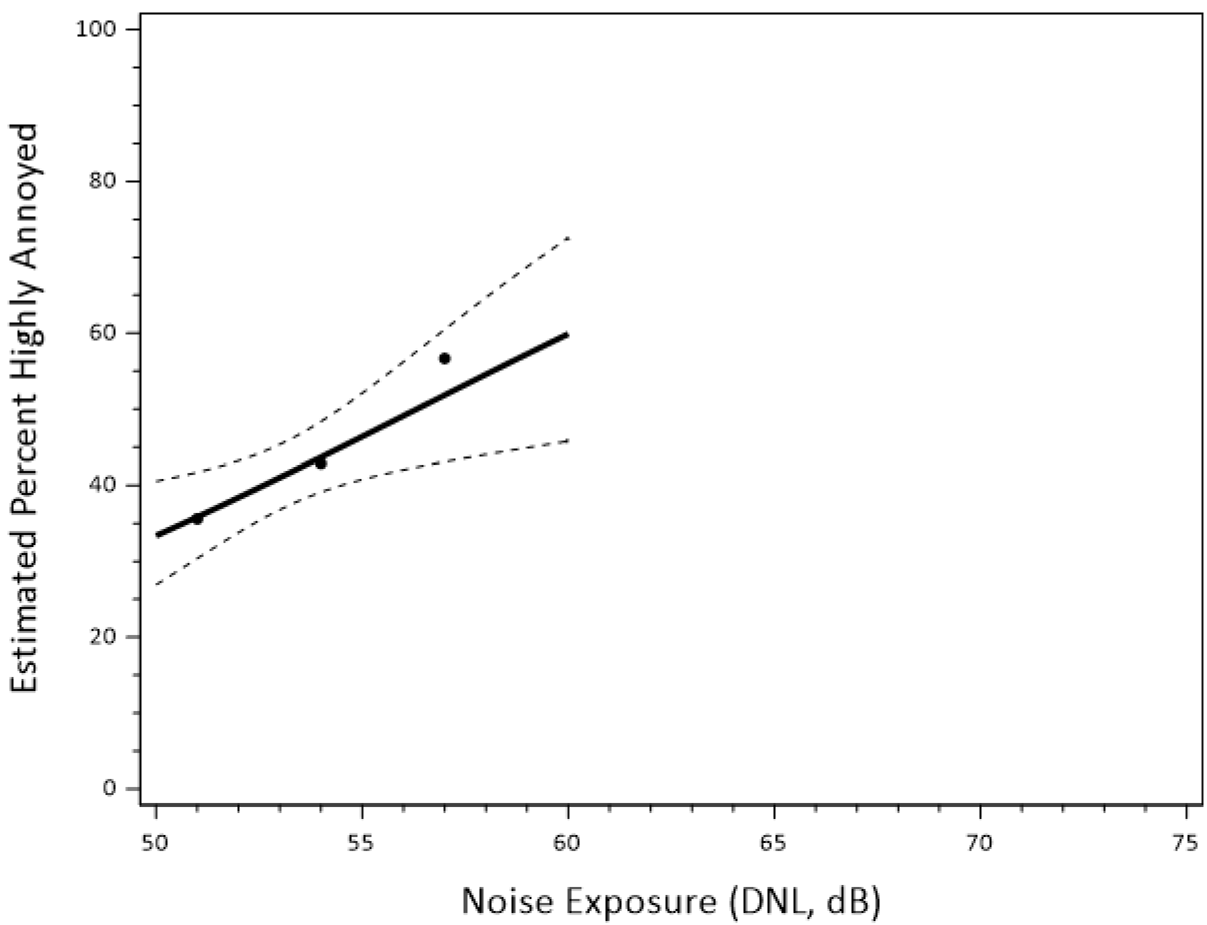

Figure I-1. Dose-Response Curve for ABQ

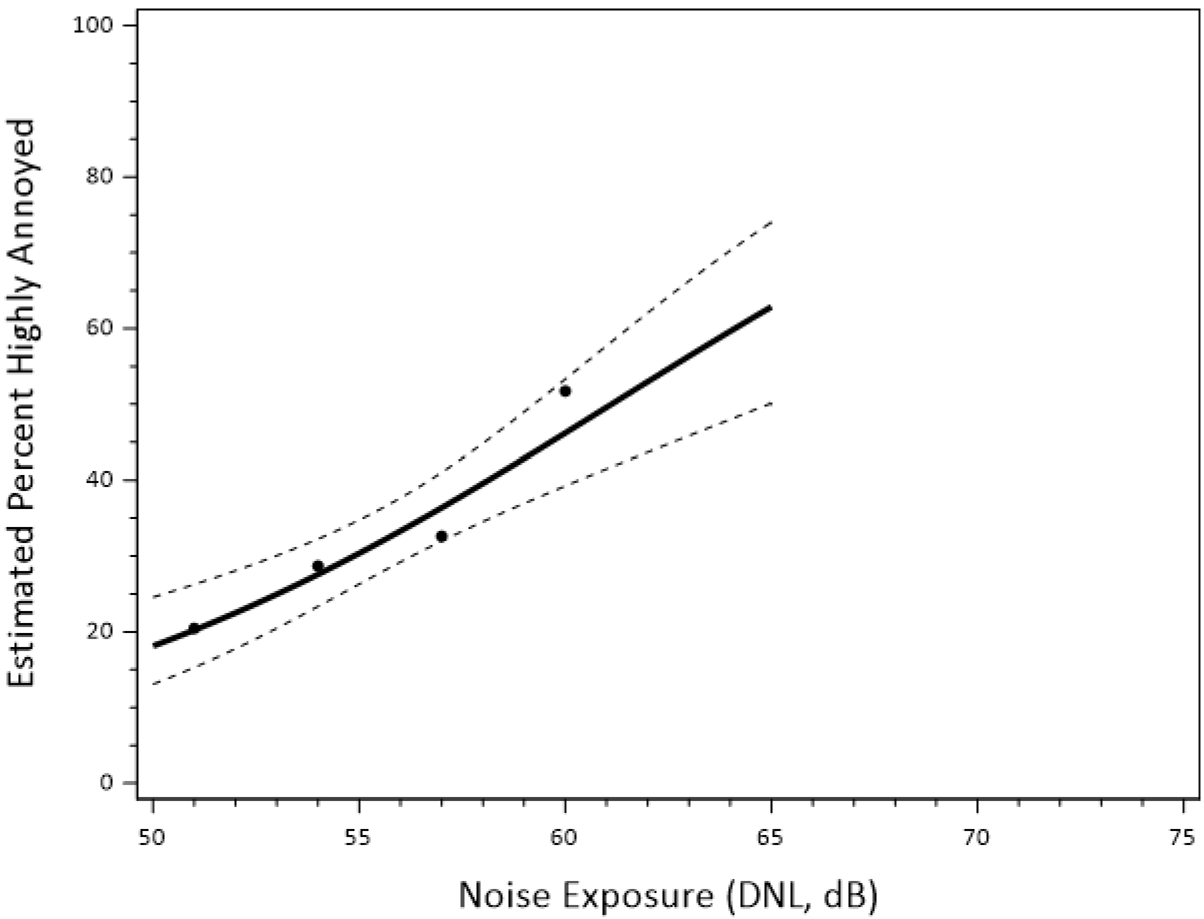

Figure I-2. Dose-Response Curve for ALB

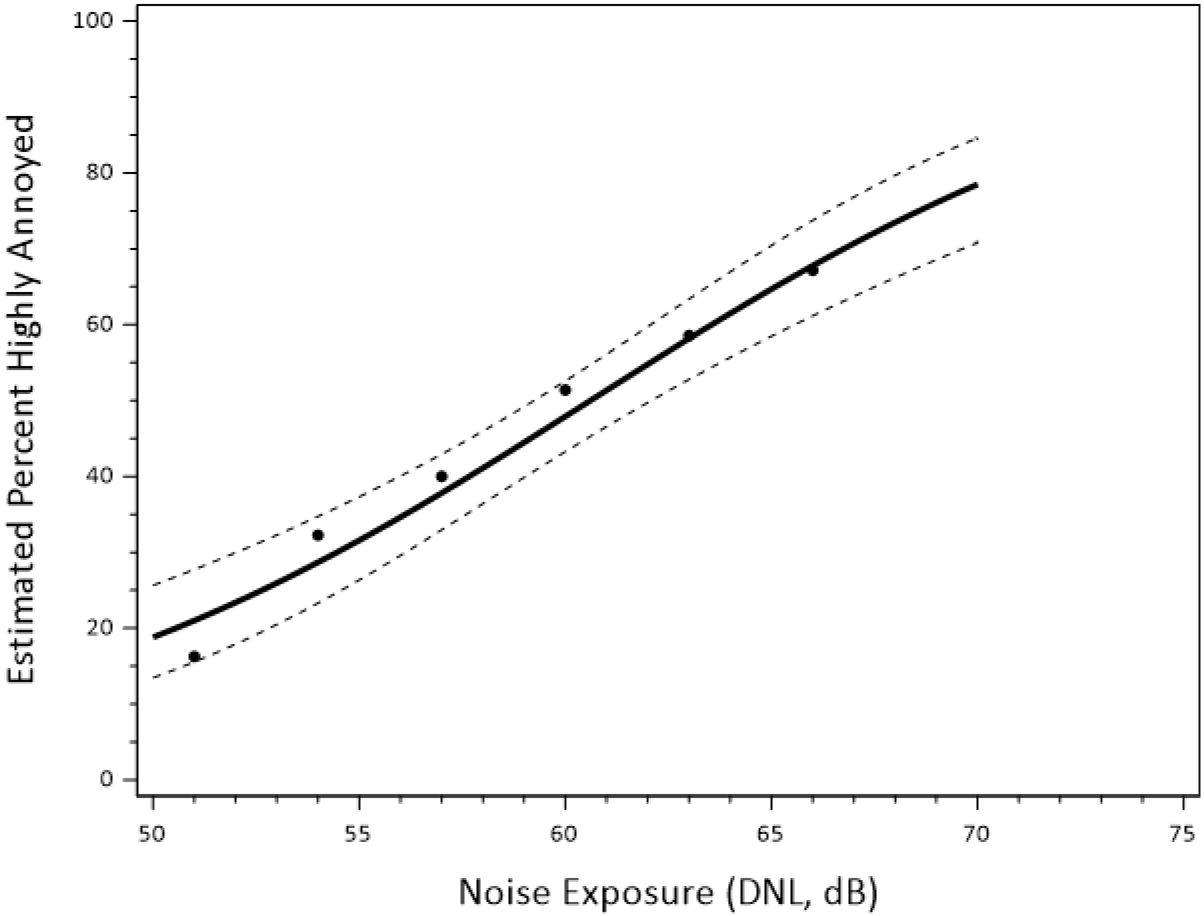

Figure I-3. Dose-Response Curve for ATL

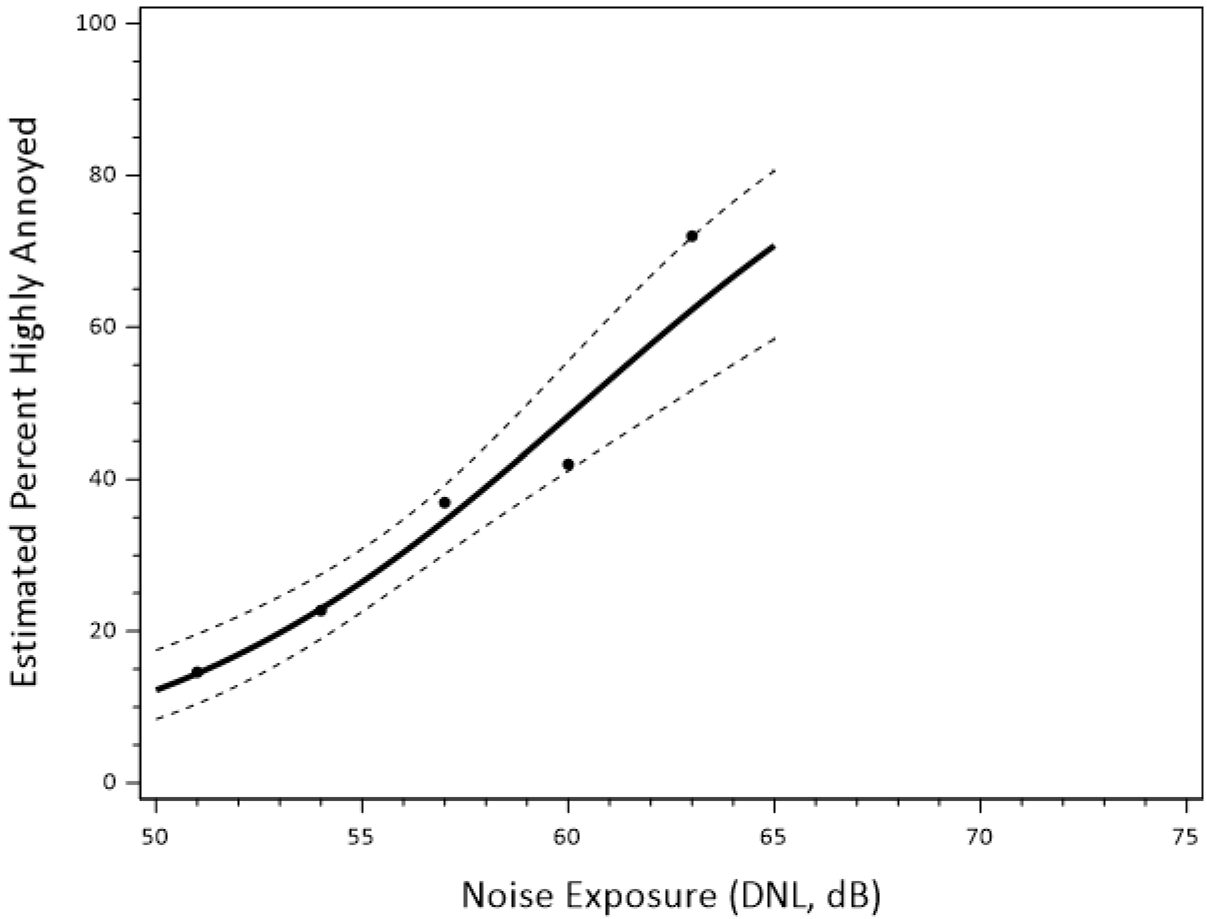

Figure I-4. Dose-Response Curve for AUS

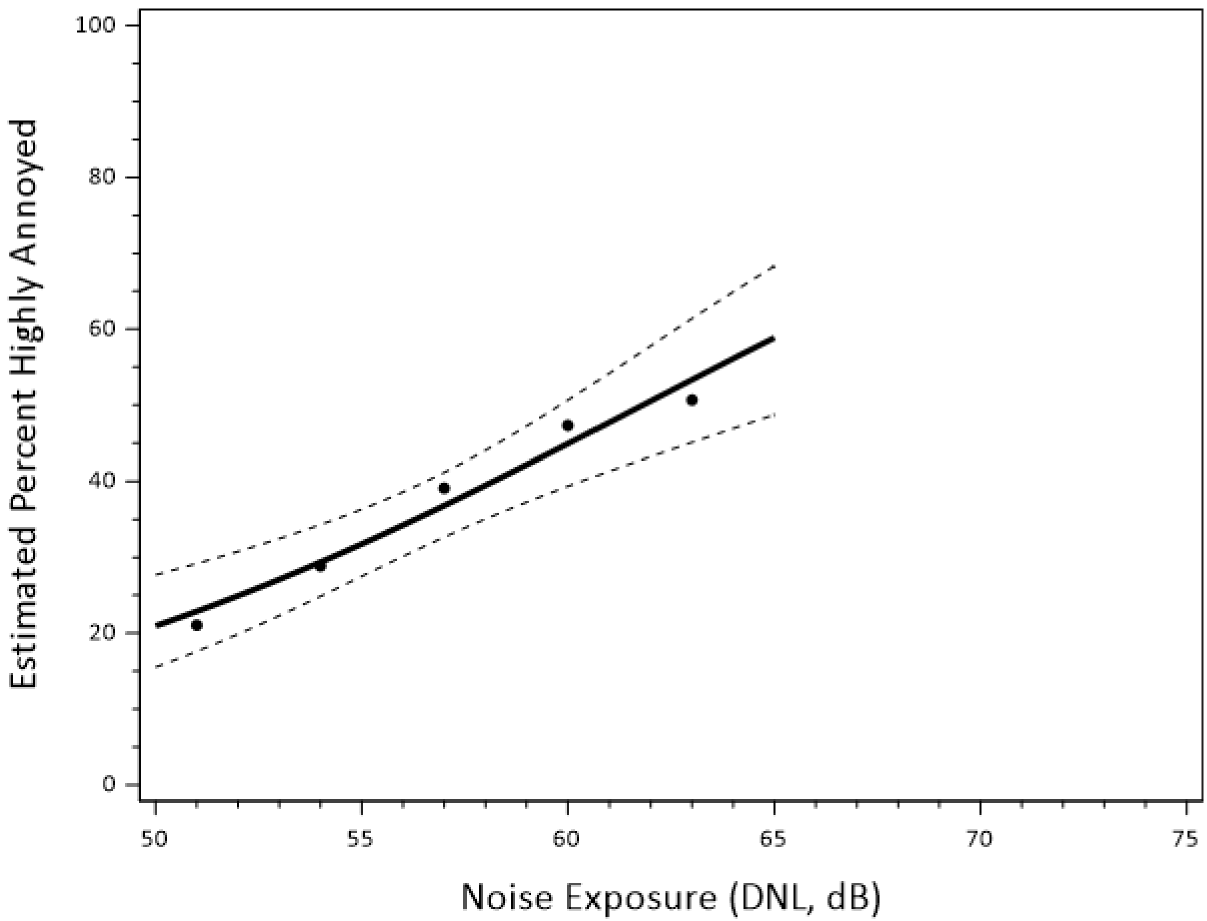

Figure I-5. Dose-Response Curve for BDL

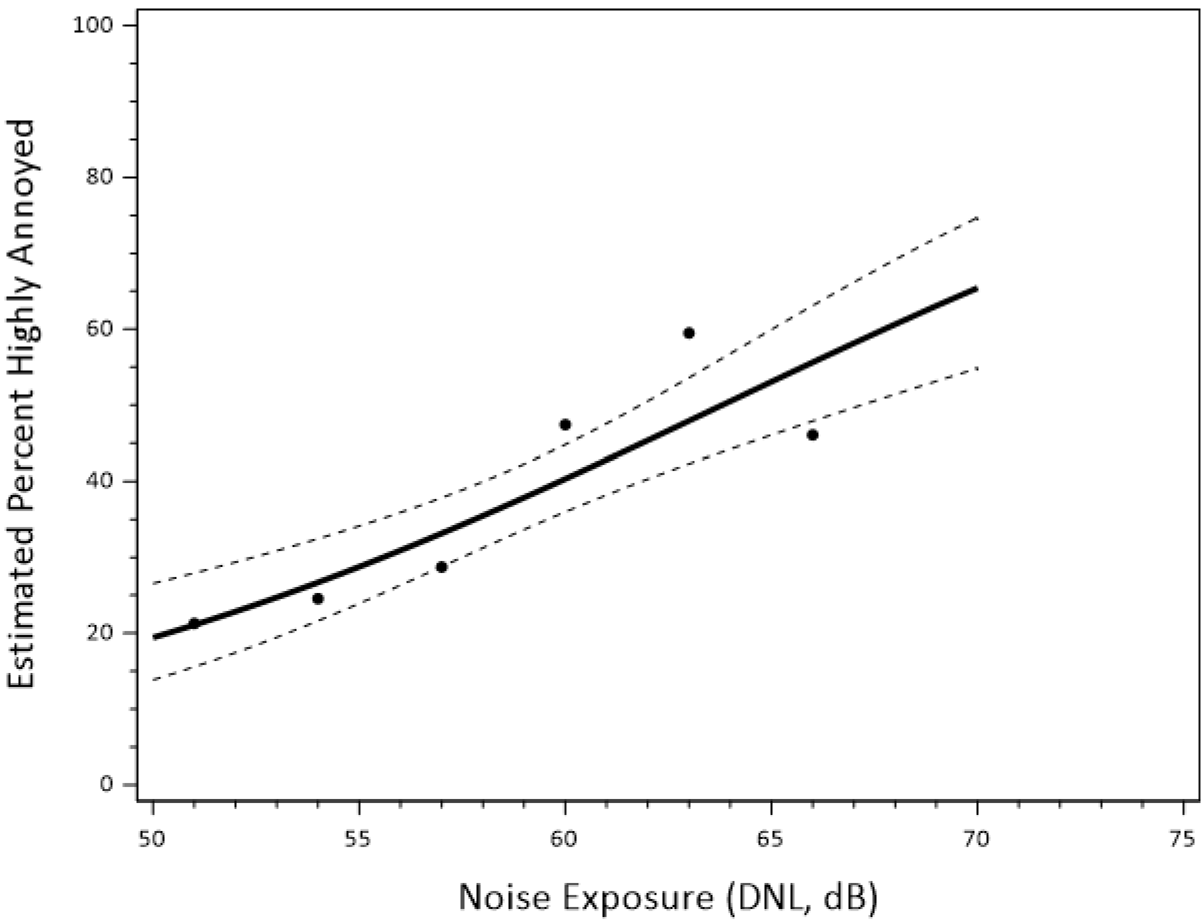

Figure I-6. Dose-Response Curve for BFI

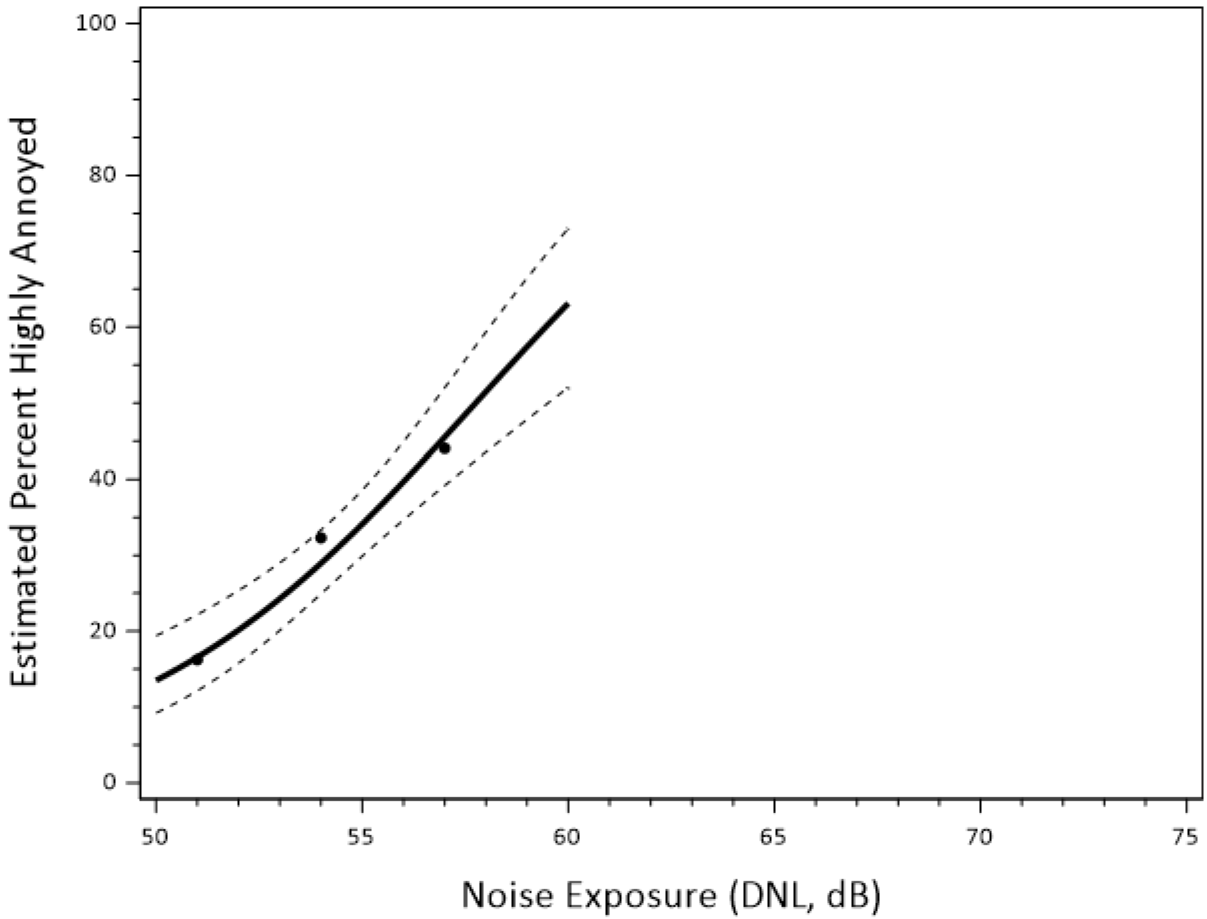

