RONALD REAGAN WASHINGTON NATIONAL AIRPORT (DCA)
AIRPLANE NOISE ASSESSMENT
FINAL REPORT

Prepared for: The Government of the District of Columbia
Department of Energy and Environment

Prepared by: CSDA Design Group
Randy Waldeck, PE
475 Sansome Street, Suite 800
San Francisco, CA 94111

Freytag & Associates
Jack Freytag, PE

Hughes AV
Dennis Hughes

DC Government Grant No. 2018-1810-AQD
CSDA Project No. 1820.01

SEPTEMBER 2018

Table of Contents

Section **Page**

475 Sansome Street Suite 800 San Francisco, CA 94111 415.693.9800 www.csdadesigngroup.com
San Francisco • Los Angeles

List of Figures

Figure **Page**

List of Tables

1.0 Project Description

The District of Columbia (DC) issued grants to assess airplane noise impacts from Ronald Reagan Washington National Airport (DCA) on DC communities. This report is the culmination of two airplane noise projects funded by the District Department of Environment and Energy (DOEE). The Phase 1 project was conducted from January through September 2017, and the Phase 2 project from April 2018 through September 2018. Both utilized the same project team comprised of CSDA Design Group, Freytag & Associates LLC, and Hughes AV Associates; Freytag managed the initial phase and CSDA managed the second phase. The principle activities for both projects were:

- Document the air traffic control procedures and changes made from 2004 through 2018.
- Review historical noise monitoring results from the DCA Noise Monitoring Terminals (NMTs) owned and operated by the Airport Manager, the Metropolitan Washington Airports Authority MWAA).
- Review historical MWAA noise complaint records for DCA.
- Conduct independent noise measurements and monitoring to assess interior and exterior noise levels and noise exposure, awakenings from nighttime flyovers, and compliance with a national standard for noise exposure in school classrooms.
- Review the historical policies and procedures employed by the community, the MWAA and the Federal Aviation Administration (FAA) to affect air traffic control changes from 2004.
- Use the Federal Aviation Administration standard computer model (the Aviation Environmental Design Tool, AEDT) to model noise exposure for alternative DCA aircraft operational scenarios.
- Identify policies and procedures used to alter air traffic routing that may not have followed FAA and environmental protocol.
- Develop recommendations to mitigate aircraft noise exposure to DC communities.

Our studies concluded:

- There has been an ongoing and substantial increase in aircraft noise exposure to the northwest neighborhoods of DC (e.g., Georgetown) immediately east of the Potomac River.
- Aircraft noise levels in classrooms exceed the ANSI classroom acoustics standards, which may have a detrimental effect on learning.
- Nighttime aircraft noise levels inside of northwest DC residences are high enough to awaken between 12 to 33% of the population.
- Approximately 400 flights per day from DCA produce noise levels in northwest DC which is at or above 65 dBA, the level at which speech communication begins to be impaired.
- Several of the changes in aircraft routing did not follow FAA policies and protocol and were not in full compliance with the National Environment Policy Act (NEPA).
- MWAA complaint records and noise monitoring results for periods prior to 2015 are questionable and do not adequately describe the historical noise environment, nor community attitudes toward aircraft noise.
- Noise modeling results show a significant potential for noise reduction to DC communities.
- Several alternative air traffic control procedures are recommended to reduce noise exposure to DC communities.

Section 2.0 contains a glossary of terminology used in this report.

2.0 Glossary of Terms

AEDT — **Aviation Environmental Design Tool**. The FAA mandated software system designed to model aviation related operations in space and time to compute, noise, air emissions, and fuel consumption.

ATC — **Air Traffic Control**. A service operated by the FAA to promote the safe, orderly, and expeditious flow of air traffic.

BWI — **Baltimore/Washington International Thurgood Marshall Airport**, Baltimore, Maryland.

CATEX — **Categorical Exclusion**. The NEPA environmental assessment process whereby the proposed project or action is declared exempt from customary environmental review requirements.

CWG — **Reagan National (MWAA) – Community Noise Working Group.**

dBA — **A-weighted decibel**. An international standard measure of sound levels biased by frequency to approximate the subjective loudness of sounds at different frequencies. Low frequency sounds contain more acoustic energy than higher frequency sounds judged to be the same loudness.

DCA — **Ronald Reagan Washington National Airport**, Washington, District of Columbia.

DME — **Distance Measuring Equipment.** A transponder-based radio navigation technology that measures slant range distance by timing the propagation delay of VHF or UHF radio signals.

DNL — **Day-night average sound level (DNL or symbol L_{dn})**. The twenty-four-hour average A-weighted sound level after the addition of 10 decibels to events occurring between 10:00 pm and 7:00 am. DNL is the 24-hour noise exposure standard for community noise throughout the U.S. as prescribed by the Federal Aviation Administration and the Environmental Protection Agency. Appendix A provides a discussion of community noise metrics and DNL.

DOEE — **Office of Environment and Energy**. The District of Columbia agency responsible for assessing and regulating environmental issues throughout DC. DOEE is the sponsor of this project.

EPA — **Environmental Protection Agency**. The U.S. agency responsible for assessment and control of all environmental impacts throughout the U.S.

FAA — **Federal Aviation Administration**. The U.S. agency controlling all navigable airspace and aircraft transport throughout the U.S.

FICAN — **Federal Interagency on Aviation Noise**. A committee of government experts formed in 1993 to facilitate research and development regarding aircraft noise.

FICON — **Federal Interagency on Noise**. A committee of government experts formed in 1991 to review technical and policy issues about noise around airports.

FICUN **Federal Interagency on Urban Noise**. A committee of government experts formed in 1979 to develop policy and guidance on noise.

FONSI **Finding of No Significant Impact**. A NEPA determination of no further environmental assessment required.

GPS **Global Positioning System**. A satellite-based radio navigation system owned by the United States government and operated by the United States Air Force.

Heat maps Maps depicting various ranges of DNL noise exposure or flight track density by color-coding. An alternative display of DNL noise contours.

HUD **Department of Housing and Urban Development**. The U.S. agency dealing with housing issues.

IAD **Washington Dulles International Airport**, Washington, District of Columbia.

IAP **Instrument Approach Procedure.** A procedure containing a series of predetermined maneuvers for the orderly transfer of an aircraft under instrument flight conditions from the beginning of the initial approach to a landing or to a point from which a landing may be made visually. It is prescribed and approved for a specific airport by a competent authority.

IFR **Instrument Flight Rules.** One of two sets of regulations governing all aspects of civil aviation aircraft operations; the other is visual flight rules (VFR).

INM **Integrated Noise Model.** An FAA / industry computer noise modeling program widely used for evaluating aircraft noise impacts in the vicinity of airports. The INM has been replaced by the AEDT.

Metroplex A sprawling metropolitan area. The FAA defines specific metroplexes to manage ATC throughout the metroplex area.

MWAA **The Metropolitan Washington Aviation Authority**. An independent airport authority, created in 1985 with the consent of the United States Congress to oversee management, operations, and capital development of the two major airports, DCA and IAD.

NEPA **National Environmental Policy Act.** A U.S. environmental law that promotes the enhancement of the environment and established the President's Council on Environmental Quality (CEQ).

NextGen **Next Generation Air Transportation System.** A comprehensive overhaul of the National Airspace System (NAS) designed to make air travel more convenient and dependable, while ensuring flights are as safe and secure as possible. It moves away from ground-based surveillance and navigation to new and more dynamic satellite-based systems and procedures and introduces new technological innovations in areas such as weather forecast, digital communications, and networking.

NM **Nautical Mile**. A distance of 1852 meters (approximately 6076 ft. or 1.15 statute miles).

NMT **Noise Monitoring Terminal**. An MWAA monitoring system that records the time, several noise metrics, and aircraft data of individual aircraft flyover events in the vicinity of MWAA airports. There are 15 Noise NMTs in the region near DCA, three of which are located within DC.

NOP **National Offload Program**. Historical radar track and flight plan data around airports collected and managed by the FAA.

OAPM **Optimization of Airspace & Procedures in the Metroplex**. A systematic, integrated, and expedited method to implementing PBN procedures and associated airspace changes.

PBN **Performance-based navigation.** A specification that aircraft required navigation performance (RNP) and area navigation (RNAV) systems performance requirements be defined in terms of accuracy, integrity, availability, continuity, and functionality required for the proposed operations.

RNAV **Area Navigation**. A method of IFR navigation that allows an aircraft to choose a user-defined course within a network of GPS waypoints or fixes, rather than navigate using ground-based navigational aids.

RNP **Required Navigation Performance**. A type of PBN that allows an aircraft to fly a specific path between two 3D-defined points in space. RNAV and RNP systems are fundamentally similar.

ROA **Record of Approval.** Official FAA acceptance of a completed noise compatibility study under 14 CFR150.

SID **Standard Instrument Departure**. These procedures contain a preplanned Instrument Flight Rule (IFR) (i.e., ATC departure) procedure printed for pilot/controller use in graphic form to provide obstacle clearance and a transition from the terminal area (i.e., around the airport) to the appropriate en route structure.

STAR **Standard Terminal Arrival Route**. These procedures contain a preplanned Instrument Flight Rule (IFR) (i.e., ATC arrival) procedure published for pilot use in graphic and/or textual form. STARs provide transition from the en route structure to a prescribed outer location, termed a fix or waypoint, or an instrument approach fix/arrival waypoint in the terminal (airport) area. Fixes/waypoints are designated by a five-letter sequence.

TARGETS **Terminal Area Route Generation, Evaluation, and Traffic Simulation**. The FAA's procedural design software.

TACAN **Tactical Air Navigation**. A navigation system originally used by military aircraft. It provides the user with bearing and distance (slant-range or hypotenuse) to a ground-borne station. It is a more accurate version of the VOR/DME system that provides bearing and range information for civil aviation.

VFR **Visual Flight Rules**. A set of regulations under which a pilot operates an aircraft in weather conditions generally clear enough to allow the pilot to see where the aircraft is going; one of two sets of regulations governing all aspects of civil aviation aircraft operations (the other is IFR).

VOR **Very High Frequency (VHF) Omni-Directional Range.** The conventional ground-based navigation stations used by pilots to identify their positions.

XML **Extensible Markup Language**. A markup language that defines a set of rules for encoding documents in a format that is both human and machine readable.

475 Sansome Street Suite 800 San Francisco, CA 94111 415.693.9800 www.csdadesigngroup.com
San Francisco • Los Angeles

3.0 Historical Air Traffic Control Procedures

3.1 Background

The primary objective of FAA Air Traffic Control (ATC) is the safe operation of aircraft at all times throughout the U.S. aviation system. Secondary objectives are the efficient routing of aircraft and minimal environmental pollution, including noise and air quality. The FAA has established ATC procedures for aircraft taxiing at airports, taking off and landing, and travelling en route between airports. Air Traffic Controllers administer these procedures[1].

Prior to departing, commercial, charter and most general aviation, aircraft pilots file a flight plan specifying a Standard Instrument Departure (SID) routing and a Standard Terminal Arrival Procedure (STAR, an approach procedure). The requested flight plan is then processed by ATC automation prior to receiving departure clearance. If necessary, ATC will modify the requested routing and the pilot will then receive an alternate route clearance prior to departure by ATC.

The flight continues as cleared until ATC directs a change to accommodate other air traffic. Changes in flight plans occur routinely, particularly when arriving at the destination airport. Pilots are often given "vectors" by ATC directing them to fly alternate routes for landing. Thus, published procedures are often not followed because of new direction given to the pilots by ATC, particularly at the arriving airport.

There are three primary systems for ATC navigation in use throughout the U.S. today. These are Conventional, Area Navigation (RNAV) and Required Navigation Performance (RNP). These are shown in a schematic example in Figure 3-1.

[1] Reagan National. *Reagan National - Aircraft Procedures & Guidelines*. [Online]. Available: http://www.flyreagan.com/dca/reagan-national-aircraft-procedures-guidelines.

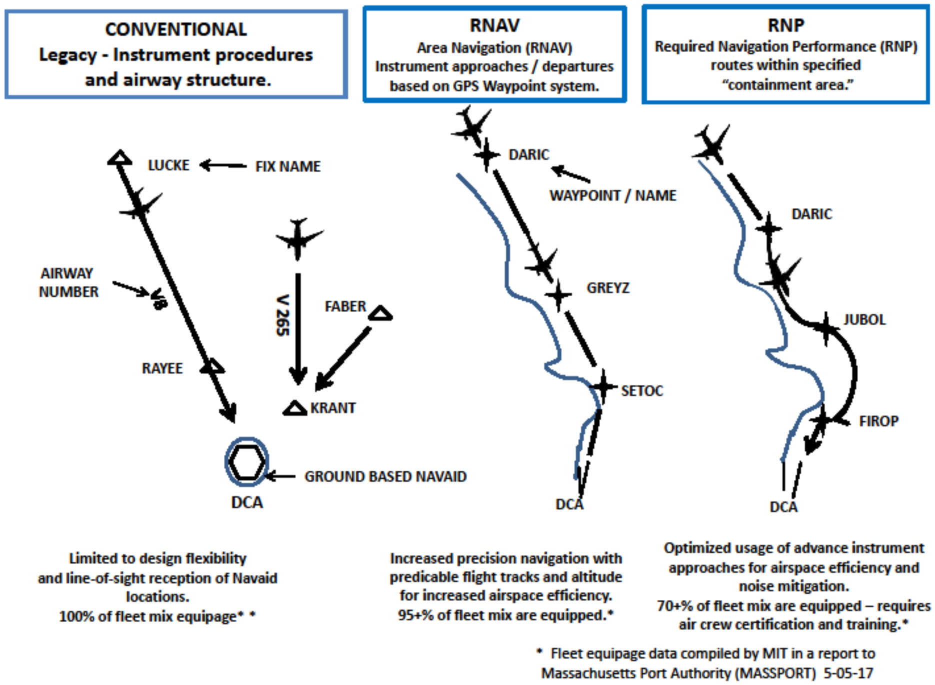

Figure 3-1: Schematic Example of Current Air Traffic Control Methods

3.2 Conventional ATC

Conventional ATC[2] is based upon a system of **Very High Frequency (VHF) Omni-Directional Range** (VOR) transmitters located throughout the country / system. The VOR system was established at the end of World War II replacing an earlier system of low frequency radio beacons. VORs serve as local 'north poles' allowing the pilot to determine their direction from the station via a 'radial', or magnetic direction from the VOR. Air routes are established along a series of VORs, termed waypoints or fixes, whereby the pilot flies outbound on a radial from one station and then inbound on a radial of the course to the next station. VOR stations are short range; the signals are line-of-sight between transmitter and receiver and are useful for up to 200 miles.

VORs are often combined with a portion of a tactical air navigation system (TACAN) to provide VOR/DME (for Distance Measuring Equipment). This gives the pilots both a direction and distance from the station. DME is often used as part of conventional STAR and SID (arrival and departure) procedures when the station is located at the airport. The pilot therefore always knows the distance to the airport runway. Also, the VOR station may be located a distance from the airport but aligned with a primary runway; this allows the pilot to fly the 'back course' with a known DME distance to the airport runway.

[2] Standard Instrument Departure (SID), Standard Terminal Arrival Route (STAR) and Instrument Approach Procedure (IAP). These procedures are available for purchase in paper or electronic format. Air traffic control procedures are published periodically by the FAA to advise pilots of acceptable methods of aircraft operation in particular areas. These procedures include Standard Instrument rm directly from the FAA or from several licensed resellers.

VOR and DME procedures are generally limited to straight line-of–sight navigation except for a procedure termed a 'DME arc' whereby the pilot flies a constant DME distance radius from the station tracing an arc from the station.

3.3 Area Navigation (RNAV)

With the advent of global positioning system (GPS) satellites, it was no longer necessary to use ground-based VOR stations to establish aircraft waypoints or fixes. RNAV[3] was first implemented in the 1990s. This was a great savings over the conventional VOR system since it no longer required large ground-based transmitters, real estate, power, calibration, etc. The VOR system remains in use today for earlier aircraft without RNAV capability; however, VOR is being rapidly replaced by RNAV and VOR stations are being phased out. Most aircraft, including smaller general aviation planes, now have RNAV capability.

The RNAV system, like the VOR system, is capable only of straight-line navigation and arcs. However, RNAV does afford greater flexibility in routing as it is feasible to place RNAV waypoints much closer together than VOR stations. RNAV enabled routing of DCA departures up the Potomac River, something not possible with conventional VOR navigation.

3.4 Performance-Based Navigation

Performance-Based Navigation (PBN) specifies an aircraft's capability to navigate using performance standards and is comprised of RNP and RNAV systems. PBN systems provide greater efficiency and flexibility than basic RNAV systems. PBN is currently found only on air carrier aircraft and top-line business jets. Special training and certification is required for flight crews using PBN.

PBN routes are programmed into onboard autopilot systems termed Flight Management Systems (FMS). These systems precisely route the aircraft at all times. In addition to tracking waypoints, the FMS also controls the speed, altitude and turns throughout the flight. This enables PBN systems to essentially follow curved air routes.

3.5 NextGen

Next Generation Air Transportation System (NextGen) is the FAA-led modernization of the U.S. air transportation system.[4] [5] Its goal is to increase the safety, efficiency, capacity, predictability, and resiliency of American aviation. This overhaul combines innovative technologies, capabilities, and procedures that improve air travel from departure to arrival. In the year 2000, the FAA and industry came together to solve some ATC problems and modernize the system. The result of their problem solving was 'The Vision 100 – Century of Aviation Reauthorization Act' passed by Congress in December of 2003. NextGen became the "umbrella plan", covering a wide range of individual changes and programs which would become the sum of the future aviation system for the Department of Transportation (DOT) in January of 2004. This plan was further defined in the Integrated Plan for the

[3] FAA, Ronald Reagan Washington National Airport (DCA) Area Navigation (RNAV) North-Flow Departure Development History and Analysis, August 17, 2016.

[4] FAA. (2016, September 29). *NextGen Ronald Reagan Washington National Airport*. [Online]. Available: https://www.faa.gov/nextgen/snapshots/airport/?locationId=25

[5] US Government Accountability Office. (2016, November 17). *NEXT GENERATION AIR TRANSPORTATION SYSTEM: Information on Expenditures, Schedule, and Cost Estimates, Fiscal Years 2004 – 2030.* [Online]. Available: https://www.gao.gov/products/GAO-17-241R

'Next Generation Air Transportation System' in December 2004. The phasing out of noisy and inefficient aircraft was part of this vision and future plan as well as a shift from ground based navigations/radar system with radio communication, to a satellite-based global positioning system (GPS) system.

Replacement of VOR stations with GPS waypoints is a key element of NextGen, allowing for the more precise RNAV and PBN navigation protocols. RNAV or PBN navigation existed as a "test bed," before NextGen. NextGen is a multi-year plan which includes the shut-down of ground based navigational aids, aircraft upgrades for the industry PBN procedures and the modernization of the Air Traffic System. It is being implemented for more than 20 major airport areas throughout the U.S., termed Metroplexes, from 2012 to 2025.

FAA Stated Benefits of NextGen:

- Creates shorter air routes
- Saves time and fuel
- Reduces air traffic delays
- Increases air route capacity
- Provides greater safety
- Reduced controller workload
- Reduced cockpit workload
- Reduced communications
- Reduced emissions
- Reduced airspace congestion

NOTE: The term Pre-NextGen connotes the general period prior to the year 2004. Post-NextGen begins after 2025. The Washington DC Metroplex Study, which began in 2011, ended with a Finding of No Significant Impact (FONSI) issued on December 12, 2013. Actual, chronological, or approximate dates are used throughout in lieu of Pre- and Post-NextGen terminology.

4.0 Flight Track History

4.1 Historical Summary

This section provides the results of historical and incremental relocation of flights by MWAA[6] and the FAA, which commenced in 2011 and has continued into 2016. Georgetown and its historic environs have been adversely impacted by aircraft noise and from flights to and from Ronald Reagan, Washington National Airport (DCA). The Historic Georgetown community is located immediately northwest of the airport and northeast of the Potomac River. The Potomac River has evolved into a primary air route for DCA air traffic operations.

Based on historical events, this report brings the summation of events that have produced the current noise and emission impacts to DC communities and the unique composition of historic and quiet residential neighborhoods co-mingled with parks, schools, and other noise sensitive venues.

4.2 The ATC Procedures

This section summarizes the ATC procedures for DCA since 2004. These procedures are published and administered by the FAA. The history of changes in departure and arrival procedures affecting DC are discussed along with the most probable noise effects on DC communities.

The changes and noise effects discussed herein are solely from published procedures and do not incorporate information from actual monitored flight tracks or their noise impact on DC communities. Often it is necessary for aircraft to deviate from published procedures at the direction of ATC; these deviations will affect the noise impact on these communities. Such deviations are from instructions termed vectors, and their effects will be addressed in subsequent sections (for instance, aircraft fly over DC below cloud levels at the direction of vectors assigned by ATC and not according to published procedures; therefore, such noise effects are not discussed in this section).

There are nine STARs published for DCA; seven are RNAV and two are the legacy conventional type. They are:

FRDMM THREE RNAV / TRUPS THREE RNAV, RWY 19: The TRUPS STAR feeds the FRDMM STAR from the west, and intersects at the FRDMM waypoint at 8,000 feet, thence tracks to TGTHR and FERGI waypoints crossing the waypoint “above 3,000 at 210 knots.” The FERGI waypoint serves as the approach fix for both the RIVER VISUAL RWY 19 and RNAV (RNP) RWY 19 (IAPs) which track the river (north to south) landing RWY 19 at DCA.

There are two additional IAPs that feed DCA from the north: LDA Y RWY 19 / LDA Z RWY 19; both are Localizer-type directional aid (LDA) which is a NAVAID used for non-precision instrument approaches. The approach begins approximately 16.9 nautical miles northwest of the airport above 3,000 feet and proceeds southeast, over and adjacent to the river descending at a three-degree glide path, landing RWY 19.

[6] FAA. (2016, August 17). *Ronald Reagan Washington National Airport (DCA) Area Navigation (RNAV) North-Flow Departure Development History and Analysis*. [Online]. Available: https://www.faa.gov/nextgen/communityengagement/dc/media/KDCA%205%20Year%20North%20Flow%20Departure%20Analysis.pdf.

CAPSS TWO is an arrival from south of the airport, starting at 22,000 feet, proceeding north, terminating at the PACKE waypoint (approximately 10 miles east of Dulles / 1.8 miles west of Tysons Corner) northwest of DCA at 6,000 feet. Aircraft landing RWY 19 at DCA can expect radar vectors to final approach.

CLIPR ONE is an arrival from the north east, starting approximately 55 miles north east of Baltimore, above 11,000 feet descending southwest to EYESS waypoint, thence to MEGGS, and terminating at NAYES waypoint at 4,000 feet. Aircraft landing RWY 19 at DCA can expect radar vectors to final. This procedure was developed for the Washington DC Metroplex, for those aircraft originating in the vicinity of the Richmond and Norfolk Airports to access an RNAV STAR and avoid leveling-off segments.

SKILS THREE is an arrival from the northeast, similar to the CLIPR, starting in Lancaster, PA, above 12,000 feet tracking to EYESS, thence MEGGS (Silver Springs, MD), terminating at NAYES waypoint at 4,000 feet. Aircraft landing RWY 19 at DCA can expect radar vectors to final.

DEALE TWO is an arrival from the east, starting above 11,000 feet, proceeding west and terminating at MEGGS waypoint (Silver Springs, MD) at 6,000 feet. Aircraft landing RWY 19 at DCA can expect radar vectors. This procedure was developed for the Washington DC Metroplex, to replace the BILIT RNAV STAR. This procedure will integrate runway transitions to support north and south operations at DCA. A runway transition was added to support a north configuration at DCA and will eliminate the need to vector arrivals to the downwind, reducing control task complexity for this arrival flow.

The TIKEE THREE arrival was developed for the Washington DC Metroplex, to support aircraft transitioning from northwest of Washington Dulles International Airport (IAD) to the satellite airports west and south of IAD. This proposed procedure will begin at ESL VOR/DME (KESSEL, WV) and transition south to BBONE waypoint, then east to LURAY and TIKEE waypoints. The following satellite airports were incorporated to support the design:

- Culpeper Regional Airport (KCJR)
- Leesburg Executive Airport (KJYO)
- Manassas Regional Airport/Harry P. Davis Field (KHEF)
- Upperville Airport (2VG2)
- Warrenton-Fauquier Airport (KHWY)
- Stafford Regional Airport (KRMN)
- Indian Head Airport (K2W5)
- Davison Army Airfield (KDAA)
- Joint Base Andrews (KADW)
- Washington Executive/Hyde Field (KW32)
- Potomac Airfield (KVKX)
- Freeway Airport (KW00)
- Shannon Airport (KEZF)
- Quantico Marine Corps Airfield (KNYG)

The IRONS SEVEN arrival is a conventional STAR arriving in Richmond, VA, above 8,000 feet, proceeding on a northerly track descending to a point seven nautical miles south of DCA, thence a heading 320 degrees. Aircraft landing RWY 19 at DCA can expect radar vectors to final.

The conventional STAR, NUMMY TWO, is an arrival beginning 40 nautical miles west of KESSEL, WV, above 17,000 feet, east bound to descending to 6,000 feet, terminating at Herndon, VA, thence a vector heading of 070 degrees, for aircraft landing RWY 19 at DCA.

A significant change in ATC departure procedures and runway usage has affected aircraft noise impacts on DC communities. This ATC change altered the departing northbound route from a straight-out departure to a predominant route over the Potomac River. Before 2011, aircraft departing the northbound route, from DCA Runway 33, climbed straight out on a runway/VOR heading (magnetic) of 328° (the 328 radial), termed the NATIONAL departure. Those aircraft departing from Runway 01 would proceed on the runway heading until an altitude of 800' MSL was attained (typically before or at the mid span of the 14th Street Bridge), and then turn northwest over the Potomac River to intercept the same 328 radial. The FAA Part 150 Airport Noise Compatibility Planning Study for DCA[7] completed in 2004 recommended shifting northbound departures eastward over the River closer to DC to reduce noise impact to Arlington County communities and to provide more precise departure routing using advanced navigational technology. The DCA Part 150 Advisory Committee concluded that the increased noise to DC communities along the River was not significant. This recommendation was ultimately disapproved by the FAA in the 2008 Record of Approval for the Part 150 study.