Figure I-7. Dose-Response Curve for BIL

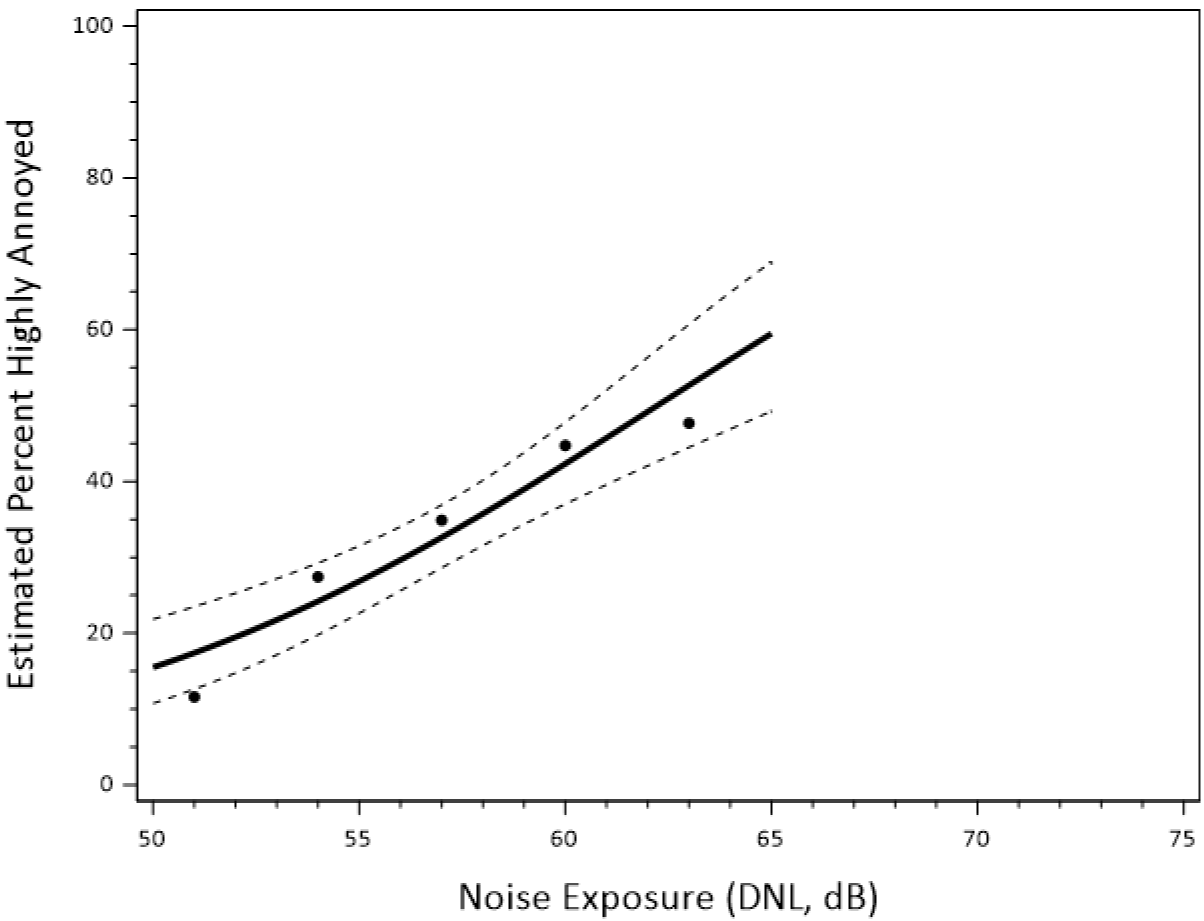

Figure I-8. Dose-Response Curve for DSM

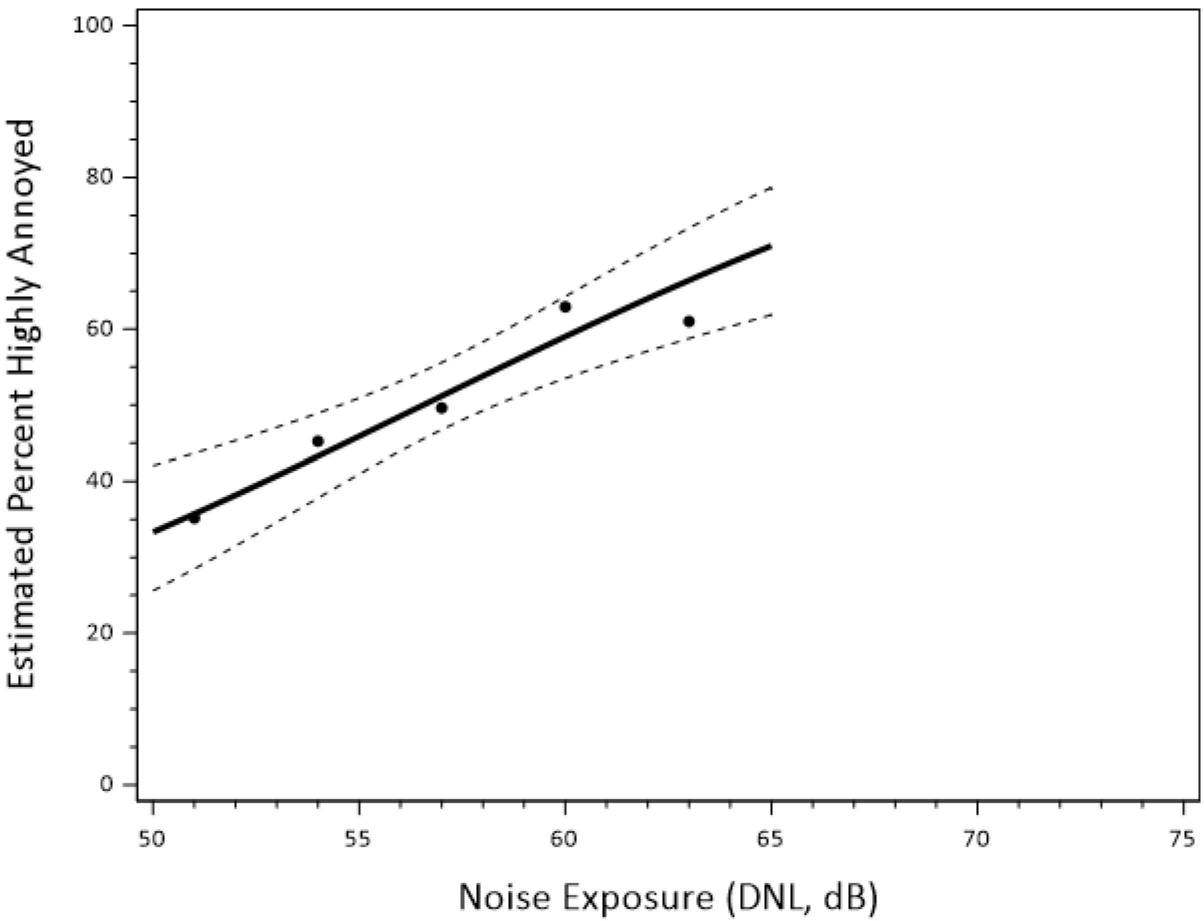

Figure I-9. Dose-Response Curve for DTW

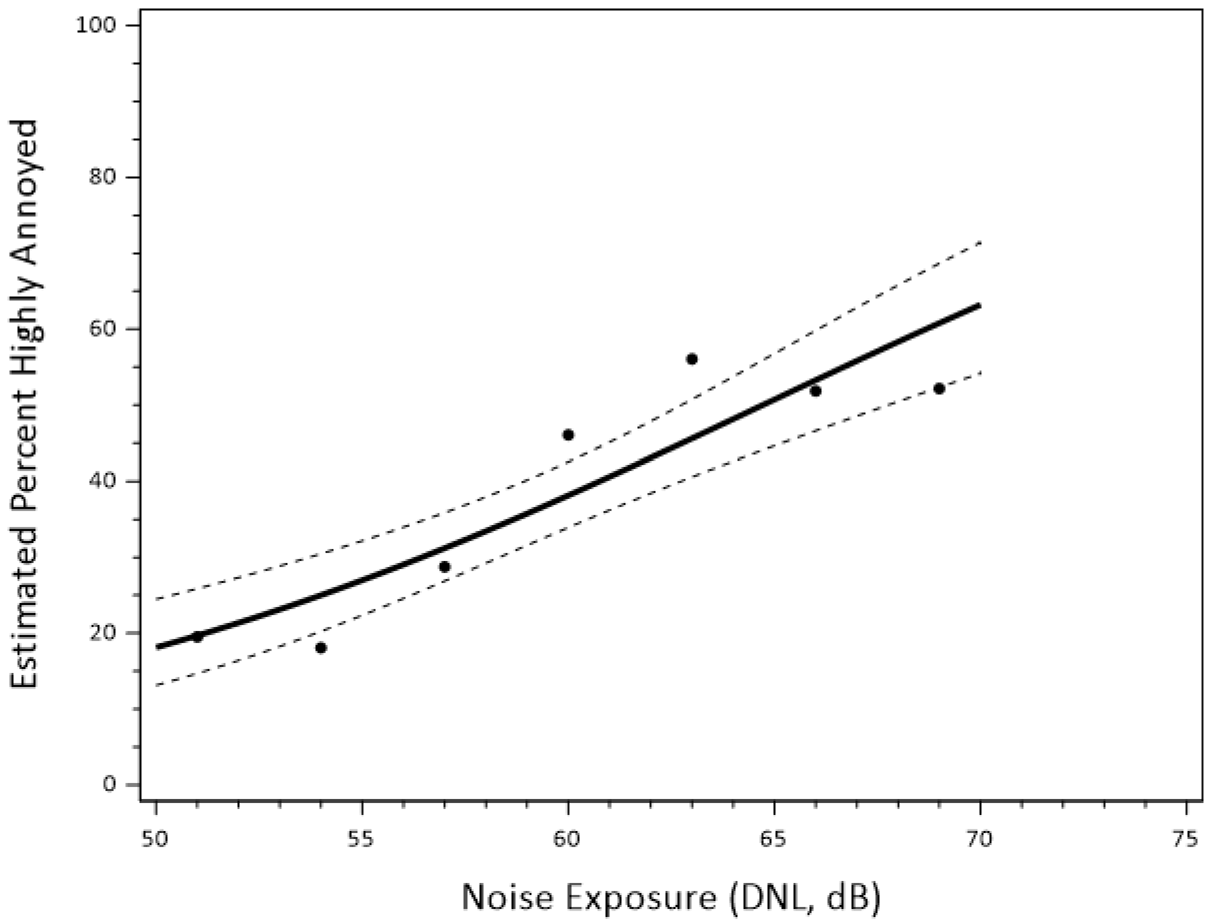

Figure I-10. Dose-Response Curve for LAS

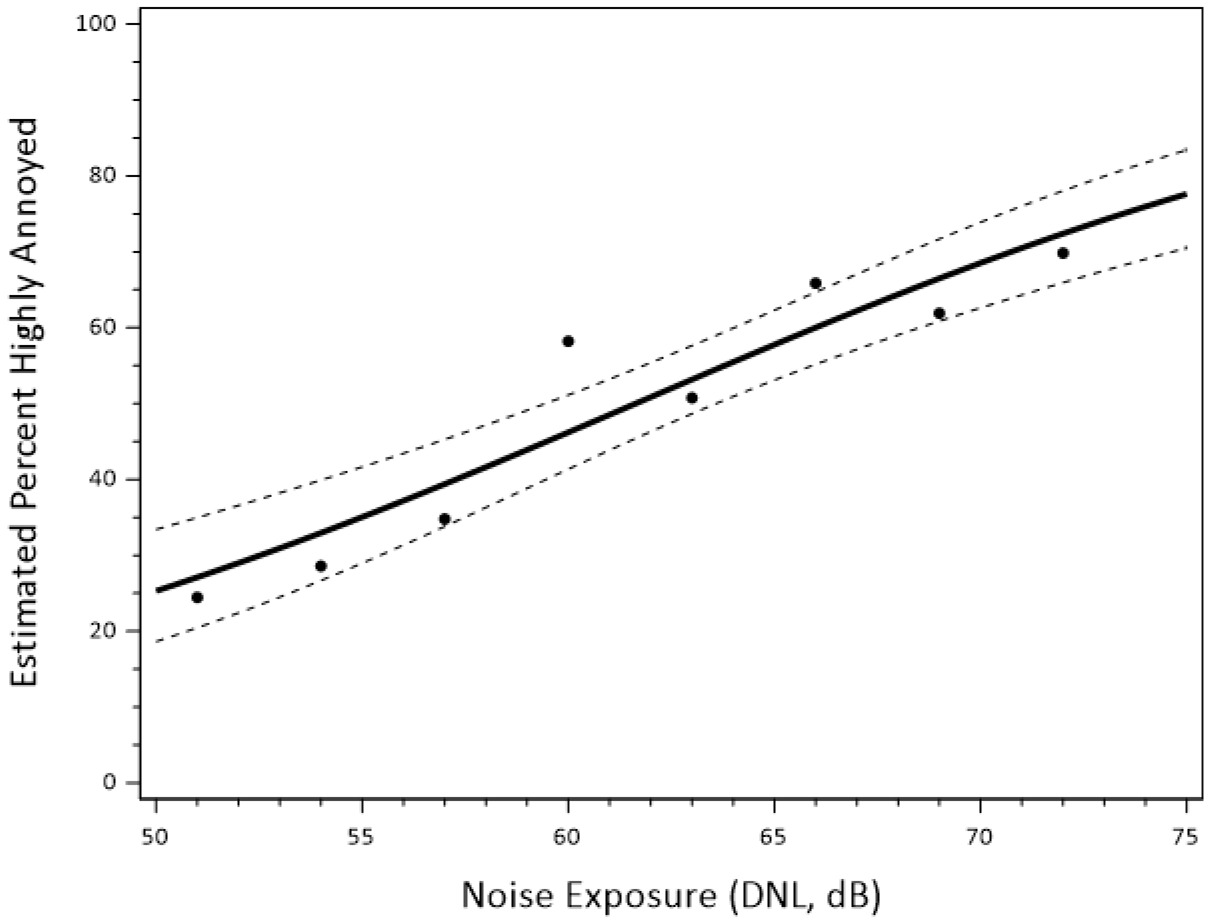

Figure I-11. Dose-Response Curve for LAX

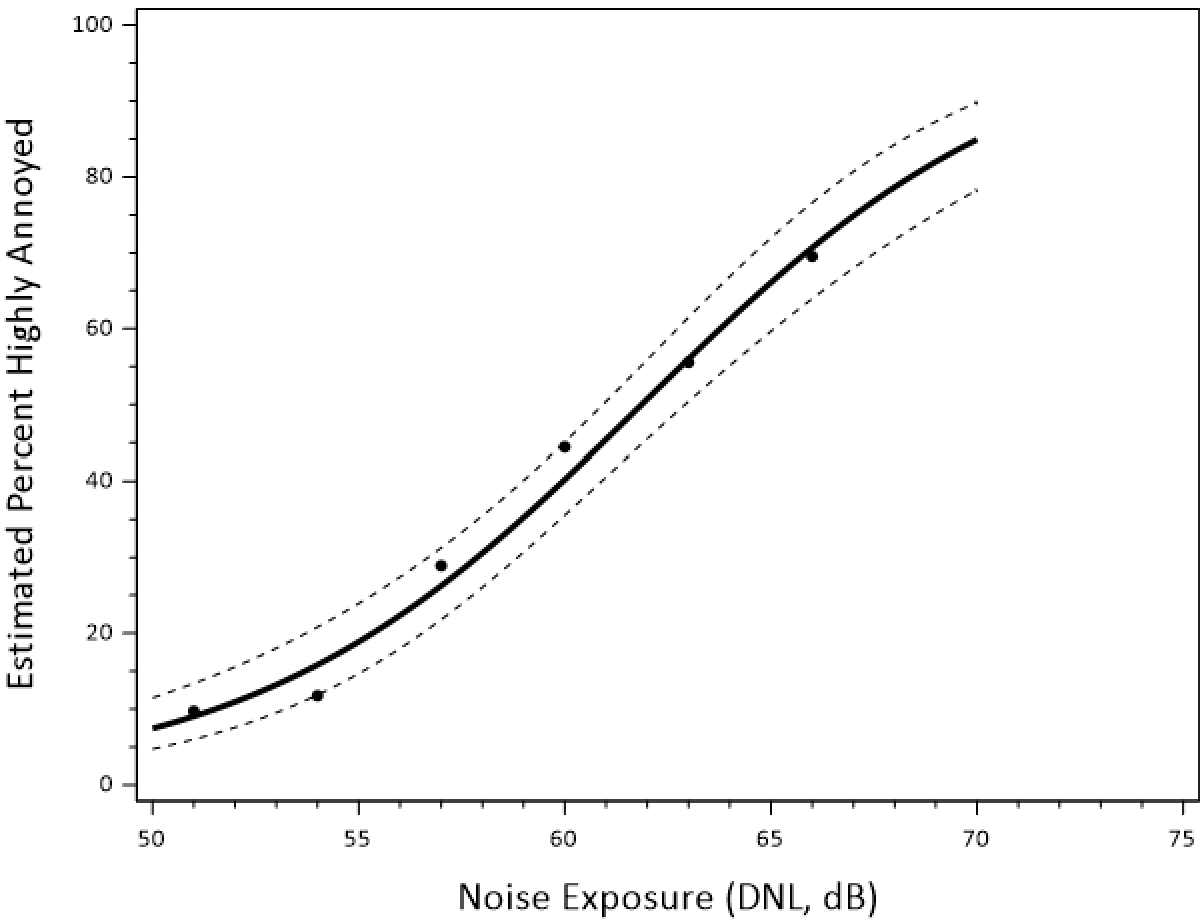

Figure I-12. Dose-Response Curve for LGA

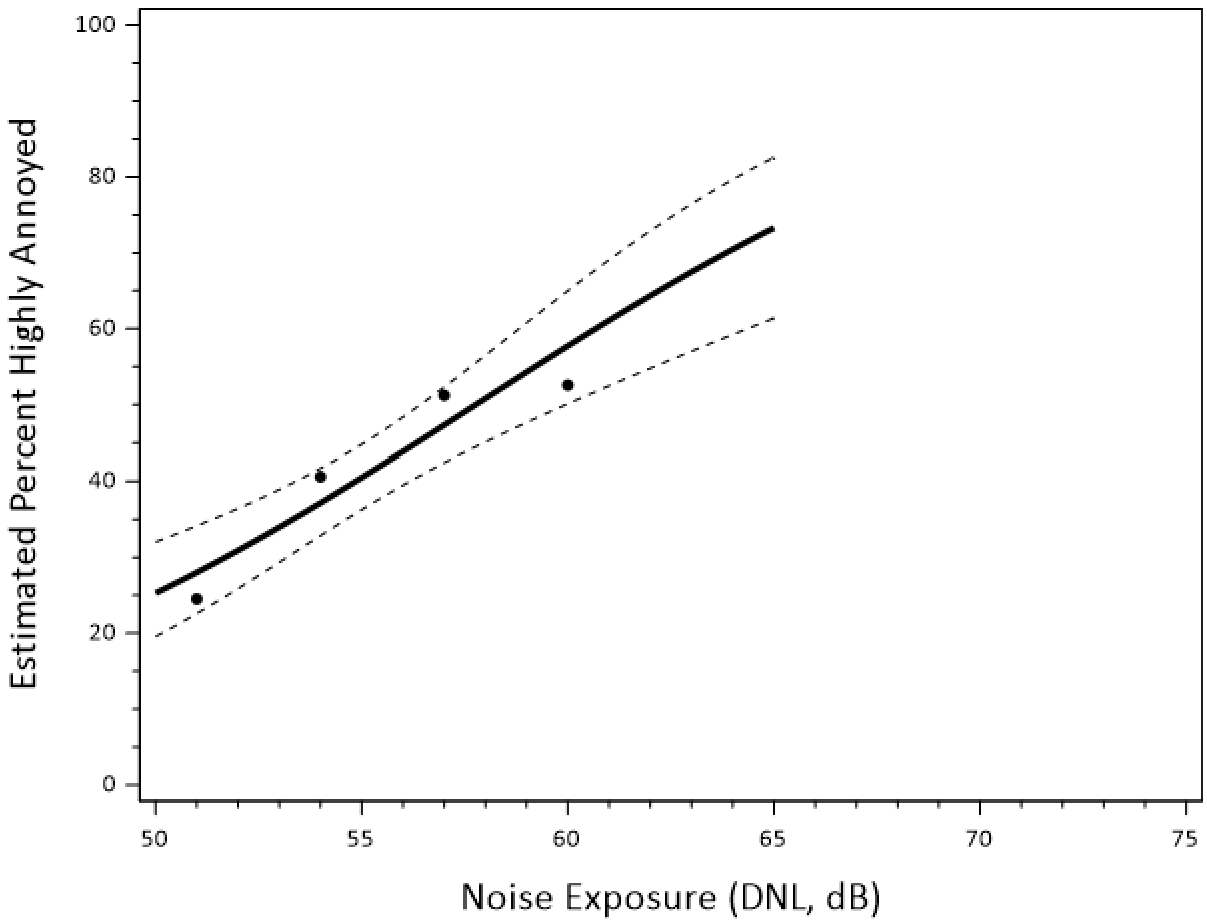

Figure I-13. Dose-Response Curve for LIT