Figure 4-1 illustrates the legacy NATIONAL departure track (328 Radial) in yellow and the "over the proposed River departure track," originally proposed in 2004, in red. Note that the flight tracks indicated in the figure show the centerline of the flight path; actual flight tracks can vary up to one to two nautical miles from the centerline due to aircraft performance, winds, etc. Figure 4-2 shows the new flight tracks on the "over the River" (LAZIR) route and the old National flight tracks from March of 2015 (graphic provided by MWAA).

[7] Ricondo & Associates, et. al. (2004, November). *Ronald Reagan Washington National Airport, FAR Part 150 Noise Exposure Maps and Noise Compatibility Program*.

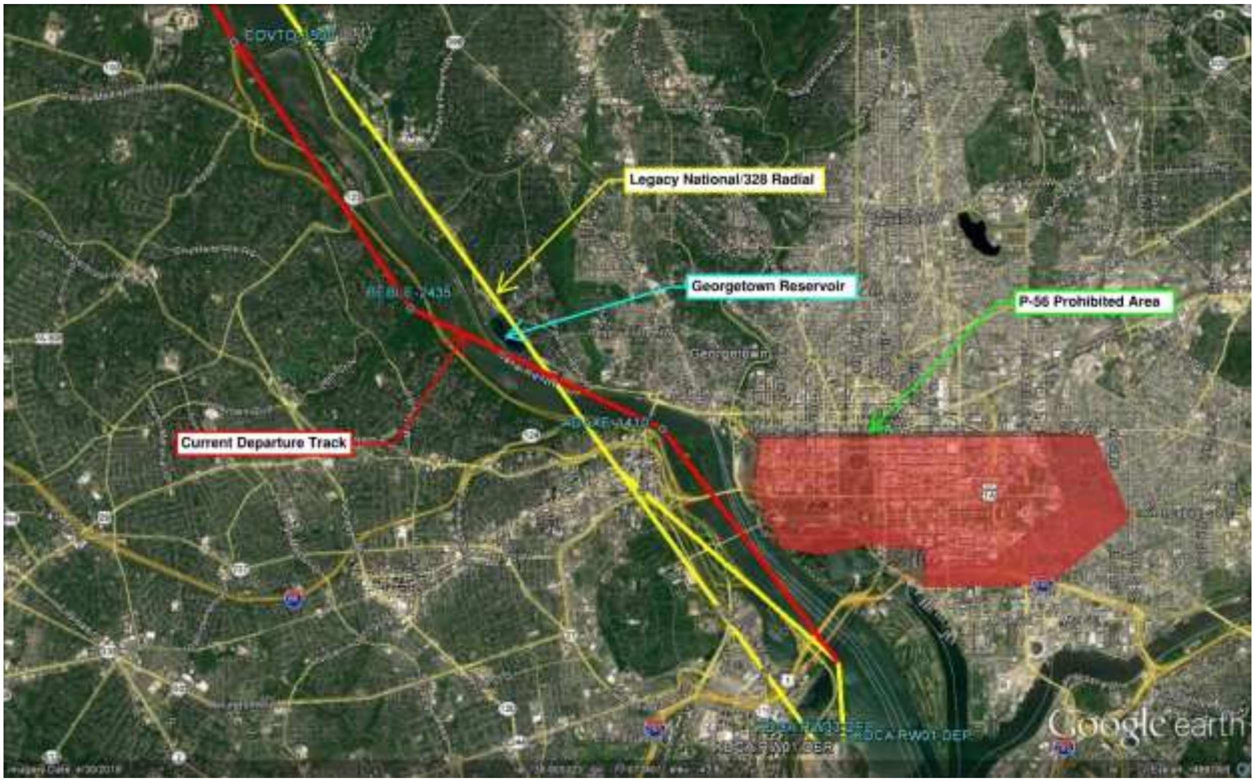

Figure 4-1: Pre-and Post-2011 Northbound DCA Departures (from published procedures)

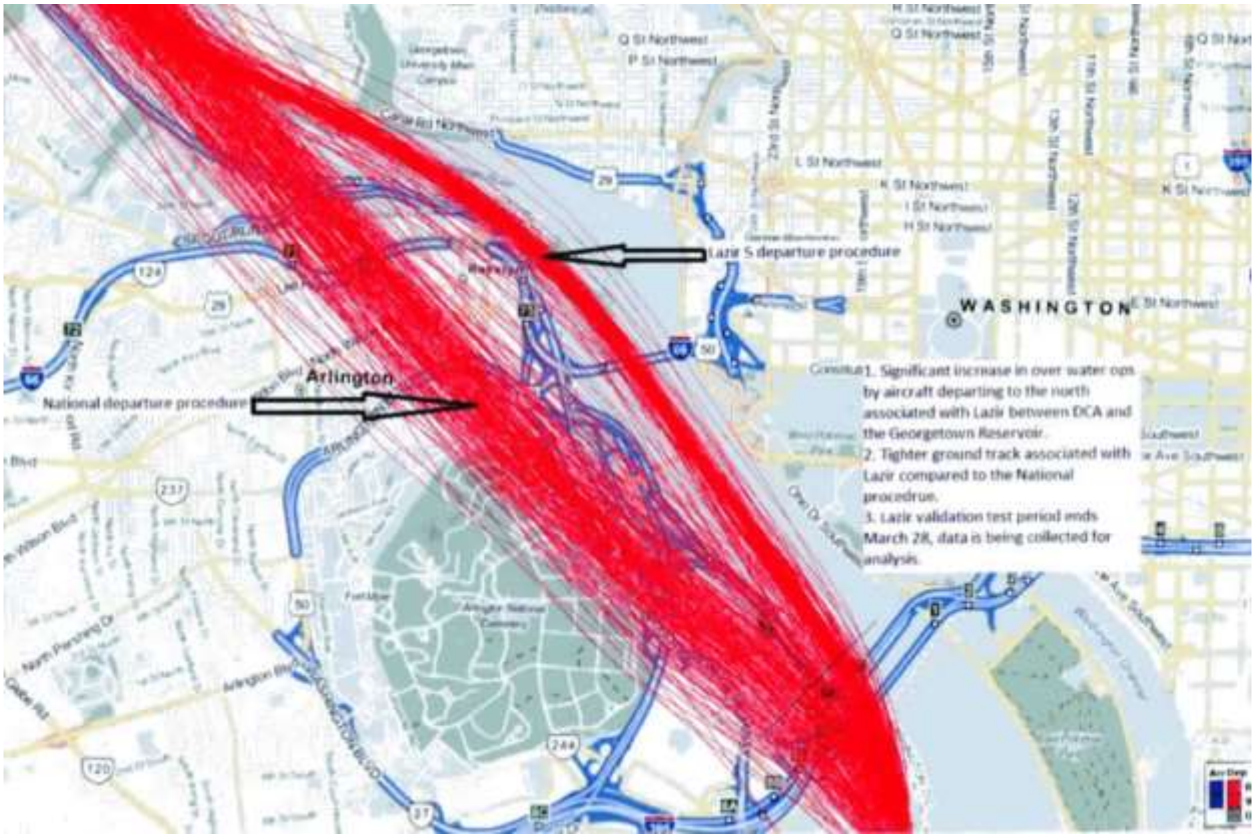

Figure 4-2: Actual Flight Tracks Flown in March 2015

The old and new routes cross near the Georgetown Reservoir, where the noise exposure is greater to DC south of this point, and greater to parts of Arlington north of the Reservoir. However, aircraft climb throughout their departure and attain a higher altitude as they proceed north. The FAA did not quantify the change in noise north of Roosevelt Island.

The new routing up the River was first implemented in 2011 by the LAZIR ONE Standard Instrument Departure (SID), and all subsequent routings followed the same initial departure track. The new routing is directed by a series of fixes, also called waypoints. Subsequent changes to ATC procedures are summarized in Table 4-1. Operational changes which affected aircraft noise exposure over DC are discussed in subsequent sections, along with recommendations for mitigating the aircraft noise.

No significant changes were made to DCA approaches from the north during this period (2011). Only the departure routes were modified.

Table 4-1: Summary of ATC Changes at DCA, YR 2008 – 2017

Start Date	Procedure (SIDs or IAPs)	Action
9-Sep-99	RIVER VISUAL RWY 19 (4)	Amended
5-Jul-07	LDA Z RWY 19	Amended
9-Jan-08	DCA Part 150 ROD	Enacted
10-Mar-11	LAZIR ONE SID	Enacted
9-Feb-12	LAZIR TWO SID	Amended
26-Jul-12	OAPM -- FRDMM RNAV STAR	Enacted
26-Jul-12	OAPM – TRUPS RNAV STAR	Enacted
20-Sep-12	LAZIR THREE SID	Amended
10-Jan-13	LAZIR FOUR SID	Amended
27-Jun-13	TRUPS TWO RNAV STAR	Amended
27-Jun-13	FRDMM TWO RNAV STAR	Amended
31-Dec-13	OAPM FONZI	Enacted
25-May-14	RNAV RNP RWY 19	Enacted
8-Jan-15	LAZIR FIVE SID	Enacted
30-Apr-15	FRDMM THREE RNAV STAR	Amended
30-Apr-15	TRUPS THREE RNAV STAR	Amended
30-Apr-15	OAPM -- DIXXE SID (E)	Enacted
30-Apr-15	OAPM -- DOCTR SID (E)	Enacted
30-Apr-15	OAPM -- SOOKI SID (E)	Enacted
30-Apr-15	LDA Y RWY 19	Enacted
30-Apr-15	LDA Z RWY 19 (3)	Amended
25-June-15	OAPM – HORTO SID (W)	Enacted
25-June-15	OAPM – BURTZ SID (W)	Enacted
25-June-15	OAPM – REBLL SID (W)	Enacted
25-June-15	OAPM – HAFNR SID (W)	Enacted
25-June-15	OAPM – WYNGS SID (W)	Enacted
25-June-15	OAPM – SCRAM SID (W)	Enacted
20-Aug-15	HAFNR TWO SID (W)	Amended
20-Aug-15	HORTO TWO SID (W)	Amended
20-Aug-15	BURTZ TWO SID (W)	Amended
20-Aug-15	DIXXE TWO SID (E)	Amended
20-Aug-15	SCRAM TWO SID (W)	Amended
20-Aug-15	LAZIR SIX SID	Amended
20-Aug-15	RNAV RNP RWY 19 (2)	Amended
15-Oct-15	LAZIR SIX SID	Cancelled
15-Oct-15	DIXXE TWO SID (E)	Cancelled
15-Oct-15	BOOCK ONE SID (E)	Enacted
10-Dec-15	RIVER VISUAL RWY 19 (5)	Amended
31-Mar-16	BURTZ TWO SID (W)	Cancelled
31-Mar-16	CLTCH ONE RNAV SID (W)	Enacted
31-Mar-16	HAFNR TWO SID (W)	Cancelled
31-Mar-16	OAPM – JDUBB SID (W)	Enacted
31-Mar-16	BOOCK TWO SID (E)	Amended
31-Mar-16	SCRAM THREE SID (W)	Amended
Always	RADAR vectoring	

4.3 Evolution of Impact on DC

In 2002, DCA began holding public meetings as part of their outreach for input into an updated noise control program that was approved by a FAA Record of Approval on June 2, 1997. The purpose of this update was to enhance the existing noise abatement program at the Airport. The last noise abatement measure, recommended in the 1997 study, was to establish a program to monitor and report on aircraft performance over the river corridors. The results of this measure then flowed into the update as a prime measure, one expected to make a significant change in air traffic control.

4.4 The Part 150 Noise Compatibility Study

In the year 2004, MWAA completed the Code of Federal Regulation (CFR) Part 150 study for Airport Noise Compatibility Planning (NCP)[8] [9], with submittal to the FAA. These studies are undertaken periodically at major airports to evaluate community noise exposure, collect community input, and develop noise abatement measures. Community participants included DC, FAA, Department of the Interior (National Park Service), Arlington County, Prince George's County, Air Transport Association, Montgomery County, EPA., City of Alexandria, MWAA, Fairfax County, Airline Pilots Association, and Citizens for the Abatement of Aircraft Noise. This Part 150 study is the origin of our history of ATC changes at DCA.

14 CFR Part 150, §150.1 Scope and purpose, states:

> *This part prescribes the procedures, standards, and methodology governing the development, submission, and review of airport noise exposure maps and airport noise compatibility programs, including the process for evaluating and approving or disapproving those programs. It prescribes single systems for (a) measuring noise at airports and surrounding areas that generally provides a highly reliable relationship between projected noise exposure and surveyed reaction of people to noise; and (b) determining exposure of individuals to noise that results from the operations of an airport. This part also identifies those land uses which are normally compatible with various levels of exposure to noise by individuals. It provides technical assistance to airport operators, in conjunction with other local, State, and Federal authorities, to prepare and execute appropriate noise compatibility planning and implementation programs.*

The DCA, Part 150 Noise Compatibility Update, Recommended Noise Abatement Measures, proposed the following in the NCP:

> *Noise Abatement Measure 1: Form a working group to develop advanced navigation procedures for arrivals and departures on all runways, encourage the use of advanced navigation technology by airlines to provide pilots the ability to follow more predictable and precise flight tracks along the center of the Potomac and Anacostia River corridors. (NCP Page VI-3)*

---

[8] RICONDO & Associates et al. (2004, November). *FAR Part 150 Noise Compatibility Program Update* [Online]. Available: http://www.mwaa.com/sites/default/files/archive/mwaa.com/file/NCProgramUdpate.PDF

[9] Federal Aviation Administration. (2008, January 09). *Record of Approval Ronald Reagan Washington National Airport*. [Online]. Available: http://www.flyreagan.com/sites/default/files/dca_part_150_noise_compatibility_update_faa_record_of_approval_2008.pdf

The proposed measure:

> *Would form a working group to identify advanced navigation procedures that would provide a more predictable and precise flight track for aircraft to follow the center of the rivers. An advanced navigation procedure could reduce the number of aircraft that stray off the river corridors, reducing noise exposure for along the river corridors. There are no residents or incompatible land uses located in the DNL 65 dBA noise contour.*

The members of the Part 150 advisory committee agreed to examine measures and options for improving the ability of pilots to navigate the center of the Potomac River. The advisory committee determined that new advanced navigation could provide the desired outcome of adherence to the center of the Potomac River and supported the development of new navigational procedures for DCA. This would result in reduced noise levels for residential land uses along the river corridors because the aircraft would follow the river on a tighter, narrower flight path. Some communities in Virginia would benefit from lower DNLs while some in DC would incur higher DNLs. The excerpt from the Part 150 Study states:

> *Residential land uses along the river corridors because the aircraft would follow the rivers on a tighter, narrower flight path. For some communities in Virginia, the reduction in DNLs was estimated to be as much as 3 dBA. It was estimated that there would be an increase in DNL of 1 dBA east of the river, over part of Georgetown, as would be expected when aircraft stay closer to the centerline of the river rather than flying over the Virginia shoreline in Rosslyn. The Committee stated that the benefit to the neighborhoods in Virginia justified the increases in noise of lesser magnitude over part of Georgetown. An advanced navigation procedure would provide a more precise and predictable flight track for aircraft to follow during both instrument and visual approaches.*

It was under this proposed measure that the FAA based the "purpose and need" for development of the LAZIR and HAMMI SIDs. FAA Orders 7100.9D and 8260.44A specified the design criteria to be used in developing RNAV procedures, including the fact that their main purpose was to improve safety, and not to be used solely for noise abatement.

The FAA, Record of Approval (ROA), 14 CFR Part 150 Noise Compatibility Program, DCA, Arlington Virginia, was signed on January 10, 2008. The ROA disallowed the "over the river" flight path recommendation contained in the Part 150 study.

Products of a Part 150 study are a noise compatibility plan and noise exposure (noise contour) maps of existing and forecast conditions. MWAA and their Part 150 Advisory Group proposed eight noise mitigation measures. One significant measure was the creation of a new departure procedure for Runways (RWYs) 01 and 33, using "advanced navigation" and "moving the flight track to the River environs."

In evaluating that measure, the MWAA consultant used the FAA's Integrated Noise Model (INM) version 6.1 computer noise model. The model assumed that all turbojet aircraft were departing from RWY 01 and would use the advanced navigation procedure. The modeling efforts showed that "aircraft followed the River centerline more closely, and that there was less dispersion of aircraft of the generalized flight tracks."[10]

We have identified the following problematic issues with the analysis of the new departure procedure:

- No RNAV Standard Instrument Departure (SID) for the airport existed nor was provided for the noise modeling. Therefore, it is unclear what exactly was modeled and does not allow us to determine whether the modeling is accurate.
- Concentrating flight tracks will naturally reduce impacts and cut out dispersion, as concentrating flight tracks narrows the noise impact areas and thereby reduces noise exposure impact.
- Flight track and altitudes used for the modeling remain unknown.
- The proposed departure procedure would add more track miles to the departure procedure, with additional emission and noise impacts.
- Procedural relocation of flight tracks, strictly for noise abatement, is not compliant with FAA Orders 7100.9, 1050.1E/F, 7100.4 and JO 7400.2G.
- The noise study is non-compliant for the development of air traffic procedures and therefore cannot be used as a basis for environmental review or approval per FAA Order 1050.1E.
- Environmental benefits and detriments are unknown.
- Added airline operational costs were not reviewed.
- An Environmental Assessment (EA) was not performed for this proposed departure route change.

Apparently ignoring these issues, the MWAA presented the Part 150 Advisory Committee with the following predictions for deliberation:

- Virginia communities could expect a DNL (day-night average sound level) noise exposure reduction, estimated to be as much as 3 dBA.
- Georgetown and vicinity could expect an increase in DNL of 1 dBA. Aircraft would be expected to stay closer to the centerline of the River rather than flying over Arlington and the commercial areas of Arlington, Virginia.

The Part 150 Advisory Committee Report compiled by MWAA's consultant stated: "the benefit to neighborhoods in Virginia justified the increases in noise of lesser magnitude over part of Georgetown." Accordingly, moving the flight track over the rather narrow portion of the Potomac River north of the airport reduced noise for residents west of the river and increased noise for residents east of the river (i.e., it transferred the noise footprint from Virginia to DC), and the increase of noise in DC was greater than the INM model predicted. Moreover, the movement of the flight track solely for the purpose of transferring noise from one community to another is contrary to FAA policy.

As the FAA's Senior Vice president for Mission Support Services correctly informed the Reagan National Community Noise Work Group (CWG) in December of 2015, "Noise cannot be eliminated, and absent a safety and efficiency purpose and need, done with all associated NEPA review and requirements, we simply cannot shift it from one community to another just because one community believes it is fairer to do so."

---

[10] Ricondo & Associates et al. (2004, November). *FAR Part 150 Noise Compatibility Program Update.* [Online]. Available: http://www.mwaa.com/sites/default/files/archive/mwaa.com/file/NCProgramUdpate.PDF

4.5 Further ATC Routing Changes: LAZIR SID

4.5.1 LAZIR ONE

One of the early RNAV procedures was the creation of the LAZIR SID from DCA in 2011. The concept for the LAZIR noise abatement measure came from the, DCA 2004 Part 150 Study. Background and procedural development documents from the FAA regarding LAZIR ONE are very limited or not available. Some documents are even being held by the FAA, exempt from the Freedom of Information Act (FOIA), by “Exemption 5 deliberative process privilege,” due to litigation.

While LAZIR development started early in 2010, several steps were required prior to its publication and implementation date of March 10, 2011 in compliance with FAA Order 7100.9. As a matter of processing an instrument procedure for publication and implementation, the FAA must complete an Environmental Review to ensure that the Federal action complies with the National Environmental Policy Act (NEPA) and its implementing regulations.

Using the FAA’s procedural design software, Terminal Area Route Generation, Evaluation, and Traffic Simulation (TARGETS) INM Noise Plug-in tool,[11] the FAA conducted a noise analysis of the LAZIR and HAMMI SIDs on September 30, 2010, in terms of the national standard ‘day-night average sound level’ (DNL) standard. The INM Plug-in is a program developed by the MITRE Corporation (proprietary to the FAA) to meet the criteria requirements of the NEPA. MITRE also built the input files for the analysis. This assessment overlays new DNL noise exposure areas over previous areas to identify areas where FAA exceedance criteria thresholds (from FAA Order 1050.1E) are found.

Posted on the MWAA web site is a link to an FAA file that refers to a noise modeling report for the LAZIR ONE; Categorical Exclusion (CATEX) under NEPA (CATEX per 40 CFR 1508.18): “2011 Original LAZIR ONE CATEX and Noise Modeling Report” (https://www.faa.gov/nextgen/communityengagement/dca/). However, the CATEX Declaration does not cite this modeling as a basis of decision.

The resulting Noise Modeling Report uses a prototype INM patch offering only an elementary evaluation of the potential noise impacts.

The TARGETS noise assessment used an existing DNL noise exposure before the LAZIR SID and used a computer model to develop the DNL with implementation of the LAZIR SID. It then subtracted the pre-LAZIR DNL values from the post-LAZIR values. This assessment overlays projected DNL noise exposure areas over previous areas to identify any locations which exceed FAA thresholds. These FAA criteria thresholds from FAA Order 1050.1E, are:

- For DNL 65 dBA and higher: +1.5 dBA
- For DNL 60 dBA to <65 dBA: + 3 dBA
- For DNL 45 dBA to <60 dBA: + 5 dBA

[11] ARJ-37, RNAV/RNP Group. (2010, September 30). *Targets INM Noise Plug-in for Ronald Reagan Washington National Airport KDCA Washington DC* [Online]. Available: https://www.faa.gov/nextgen/nextgen_near_you/community_involvement/dca/media/CAT_EX_DCA_SIDS_LAZIR_ONE_HAMMI_ONE.pdf

The TARGETS INM Plug-in output revealed two areas exceeding the FAA Order 5 dBA significant noise increase criteria. The areas are outlined in yellow in Figure 4-3. The larger area of noise increase is where noise previously at or below 60 DNL is increased by 5 dBA or more; the smaller area is where noise previously above 65 DNL is increased by 1.5 dBA or more.

Figure 4-3: FAA INM Areas of Noise Increase

The FAA Eastern-Region Service Center used the "Categorical Exclusion / Record of Decision-Short Form" for its declaration of a CATEX (categorical exclusion from NEPA). This declaration was signed by the Operations Support Group Environmental Specialist on January 26, 2011, citing FAA Order 1050.1E, Environmental Impacts: Policies and Procedures, §311p: "Establishment of new procedures that routinely route aircraft over non-noise sensitive areas." However, this citation of 311p is dubious since aircraft are routed over noise-sensitive areas. Managerial signature review was not completed until August 5, 2011.

After receiving "fast track" action by the PBN office, escaping FAA protocols and employing less than diligent quality assurance checks, the LAZIR ONE (RNAV) procedure was published on March 10, 2011: "Congressional interest per AJV-14 makes these AVN P1."

We have identified the follow problematic Issues:

- In the "Purpose" section and report body there is no reference that the findings are the basis for the CATEX.
- All environmental reviews must be completed and approved prior to the procedure being entered for production, per FAA Order 7100.9. The Report was dated September 30, 2010 and publication date for the LAZIR ONE was March 30, 2011.

- All environmental reviews must be completed and approved prior to the procedure being entered for production, per FAA Order 7100.9. The CATEX was dated January 26, 2011 and made no mention of the Report as a basis for the CATEX decision. Publication date for the LAZIR ONE was March 30, 2011.
- The Report is not compliant with FAA Order 1050.1E.
- The "Procedural TARGETS Package" was not included in the report.
- Full track evaluation was not included in the report.

4.5.2 LAZIR TWO

Amended LAZIR ONE, only change was to add note: ATC ASSIGNED (no environmental impact).

4.5.3 LAZIR THREE

Amended LAZIR TWO, update on notes and produced no noise impact.

4.5.4 LAZIR FOUR

The SID designs used in the Washington DC Metroplex are of the same initial coding (identification and location) and waypoints as the published LAZIR4 RNAV SID to COVTO waypoint they hoped would provide a consistent departure and predictable track over the River utilizing PBN procedures to avoid Prohibited Area (i.e., Areas P-56A and P-56B). The amendment change charted fix OTTTO to the west side of departure controller's frequency box produced no noise impact. The "OTTTO" waypoint was established on the procedure (charted on various navigation charts) near the town of Nottingham, Maryland.

4.5.5 LAZIR FIVE

Published on January 08, 2015, and was then canceled on August 20, 2015, due to the LAZIR SIX implementation. The LAZIR FIVE amendment added chart TOP ALTITUDE 5000 to additional flight data but produced no noise impact and replaced LON VORTAC with OTTO with additional flight data and fixes and NAVAIDS. This also caused no change in noise impact because it did not route aircraft closer to DC.

4.5.6 LAZIR SIX

The LAZIR SIX was implemented on August 20, 2015 with no track or altitude changes and removed (canceled) on Oct 15, 2015. However, it was referred to for over a year by the FAA and MWAA in presentations, public workshops, outreach material and meeting documents, as though it existed. In a review of MWAA Community Workgroup minutes dated February 16, 2017, this practice of using LAZIR continues to date. Figure 4-4 below shows the LAZIR SIX SID.

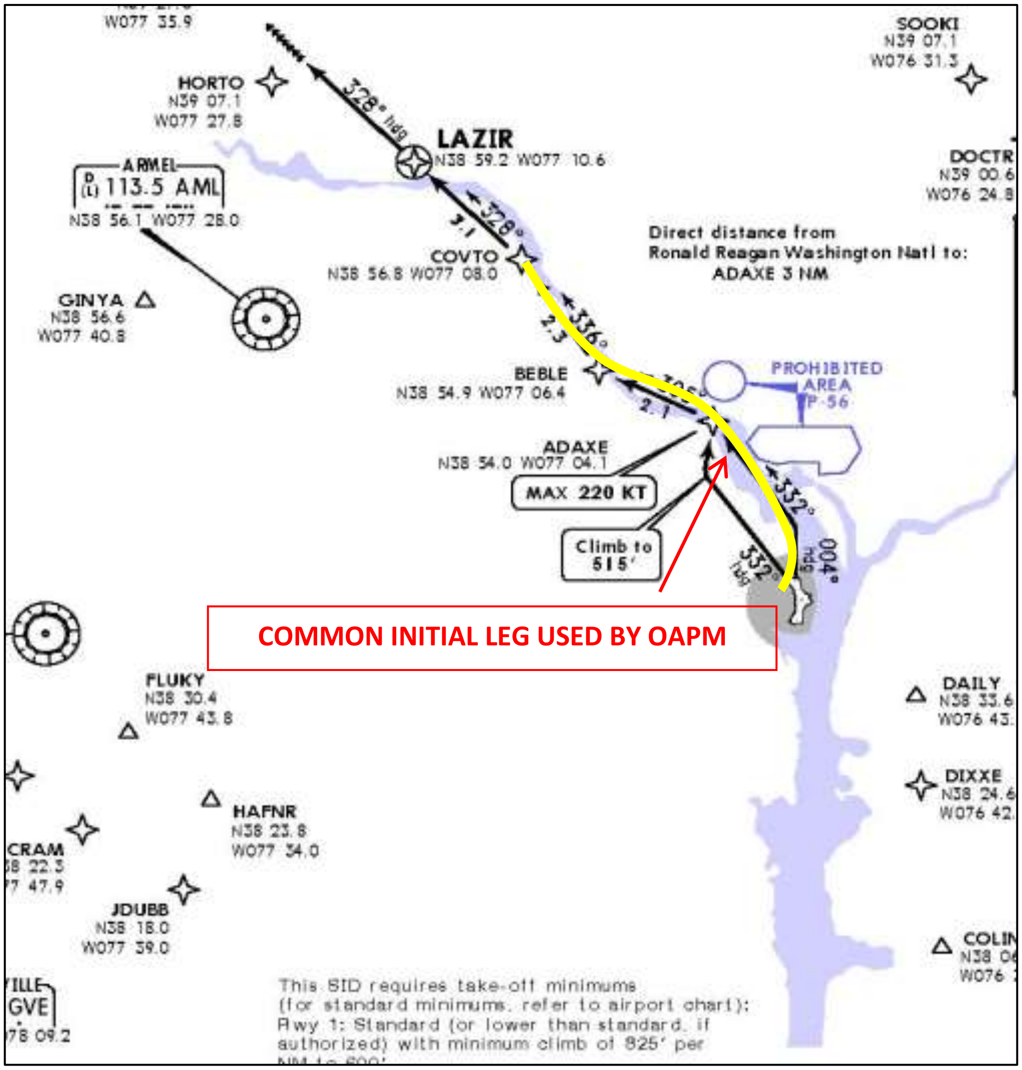

Figure 4-4: FAA Publication Chart – River Visual Runway 19

4.6 Washington DC Metroplex Study (OAPM)

Optimization of Airspace and Procedures in the Metroplex (OAPM) was developed in direct response to the recommendations from RTCA's Task Force 5 on the quality, timeliness, and scope of Metroplex solutions. OAPM focuses on a geographic area, rather than a single airport. This approach considers multiple airports and the airspace surrounding a metropolitan area, including all types of operations, as well as connectivity with other Metroplexes. OAPM projects have an expedited life-cycle of approximately three years from planning to implementation.

The DC OAPM FONSI was released and noticed to the public on December 30, 2013. The Draft EA was made available to the public on June 20, 2013 and written comments were accepted by the FAA until July 20, 2013.

OAPM are special aircraft operating procedures to minimize noise exposure and increase efficiency. From Table 4-1: Summary of ATC Changes at DCA, YR 2008 – 2017, OAPM was applied to six ATC procedures for DCA. These procedures require special on-board navigation performance monitoring and alerting systems (now typically found on most commercial aircraft) to adjust throttle conditions to minimize noise emission to ground receptors.

In September 2009, the Federal Aviation Administration (FAA) received the Radio Technical Commission for Aeronautics (RTCA) Task Force 5 Final Report on Mid-Term NextGen Implementation containing recommendations concerning the top priorities for the implementation of NextGen initiatives. A key component of the RTCA recommendations is the formation of teams leveraging FAA and industry PBN expertise and experience to expedite implementation of optimized airspace and procedures.

Historically, aircraft taking off used the maximum rate of climb available (limited by the aircraft stall speed) to maximize altitude as soon as possible. This was the safest procedure because it affords the maximum time and distance to recover from an emergency condition such as engine or control malfunction. However, with the excellent engine reliability and redundancy of a second (or more) engine, new aircraft departure procedures allow for noise abated takeoffs. Minimizing takeoff noise is complex since reducing power lowers engine noise emissions but also lowers the climb profile bringing the aircraft closer to the ground noise receptors. OAPM procedures are different for each aircraft type and automatically adjust throttle settings during takeoff to minimize noise to the community below.

Similarly, OAPM for approaches also adjusts throttle settings to minimize noise to the ground noise receptors. Basically, OAPM for approaches maximizes the glide potential and energy management of the aircraft.

In addition to reducing noise exposure, OAPM procedures also enhance fuel consumption, air safety and operational costs.

4.7 OAPM SIDs

The OAPM Study Team recommended the development of optimized PBN departure procedures and extensions to the LAZIR and HAMMI RNAV SIDs. These SIDs replaced the LAZIR RNAV SID and will extend further into the en route environment.

The SID designs used the same initial OAPM coding and waypoints as the published LAZIR4 RNAV SID to COVTO waypoint. These provide a consistent departure climb and track over the River utilizing PBN procedures to avoid the National Mall, Capitol, and White House (Prohibited Areas P-56A and P-56B). Figure 4-4 shows the OAPM SID designs.

The proposed OAPM SIDs are named as follows:

1. BUTRZ RNAV SID (CLTCH)
2. DIXXE RNAV SID (BOOCK)
3. DOCTR RNAV SID
4. HAFNR RNAV SID (JDUBB)
5. HORTO RNAV SID
6. POOCH RNAV SID (SCRAM)
7. REBLL RNAV SID

8. SOOKI RNAV SID
9. WYNGS RNAV SID

Each SID was to be integrated into the automated preferential departure routing (PDR) system to reduce control complexity for the DCA tower and the potential erroneous SID assignment. Of the nine new SIDs, all have a common initial leg with full impact to DC, and only three track eastbound when transitioning to the en route traffic structure.

4.8 RADAR Vectoring

Those aircraft being RADAR vectored off the runway or arriving are flying a magnetic heading as directed by ATC, Potomac Terminal Radar Approach Control (TRACON), DCA Air Traffic Control Tower (ATCT) and are not subject to strict navigational compliance or criteria as those assigned a SID as part of their flight plan clearance. Additionally, the traffic being vectored is not included in any environmental impact study conducted by the airport authority or the FAA. Both STARs and SIDs were developed to required Navigation Performance Level type RNP-1.

4.9 STARs

The specific routes analyzed are nine STARs. Of the nine published procedures, only two (FRDMM THREE RNAV and TRUPS THREE RNAV) feed the arrival routes north of the airport which transition to the arrival final landing south on Runway 19.

4.10 Instrument Approach Procedures (IAPs)

DCA has twelve Instrument Approach Procedures (IAPs). After preliminary review, only three have an impact on DC and are analyzed for impact: RNAV RNP RWY 19, LDA Y/Z RWY 19, and the RIVER VISUAL RWY 19.

4.11 Standard Instrument Departures (SIDs)

DCA has a total of ten SIDs for the airport. The NATION SEVEN is a legacy "conventional departure," and the other nine are RNAV procedures developed through the DC OAPM. See Figure 4-4 above.

4.12 TARGETS AEDT Environmental Plug-in Report

In May 2016, the FAA completed "TARGETS AEDT Environmental Plug-in Report" for DCA. A new group of nine SIDs were proposed for DCA in Arlington, VA as an alternative to existing routes using historic LAZIR Waypoints.[12] Using an FAA prototype noise screening tool, the Terminal Area Route Generation, Evaluation, and Traffic Simulation (TARGETS) Aviation Environmental Design Tool (AEDT) Environmental Plug-In, a noise modeling analysis was completed to screen for potential increases in noise resulting from implementation of the proposed procedures.

Historic track data was obtained and modeled to establish a baseline scenario. After the baseline scenario was established, aircraft operations assigned to the proposed procedure were modeled as flying the proposed procedure instead of their historical tracks where the procedure was modified to

[12] ATO, AJV-114, Environmental Policy Team Office. (2016, May 23). *TARGETS AEDT Environmental Plug-in Report for Ronald Reagan Washington National Airport Arlington, VA.* [Online]. Available: http://www.flyreagan.com/sites/default/files/dca_noise_screening_report-final_20160907.pdf

establish an alternative scenario. Aircraft operation counts were adjusted to represent an average annual day (AAD), and the model was used to calculate the noise exposure for the baseline and alternative scenarios on that AAD. The baseline and alternative scenarios were then compared to determine whether the procedure would result in an increase in noise by the standards of the NEPA in the environment surrounding the airport.

The results of the FAA TARGETS noise analysis indicated that no noise impact is expected because of implementation of this group of SIDs at DCA. However, the FAA abandoned work on LAZIR B so this remains an academic exercise.

4.13 Flight Track Comparative Analysis

A sample of northbound flight tracks (RWY 01) from 2010 are depicted in Figure 4-5, in the form of track density "heat maps," with warmer colors (yellow, orange, red) corresponding to a greater density of departure flight tracks. The AEDT heat maps have been produced, in compliance with FAA Order 1050.1F, from National Offload Program (NOP) radar track source data.

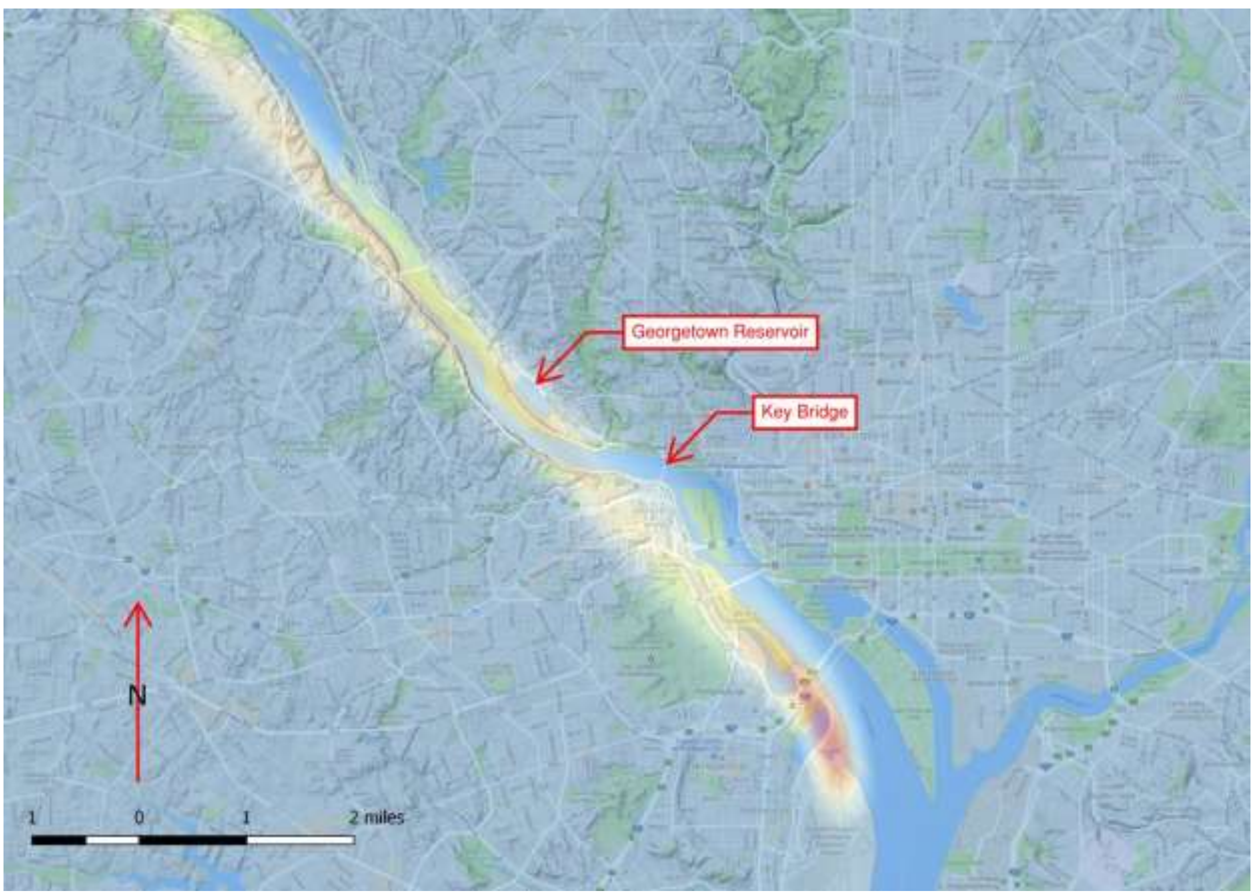

Figure 4-5: YR 2010 All Runway 01 North Departures Track Density (from AEDT modeling)

In Figure 4-6 below, the geographical relocation of the major flight track to the east over the river is evident through the flight track density map.

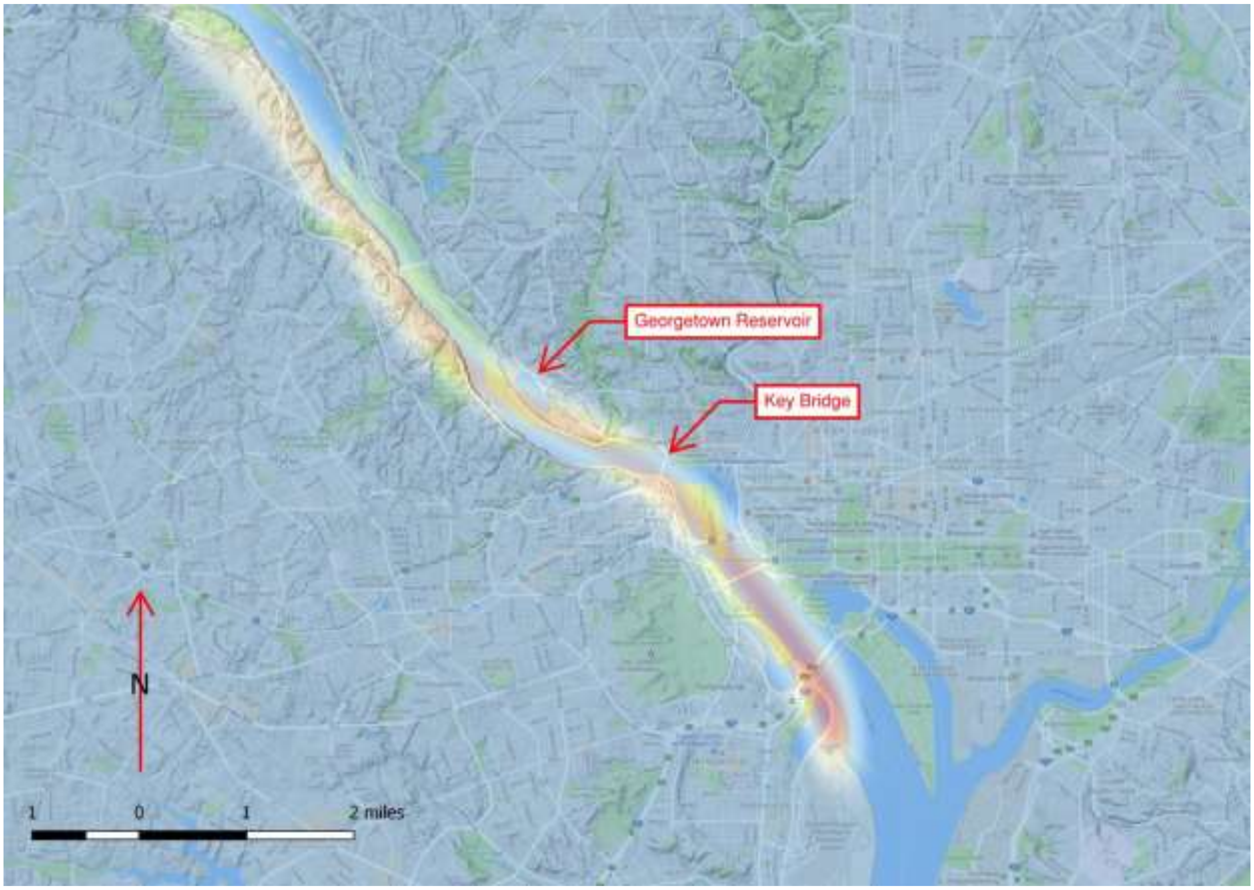

Figure 4-6: YR 2015-16 All Runway 01 North Departures Track Density (from AEDT modeling)

Noise abatement measures generally refer to actions that are intended to reduce the extent of aircraft noise to which existing and planned noise-sensitive land uses and population are or will be exposed. The objective of these measures is "Doing no harm."

Figure 4-7 provides a closer/zoomed-in visual evaluation of impacts of the nine RNAV SID procedures produced through DC Metroplex Optimization of Airspace & Procedures in the Metroplex (OAPM) and implemented beginning April 30, 2015 continuing through the current time.

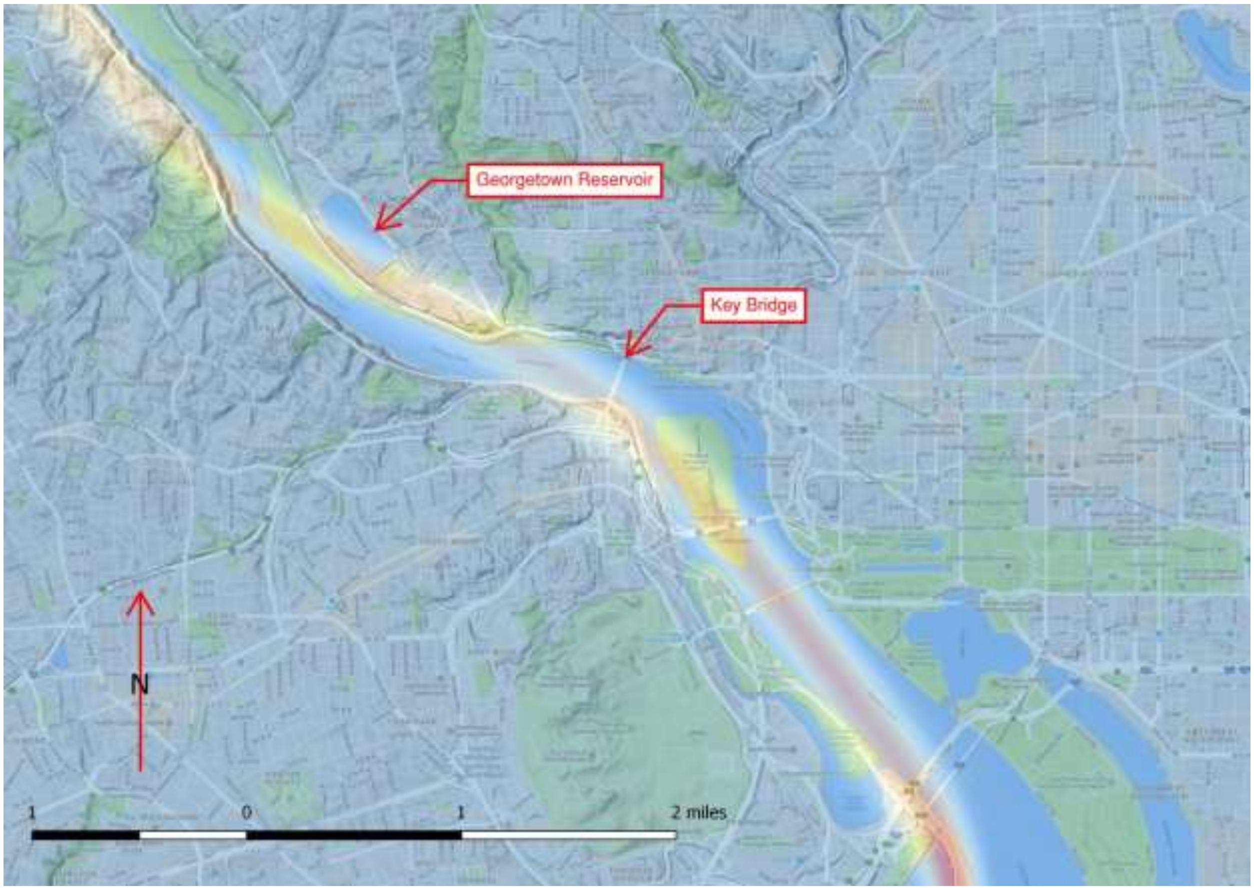

Figure 4-7: YR 2015-16 All Runway 01 North Departures Track Density (Zoom In)

4.14 RNAV Procedures

The design of RNAV procedures has endured a long journey through inputs from the aircraft and avionics industry, and through air traffic and Flight Standards criteria compliance.

As depicted in Figure 3-1, the flight track is constructed with a series of track routes and waypoints. Each route must have a specific length to the next waypoint, and each turn contains bank-angle and speed criteria for the type of aircraft in the fleet mix.

4.15 P-56 Complex

One of the challenges at DCA is the proximity of restricted area P-56, 1.5 miles from the north end of the DCA RWYs 01 / 33. This restricted area is the Capitol Mall area extending from the Lincoln Memorial on the west end to the Capitol and Supreme Court on the east end. The primary order for flight track design criteria and compliance is FAA Order 8260.58A, the U.S. Standard for PBN Instrument Procedure Design. A further complication is the speed restriction (wavier of criteria) on departures required to complete the needed turn and climb rates.

The airport has declared RWYs 19 / 01 as their preferential operational runways. MWAA / FAA has also reduced the usage of RWY 33, which we believe to be for noise mitigation in Arlington and Rosslyn; this place is a higher burden of use on RWY 01 for northbound traffic. According to MWAA's 2015 Annual Aircraft Noise Report, 61 percent of all departures used RWY 01.

4.16 Operational Demands: DCA, IAD, BWI (Forecast)

The total number of air traffic operations at IAD, DCA, and Baltimore/Washington International Thurgood Marshall Airport (BWI) over the last ten years has been graphically displayed in Figure 4-8. BWI has the highest potential for future growth (1.7%/YR), while IAD and DCA remain constant at the lower end for future growth. See also Table 4-2 for historic flight operations data for BWI.

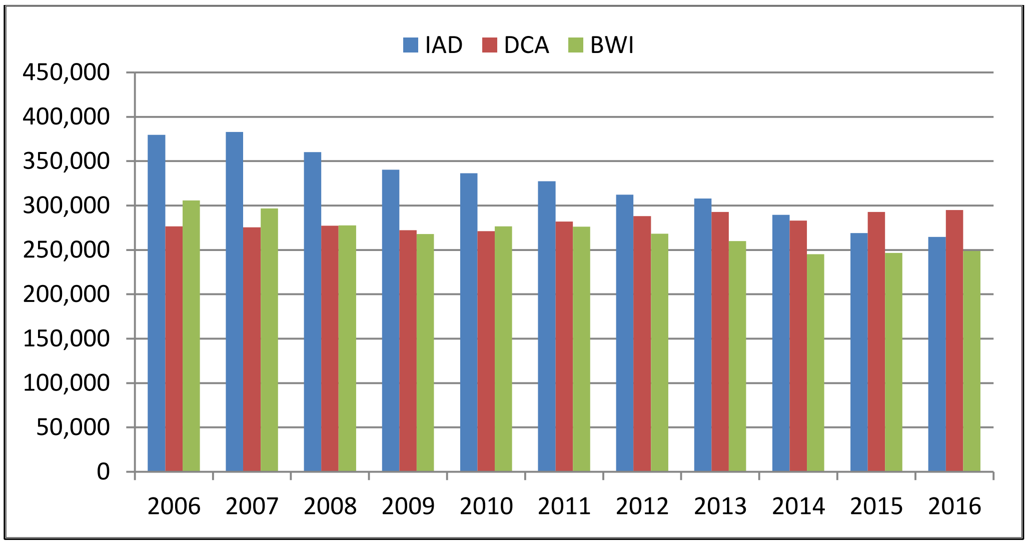

Figure 4-8: Total ATC Operations (IAD, DCA, and BWI)

Table 4-2: Baltimore Airport Annual Flight Operations

	2015	**2014**	**2013**	**2012**
Average Number of Passenger (per day)	65,270	61,131	61,639	62,138
Total Commercial Passengers per year (millions)	23.82	22.31	22.5	22.68
Percentage Change from previous year (Δ%)	+6.8%	-0.5%	-0.8%	+1.3

Table 4-3 for DCA from 2010 through 2016 shows an 8.8 percent increase in overall flight operations over the six-year period at an average rate of 1.4 percent annually. During the same period, passenger traffic increased more than 30 percent, an average of about 5 percent per year. The large growth in passenger traffic as compared to operations growth likely reflects the upgauging (moving to larger aircraft) by air carriers, as this period covered major capital investments by MWAA on infrastructure and by the airlines to update their fleet.