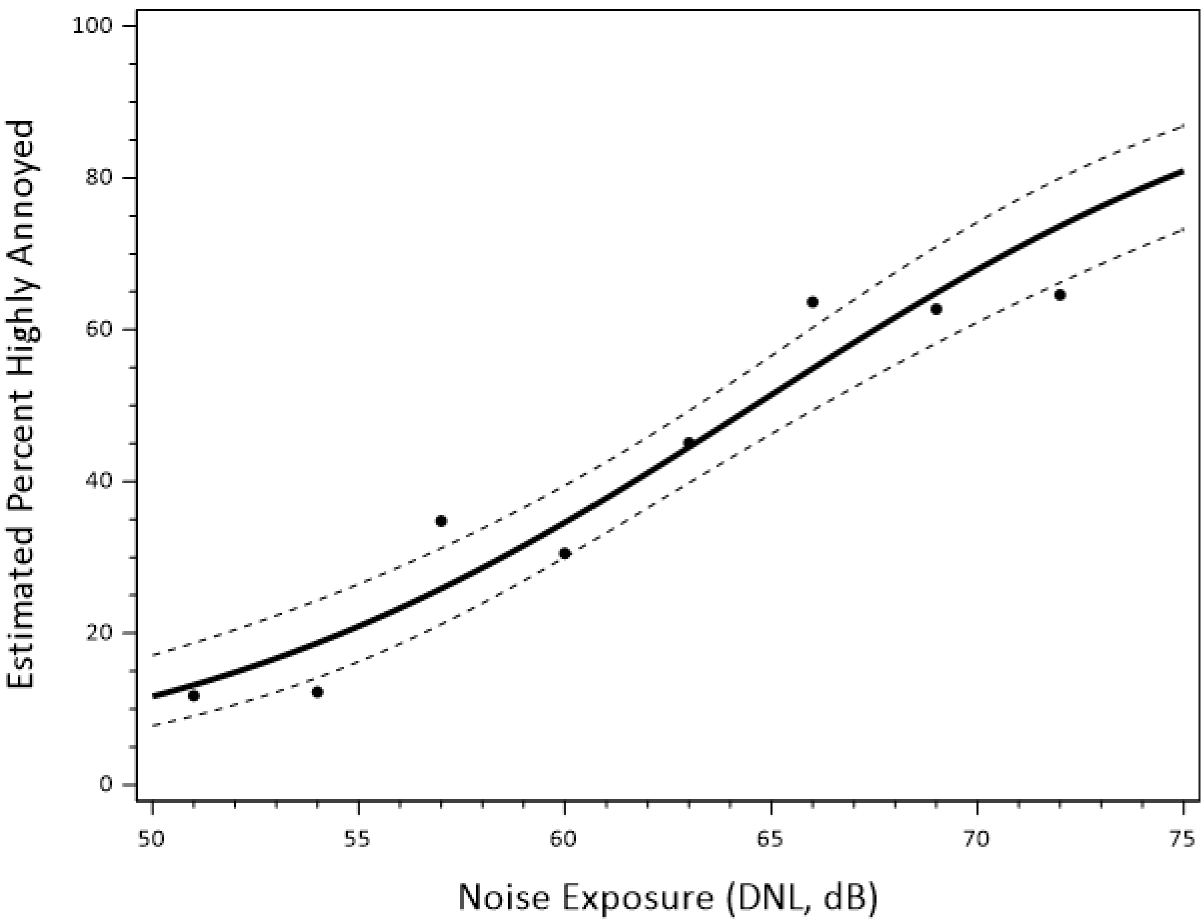

Figure I-14. Dose-Response Curve for MEM

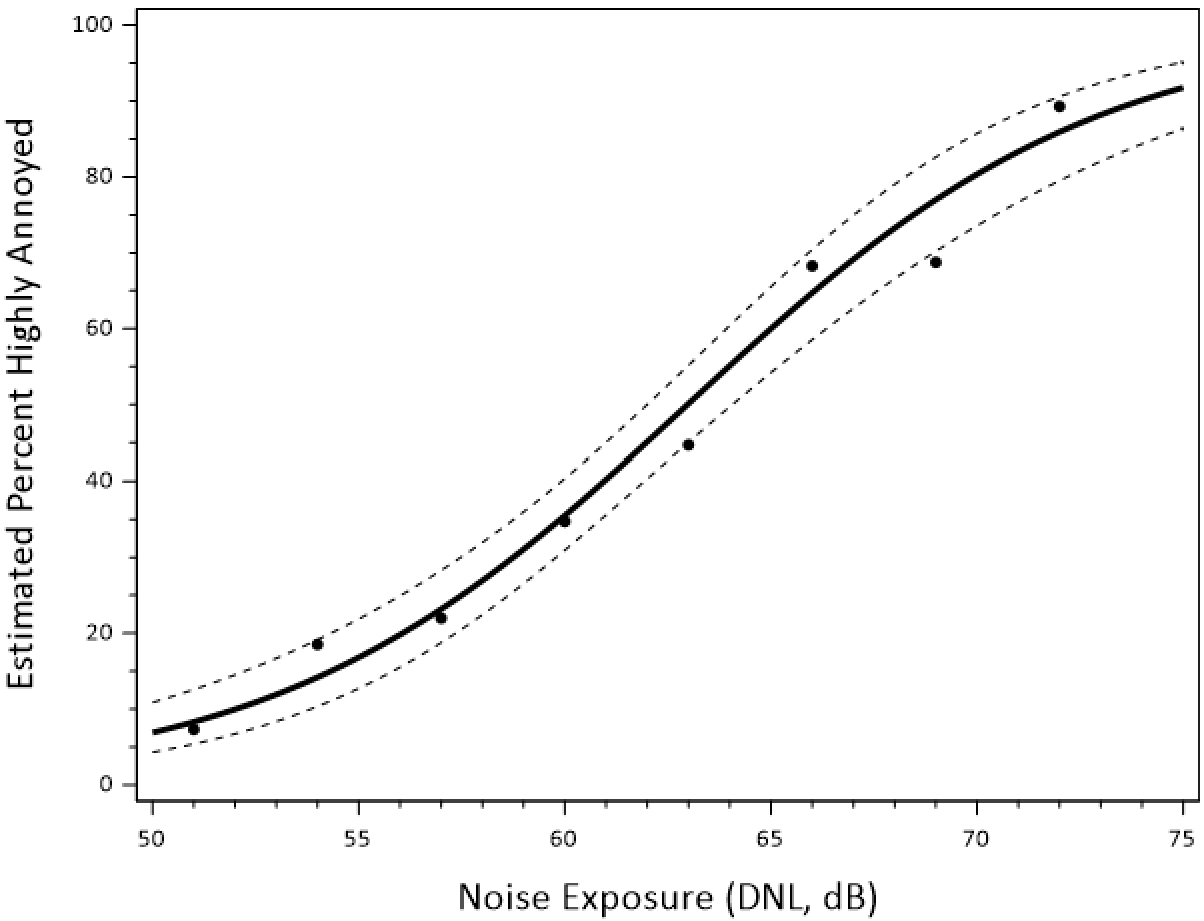

Figure I-15. Dose-Response Curve for MIA

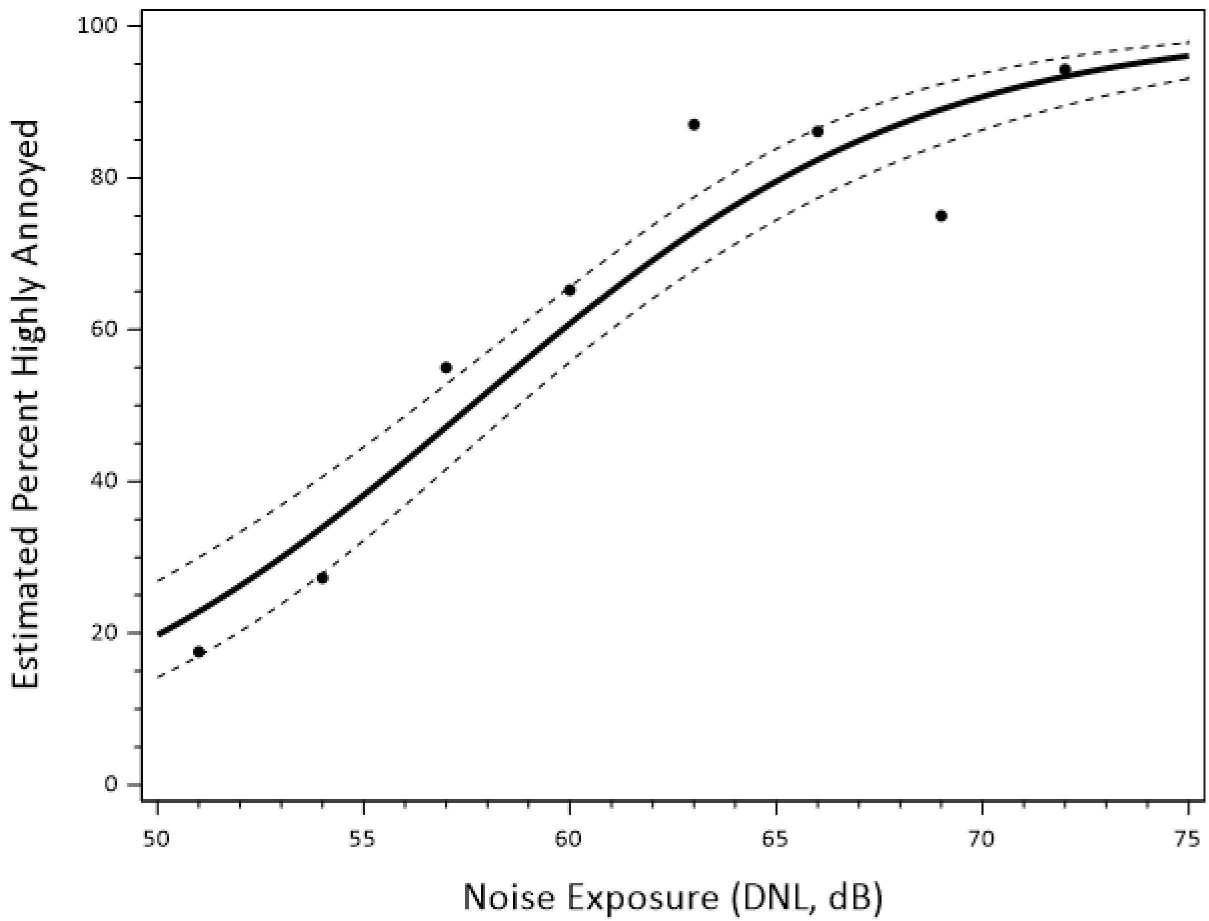

Figure I-16. Dose-Response Curve for ORD

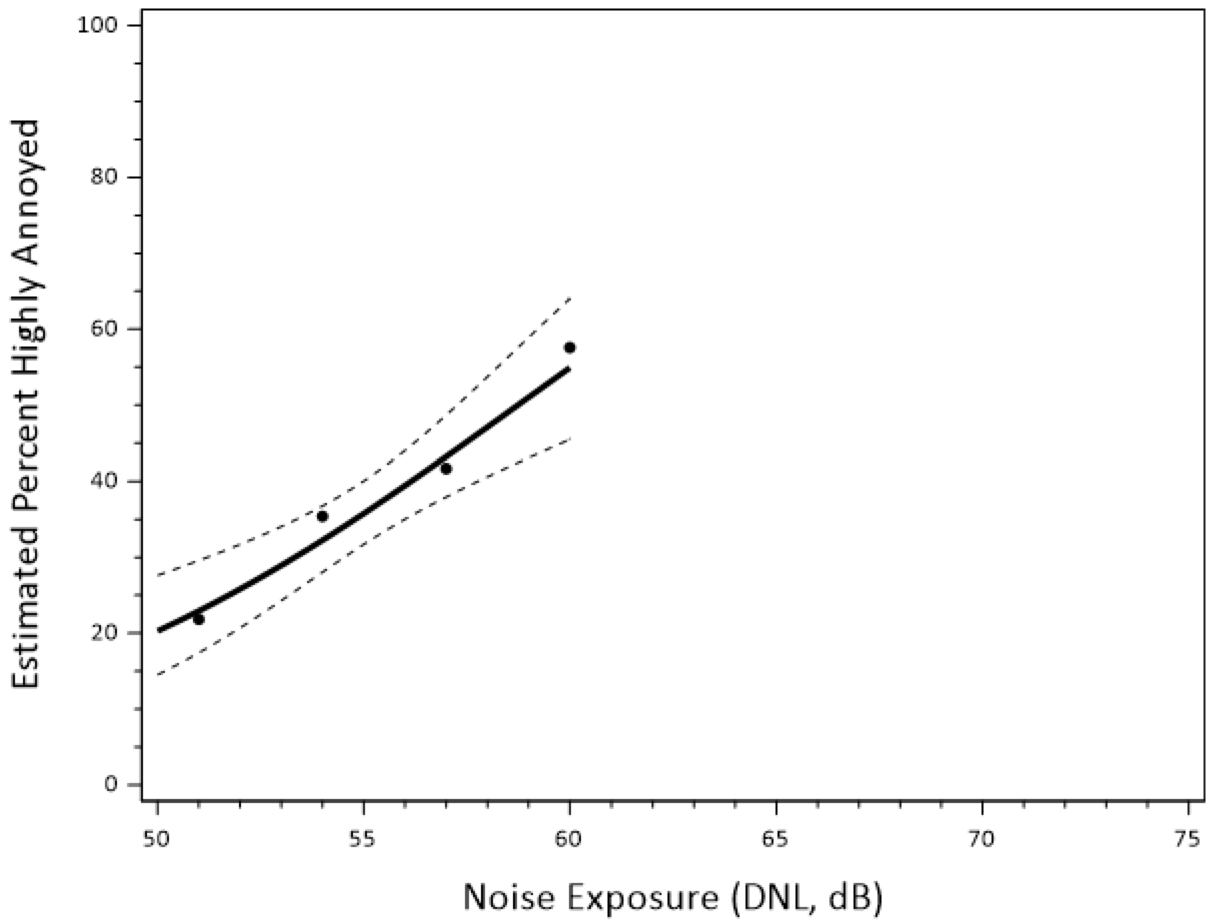

Figure I-17. Dose-Response Curve for SAV

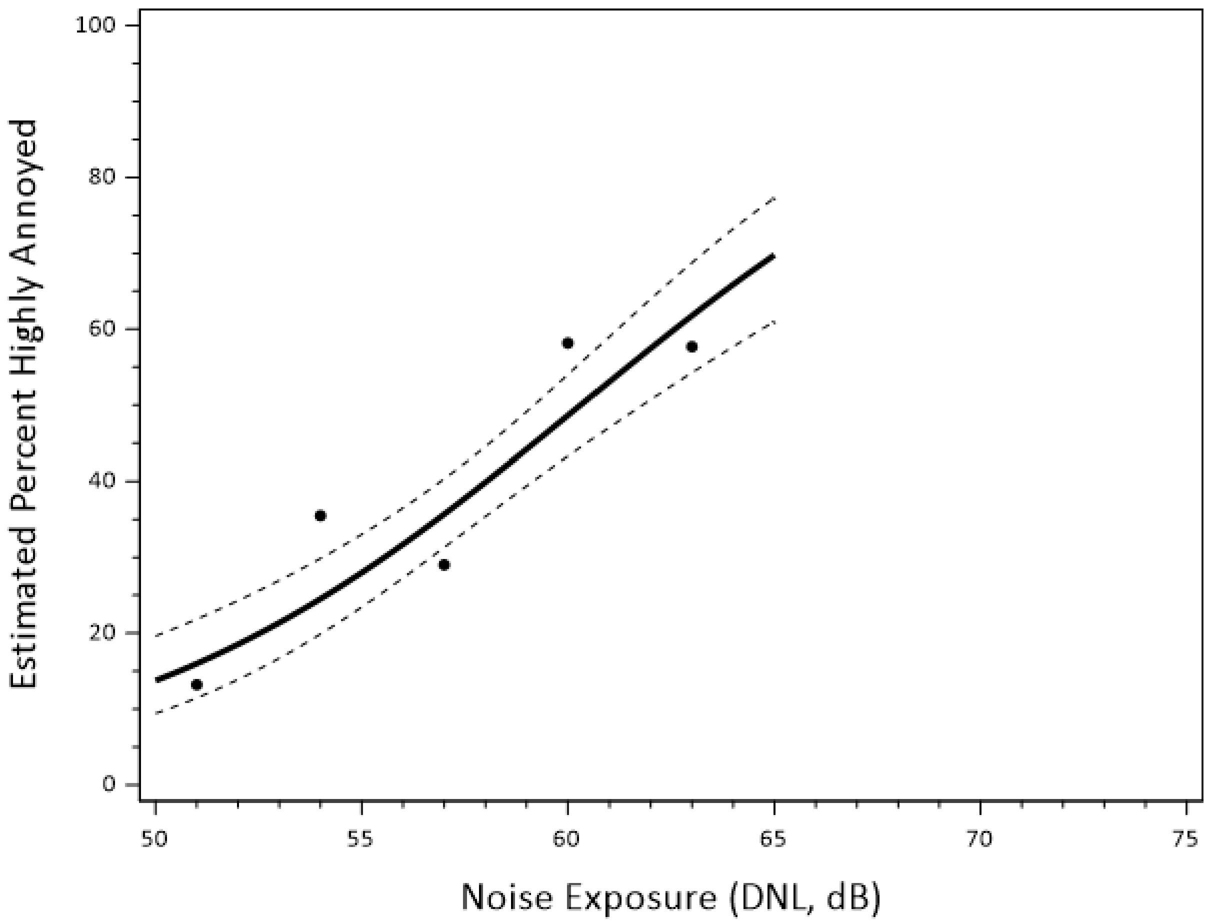

Figure I-18. Dose-Response Curve for SJC

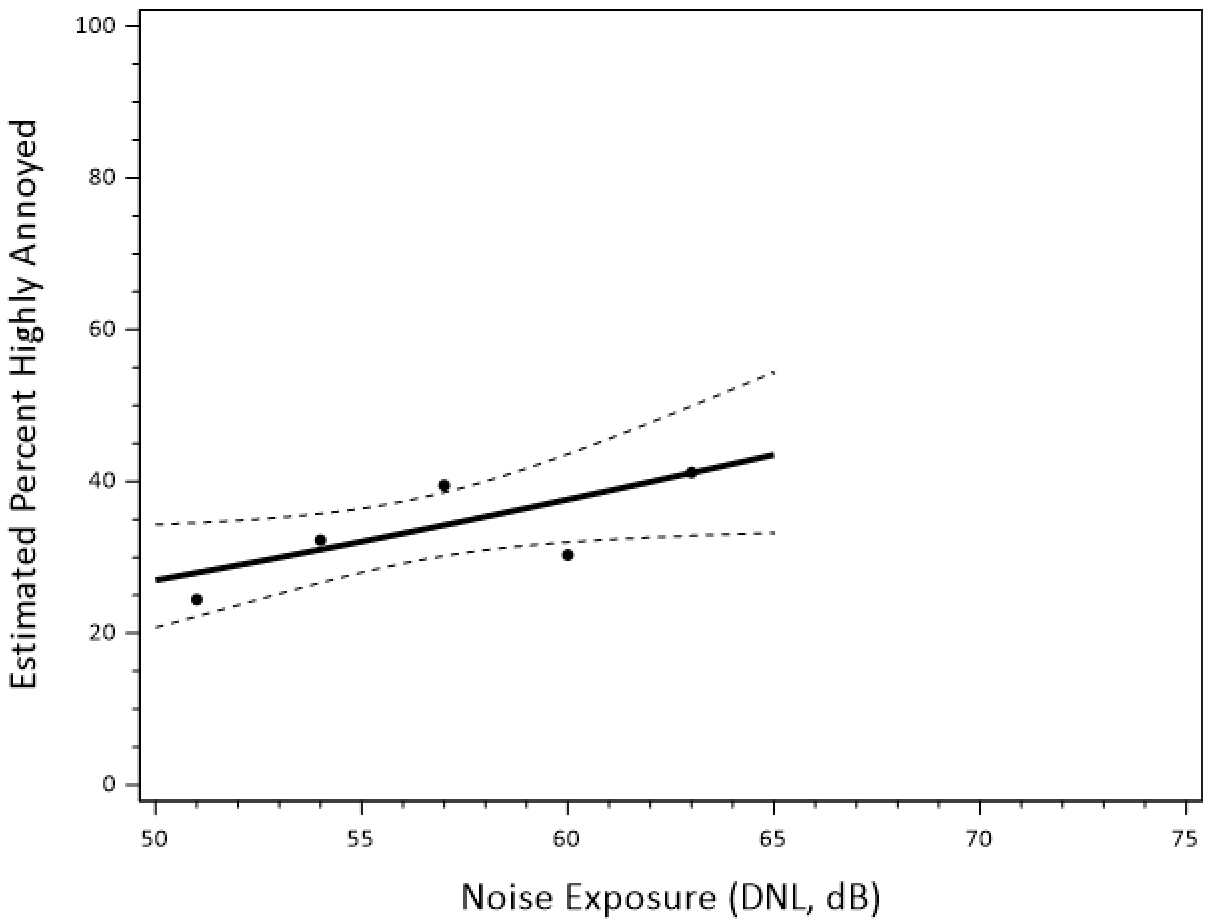

Figure I-19. Dose-Response Curve for SYR

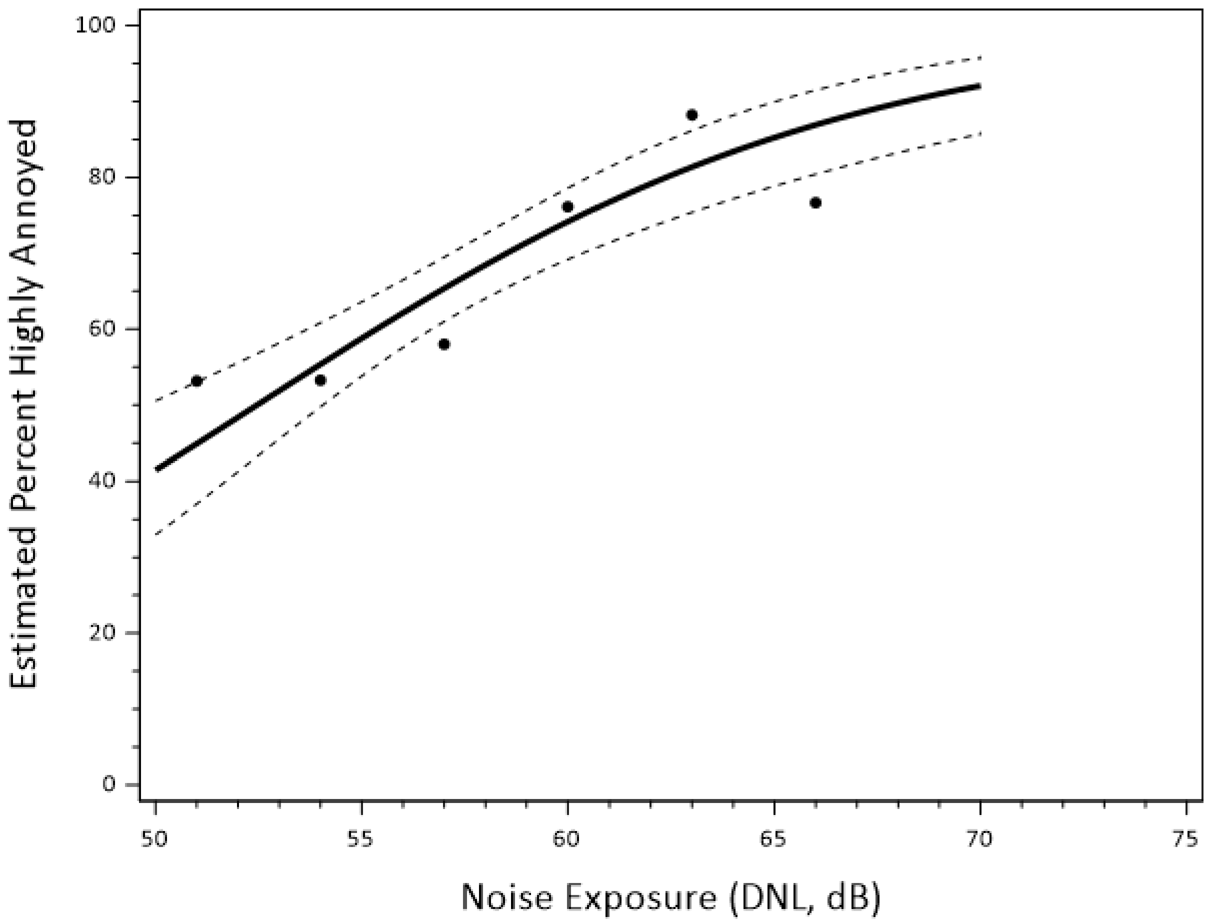