Table 4-3: DCA Historical Operations and Passenger Count

Year	Operations	Passengers
2006	276,419	18,550,785
2007	275,433	18,679,343
2008	277,298	18,028,287
2009	272,146	17,577,359
2010	271,097	18,118,713
2011	281,770	18,823,094
2012	288,176	19,655,440
2013	292,656	20,415,085
2014	283,180	20,415,085
2015	292,781	23,039,429
2016	295,038	23,595,006

4.17 Forecast Operations

Table 4-4 shows that DCA qualifies as a large hub with one percent or more of total U.S. passenger enplanements. A medium hub airport enplanes from 0.25 percent to 0.99 percent of total U.S. passenger enplanements. Those small and non-hub airports enplane from 0.05 to 0.249 percent, and less than 0.05 percent respectively. As depicted in Table 4-4, the forecast for DCA growth is 0.14 percent per year through the year 2045; see Figure 4-9.

Table 4-4: Operations at Large Hub Airports, in Thousands (Data from FAA TAF 2015-2045)

									Airport Ranking	
Loc ID	Region	Airport Name	2015	2015 Percent*	2016	2020	2045	Rate** 2015-2045	2015	2045
ORD	AGL	CHICAGO O'HARE INTL	881	0.90	872	836	1,148	0.88	1	3
ATL	ASO	HARTSFIELD - JACKSON ATLANTA INTL	877	0.89	899	942	1,478	1.75	2	1
DFW	ASW	DALLAS/FORT WORTH INTL	684	0.69	677	688	1,061	1.47	3	4
LAX	AWP	LOS ANGELES INTL	648	0.66	686	784	1,150	1.92	4	2
DEN	ANM	DENVER INTL	551	0.56	566	589	876	1.55	5	6
CLT	ASO	CHARLOTTE/DOUGLAS INTL	546	0.55	546	592	894	1.65	6	5
LAS	AWP	MC CARRAN INTL	521	0.53	533	574	855	1.66	7	7
IAH	ASW	GEORGE BUSH INTERCONTINENTAL/HOUSTON	508	0.51	480	464	728	1.21	8	11
JFK	AEA	JOHN F KENNEDY INTL	443	0.45	459	481	742	1.73	9	9
PHX	AWP	PHOENIX SKY HARBOR INTL	438	0.44	442	468	721	1.66	10	12
SFO	AWP	SAN FRANCISCO INTL	429	0.43	447	488	732	1.79	11	10
EWR	AEA	NEWARK LIBERTY INTL	414	0.42	428	454	667	1.60	12	13
PHL	AEA	PHILADELPHIA INTL	413	0.42	402	366	500	0.64	13	20
MIA	ASO	MIAMI INTL	409	0.41	417	439	643	1.51	14	14
MSP	AGL	MINNEAPOLIS-ST PAUL INTL/WOLD-CHAMBERLAIN	405	0.41	411	428	610	1.37	15	16
DTW	AGL	DETROIT METROPOLITAN WAYNE COUNTY	380	0.38	392	394	549	1.23	16	18
SEA	ANM	SEATTLE-TACOMA INTL	372	0.38	408	464	743	2.33	17	8
BOS	ANE	GENERAL EDWARD LAWRENCE LOGAN INTL	372	0.38	395	426	627	1.75	18	15
LGA	AEA	LAGUARDIA	369	0.37	375	385	387	0.15	19	25
SLC	ANM	SALT LAKE CITY INTL	315	0.32	318	339	504	1.57	20	19
HNL	AWP	HONOLULU INTL	314	0.32	308	325	435	1.08	21	23
MCO	ASO	ORLANDO INTL	311	0.31	323	354	572	2.04	22	17
IAD	AEA	WASHINGTON DULLES INTL	299	0.30	291	303	436	1.26	23	22
DCA	AEA	RONALD REAGAN WASHINGTON NATIONAL	296	0.30	300	308	309	0.14	24	29
FLL	ASO	FORT LAUDERDALE/HOLLYWOOD INTL	275	0.28	287	324	492	1.96	25	21
MDW	AGL	CHICAGO MIDWAY INTL	254	0.25	252	264	378	1.33	26	26
BWI	AEA	BALTIMORE/WASHINGTON INTL THURGOOD MARSHALL	245	0.25	248	271	411	1.74	27	24
PDX	ANM	PORTLAND INTL	215	0.22	226	253	374	1.85	28	27
SAN	AWP	SAN DIEGO INTL	195	0.19	196	216	326	1.72	29	28
TPA	ASO	TAMPA INTL	190	0.19	189	197	288	1.39	30	30
Totals			12,569	12.71	12,773	13,416	19,636	1.49		

Percent of total US operations.

**Annual compound growth rate.

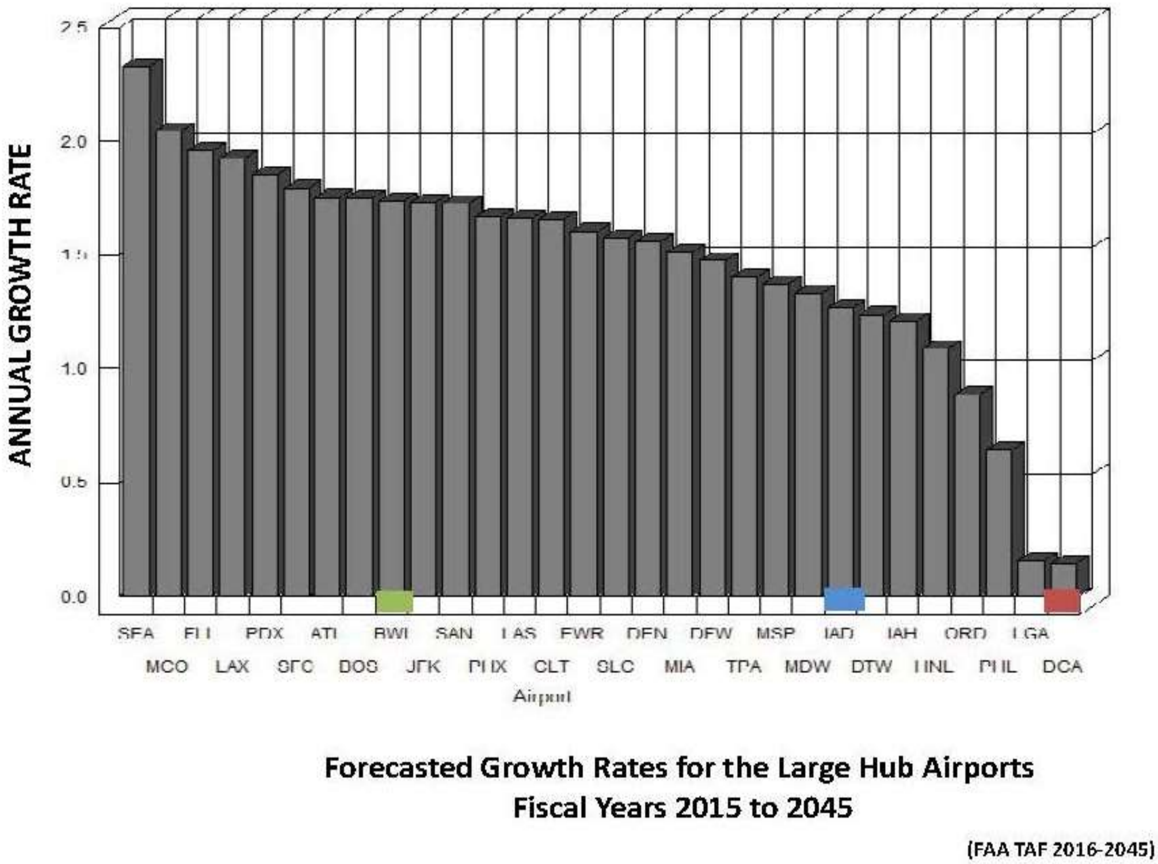

Figure 4-9: Large Hub Forecasted Growth Operational Demands: Arrivals/Departures

As noted earlier, the purpose of the LAZIR procedure (and the subsequent transfer of all northbound RNAV traffic to the initial LAZIR track) was to move the traffic and noise from RWYs 01 / 33 away from Arlington and over the Potomac River. These procedures transferred noise to the national parks and noise sensitive residential communities of DC.

While both the NATIONAL and LAZIR impact DC, those departures from RWY 01 produce the most overall impact from the end of the runway throughout the entire flight track.

Irrespective of any noise increases at the various stages of flight, FAA data shown in Table 4-5, indicates that the initial implementation of LAZIR ONE, absent of runway usage, placed approximately 18.45 percent of all northbound departures, over and near the “Historic District.”

Table 4-5: Years 2011 – 2015 Runway 01 / 33 Procedural Usage /Relocation

Year	Total RUNWAYs 01 / 33	Conventional	RNAV	Percent Change Est.
2011 (MARCH 1)	60,957	49,711	11,246	18.45%
2012	85,091	71,447	13,644	16.03%
2013	84,312	81,344	2,968	3.5%
2014	90,410	90,410	2,768	3.06%
2015	91,403	91,403	51,133	55.94%

Note: Data from FAA Data; 8/17/16 MWAA Meeting.

Runway utilization, from the MWAA 2015 Annual Report, showed that 61 percent of all departures from DCA utilized Runway 01, northbound, directly affecting DC. During the same time period, only 1.5 percent of departures utilized RWY 33. During the same period, 40,070 aircraft used the NATIONAL (Conventional) SID; however, specific runway usage is not available for those flights.

The MWAA 2016 Annual Aircraft Report revealed a continuance with 62.3 percent usage on Runway 01 and 3 percent on Runway 33. An imbalance of runway usage remains apparent. Additionally, a total of 34.6 percent of all year 2015 arrivals to DCA utilized RWY 19 for arrival and only 1.3 percent of arrivals used RWY 15. This unbalanced runway usage is another benefit to the western shoreline. The annual arrival traffic data for 2016 runway usage reported that approximately 1 percent of traffic landed on Runway 15, while 33.1 percent of all arrivals landed on RWY 19. The imbalance of runway usage for arrival traffic also remains apparent.

4.18 Arrivals

We have only addressed the influences of the departures on DC. Arrivals or Instrument Approaches from the north landing RWY 19 / 15 were not spared from "*relocation of air traffic to the river.*" Figure 4-10 shows the changed arrival paths.

FAA PRESENTATION

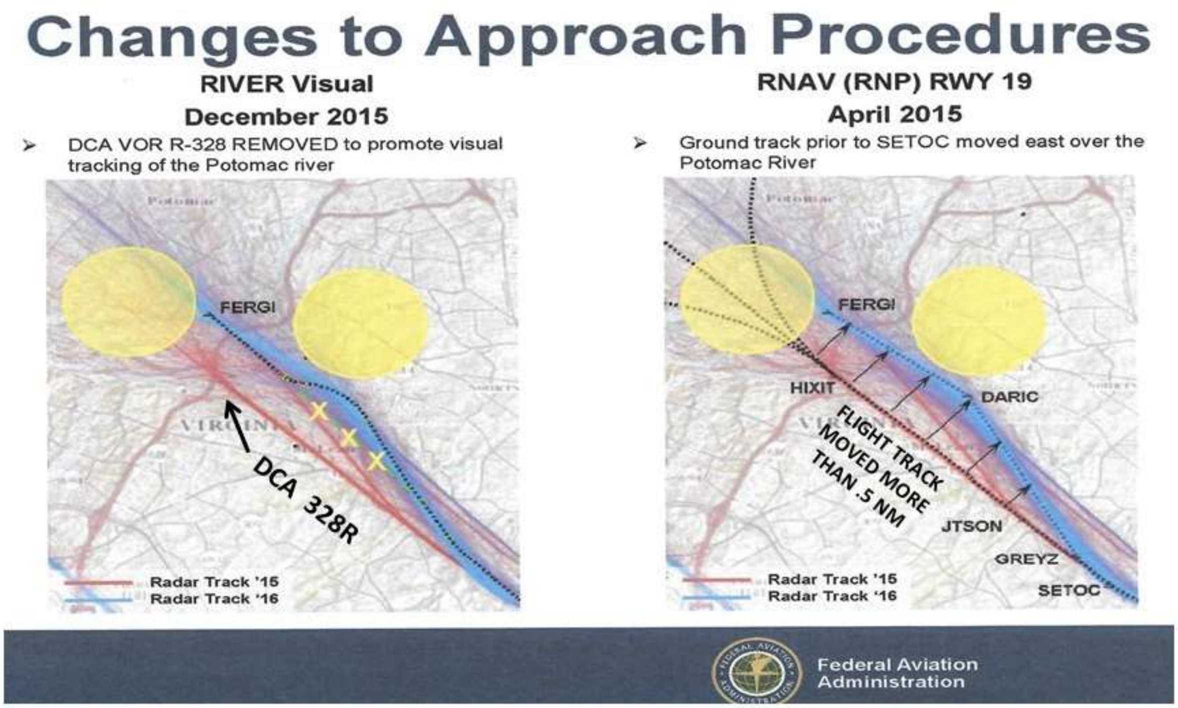

Figure 4-10: River Visual and RNP Runway 19 Approach Change

We have identified the follow issues with the relocated arrival paths:

- Flight tracks moved (relocated) more than a half mile east off of the western shoreline.
- No environmental review documents presented; original approach was amended.
- Lack of compliance to FAA Orders 7100.9, 1050.1E, and 7100.4.
- Increased track miles on the approaches.
- Increase operation cost to user.
- Increased environmental impacts to historic and noise sensitive neighborhoods; noncompliance with FAA order 1050.1E, Appendix A, §6.2 (h).

As shown in Figure 4-11, the circled yellow area covers the entire flight that is being relocated off the western shoreline, east to the River and beyond. This area is approximately five nautical miles in length (from the FERGI waypoint to the GREYZ waypoint). The RNP RWY 19 was amended May 29, 2014 and the River Visual RWY 19 was amended accordingly on December 10, 2015.

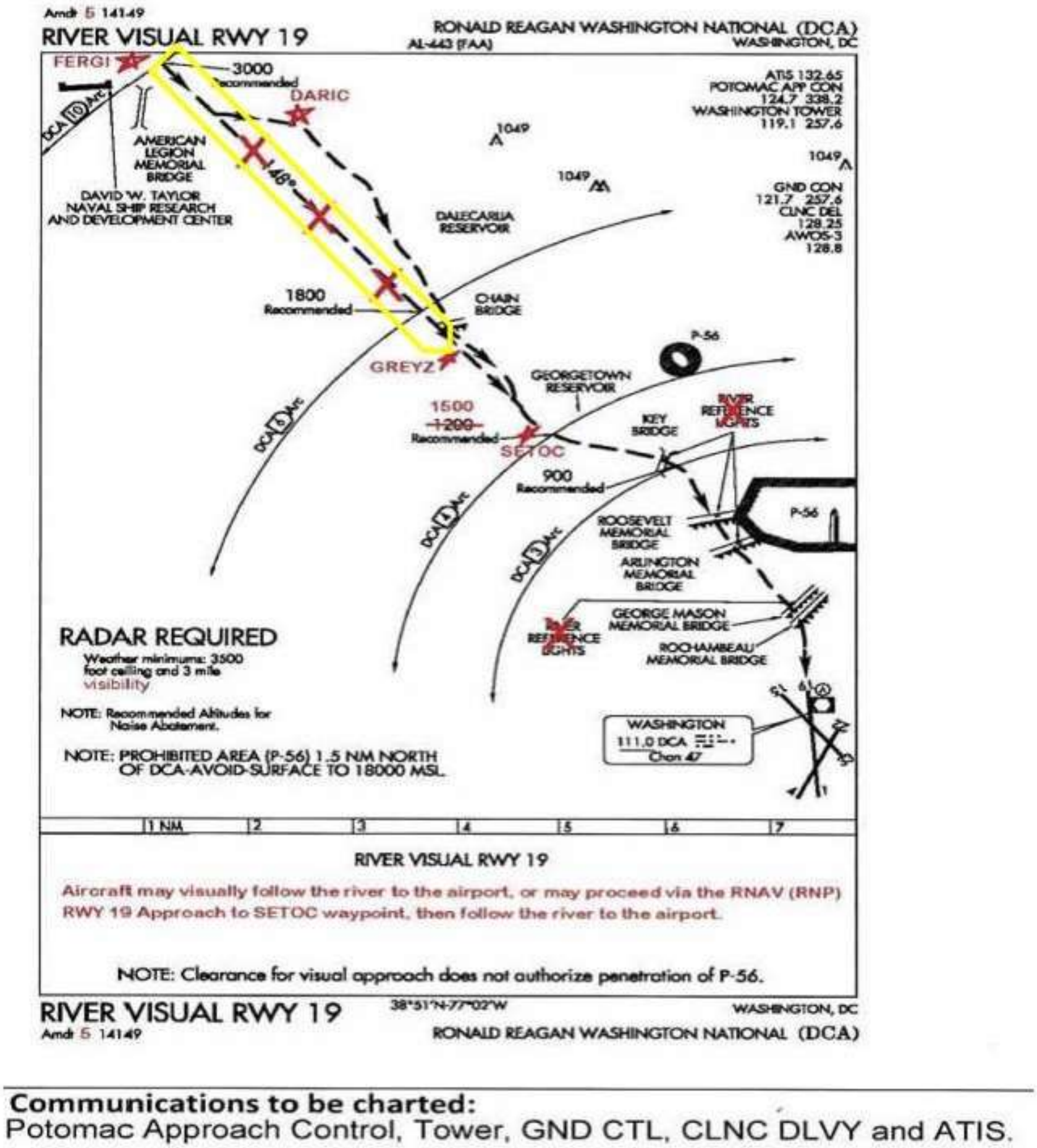

Figure 4-11: FAA Publication Chart, River Visual Runway 19

4.19 Summary and Conclusions

Noise concerns from DCA were voiced by communities around Arlington promoting increased community action. In 2002, communities around DCA participated with MWAA and the FAA in an FAA-sponsored noise compatibility study, termed a Part 150 study, superseding a 1997 study. The study was completed in 2004 with recommendations for establishing new DCA departure routes up the Potomac River to provide noise relief to Arlington communities. The FAA's ROA for the Part 150 ultimately disallowed the implementation of the "over the river" departure as changes to flight paths are not allowed purely for noise mitigation (as there were no noise-impacted properties within the DNL 65 dBA contour). However, this "over the river" departure was subsequently implemented via a procedural change, as discussed in the following paragraph.

Subsequent to the Part 150 study, the advent of NextGen departure procedures, such as RNAV and RNP, enabled more precise routing. From 2004 through 2016 the FAA added, altered, and deleted this routing 43 times; most of the new departure routes were similar and named LAZIR. The Part 150 study predicted a 3 dBA noise exposure reduction to Arlington with only a 1 dBA increase to Georgetown communities along the Potomac River. This prediction proved incorrect and the increase to Georgetown is greater (i.e., 3+ dBA). Further, the FAA did not follow its own environmental procedures in establishing the new routing. When their own technical investigations showed increases exceeding FAA standards, they invoked a CATEX to avoid compliance with their own standards. The primary objective was to move the traffic and noise from DCA RWYs 01 / 33 away from Arlington (i.e., moved it east towards DC) and over the Potomac River. These procedures transferred noise to the national parks and noise sensitive residential communities of DC.

5.0 DCA Noise Monitoring System Analysis

5.1 Background

Noise monitoring terminals (NMT) were first installed around DCA Reagan National in 1978 when the FAA operated the airport. As the MWAA assumed operation of DCA, they continued the original monitoring program and began publishing NMT results in 2010.[13]

The monitors operate by recording the A-weighted sound level each second while concurrently recording the time. The system then electronically examines the sequence of recorded sound levels and identifies discrete noise "events." Some events may be from aircraft flyovers and others from community noise events such as road traffic. Events are detected by proprietary algorithms analyzing a series of sequential noise events exceeding a threshold level.

The MWAA has reported monthly noise levels for the calendar in their annual reports (posted on their website) since 2010. The original noise monitors were replaced with a newer, more advanced system in 2015 and began reporting new data in February 2015. Unfortunately, it is not known how the earlier noise monitors distinguished between aircraft and community noise events from 2010 through 2014, and whether the event listing from the old monitors provided to DOEE is exclusively from aircraft flyovers or if they also contain additional community noise events. The newer noise monitors (2015 to present) are a proven reliable system and report aircraft noise events and community noise events separately. Appendix D is an example of a part of a typical NMT report from a newer monitor.

Of the 21 current NMTs recording DCA noise, three NMTs are located within DC (listed below from north to south) and are shown in Figure 5-1 below:

- NMT #4 Potomac Palisades 5334 Carolina Pl., NW
- NMT #6 Georgetown Visitation School: 1524 35th St., NW.
- NMT #17 Southwest DC Fort McNair Base: 1400 4th St., SW

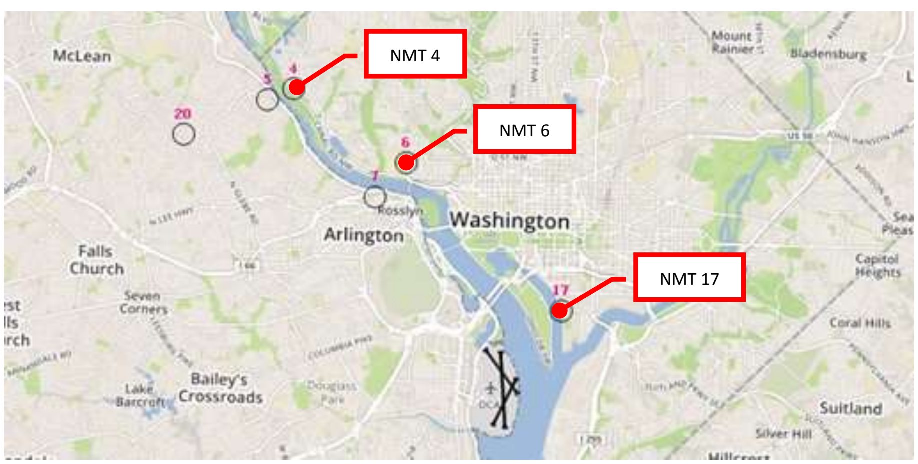

Figure 5-1: Noise Monitoring Terminal Locations

[13] MWAA. *Noise Monitoring Terminal Data*. [Online]. Available: http://www.flyreagan.com/dca/reagan-national-noise-reports-and-data

The team analyzed DC NMT reports for the years 2010, 2012, 2014, 2015, 2016 and a part of 2017 with two objectives:

- To determine the DNL increase for each site between 2010 and 2016. This assessment is with respect to the noise impact criteria in FAA Advisory Circular 1050.1f.
- Provide a general assessment and explanation of flights per day, and traffic volumes per day of the week, month of the year, number of flights, range of sound levels recorded and a comparison of SELs for flights over each NMT.

5.2 Regulatory Environment – FAA Order 1050.1E and 10501.F

5.2.1 FAA Advisory Circular 1050.1E

FAA Order 1050.1E became effective March 20, 2006. This order updated the FAA agency-wide policies and procedures for compliance with the NEPA and implementing regulations issued by the Council on Environmental Quality (CEQ). 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 FAA implemented the CEQ regulations in its Order 1050.1E which provides in Section 9 that:

> *The order [1050.1E] is not a substitute for the regulations promulgated by CEQ, rather, it supplements the CEQ regulations by applying them to FAA programs. Therefore, all program offices and administration offices shall comply with both the CEQ regulations and the provisions of this order.*

Therefore, the language and purpose of the CEQ regulations are controlling in all cases and shall supersede any interpretation by other agencies that are contrary to the meaning and spirit of the CEQ regulations.

5.2.2 FAA Order 1050.1E, § 11b, Noise-Sensitive Area

The FAA defines a Noise Sensitive Area as "An area where noise interferes with normal activities associated with its use. Normally, noise sensitive areas include residential, educational, health, and religious structures and sites, and parks, recreational areas (including areas with wilderness characteristics), wildlife refuges, and cultural and historical sites," such as DC.

5.2.3 FAA 1050.1E, §14.2b, FAA Responsibilities

FAA responsibility stipulates that all detailed noise analysis must be performed using the most current version of the Noise Integrated Routing System (NIRS).

The NIRS, Version 6.1, is an FAA noise-assessment program designed to provide an analysis of air traffic changes over broad areas. It is intended to work in conjunction with other Air Traffic modeling systems that provide the source of routes, events, and Air Traffic procedures such as altitude restrictions. In March 2012, NIRS was replaced by AEDT version 2a, for analysis of air traffic airspace and procedure actions.

5.2.4 FAA Order 1050.1E 14.5a, FICON Report

The Federal Interagency Committee on Noise (FICON) report, "Federal Agency Review of Selected Airport Noise Analysis Issues," dated August 1992, concluded that the DNL is the recommended metric and should continue to be used as the primary metric for aircraft noise exposure. However, DNL analysis may optionally be supplemented on a case-by-case basis to characterize specific noise effects. Because of the diversity of situations, the variety of supplemental metrics available, and the limitations of individual supplemental metrics, the FICON report concluded that the use of supplemental metrics to analyze noise should remain at the discretion of individual agencies. The FAA chose not to use supplemental data for the DCA Part 150 Study or the DC OAPM.

5.2.5 FAA Order 1050.1E, §14.5d

For proposed air traffic or special use airspace actions 3,000 feet above ground level (AGL), FAA-approved screening shall be used. NIRS allows the user to evaluate potential noise impacts resulting from changes in airport arrivals and departures by screening proposed changes to determine whether the change increases the community noise level by 5 decibels or more beneath the aircraft route. Where a proposed change would cause an increase in noise of 5 decibels or greater in areas where the DNL is less than 60 dBA, the FAA considers whether there are extraordinary circumstances that warrant preparation of an environmental assessment.

5.2.6 FAA Order 1050.1E, §14.5e

For air traffic airspace actions where the study area is larger than the immediate vicinity of an airport, incorporates more than one airport, or includes actions above 3,000 feet AGL, noise modeling will be conducted using NIRS. For those types of studies, NIRS will be used to determine noise impacts from the ground to 10,000 feet AGL. This noise analysis will focus on the change in noise levels as compared to populations and demographic information at population points throughout the study area. Noise contours will not be prepared for the NIRS analysis. However, NIRS will be used to produce change-of-exposure tables and maps at population centroids.

5.2.7 FAA Order 1050.1E, §15

Major development proposals often involve the potential for induced or secondary impacts on surrounding communities. Examples include: shifts in patterns of population movement and growth; public service demands; and changes in business and economic activity to the extent influenced by the airport development. Induced impacts will normally not be significant except where there are also significant impacts in other categories, especially noise, land use, or direct social impacts.

5.2.8 FAA Order 1050.1F

FAA Order 1050.1F became effective July 16, 2015, revised from the previous version 1050.1E.

5.2.9 Section B-1.6. Supplemental Noise Analysis

DNL analysis may optionally be supplemented on a case-by-case basis to characterize specific noise impacts. There is no single supplemental methodology that is preferable in all situations and these metrics often do not reflect the magnitude, duration, or frequency of the noise events under study.

In addition, the FAA will consider the use of appropriate supplemental noise analysis when it identifies, within the study area of a proposed action or alternative(s), one or more Section 4(f) properties (including, but not limited to, noise sensitive areas within national parks; national wildlife and waterfowl refuges; and historic sites including traditional cultural properties) where a quiet setting is a generally recognized purpose and attribute. In considering the use of supplemental noise analysis for such properties, the FAA will consult with the officials having jurisdiction over the properties. Such supplemental noise analysis is not, by itself, a measure of adverse aircraft noise or significant aircraft noise impact.

5.2.10 Appendix B, §B-1.4

For air traffic airspace and procedure actions where the study area is larger than the immediate vicinity of an airport, incorporates more than one airport, and/or includes actions 3,000 feet AGL, an FAA-approved model must be used. The noise analysis will focus on a change-in-exposure analysis, which examines the change in noise levels as compared to population and demographic information at population points throughout the study area. This is normally a noise grid analysis. Multiple grids may be created, but at least one grid must consist of population centroids from the U.S. Census blocks. Discrete receptor points can also represent select noise sensitive area(s) or comprise a general receptor grid over the study area, either densely or sparsely spaced. Noise contours may be created at the FAA's discretion; however, noise contours are not required and are not normally used for the analysis of larger scale air traffic airspace and procedure actions. If the study encompasses a large geographical area, it is not recommended that contours be created for the representation of results below DNL 55 dBA due to fidelity of receptor sets needed to create an accurate representation of the contour.

For air traffic airspace and procedure actions evaluated as described above, change-of-exposure tables and maps at population centers are provided to identify where noise will change by the following specified amounts:

- For DNL 65 dBA and higher: +1.5 dBA
- For DNL 60 dBA to <65 dBA: +3 dBA
- For DNL 45 dBA to <60 dBA: +5 dBA

5.3 Noise Monitor Operations

Both the old and new monitors use the same general operation. A total of 21 NMTs have been installed in areas potentially affected by noise from DCA operations.[14] These were installed and are operated by the MWAA.

The monitors begin recording all noise above a certain threshold level, recording the noise energy throughout the event until the sound drops below a second threshold level (which may or may not be the same as the trigger threshold). The monitors then sum this energy into a single SEL noise event. They also record other parameters shown in the "Detailed Noise Event Report" in Appendix D.

The current noise monitors appear to have been well-maintained and routinely calibrated according to appropriate acoustical standards. Our review of the data for the years analyzed show reasonable and

[14] Reagan National Airport, Noise Monitoring System: http://www.flyreagan.com/dca/reagan-national-noise-monitoring-system.

consistent data results for the new noise monitoring system. We conclude that the data from the newer monitoring system is correct and reliable, while we were unable to verify and validate the data from the earlier monitoring system.

5.4 Analyses Procedures

As discussed in Appendix A, noise metrics for community noise assessment, including aircraft noise impact, are integrated measures incorporating both the level and duration of noise events. The SEL metric is such a measure, and SEL values are summed on an energy basis to compute daily, month and annual DNL values.

Our analysis consisted of taking the “raw” noise event listing and calculating the daily and monthly DNL values; we then compared our calculated values to those published by MWAA. Appendix D – Typical NMT Report from a Newer Monitor shows the “raw” data used in our calculations.

5.5 Results and Conclusions

The discrepancies in the old monitoring system’s data are evident when the DNL calculated from the detailed event listings is compared to those published in the annual noise reports available on MWAA’s website. The calculated and published data from NMTs 4, 6, and 17 are shown in Table 5-1 through Table 5-3. This shows the following for the four calendar years analyzed; note we did not analyze 2015 data due to the changeover in monitoring systems, the testing of the LAZIR flight path in the second half of March, and the implementation of the LAZIR routes in April and June:

- DNL values computed by the project team from the raw data results from the monitors, and
- DNL values reported from the MWAA annual report monthly data.[15]

[15] http://www.mwaa.com/sites/default/files/archive/mwaa.com/file/2010_Noise_Report.pdf; http://www.mwaa.com/sites/default/files/archive/mwaa.com/file/2012_Noise_Report.pdf; http://www.mwaa.com/sites/default/files/archive/mwaa.com/file/2014_Noise_Report.pdf; http://www.flyreagan.com/sites/default/files/2016_mwaa_annual_aircraft_noise_report_final.pdf

Table 5-1: NMT #4 DNL Analysis

Data Source	Calendar Year DNL (dB)						
	Old System					New System	
	2010	2012		2014		2016	
	Aircraft	Aircraft	Diff re: 2010	Aircraft	Diff re: 2010	Aircraft	Diff re: 2010
DNL: Computed from event listing (dB)	55.1	59.0	+3.9	56.4	+1.3	57.7	+2.6
DNL: from MWAA Annual Reports (dB)	54.3	55.7	+1.4	54.0	-0.3	57.7	+3.4

Table 5-2: NMT #6 DNL Analysis

Data Source	Calendar Year DNL (dB)						
	Old System					New System	
	2010	2012		2014		2016	
	Aircraft	Aircraft	Diff re: 2010	Aircraft	Diff re: 2010	Aircraft	Diff re: 2010
DNL: Computed from event listing (dB)	55.8	54.9	-0.9	53.5	-2.3	57.3	+1.5
DNL: from MWAA Annual Reports (dB)	53.8	51.3	-2.5	51.5	-2.3	57.3	+3.5

Table 5-3: NMT #17 DNL Analysis

Data Source	Calendar Year DNL (dB)						
	Old System					New System	
	2010	2012		2014		2016	
	Aircraft	Aircraft	Diff re: 2010	Aircraft	Diff re: 2010	Aircraft	Diff re: 2010
DNL: Computed from event listing (dB)	58.5	57.5	-1.0	57.4	-1.1	54.8	-3.7
DNL: from MWAA Annual Reports (dB)	55.3	56.9	+1.6	56.5	+1.2	54.8	-0.5

Several conclusions are evident from these results:

- DNL results published in MWAA's annual reports (for 2010 through 2014) do not agree with the values we computed from the detailed event listings provided to us by MWAA.
- DNL results published in MWAA's annual reports from the new monitors (2015 to present) agree with the values we computed from the detailed event listings available on MWAA's website.

Several trends are evident from the variation in annual DNL for each of the three NMTs. The DNL at the southernmost NMT #17 declined from 55.3 dBA in 2010 to 54.8 dBA in 2016. This is likely due to the gradual change in northbound departure routes from DCA from RWY 4 to RWY 1 over the Potomac River. Both NMT #6 and NMT #4 further north, near the east bank of the River encountered increased DNL values (3.5 and 3.4 dBA, respectively) during the same period. The largest increase is from NMT #6 from a DNL of 53.8 dBA in 2010 to 57.3 dBA in 2016.

5.6 Calculated Aircraft DNL with and without Community Events

The earlier monitoring system reported both aircraft DNL and other "community" DNL values. The newer system reports aircraft DNL but does not compute community DNL values. The monthly and annual DNL values were computed both with and without the community noise contribution for the three NMTs. Table 5-4 shows the annual results of this assessment for NMT #4 for YR 2015 and YR 2016.

Table 5-4: 2015 and 2016 Annual DNL Values with and without Community Noise at NMT #4

Year	Aircraft Only DNL (dBA)	Community Only DNL (dBA)	All Events DNL (dBA)
2015	57.9	55.0	59.7
2016	57.7	52.3	58.8

Note: The DNL values presented in the table above are only from a summation of noisy events (i.e., does not include the noise contribution of noise between events; actual DNL values at the NMT locations are likely higher than presented above).

It is clear from these results that aircraft noise was the predominant noise source at NMT #4 during 2015 and YR 2016. A deeper analysis of aircraft noise, presented in terms of DNL and other supplemental metrics is contained in subsequent sections of this report.

5.7 Temporal Analysis of NMT Events

Examining the NMT data also reveals certain elements of the overall noise exposure. Specifically, the monthly volume of operations, monthly DNL values, average overflights by day of the week, and the average daytime versus nighttime noise contribution were computed for recent (2016) operations.

Table 5-5 shows the total number of aircraft flyovers at NMT #6; whereas Table 5-6 shows the total number of events (flyovers + community) at NMT #6. Finally, Table 5-7 and Table 5-8 show the distribution of events by day of the week.

The daytime and nighttime noise exposure contributions were computed for NMT #6 for January 2016 according to the DNL criteria. The nighttime criterion penalizes nighttime noise events by 10 dBA, an amount equating a single nighttime noise event equal to ten daytime noise events of the same level. This independent analysis found 21,856 daytime events and 3,167 nighttime events for the month (i.e., 87% daytime and 13% nighttime). This resulted in a daytime DNL contribution of 55.4 dBA and a nighttime contribution of 59.0 dBA. Thus, the nighttime noise contribution from flyovers was judged to be subjectively more annoying, although there were six times fewer nighttime events.

Table 5-5: Typical Monthly Flyovers at NMT #6 (2016)

Month	Jan	Feb	Mar	Apr	May	Jun
Number of Flyovers	10,814	10,728	10,541	11,928	12,496	12,223
Annual Percent	7.7%	7.6%	7.5%	8.5%	8.9%	8.7%

Month	Jul	Aug	Sep	Oct	Nov	Dec	Total
Number of Flyovers	12,160	12,251	11,969	12,411	11,856	11,382	**140,759**
Annual Percent	8.6%	8.7%	8.5%	8.8%	8.4%	8.1%	100%

Table 5-6: Typical Monthly Events at NMT #6 (2016)

Month	Jan	Feb	Mar	Apr	May	Jun
Number of Events	25,023	26,352	22,282	27,758	30,293	25,872
Annual Percent	8.3%	8.7%	7.4%	9.2%	10.0%	8.5%

Month	Jul	Aug	Sep	Oct	Nov	Dec	Total
Number of Events	22,954	21,449	22,413	26,110	25,700	26,444	**302,650**
Annual Percent	7.6%	7.1%	7.4%	8.6%	8.5%	8.7%	100%

Table 5-7: Average Daily Flyovers at NMT #6 (2016)

Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Total
Number of Flyovers	18,759	20,994	21,391	21,760	21,745	21,872	14,205	**140,759**
Annual Percent	13.3%	14.9%	15.2%	15.5%	15.4%	15.5%	10.1%	100%

Table 5-8: Average Daily Events at NMT #6 (2016)

Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Total
Number of Events	36,513	44,539	47,087	45,851	47,376	47,752	33,532	**302,650**
Annual Percent	12.1%	14.7%	15.6%	15.1%	15.7%	15.8%	11.1%	100%

Various trends were also evaluated for 2016, the most current year with annual statistics. At NMT #6 March had the fewest flights (10,541 or 7.5% of annual) and May the most flights (12,496 or 8.9% of annual), less than a 20 percent difference. No strong seasonal trend was found. A slightly stronger trend was measured for days of the week with Saturdays having the fewest flyovers (14,205 or 10.1% annually) and Friday with the most, half again as many (21,872 or 15.5% annually). A separate assessment of daytime and nighttime noise was made for January 2016. While there were fewer nighttime flyovers producing lesser noise exposure, the 10 dBA penalty assigned to the DNL metric deemed the nighttime noise contribution the greater annoyance.

5.8 Results and Conclusions

- The DNL calculations conducted on the 2010-2014 Excel spreadsheet provided to DC by MWAA via FOIA do not match that published in the MWAA Annual Reports. Thus, the published MWAA data is questionable, and we were unable to determine how they derived the reported DNL values for aircraft noise.
- Our DNL calculations on the 2016 data (new monitoring system) match the published MWAA Annual Report data.
- We conclude that only the DNL aircraft results should be compared between monitoring systems. However, we were unable to determine how MWAA came up with the aircraft DNL results for 2014 and prior years, so we believe the aircraft noise results for 2014 and prior years should be viewed skeptically.

6.0 DCA Noise Measurements and Noise Monitoring Terminals Analysis

6.1 Summary

This section presents the results of noise measurements conducted in 2017 and 2018. The 2017 measurements were conducted during June 12 through July 12, 2017, and the 2018 measurements were conducted June 20 through July 15, 2018, in the Georgetown community most noise-impacted by flights to and from DCA.

For the Phase 1 (2017) measurements, eleven long-term (i.e., all day and/or all night) noise measurements were conducted in exterior and interior spaces; each interior location was only measured for one day (for schools) or one night (for residences) whereas the exterior locations were measured for multiple days. For the Phase 2 (2018) measurements, 6 long term (30 day) exterior measurements were conducted and 6 short-term (7 day) interior noise measurements were conducted. Exterior and interior measurements occurred at the same address/location.

The measurements were conducted to quantify typical day and nighttime noise exposure over the area, to assess awakenings from aircraft flyovers and to determine if classrooms in the area complied with recommended acoustical standards. Noise exposure measurements were measured and reported in terms of national and international standards: single event level (SEL) and DNL. Awakenings were assessed in three residences in accordance with American National Standard (ANSI/ASA) S12.9-2008, “Quantities and Procedures for Description and Measurement of Environmental Sound – Part 6: Methods for Estimation of Awakenings Associates with Outdoor Noise Events Heard in Homes.” The acoustical performance of four classrooms was assessed per ANSI/ASA S12.60, “Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools.”

Exterior DNL values varied from the low 50s to almost 65 dBA, the level at which residences are eligible for retrofit noise insulation.[16] The awakening analysis showed that between 12.5% and 34.3% of the population would be awakened at least once. The classroom analyses showed that one of the three classrooms complied with the acoustical performance standards while the other two failed to fully comply, but by a small margin.

6.2 Measurement Description

6.2.1 Equipment

For the Phase 1 measurements, environmental noise measurements were conducted from Monday, June 12, 2017 through Thursday, June 15, 2017. At two exterior locations, measurements were conducted for a month (June 12 to July 12, 2017). The equipment used was Type 1 digital sound level meters, set to log the sound level one time per second (i.e., one second logging). A Type 1 sound level meter has an accuracy of ±1 dBA, per ANSI Standard S1.4. Both the overall noise level and spectral sound data was recorded, and the meters were set to make audio recordings of all noisy events above 65 dBA. Larson Davis Model 831 sound level meters were utilized for most of the measurements; the two one-month measurements were conducted utilizing Bruel & Kjaer Type 2250 sound level meters. All meters were calibrated before and after the measurements, with no significant drift in response, and all meters were time synchronized.

[16] Note that eligibility for sound insulation is based upon the “average annual” DNL being 65 dBA or greater.

6.3 Measurement Locations

The Phase 1 measurements were conducted at three residential locations, at both the exterior and interior of the dwellings. In addition, exterior measurements were conducted at Georgetown University and Georgetown Visitation School along with two interior locations at each school. Note that the interior measurements were conducted for only one day (for schools) or one night (for residences). Table 6-1 below summarizes the measurement locations:

Table 6-1: Phase 1 Noise Monitoring Locations

Location Name	Measurement Location
R1: Reservoir Rd Residence	Exterior: Back Deck Interior: Upstairs Bedroom
R2: MacArthur Blvd Residence	Exterior: Roof Interior: Living Room
R3: Hillandale Residence	Exterior: Front Yard Interior: Master Bedroom
S1: Georgetown University	Exterior: Lauinger Library Rooftop Interior 1: Healy Hall Classroom 106 Interior 2: White-Gravenor Chemistry Lab 404
S2: Georgetown Visitation Preparatory	Exterior: Sports Field Interior 1: Nolan Center Auditorium Interior 2: Fannasi Building, Classroom F-2

The Phase 2 measurements were conducted at four residential locations, at both the exterior and interior of the dwellings. In addition, exterior measurements were conducted at Georgetown University and Georgetown Day School along with two interior locations at each school. Exterior measurements were one month long; interior measurements were approximately one week; however, interior noise levels for the unmeasured three weeks was calculated by applying the building facade's noise reduction to the 30 days of exterior noise data to derive interior noise levels. Table 6-2 below summarizes the measurement locations:

Table 6-2: Phase 2 Noise Monitoring Locations

Location Name	Measurement Location
L1: 47th Street Residence	Exterior: Back Deck Interior: Kids Bedroom, 2nd Floor
L2: Charleston Terrace Residence	Exterior: Roof Interior: Living Room
L3: Georgetown Day School	Exterior: Roof Interior: Classroom B406
L4: Georgetown University	Exterior: Lauinger Library Rooftop Interior: Healy Hall Classroom 105
L5: Hillandale Residence	Exterior: Upstairs Deck Interior: Guest Bedroom, 2nd Floor
L6: Reservoir Road Residence	Exterior: Upstairs Back Deck Interior: Upstairs Bedroom

The measurement locations are shown on the various figures in the following subsections.

6.4 Measurement Procedure

The exterior monitors were located with clear line-of-sight to the sky to accurately capture aircraft flyovers. The meters were located at least six feet away from all acoustically reflective elements such as exterior walls, and care was taken to install the meters away from noise sources such as mechanical/HVAC equipment. The interior meters were located at least three feet away from reflective elements such as walls and floors, typically at least six feet away from the exterior walls. Typical photos of exterior and interior sound level meter installations are shown in Figure 6-1 and Figure 6-2.

Figure 6-2: Interior Sound Level Meter

Figure 6-1: Exterior Noise Monitor

6.5 Data Analysis Methodology

6.5.1 Identification of Flyovers

As mentioned in the previous section, all sound level meters were programmed to record the sound level one time per second, in terms of overall dBA and the spectral (frequency) content (i.e., third octave bands). During the measurements, the logged sound level contained contributions from aircraft flyovers, local community events (e.g., vehicular pass-bys, bells ringing at Georgetown University), and background noise (e.g., birds).

In order to quantify aircraft noise levels at each exterior monitoring location, it is necessary to isolate flyover noise from other, non-aircraft noise sources. The procedure for identification of flyover events consists of two primary steps, as follows:

1. Run an “event” search/analysis for all noisy events above 65 dBA exterior and 35 to 45 dBA interior. The 65 dBA exterior exceedance threshold was chosen based upon typical background noise levels at the measurement locations (which were typically between 45 and 60 dBA, depending on time of day); similarly, the interior threshold was selected based upon the interior background noise levels. After running the event search, a listing of all noisy events including event time, duration, and associated sound levels was generated.

2. Identify all aircraft flyover events. For every exceedance event, staff listened to the associated audio recording in order to identify the cause of the noisy event. The source of each event was logged.

6.6 Calculation of SEL

Aircraft flyover events are typically quantified in terms of SEL whose mathematical symbol is L_{AE}. The SEL is a statistical noise descriptor, which sums the acoustic energy over the duration of a flyover event (which is typically 10 to 20 seconds) into a reference duration of one second (see formula below):

$$SEL = Leq + 10 * LOG(event\ duration)$$

For every identified flyover event, our analysis software calculated overall duration, L_{eq}, L_{max} (maximum level), and SEL.

6.7 Calculation of DNL

The DNL noise exposure (i.e., the 24-hour average noise exposure with a 10 dBA penalty for events occurring between 10:00 pm and 7:00 am) can be calculated from a series of flyover events if the SEL of each event is known. For every exterior noise monitoring location, the daily DNL was calculated per the following formula:

$$L_{dn} = 10*\log10 \left[\!\left[\left(\frac{15}{24}\right) * \left(\frac{To}{Td}\right) \sum_{i=1}^{Nd} 10^{(0.1*LAEi} \right]\!\right] + 10*\log10 \left[\!\left[\left(\frac{9}{24}\right) * \left(\frac{To}{Tn}\right) \sum_{i=1}^{Nn} 10^{(0.1*(LAEi+10)} \right]\!\right]$$

Where: L_{dn} is the day-night average sound level
$LAEi$ is the sound exposure level
Nd is the number of daytime sound exposure level events
Nn is the number of nighttime sound exposure level events
Td is the 15 daytime hours or 54,000 seconds
Tn is the 9 nighttime hours or 32,400 seconds
To is the reference time of 1 second

The 15 daytime hours are from 7:00 am to 10:00 pm; the 9 nighttime hours are from 10:01 pm to 6:59 am.

6.8 Supplemental Metrics

Various public agencies (e.g., DoD) and experts have acknowledged some of the limitations of the exclusive use of the DNL to quantify aviation noise impacts. While the DNL is one of the only metrics that has significant social research/surveys used to back up the thresholds of significance, there are other supplemental noise metrics that are useful in quantifying and describing aviation noise impacts. However, it should be noted that, with the exception of the classroom noise metrics, there are no generally accepted thresholds of significance/impact for these metrics.

DNL is the only noise exposure standard adopted by the EPA, and the only standard used by the FAA and every other government agency to assess community noise annoyance. It is applied for aircraft noise, highway noise, industrial noise and all other noise sources assessed under the NEPA. The DNL is also the only noise metric for which there is a scientific and comprehensive assessment of the degree of community noise annoyance. Appendix A – Acoustic Properties, Perception, Noise Measures, Metrics and Day-Night Average Sound Level (DNL) discusses the DNL metric and its correlation with community noise annoyance in more detail.

DNL is often misunderstood by the public both in its technical basis and in its noise policy ramifications. Sound and other human perception obeys the Weber-Fechner law which expresses the relationship between the magnitude of a physical stimulus (including noise) and the intensity or strength that people feel. This relationship is logarithmic and non-linear (e.g., two cars passing by produce twice the sound energy of a single car, but are perceived as only marginally louder. It would take ten identical cars to be perceived as twice as loud). Thus, the energy summation scheme embedded in the DNL descriptor is not intuitive. Secondly, DNL only relates to the percent of the population "highly annoyed" at specific levels. The FAA, prior to NextGen, established a noise mitigation criterion of 65 DNL (with 12.5% highly annoyed); this was principally for sound insulating homes at no cost to the owner. Those individuals with noise exposure below 65 DNL often felt that the DNL metric was flawed in not including them in FAA noise mitigation programs.

Therefore, much of the public believes that additional metrics (aka "supplemental metrics") are required. This is stated in a paper by William Albee, Wyle Laboratories, "Why We Must Supplement DNL Noise Analysis", 2002; another by Mary Ellen Eagan, HMMH, "Using Supplemental Metric to Communicate Aircraft Noise Effects," 2007; and in a DoD Noise Working Group, Technical Bulletin, "Using Supplements Noise Metrics and Analysis Tools", December 2009. All cite public interest in new metrics and a lack of understanding of DNL.

The principle supplemental metrics discussed are:

- Maximum A-weighted Sound Levels (MXAL): A measure of the maximum sound level during an aircraft flyover
- SEL: A measure of duration and magnitude of a single noise event in A-weighted decibels
- Equivalent Sound Level (L_{eq}): The average noise level over a specified time, such as school hours
- Time Above (TA or TAL): The amount of time that a noise event exceeds a maximum decibel level (MXAL) threshold
- Number of Events (N-Level, NA, or NAL): The number of noise events above a maximum decibel level threshold during a specified period
- Rattle: The low frequency noise effects on loose items and building elements
- Sleep Interference: The percent of the population awakened in a specific interior noise environment
- Learning: The noise effects of aircraft noise on children's learning

While the public may relate well to these metrics, only the last two, sleep interference and learning, have scientific standing. These metrics, like the DNL, were developed from scientific research into the noise exposure effects on humans, and have documented procedures published by the American National Standards Institute (ANSI).

Measures as 'Time Above' and 'Number of Events' are more readily understood by the public, but we find no research on their effects on annoyance or other human factors. It would be useful to conduct studies on these metrics to evaluate their effects on humans.

The TA is a useful descriptor of the noise impact of an individual event, and also for multiple events occurring over a certain time period. TA analysis is usually conducted along with NA analysis, so the results show not only how many events occur above the selected threshold(s), but also the total duration of those events above those levels for the selected time period. TA has application for describing the noise environment in schools, particularly when comparing the classroom or other noise sensitive environments for different operational scenarios.

The NA metric has a distinct advantage in communicating current and projected noise exposure in a way not available through the use of other metrics or tools. It is the only supplemental metric that combines single-event noise levels with the number of aircraft operations. Anecdotal evidence has shown that the public easily relates this metric to their everyday experience.

Finally, noise annoyance is known to vary considerably among individuals. While a certain percent of the population is highly annoyed with a particular noise environment, the remaining percent is not. In our experience with many communities, we find large areas of significant noise exposure but only a small fraction of that population attending any public meetings to address it.

6.9 Calculation of TA and NA Levels

The TA and NA are supplemental metrics that are useful in assessing the degree of speech interference from a noise source. TA is simply the total time that a specific sound level is exceeded over a specific measurement period, whereas NA is the number of events (flyovers) that exceed a specified level. For exterior noise, an A-weighted level of 65 dBA is used, as this is where speech communication can begin to be impacted.

6.10 School Performance Analysis

It has long been recognized that a poor acoustic environment adversely affects learning for many students. In 2010 a committee of twenty-two acoustic experts compiled and examined relevant research and formulated a new standard for schools. This standard sets forth recommended acoustical performance criteria and noise isolation design requirements and guidelines.

The main acoustical factors addressed in the standard are:

- One-hour average A- and C-weighted noise within the learning space
- Noise from heating, ventilating, and air-conditioning (HVAC) and other mechanical equipment
- Background noise in corridors and sound insulation of party walls
- Learning space reverberation time
- Sound Transmission Class (STC) and Impact Isolation Class (IIC) ratings for party walls and floor/ceiling systems
- Classroom audio distribution systems

Aircraft flyover noise is not an element of all acoustical requirements and guidelines. However, it is an important element of one-hour average A- and C-weighted noise. The noise assessment of this report evaluates the measured noise environment within classrooms and assesses compliance with the Standard.