Figure I-20. Dose-Response Curve for TUS

Appendix J Methodology and Rationale for Additional Factors Analyzed

J.1 Introduction

The following six subsections describe the rationale and methodology for six factors identified by the FAA (HMMH 2016) which may aid in understanding differences in dose-response curves between airports. These factors are analyzed in Chapter 9.

1. Climate
2. "Visible" Flight Events
3. "Noticeable" Flight Events
4. "Relatively Important" Flight Events
5. Race/Ethnicity
6. Income

Each factor is analyzed to determine if it modifies the location or shape an airport-specific or the national dose-response curve. The analysis of each factor was undertaken by including extra terms in the basic regression model in Equation (1.1) that describe how the factor values modify the intercept (β_0) and slope (β_1) of the curve. The details of the statistical methods used for the analysis are described in Appendix H (Section H.3).

Factors 1 through 4 use data from calendar year 2015. The following subsections address each of the six factors.

For Factors 5 and 6 (race/ethnicity and income), analyses of whether annoyance differed meaningfully among minority populations (Section J.6) and low-income populations (Section J.7) were undertaken for consistency with the responsibilities under Executive Order (EO) 12898 and US Department of Transportation Order 5610.2(a). These require the FAA to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health environmental effects of its programs, policies, and activities on minority populations and low-income populations" (EO 12898).

J.2 Climate

Climate has been found to be associated with reports of aircraft noise annoyance (Miller et al. 2014a). In considering what climate factors would most likely encourage open windows and/or outside activity, and hence increased exposure to higher aircraft sound levels, the sum of annual cooling degree days (CDD) and heating degree days (HDD) was thought to best overall indicate a climate of moderate temperatures. The smaller the sum, the more moderate and less variable the temperatures would be.

The primary reference used for degree day data was the website of the National Centers for Environmental Information, a part of the National Oceanic and Atmospheric Administration (NOAA). NOAA provides definitions of CDD and HDD (NOAA 2017) as follows:

Cooling Degree Days:

A form of Degree Day used to estimate energy requirements for air conditioning or refrigeration. Typically, cooling degree days are calculated as how much warmer the mean temperature at a location is than 65 °F on a given day. For example, if a location experiences a mean temperature of 75 °F on a certain day, its CDD is 10 because 75 - 65 = 10.

Heating Degree Days:

A form of degree day used to estimate energy requirements for heating. Typically, heating degree days are calculated as how much colder the mean temperature at a location is than 65 °F on a given day. For example, if a location experiences a mean temperature of 55 °F on a certain day, its HDD is 10 because 65 - 55 = 10.

Detailed daily data from calendar year 2015 were used to compute annual total degree days for each airport (NOAA 2015). For a few airports, degree data were not found in the NOAA database, and a similar database derived from historical Weather Underground data was used (Weather Company 2016). A comparison of the NOAA data and Weather Underground showed virtually identical degree day data. Table J-1 shows the annual total degree days for each airport in the sample.

Table J-1. Annual Total Degree Days for the Sampled Airports, 2015

Airport Identifier	Annual Total Degree Days
ABQ	5,296
ALB	7,299
ATL	4,355
AUS	4,644
BDL	6,844
BFI	4,274
BIL	6,635
DSM	6,567
DTW	6,822
LAS	5,560
LAX	2,150
LGA	6,029
LIT	5,192
MEM	5,123
MIA	5,370
ORD	6,912
SAV	4,218
SJC	2,644
SYR	7,417
TUS	4,565

J.3 "Visible" Flight Events

The hypothesis is that the possibility of seeing aircraft increases the degree of annoyance beyond that produced by hearing aircraft.

The concept of passing over or nearly over may be quantified by the elevation angle α of the flight track above the horizon at the track point of closest approach. Figure J-1 depicts the important variables associated with the position of an aircraft relative to a receiver on the ground. The elevation angle, α, ranging from 0 degrees to 90 degrees, can specify how much "over" an aircraft flies. The slant distance determines how close the flight is to the receiver. FAA's decision was to define VISIBLE as the number of flights for which the point of closest approach has a value of α equal to or greater than 45 degrees above the horizon, and with a slant distance less than 12,000 feet. At a slant range of 12,000 feet (approximately 2 nautical miles), a Boeing 737-900 (approximately 140 feet in length) subtends slightly more than 0.5 degrees. Coupling this slant range with a field of view of 180 degrees, the aircraft would consume less than 1 percent of the field of view. With the secondary criteria of the aircraft being at least 45 degrees above the horizon, the field of view would be no more than 90 degrees and the aircraft would consume much less than 1 percent of the field of view. The secondary criteria was chosen because at angles less than 45 degrees from the horizon, it is unlikely aircraft flyovers would be visible to urban or suburban respondents due to intervening trees, buildings, etc.

With its 'detailed grid' output for each respondent, the INM was used to determine the spatial relationship of aircraft flights with respect to a given location on the ground.

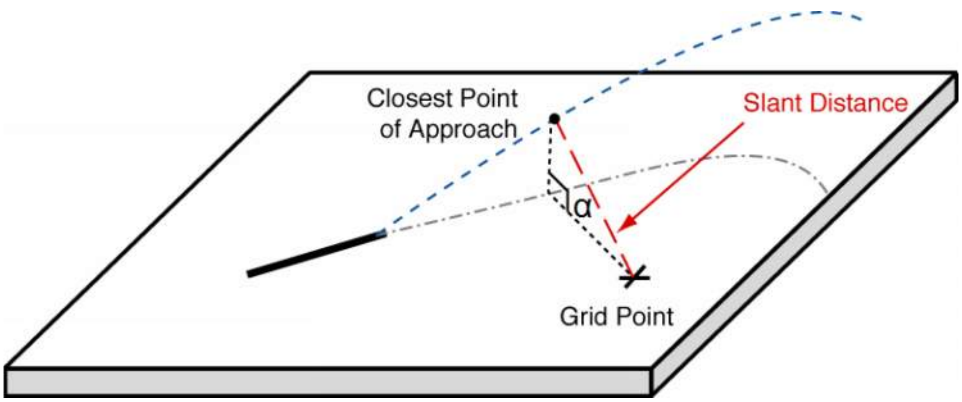

Figure J-1. Concept of Point of Closest Approach, Slant Distance, and Elevation Angle, α

J.4 "Noticeable" Flight Events

The concept of "noticeability" here means that some aspect of aircraft flights, possibly in addition to their sound level, may raise awareness of the planes and hence increase the annoyance. A flight event was deemed 'noticeable' if it had a Maximum (A-weighted) Sound Level (L_{max}) of at least 50 dB at the respondent's location. INM's computation of DNL includes every modeled flight track, and many of those events may have low sound level, making them unlikely to be noticed or even detected by the respondent. The number of noticeable flight events gives an alternative view of noise exposure that concentrates on the events thought to be most likely to annoy a respondent.

Aircraft events must exceed some sound level if residents are to notice them. Various research efforts have addressed noticeability from the perspective of whether such variables as background noise or task accomplishment affect when a test subject becomes conscious of an intruding sound. One study (Potter et al. 1977) found that "test subjects required [audible warning device] signals about 6 to 12 dB above those that an ideal [completely attentive] observer would require to detect essentially all warning signals with a negligible false alarm rate." The test subjects were required to accomplish tasks to steer the test vehicle and to maintain a constant speed and to brake when they heard the signal.

Another study (Sternfeld et al. 1972) divided subjects into two groups, one to do work tasks, the other to do leisure activities. The study reported "during leisure activities there were more occasions when the VTOL aircraft sounds were not noticed than during work activities."

For testing of whether "noticing" more events results in more annoyance, it was assumed the event noise needs to be noticed because subjects are usually engaged in some task while at home. In other words, it was not expected the respondents would normally be sitting outside, waiting to hear an aircraft (detection). From Potter (1977), it is estimated that noticing during a task occurs when the event's noise level is approximately 10 dB above detection. For typically shaped background levels (sloping downward from low frequency levels to high frequency levels at about 4 to 6 dB per octave), jet aircraft can be detected when their A-weighted level is about 7 dB lower than the background noise (Miller 1997). For noticeability, the jet aircraft noise must be about equal to the background noise. For the survey areas, it is assumed that the non-aircraft outdoor background levels generally are below 50 dBA for at least 50 percent of the day. Hence, using a threshold of 50 dBA for counting "noticeable" aircraft seems reasonable.

Using INM's detailed grid point output, the Number of Events (at or) Above a L_{max} of 50 dBA (or NA50 L_{max}), NUMBERABOVE50, was computed for each respondent location.

J.5 "Relatively Important" Flight Events

An alternative description of the objective of this analysis is: At a given exposure in terms of DNL, are people who experience many lower level events more likely to be annoyed than people who experience fewer high level events?

The DNL at any particular location is composed of the contributions from many different aircraft operations. Some of these aircraft operations make a large contribution to the total DNL because the aircraft was a relatively loud aircraft type, the aircraft flight path was very close to the location, or the aircraft operations occurred at night. Typically, a large number of operations at the airport contribute little to nothing at a particular location because they do not fly near the site.

The variable, IMPORTANT, reports the number of important aircraft operations at a particular location by quantifying the number of aircraft operations on an average annual day necessary to produce a DNL one decibel lower than the total DNL. The contributors to the total DNL at each location were ordered from highest to lowest partial DNL (most important to least important). Starting with the highest partial DNL and progressing toward the lowest, the partial DNLs were added until the sum reached a value one decibel lower than the total DNL. As these noise values were added, the number of aircraft operations represented by each contributor was also summed to produce the total number of important operations.

J.6 Race/Ethnicity

The NES asked each mail respondent two questions about race/ethnicity. Question 9 asked: "Are you Spanish, Hispanic, or Latino?" Question 10 asked: "What is your race? One or more categories may be selected" with response options White, Black or African American, American Indian or Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander. These questions are consistent with the US OMB's requirements for race and ethnicity classification (OMB 1997). The minority population is defined as the population that does not report ethnicity and race as "non-Hispanic white alone" (US Census Bureau 2011).

In accordance with the guidelines in FAA (2016), a variable MINORITY was created for each respondent based on the responses to questions 9 and 10. This variable had a value of 1 if the respondent reported being Hispanic on Question 9 or marked at least one of the last four response options (Black or African American, American Indian or Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander) on Question 10. The variable had a value of 0 if the respondent reported being non-Hispanic in Question 9 and marked only category White in Question 10.

Across all airports, 4,849 respondents (43.4 percent) were classified as minority and 5,136 were classified as non-minority. The 343 respondents to the survey (3.3 percent) who had missing data for MINORITY were omitted from the analysis of this variable.

Table J-2 shows the percentage of respondents at each airport with MINORITY value of 1. The percentages range from 7.4 percent at SYR to 90.7 percent at MIA.

Table J-2. Percentage of Respondents with MINORITY = 1 at Each Airport

Airport Identifier	NES Percent Minority Among Respondents
ABQ	65.7
ALB	14.3
ATL	85.7
AUS	63.3
BDL	11.0
BFI	51.2
BIL	9.9
DSM	9.2
DTW	42.5
LAS	42.2
LAX	71.2
LGA	75.3
LIT	73.3
MEM	66.3
MIA	90.7
ORD	23.7
SAV	21.4
SJC	64.9
SYR	7.4
TUS	81.5

J.7 Income

FAA guidelines (FAA 2016) specify obtaining information on low-income populations from the most recent 5-year estimates from the American Community Survey (ACS). Footnote 4 of the FAA document defines low-income populations as “those that are below the Census one times poverty level.”

The NES did not ask mail respondents about income or other information that could be used to determine poverty status. Consequently, the 2010-2014 ACS 5-year estimates were used to find the percentage below the poverty level (PCTBELOWPOVERTY) in the Census block group corresponding to the address of each respondent. The variable PCTBELOWPOVERTY is a characteristic of the block group in which the respondent resides. A respondent with PCTBELOWPOVERTY = 14.4 lives in a block group in which 14.4 percent of the population resides in households that are below the Census poverty level. The poverty status of the respondent’s household, however, is unknown; therefore, possible modifying effects of individual respondents' poverty status on the dose-response curve could not be assessed.