6.10.1 Noise and Learning Impacts

There have been numerous studies and research performed to determine the effect environmental noise (including aircraft) has on student learning. The following summarizes some of the relevant conclusions with respect to aircraft noise and student learning; additional information can be found in the documents referenced below:

- "Children exposed to noise at school experience some cognitive impairments, compared with children not exposed to noise; however, these effects are not uniform across all cognitive tasks"[17]
- "Children exposed to chronic environmental noise have been found to have poorer auditory discrimination and speech perception…as well as poorer memory…deficits in sustained attention and visual attention…and poorer reading ability and school performance on national standardized test"[18]
- "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."[19]
- Reading falls below average at noise exposures greater than 55 dBA (exterior)[20]
- The association between the effects of aircraft noise and student test scores is statistically significant. Up to an 12 percent decrease in a school's State ranking (based on standardized testing) was estimated for schools impacted by aircraft noise[21]
- Sound insulated schools have better test scores than schools without sound insulation[22]

6.10.2 Schools Located in Georgetown

In addition to the three measured schools (Georgetown University, Georgetown Day, and Georgetown Visitation), there are numerous additional schools located in Georgetown and Palisades area:

- Key Elementary School at 5001 Dana Pl NW
- Our Lady of Victory Catholic School at 4755 Whitehaven Parkway NW
- St. Patrick's Episcopal School at 4700 Whitehaven Parkway NW
- River School at 4880 MacArthur Blvd NW
- Lab School at 4759 Reservoir Road NW
- Georgetown Day School (lower and middle grades) at 4530 MacArthur Blvd NW
- Georgetown Visitation 1524 35th St. NW
- Montessori School of Washington at 4380 MacArthur Blvd NW
- Hyde Addison Elementary School 3219 O St NW
- Hardy Middle School 1819 35th St. NW
- Duke Ellington School of Arts 3500 R St. NW
- Washington International School 1690 36th St. NW

---

[17] Quoted from ACRP Project Report 02-26, "Assessing Aircraft Noise Conditions Affecting Student Learning," Page 2-2. This quote is a conclusion drawn from other research papers reviewed as a part of this ACRP report.
[18] Ibid, Page 2-3.
[19] SA Stansfeld, et al. "Aircraft and Road Traffic Noise and Children's Cognition and Health: A Cross-National Study." [RANCH Study} Lancet, 2005. Page 1946.
[20] ACRP Project Report 02-26, Page 2-7; based on the RANCH Study cited above.
[21] ACRP Project Report 02-26, Page 2-7, Pages 5-16 and 5-19.
[22] ACRP Project Report 02-26, Page 2-7, Page 5-19.

- The Children's House of Montessori 3133 Dumbarton St. NW
- The Field School 2301 Foxhall Rd. NW
- The French Maternal School 3115 P St. NW
- Georgetown Montessori School 1041 Wisconsin Ave NW
- Holy Trinity School 1325 36th St. NW

6.11 Awakening Calculation Methodology

Sleep disturbance studies were conducted for the DCA Airport Airplane Noise project. Each study uses a procedure from the American National Standards Institute to calculate sleep disturbance.

When investigating aircraft noise exposure, the DNL metric is commonly used to provide a single number rating to quantify the aircraft noise environment. Complementing the DNL are supplemental metrics, the most common of which is sleep disturbance. This report uses the SEL measurement results from various residences during nighttime sleeping hours to compute the probability of awakening (or the percent of the population awakened in this nighttime noise environment).

This report employs the most complex assessment method from American National Standard on awakenings. This Standard provides a method to predict sleep disturbance in home settings where people are familiar with the neighborhood noise environment (people are more easily awakened when unfamiliar with the noise environment). Sleep disturbance is restricted to behaviorally confirmed awakening as demonstrated, for example, by pressing a button upon awakening. Noise levels are quantified as indoor A-weighted sound exposure levels of outdoor events occurring less than five minutes prior to the awakening. The Standard further assumes that the sleepers have normal hearing with no sleep disorders.

The procedure for computing awakenings, set forth in the ANSI standard, was developed from research data on aircraft flyover awakenings from several independent studies (see Appendix C for list of references). The computation procedure uses three elements:

- The probability of an awakening from a single event,
- The probability of awakening as a function of time since retiring (the probability of an awakening due to a noise event increases as time in bed increases), and
- The probability of being affected by sound from distributions of single noise events.

The Standard is primarily based on sleep disturbances caused by aircraft noise. The Standard presents three methods for assessing sleep disturbance. The first method simply assesses the probability of a normal person being awakened by an aircraft noise event of a specific sound exposure level. This is the same as the percent of a normal population awakened by the aircraft noise event.

The second method presented in the standard also factors in the time since retiring. This method incorporates the effects of sleep stage on the awakening.

The third method in the standard incorporates both time since retiring and the effects of a sequence of aircraft noise events during the night. This method, applied for this report, assess the effects of measured noise events in the tested residences. This method is based upon the fact that, after a period of time, the propensity for awakening becomes constant. Appendix C describes the computation procedure.

6.12 Measurement Results and Conclusions

6.12.1 Exterior DNL

The calculated DNL for each exterior noise monitor is listed in Table 6-3 and Table 6-4 below.

Table 6-3: Phase 1 Measured Exterior DNL Values (dBA)

Location	6/13/17 (South Flow)	6/14/17 (North Flow)	Long Term: 6/13 – 7/12/17 North Flow	South Flow	Mixed Flow	Overall
R1: Reservoir Rd. Residence	56.3	61.9	-	-	-	-
R2: MacArthur Blvd. Residence	55.4	60.7	59.3	56.2	59.0	58.0
R3: Hillandale Residence	50.6	58.0	58.4	51.6	56.8	55.8
S1: Georgetown University	60.3	64.6	-	-	-	-
S2: Georgetown Visitation Preparatory	52.8	59.5	-	-	-	-

Note: DNL on 6/13 only includes events beginning at 9 am for Locations R3 through S2.

Table 6-4: Phase 2 (6/20/18-7/15/18) Measured Exterior DNL Values (dBA)

Location	North Flow	South Flow	Mixed Flow	Overall
L1: 47th Street	61.2	57.0	60.9	60.2
L2: Charleston Terrace	60.7	57.7	60.3	59.9
L3: Georgetown Day	62.9	61.2	63.2	62.5
L4: Georgetown University	63.3	60.6	62.3	62.3
L5: Hillandale Residence	58.2	52.5	57.3	56.8
L6: Reservoir Road	60.8	57.9	60.5	60.0

Note: Data from 7/7 and 7/8/18 missing from Georgetown University due to wireless network issues.

The Phase One long-term (30 day) DNL noise measurement results are presented graphically in Figure 6-3. The Phase Two DNL noise measurement results are presented graphically in Figure 6-4. Both figures are separated by flow type (North, South, and Mixed). North flow is defined as 75% of arrivals were from the south and 75% of the departures were to the North (over Georgetown) for a given day, South flow is the opposite of North Flow, and Mixed flow indicates a blend of North and South flow over a 24-hour period.

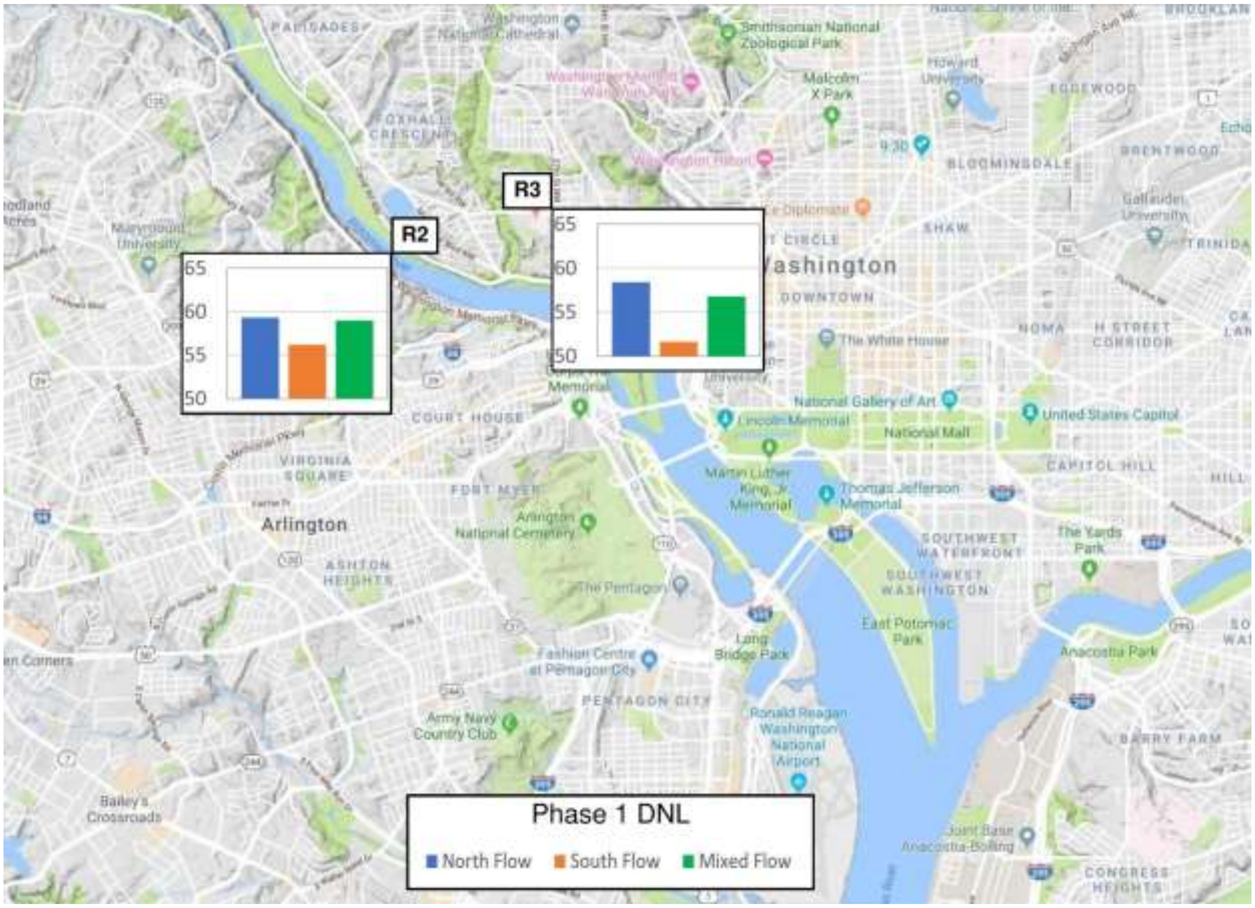

Figure 6-3: Phase 1 Measured Exterior DNL by Flow Type

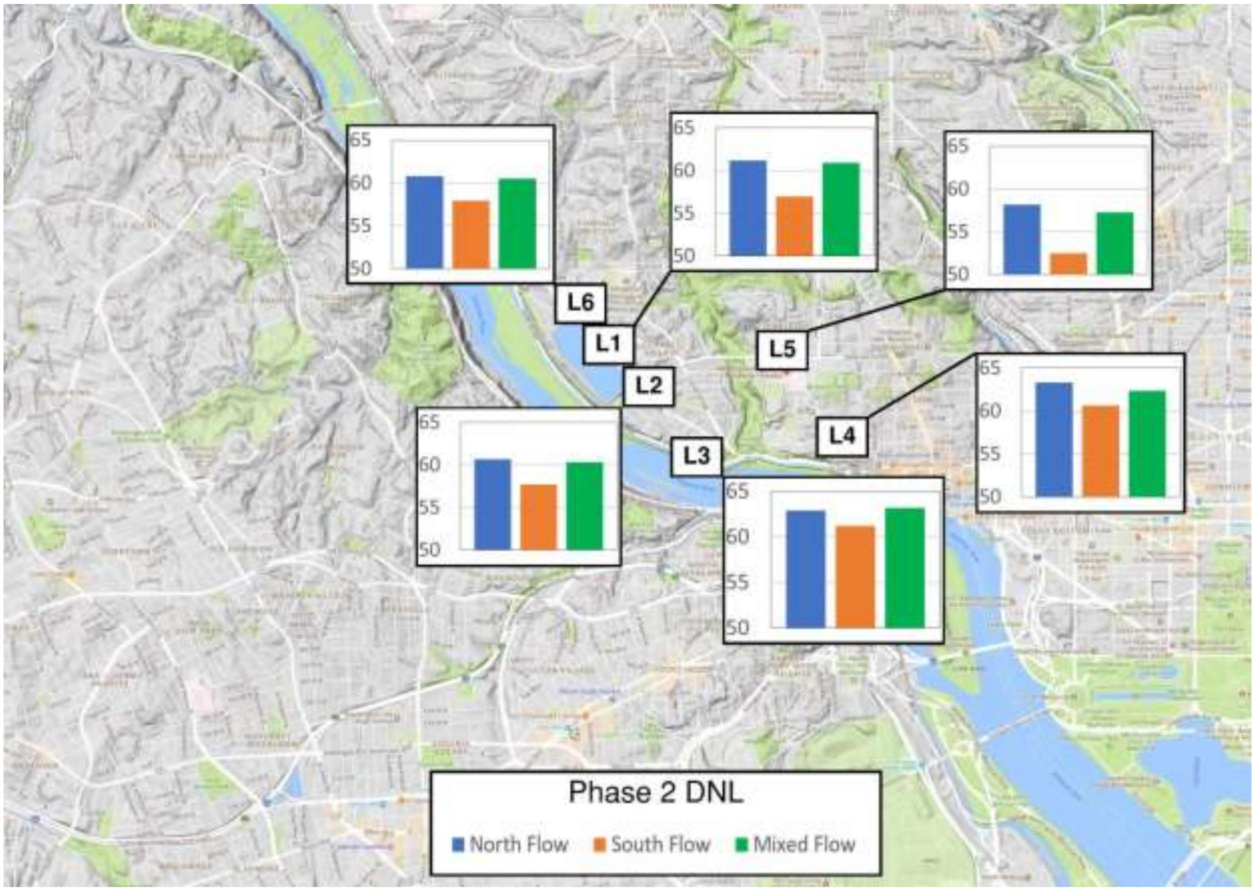

Figure 6-4: Phase 2 Measured Exterior DNL by Flow Type

As can be seen in the figure, DNL noise levels vary between 55 and 63 dBA, with North Flow DNL noise levels being 1 to 4 dBA higher than South Flow noise levels.

6.12.2 Comparison between MWAA NMT and DOEE Noise Monitor

A comparison between MWAA's NMT #6 and monitors from this measurement study was also conducted. The noise monitor located at the sports field at Georgetown Visitation Preparatory School was in close proximity to MWAA's permanent NMT #6, which is located at the School's maintenance building. Table 6-5 summarizes the results of this comparison.

Table 6-5: Comparison of Results between DOEE and MWAA

	L_{eq} (dBA)		SEL (dBA)		Event Duration (sec)		DNL (dBA)	
	MWAA	DOEE	MWAA	DOEE	MWAA	DOEE	MWAA	DOEE
Aircraft Flyover Averages	60.3	65.0	73.9	75.4	24.8	14.1	55.9	57.3
Community Noise Averages	57.9	62.9	66.0	69.8	7.0	10.0	-	-

Note: DNL is the average of two monitoring days, 6/13 and 6/14. DNL calculation for both MWAA and DOEE monitors includes data beginning at 9 am on 6/13 as that is when the DOEE monitor at Georgetown Visitation was set up.

Based on a review of the data, it appears the MWAA monitor has a lower exceedance (trigger) threshold than the 60 dBA threshold used for the above analysis of the DOEE monitors; this is because the average event duration is longer for the MWAA monitors (meaning events at NMT #6 begin earlier and end later), and the overall L_{eq} is lower for NMT #6. Since the L_{eq} is an average level over time, the longer the event duration, the lower the L_{eq} will be. However, it should be noted that the average flyover SEL is similar between the two monitors (approximately 1.5 dBA) apart. Since the SEL metric sums the acoustic energy of an event to a reference time of one second, the SEL is useful to compare noise events between two monitors when the threshold (trigger) level of one (or both) of the monitors is unknown. A difference of 1.5 dBA can be attributed is generally within the margin of error of field measurements, and can be attributed to local reflections, slight differences in meter response/calibration, etc.

The DOEE SEL values are consistently 1.5 dBA above those from MWAA. In the DNL computation, this would result in DOEE DNL values being 1.5 dBA higher than those reported by the NMT system.

6.12.3 NA Level

The average Number of Daily Flyovers above 65 dBA (NA-65) for the Phase 1 and Phase 2 measurements are shown in Figure 6-5 and Figure 6-6, respectively, separated by flow type.

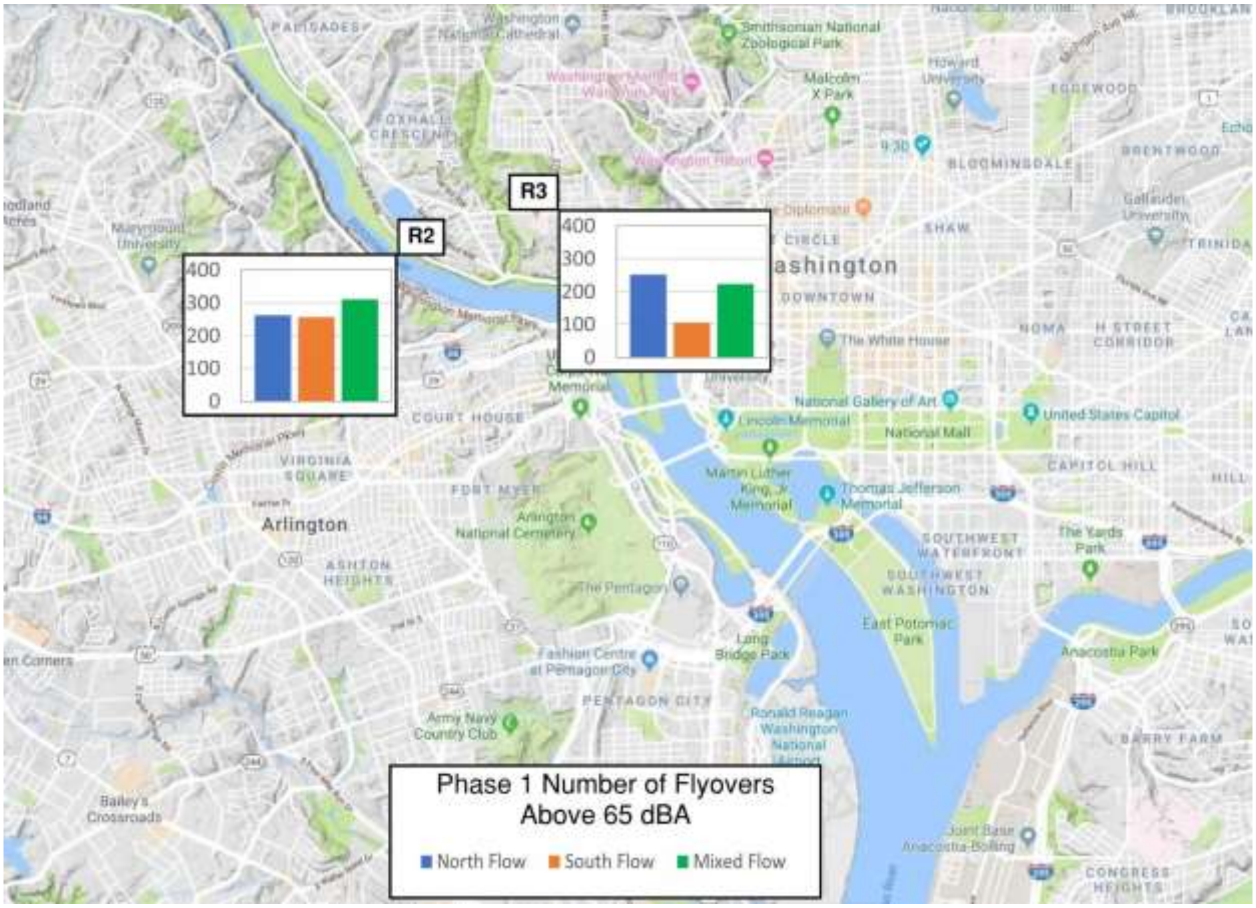

Figure 6-5: Phase 1 Number of Daily Flyovers Above 65 dBA by Flow Type

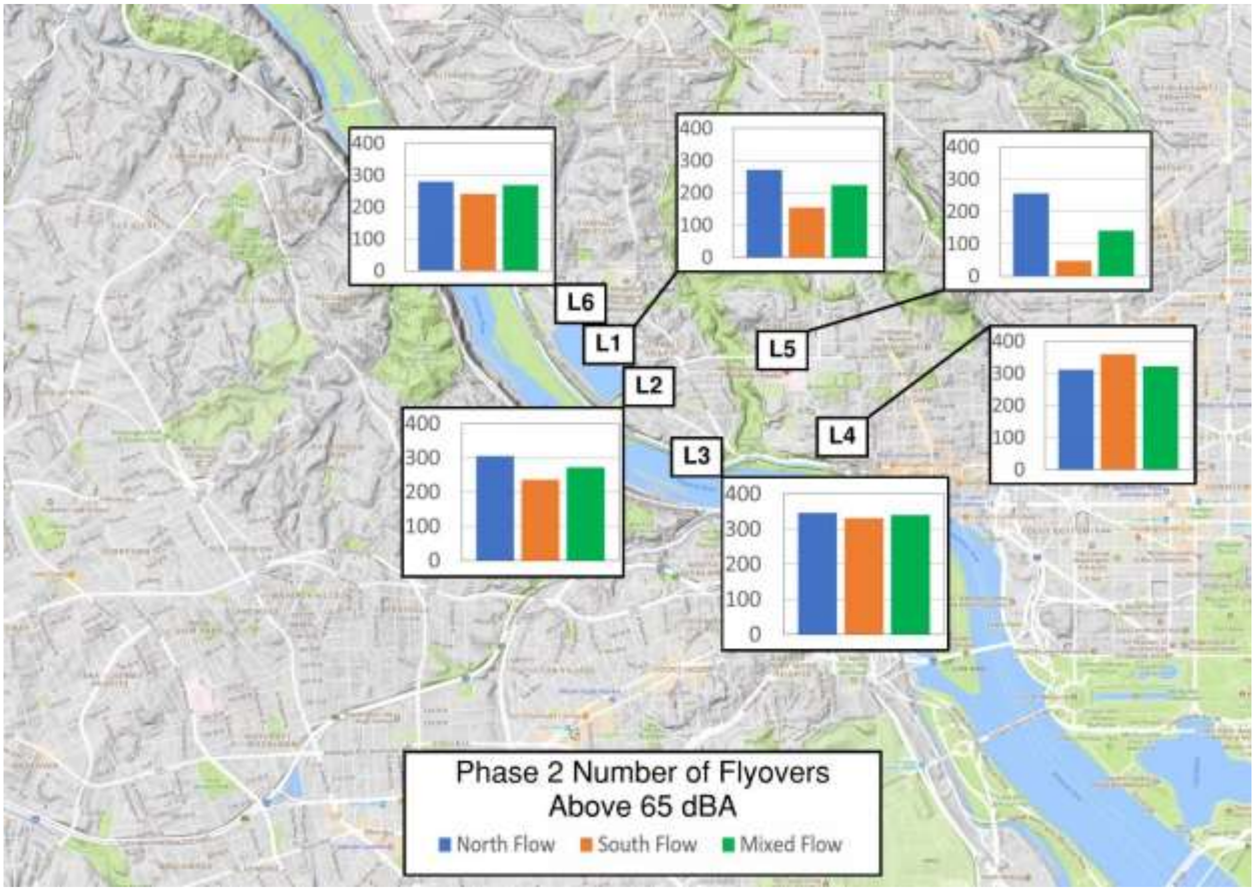

Figure 6-6: Phase 2 Number of Daily Flyovers Above 65 dBA by Flow Type

As can be seen in the figure, for locations near the Potomac River, the number of daily flyovers above 65 dBA is typically greater than 300. At locations further east/north of the river, the number of daily flyovers above 65 dBA is between 100 and 300, with a greater number of events above 65 dBA when in North Flow.

The average Number of Daily Flyovers above 75 dBA (NA-75) for the Phase 1 and Phase 2 measurements are shown in Figure 6-7and Figure 6-8, respectively, separated by flow type.

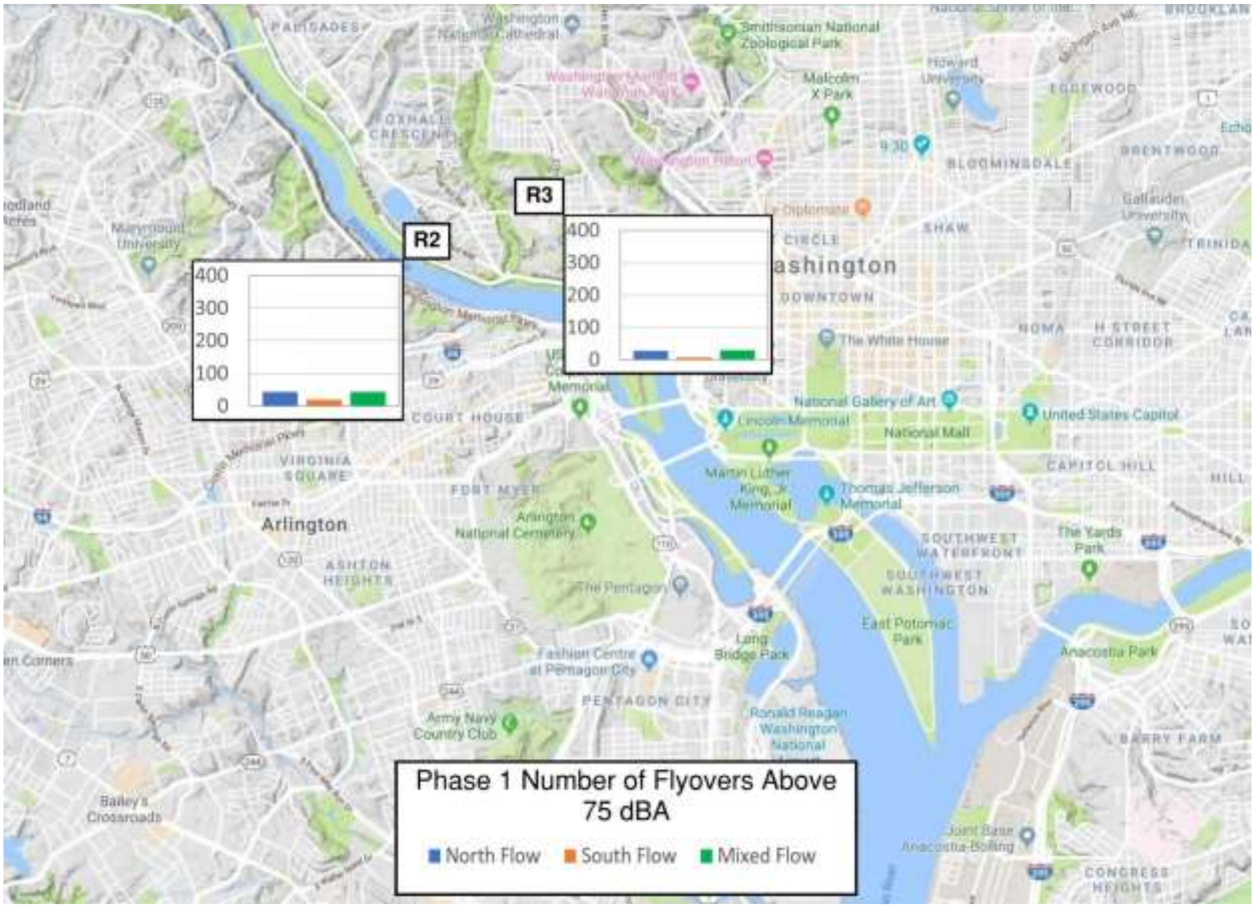

Figure 6-7: Phase 1 Number of Daily Flyovers Above 75 dBA by Flow Type

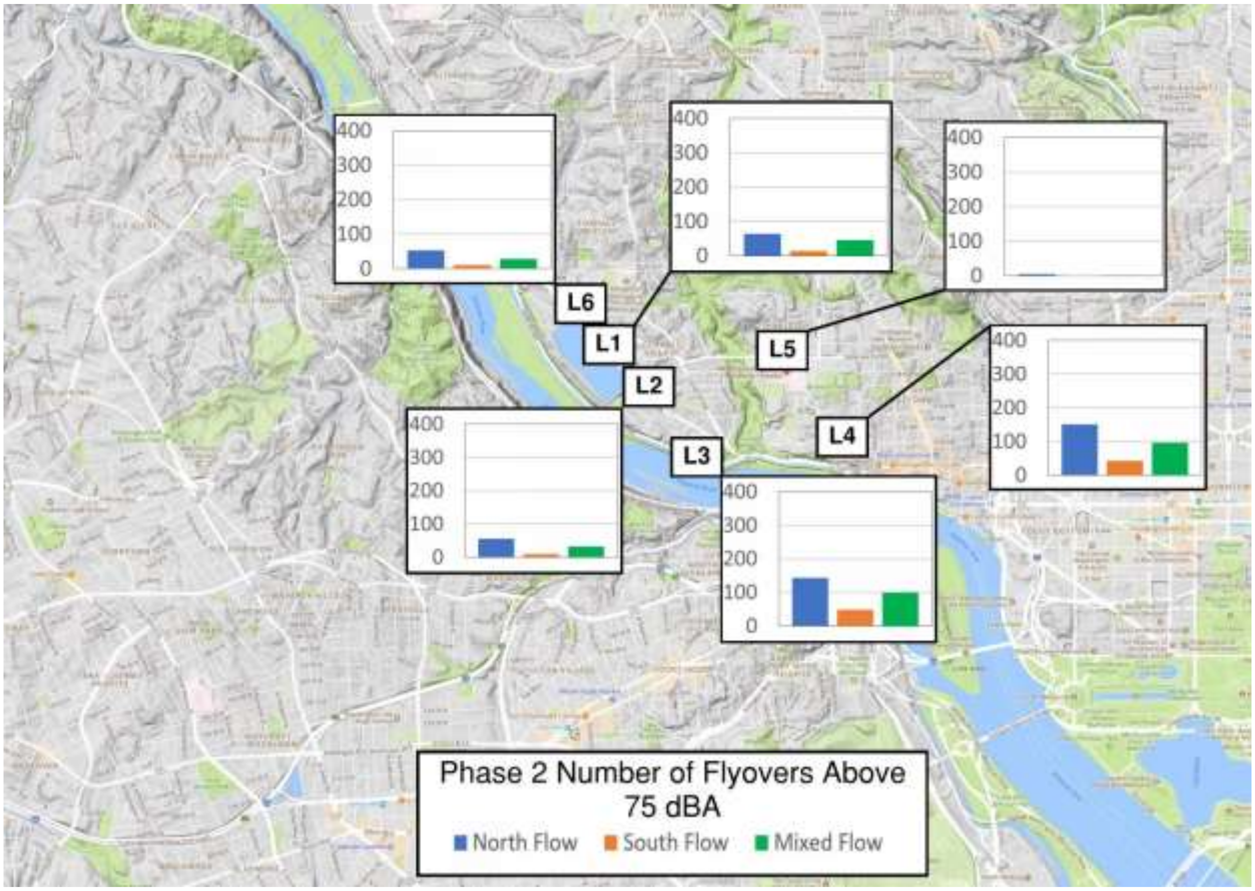

Figure 6-8: Phase 2 Number of Daily Flyovers Above 75 dBA by Flow Type

Those receivers located closest to DCA had the highest number of flyovers above 75 dBA; most locations had 100 or fewer events per day.

6.12.4 Daytime and Nighttime Average Noise Levels

The average daytime [$L_{eq(day)}$] and nighttime [$L_{eq(night)}$] aircraft noise levels were also calculated. Figure 6-9 through Figure 6-12 show the daytime and nighttime average aircraft noise levels for both Phases 1 and 2, separated by Flow Type.

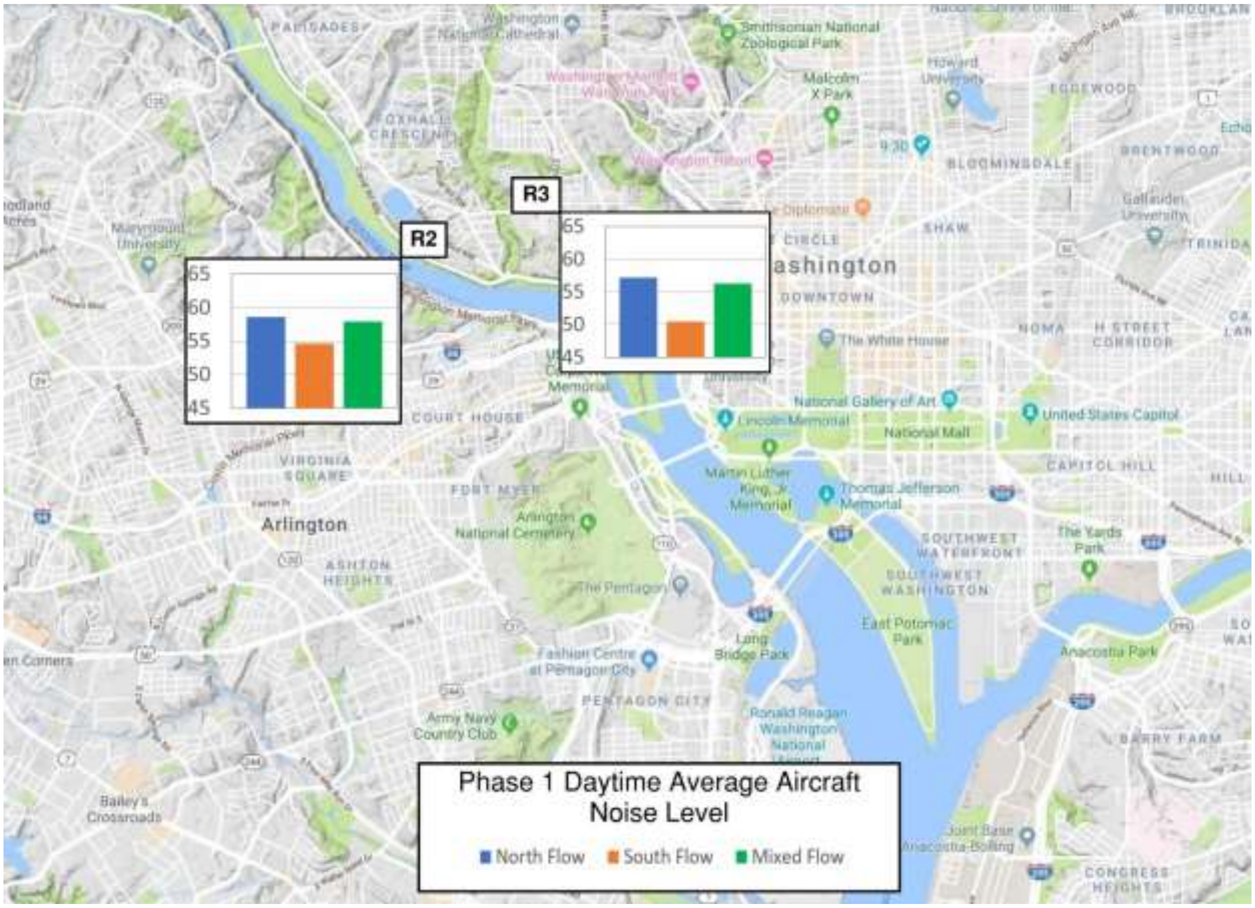

Figure 6-9: Phase 1 Daytime Average Aircraft Noise Level by Flow Type

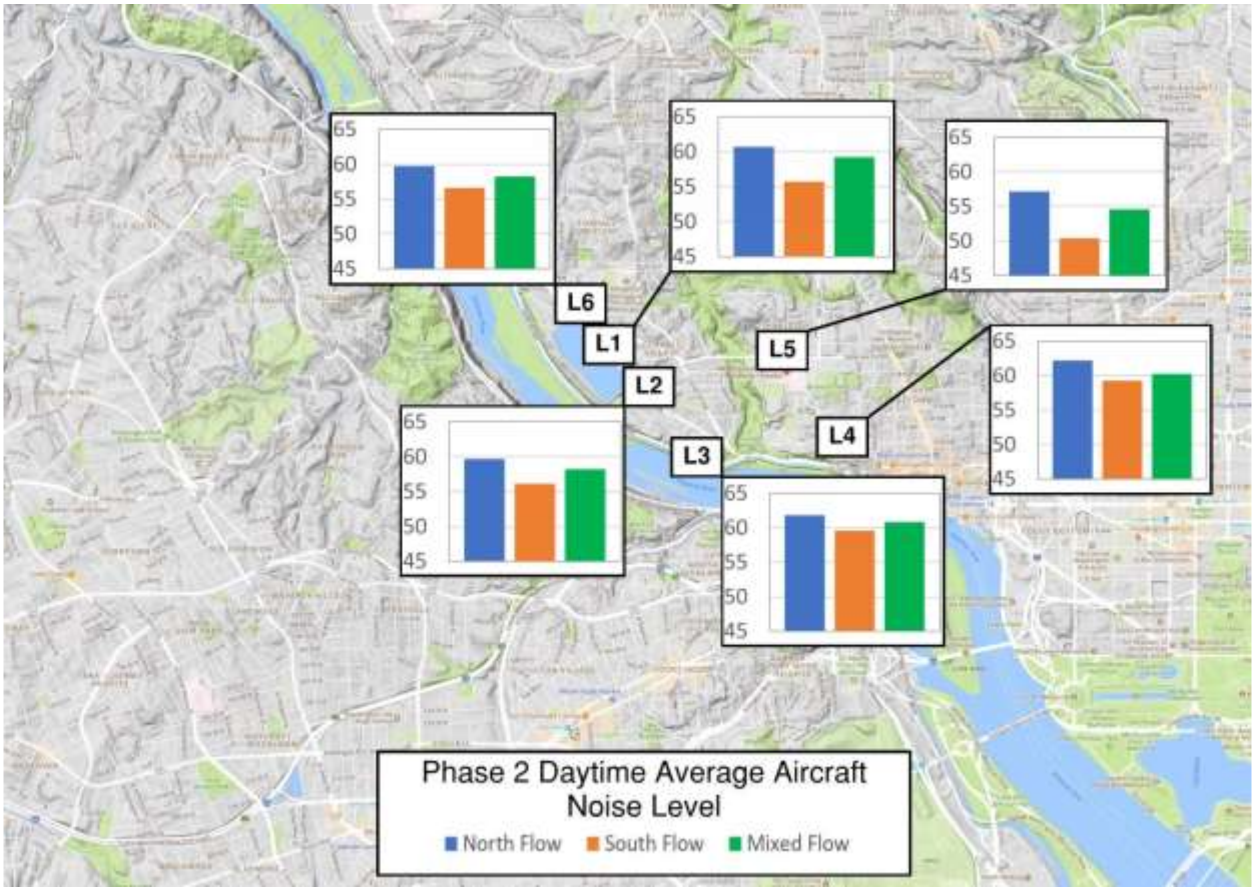

Figure 6-10: Phase 2 Daytime Average Aircraft Noise Level by Flow Type

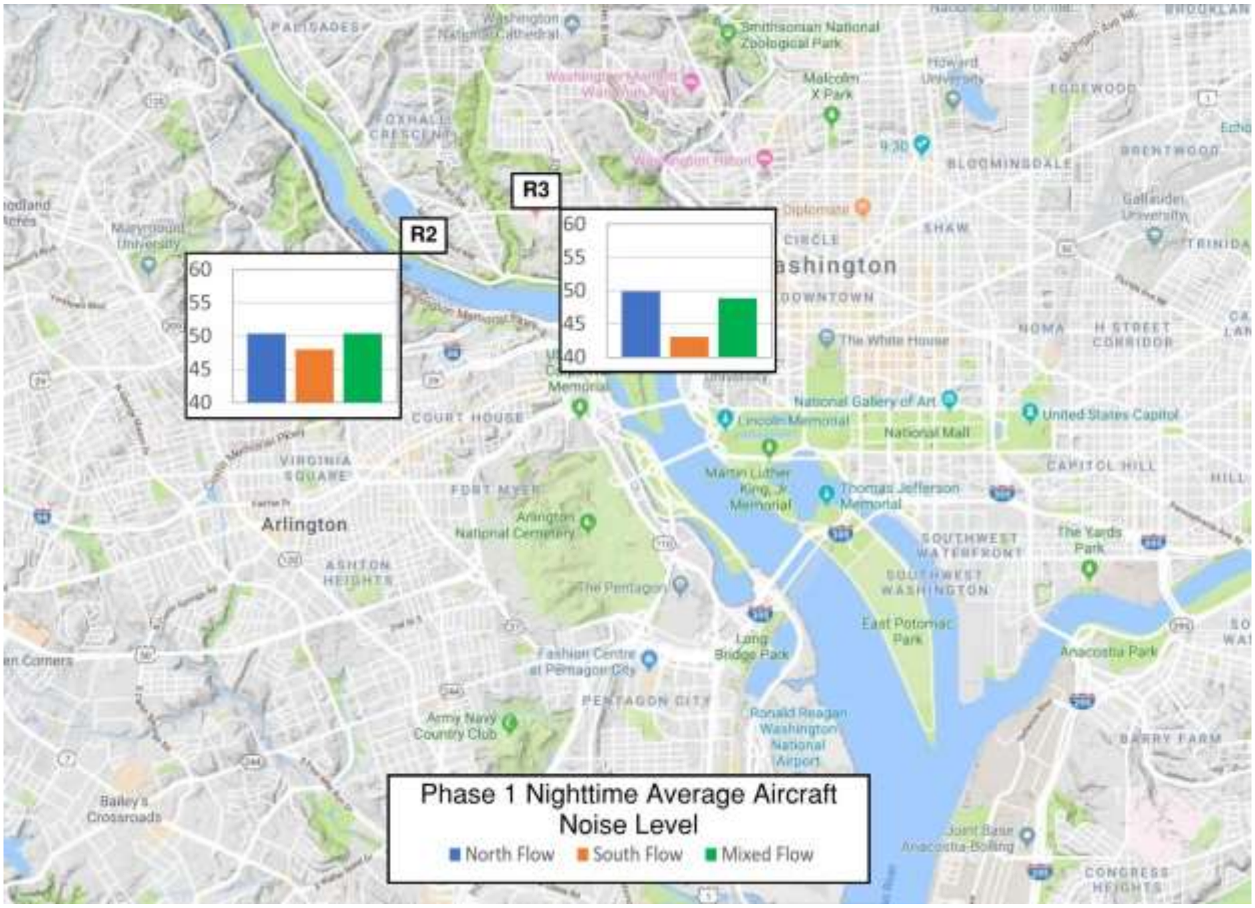

Figure 6-11: Phase 1 Nighttime Average Aircraft Noise Level by Flow Type

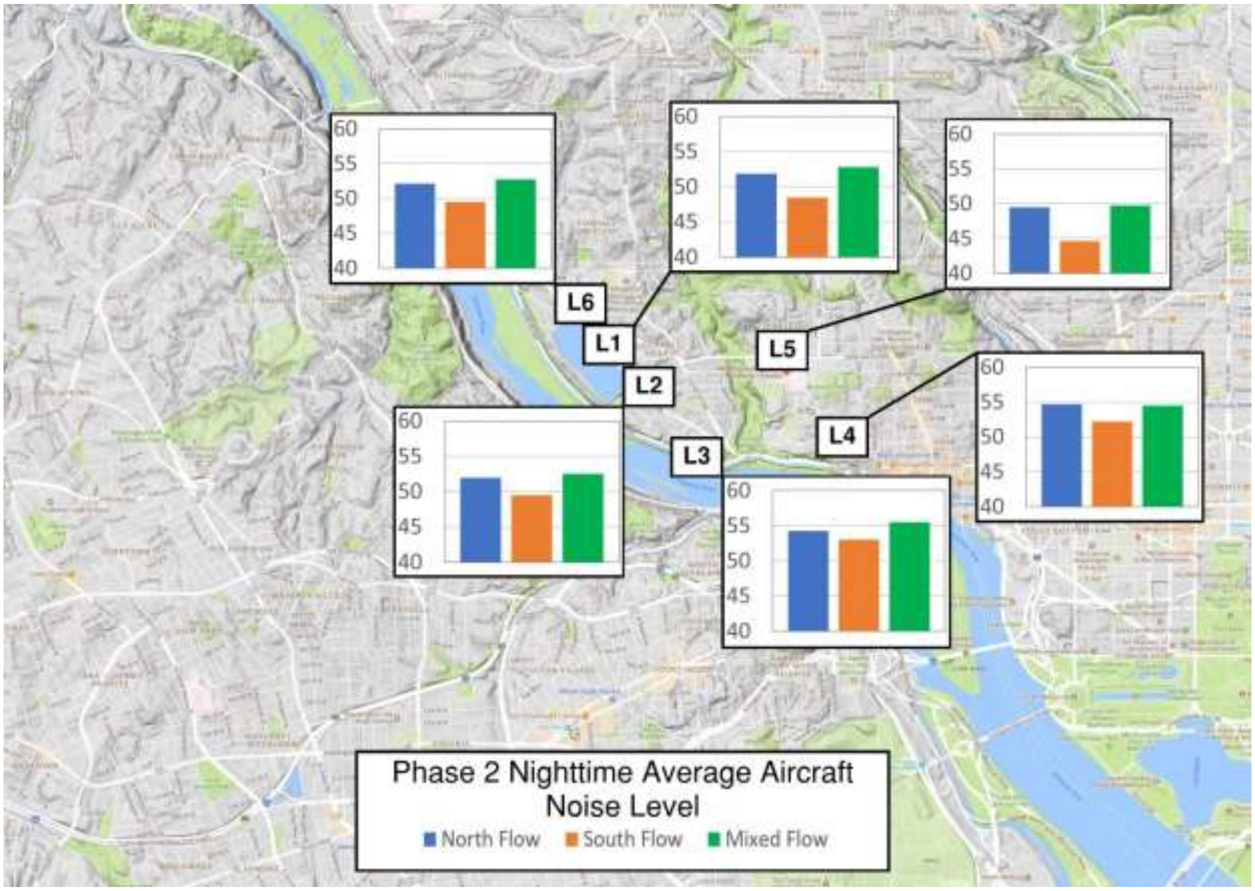

Figure 6-12: Phase 2 Nighttime Average Aircraft Noise Level by Flow Type

6.12.5 Nighttime Flight Distribution

Figure 6-13 below shows the series of measured SEL exterior flyover events during the night of June 13-14, 2017 at one of the residences. The purpose of the figure is to show the distribution of events, with the majority of nighttime events occurring between 6:00 am and 7:00 am.

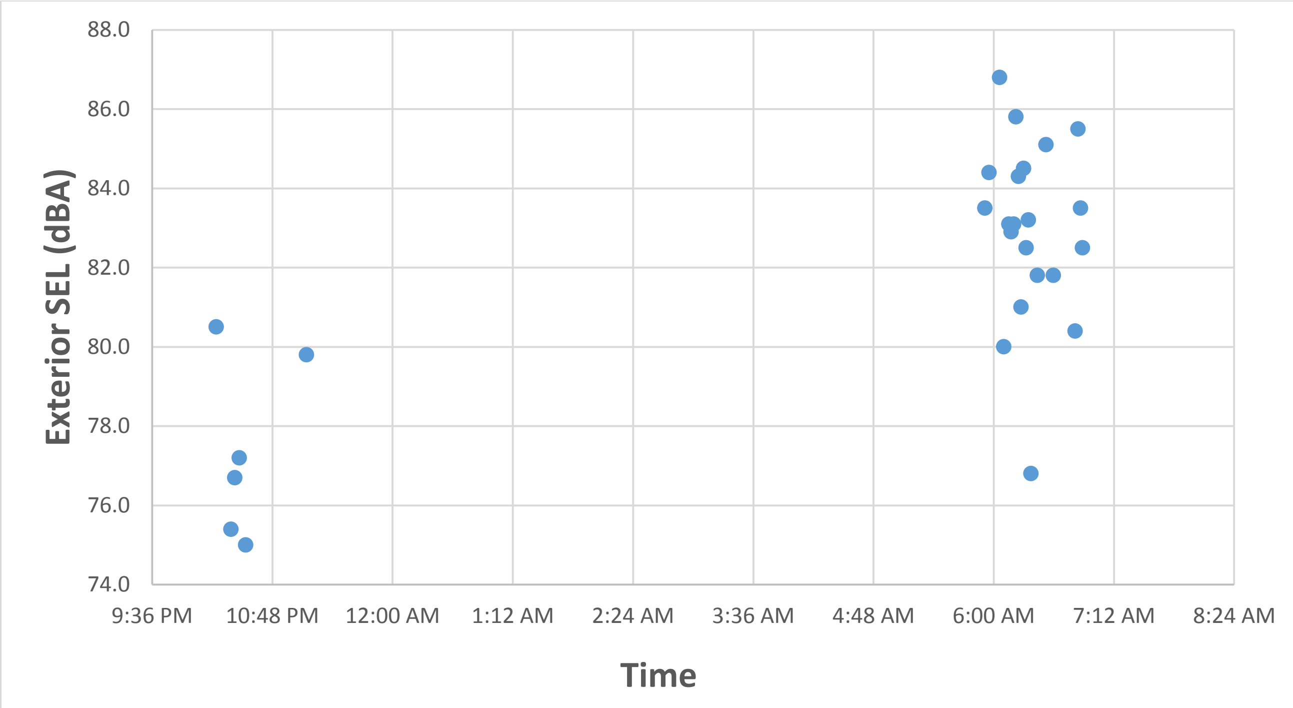

Figure 6-13: Charleston Terrace (L2) Nighttime Flyover Events (June 13-14, 2017)

6.12.6 Awakenings

Table 6-6 provides the summary results for the monitored residences. The table shows the total probability of a single person awakened during the night with the measured interior noise. It also tabulates the Noise Level Reduction (NLR) measured for each residence.

Table 6-6: Awakening and NLR Results

Residence	Location	Monitoring Period	Probability Awakened				NLR (dBA)
			Overall	North Flow	South Flow	Mixed	
R1	Reservoir Road	June 13 – 14, 2017	12.5 %	-	-	-	30
R2	MacArthur Boulevard	June 13 – 14, 2017	34.3 %	-	-	-	19
R3	Hillandale	June 13 – 14, 2017	30.9 %	-	-	-	21
L1	47th Street	June 20 – July 15, 2018	17.3%	18.2%	7.8%	28.5%	28
L2	Charleston Terrace	June 20 – July 15, 2018	32.4%	34.8%	23.5%	39.2%	21
L5	Hillandale	June 20 – July 15, 2018	20.7%	23.2%	8.7%	27.8%	24
L6	Reservoir Road	June 20 – July 15, 2018	13.0%	14.8%	4.5%	21.1%	31

The awakening results are well correlated with the NLR of each residence. That is, the home providing the greatest noise reduction from exterior flyovers receives lower noise inside, with attendant less propensity for awakening. The noise reduction of a home is a function of its construction; specifically, the NLR properties of the sleeping areas. Aircraft noise generally impinges on a home equally on most exterior facades. Most noise enters the room through the weakest acoustical link, those building element(s) with the poorest noise attenuation properties. These are invariably the windows and any open vents through the wall. Of course, open windows provide the poorest noise attenuation.

Homes may be acoustically retrofit to improve the NLR. The FAA has a national residential noise insulation program for noise impacted homes in areas where the average annual DNL is 65 dBA or greater. Retrofit of homes in other areas (with a DNL below 65 dBA) is the responsibility of the owner(s). The single greatest NLR improvement for a room is the application of a window storm sash or, replacement of the existing windows with sound-rated windows. The application of a secondary window with a minimum separation of two inches between the secondary and primary glazing panels is also an effective option. The objective of window treatment is to increase the NLR properties of the window to near that of the basic facade. Where exterior doors are included, they must also be treated to improve their NLR properties to near that of the facade.

Individual homeowners may reduce interior noise though retrofit acoustic treatment. This requires an acoustical assessment, retrofit design and construction compliant with the local building code. We recommend that an acoustical consultant, experienced in sound insulation, be contacted for retrofit design. The objective of residential sound insulation is to upgrade the NLR properties of weak acoustical elements (i.e., windows, exterior doors, vents, roof/ceiling system) with that of the facade. Homes with a heavy stucco/stone facade may be upgraded to an NLR of 30 dBA; those with lightweight wood or aluminum paneling may likely only achieve an NLR of 25 dBA.

6.13 Classroom Noise Analysis

The schools' performance standard specifies a maximum one-hour equivalent sound level (L_{eq} value), termed an Hourly Noise Level (HNL), during any hour of the teaching day. This standard is in two parts: one for the A-weighted sound level (units of dBA or dB), and one for the C-weighted sound level (units of dBC). Thus, interior school noise measurements were made applying both measurement metrics. A-weighted sound levels are frequency-biased for human response to mid-level sound, deemphasizing low frequency sound. C-weighted sound levels eliminate this bias. Aircraft noise contains more low frequency sound than most community noise sources, and is therefore more likely to exceed the C-weighted standard of 55 dBC than the A-weighted standard of 35 dBA. Table 6-7 shows measurement results with respect to the schools' HNL standards.

Note that a difference of 3 dB corresponds to a doubling of sound energy and a 10 dB difference corresponds to ten times the acoustical energy. However, subjectively, a difference of 3 dB is considered "just noticeable," a difference of 5 dB is considered "readily perceptible," and a difference of 10 dB is considered twice as loud.

Table 6-7: Peak Hours Average Sound Levels and Classroom Standard Values

Phase – Room – Date – Flow Direction	Hour	ANSI 12.60 Criteria HNL (dBA)	ANSI 12.60 Criteria HNL (dBC)	Measurements HNL (dBA)	Measurements HNL (dBC)
Phase 1 – Chemistry Lab – Rm 404* (6/14/17) North	09:51 – 10:00	35	55	34.7	51.7
Phase 1 – Healey – Rm 106* (6/13/17) North	14:00 – 15:00	35	55	**36.1**	**62.6**
Phase 1 – Fannasi – Rm F2* (6/14/17) North	13:00 – 14:00	35	55	**36.0**	**58.7**
Phase 1 – Fannasi – Rm F2 (6/14/17) North	14:00 – 15:00	35	55	**36.5**	**58.7**
Phase 1 – Fannasi – Rm F2 (6/14/17) North	15:00 – 15:43	35	55	**38.0**	**59.8**
Phase 2 – Healey – Rm 105 (6/19/18) North	12:00 – 13:00	35	55	**35.7**	54.2
Phase 2 – Healey – Rm 105 (6/19/18) North	13:00 – 14:00	35	55	32.9	**55.1**
Phase 2 – Healey – Rm 105 (6/19/18) North	16:00 – 17:00	35	55	**38.7**	54.3
Phase 2 – Healey – Rm 105 (6/20/18) North	7:00 – 8:00	35	55	34.7	**55.9**
Phase 2 – Healey – Rm 105 (6/20/18) North	9:00 – 10:00	35	55	35.0	**55.4**
Phase 2 – Healey – Rm 105 (6/20/18) North	10:00 – 11:00	35	55	**35.7**	54.6
Phase 2 – Healey – Rm 105 (6/20/18) North	11:00 – 12:00	35	55	**36.1**	54.8
Phase 2 – Healey – Rm 105 (6/20/18) North	12:00 – 13:00	35	55	**36.7**	54.3
Phase 2 – Healey – Rm 105 (6/20/18) South	17:00 – 18:00	35	55	**38.1**	54.3
Phase 2 – Healey – Rm 105 (6/21/18) North	8:00 – 9:00	35	55	**37.9**	**55.6**
Phase 2 – Healey – Rm 105 (6/21/18) North	9:00 – 10:00	35	55	**36.4**	54.6
Phase 2 – Healey – Rm 105 (6/21/18) North	11:00 – 12:00	35	55	**37.3**	53.2
Phase 2 – Healey – Rm 105 (6/21/18) North	12:00 – 13:00	35	55	**36.5**	54.9
Phase 2 – GDS – Classroom 001 (6/19/18) North	10:00 – 11:00	35	55	**36.1**	53.8
Phase 2 – GDS – Classroom 001 (6/19/18) North	11:00 – 12:00	35	55	**35.8**	53.8
Phase 2 – GDS – Classroom 001 (6/19/18) North	13:00 – 14:00	35	55	**36.9**	55.0
Phase 2 – GDS – Classroom 001 (6/20/18) North	9:00 – 10:00	35	55	**35.2**	54.0

Notes:

1) ***Denotes** that this was a partial hour measurement with results time-averaged over the full hour.
2) Values in **bold** exceed criteria.
3) For Phase 2 measurements at Healey, Room 105 the average A- and C-weighted interior sound levels were evaluated between the hours of 7:00 and 22:00. Note that data from 6/19 through 6/21 was available; there was a meter data store problem after this date which resulted in lost data.
4) For Phase 2 measurements at GDS, Classroom 001 the average A- and C-weighted interior sound levels were evaluated between the hours of 7:00 and 17:00 Monday through Friday.

Phase – Room – Date – Flow Direction	Hour	ANSI 12.60 Criteria		Measurements	
		HNL (dBA)	HNL (dBC)	HNL (dBA)	HNL (dBC)
Phase 2 – GDS – Classroom 001 (6/21/18) North	9:00 – 10:00	35	55	**35.3**	53.4
Phase 2 – GDS – Classroom 001 (6/21/18) North	10:00 – 11:00	35	55	**35.6**	54.6
Phase 2 – GDS – Classroom 001 (6/21/18) North	11:00 – 12:00	35	55	**36.4**	54.5
Phase 2 – GDS – Classroom 001 (6/21/18) North	13:00 – 14:00	35	55	**36.1**	54.3
Phase 2 – GDS – Classroom 001 (6/22/18) North	10:00 – 11:00	35	55	**35.3**	53.6
Phase 2 – GDS – Classroom 001 (6/22/18) North	11:00 – 12:00	35	55	**35.2**	53.4
Phase 2 – GDS – Classroom 001 (6/25/18) North	8:00 – 9:00	35	55	**37.7**	53.8
Phase 2 – GDS – Classroom 001 (6/25/18) North	9:00 – 10:00	35	55	**36.7**	53.9
Phase 2 – GDS – Classroom 001 (6/25/18) North	11:00 – 12:00	35	55	**35.9**	54.1
Phase 2 – GDS – Classroom 001 (6/25/18) Mixed	12:00 – 13:00	35	55	**35.4**	54.0
Phase 2 – GDS – Classroom 001 (6/26/18) North	10:00 – 11:00	35	55	**38.6**	53.1
Phase 2 – GDS – Classroom 001 (6/26/18) South	12:00 – 13:00	35	55	**35.5**	53.7
Phase 2 – GDS – Classroom 001 (6/26/18) South	13:00 – 14:00	35	55	**35.1**	53.2

Notes:

1) ***Denotes** that this was a partial hour measurement with results time-averaged over the full hour.
2) Values in **bold** exceed criteria.
3) For Phase 2 measurements at Healey, Room 105 the average A- and C-weighted interior sound levels were evaluated between the hours of 7:00 and 22:00. Note that data from 6/19 through 6/21 was available; there was a meter data store problem after this date which resulted in lost data.
4) For Phase 2 measurements at GDS, Classroom 001 the average A- and C-weighted interior sound levels were evaluated between the hours of 7:00 and 17:00 Monday through Friday.

6.13.1 Phase 1 Classroom Hourly Noise Levels

The Chemistry Lab, Room 404, complies with the schools' performance standard for a maximum one-hour average A- and C-weighted interior sound levels during the maximum aircraft noise school hour, between 9:00 a.m. and 10:00 a.m. (though a full one-hour measurement was not available and partial hour values were extrapolated for these results). The respective values of 34.7 dB and 51.7 dB are clearly below the 35 dB and 55 dB criteria values.

Healey, Room 106, exceeds the one-hour average A- and C-weighted interior sound levels during the maximum aircraft noise school hour, between 2:00 p.m. and 3:00 p.m. The respective values of 36.1 dB and 62.6 dB are both above the 35 dB and 55 dB criteria values.

Fannasi, Room F2, exceeds the one-hour average A- and C-weighted interior sound levels during the three afternoon hours after lunch. The respective A-weighted values of 36.0 dB, 36.5 dB and 38.0 dB are all above the 35 dB, and 55 dB criteria values are also all slightly exceeded.

6.13.2 Phase 2 Classroom Hourly Noise Levels

The noise level in Healey, Room 105, exceeds both the one-hour average A- and C-weighted interior sound levels for multiple hours during the school day. See Table 6-7.

At the Georgetown Day School, Classroom 001, the one-hour average A-weighted interior sound levels exceeded the criteria each day.

6.13.3 Other Georgetown and Palisades Area Schools

Although measurements were not conducted at other Georgetown-Palisades area campuses, we would expect exceedances of the ANSI classroom noise standards at the other schools based upon their proximity to the measured schools.

6.14 Noise Monitoring Terminal Analysis

An analysis of NMT #4, #6, #7, and #17 terminal data for two distinct months was conducted; calculations of DNL and the other supplemental metrics presented earlier in this section were made. The following summarizes the calculation results.

6.14.1 DNL Calculations

Table 6-8 summarizes the aircraft DNL noise levels at the four NMT locations analyzed. Figure 6-14 illustrates the calculated DNL noise levels.

Table 6-8: NMT Exterior DNL Values

	North Flow		South Flow		Mixed Flow		Overall	
Location	**October 2017**	**April 2018**	**October 2017**	**April 2018**	**October 2017**	**April 2018**	**October 2017**	**April 2018**
NMT #4: Palisades	58.2	58.5	58.2	58.6	59.2	57.7	58.4	58.5
NMT #6: Georgetown	58.3	58.3	53.9	55.3	57.6	56.1	56.9	57.4
NMT #7: Arlington	61.3	61.2	58.7	59.6	60.8	59.8	60.3	60.7
NMT #17: Southwest DC	50.1	51.4	43.1	45.2	50.0	48.5	48.8	50.1

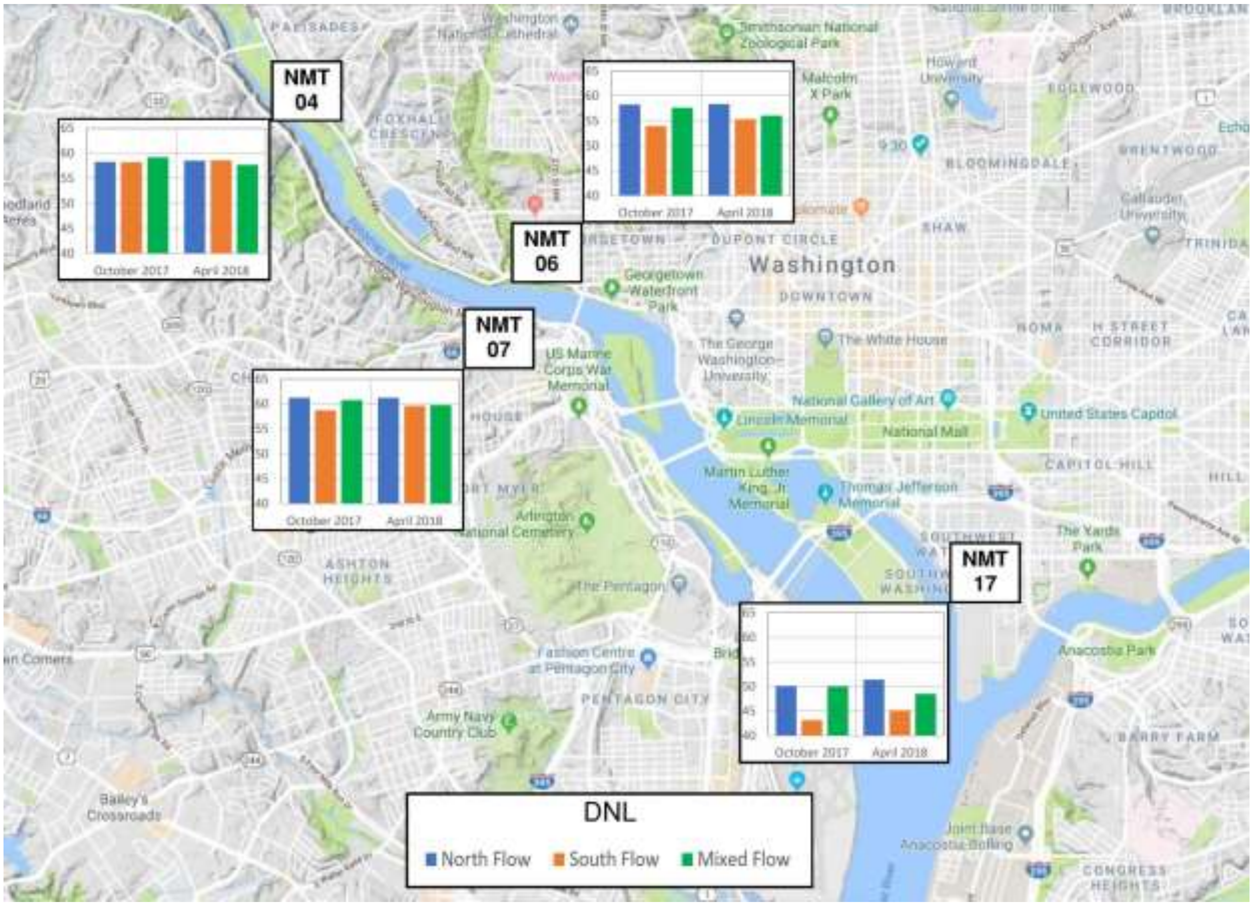

Figure 6-14: NMT Aircraft DNL Calculations by Flow

In general, the NMT #6 values are in the same range as the DNL values measured by our team.

6.14.2 NA Calculations

The number of aircraft flyovers above 65 dBA and 75 dBA was also calculated. Figure 6-15 and Figure 6-16 show the results of these calculations. In general, the findings for events above a maximum level of 65 dBA and 75 dBA are similar to those calculated from our measurements.

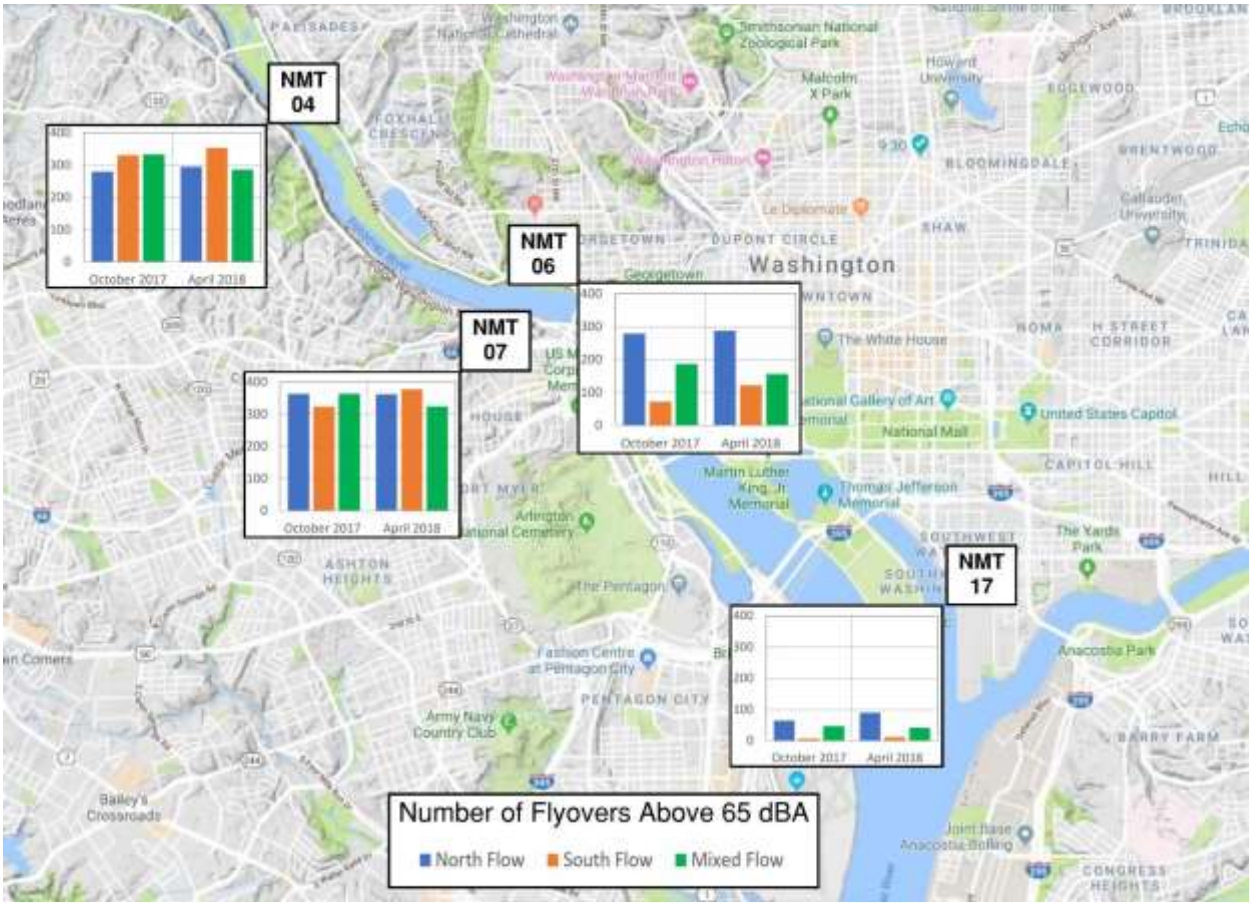

Figure 6-15: NMT Number of Daily Flyovers Above 65 dBA by Flow

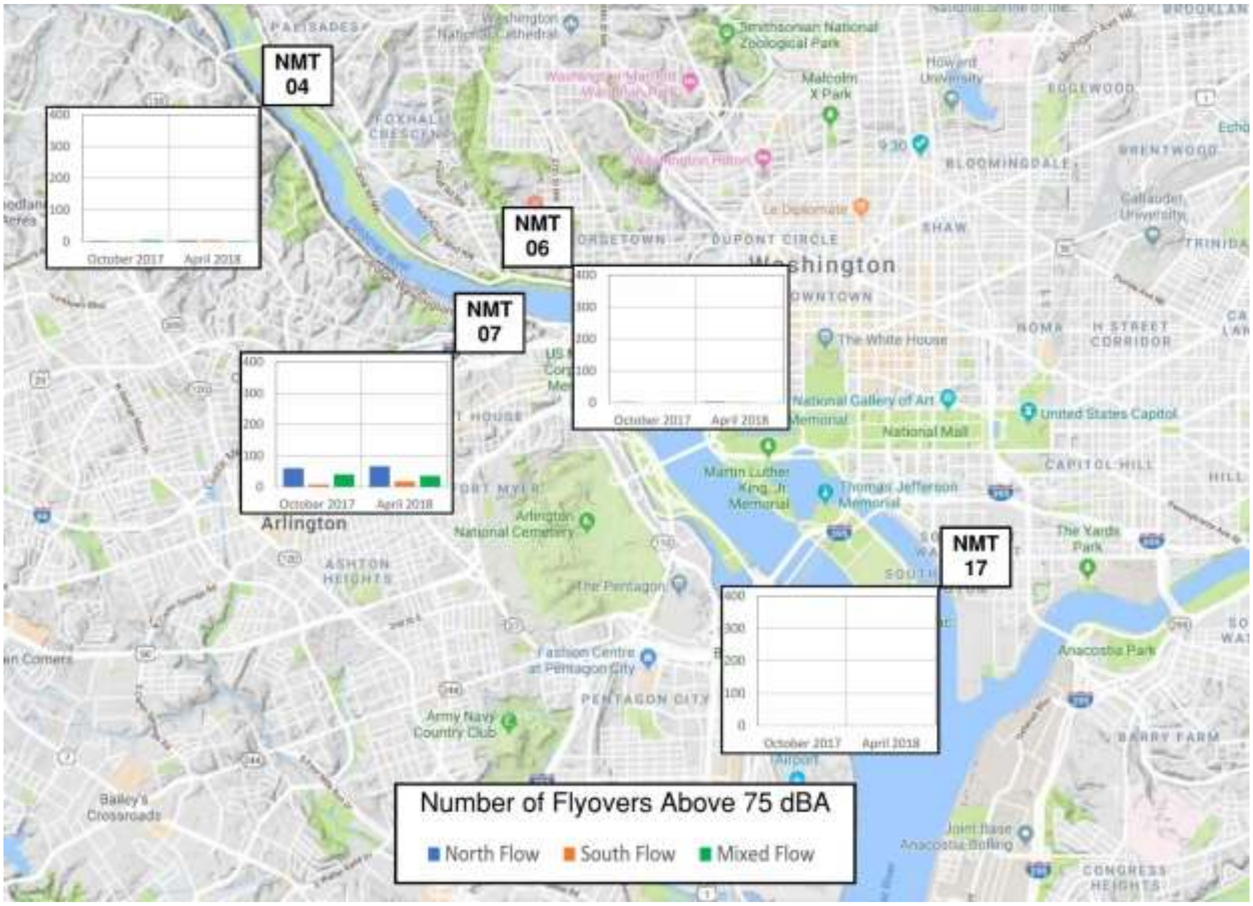

Figure 6-16: NMT Number of Daily Flyovers Above 75 dBA by Flow

6.14.3 Daytime and Nighttime Average Aircraft Noise Levels

Figure 6-17 and Figure 6-18 show the average daytime and nighttime aircraft noise levels at the four NMT locations.

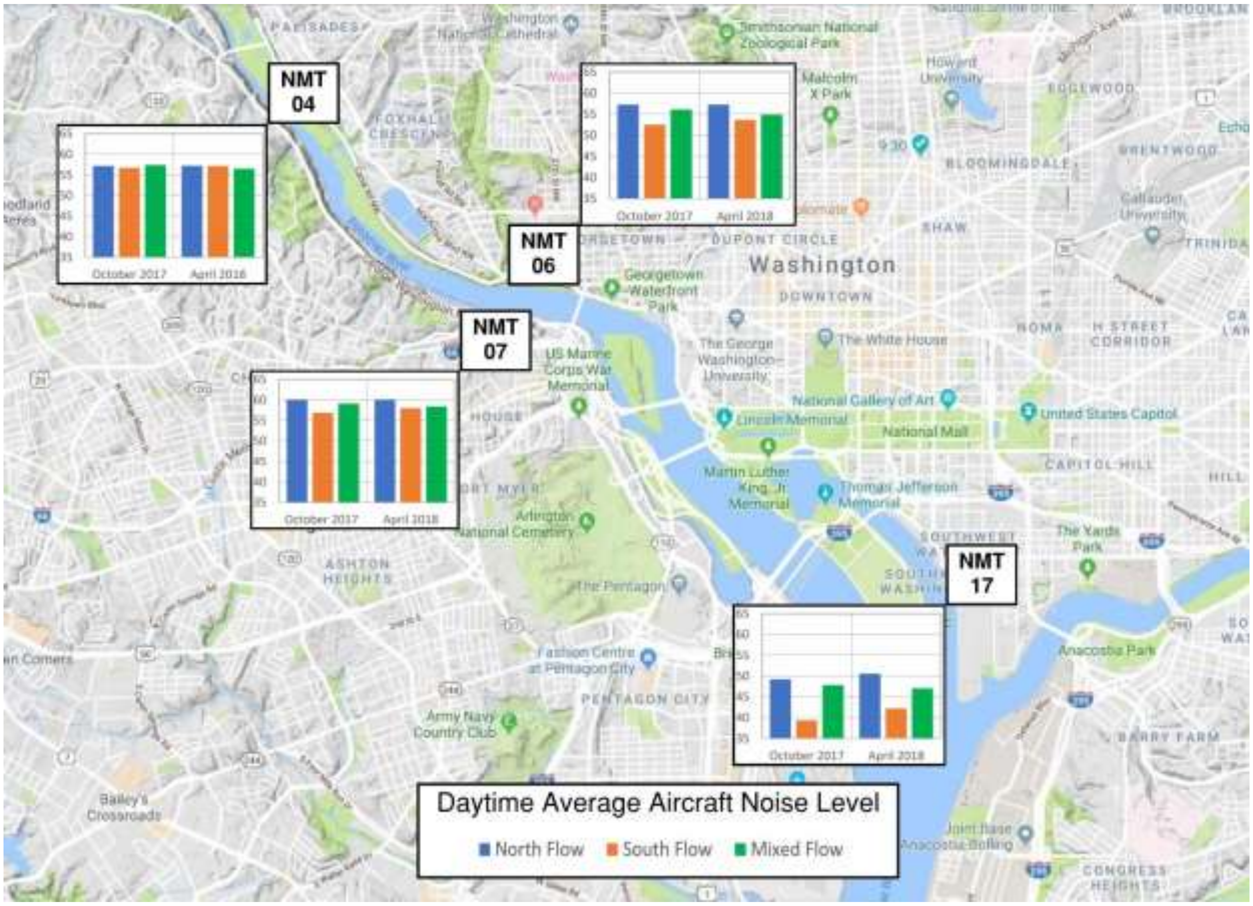

Figure 6-17: NMT Daytime Average Noise Level by Flow

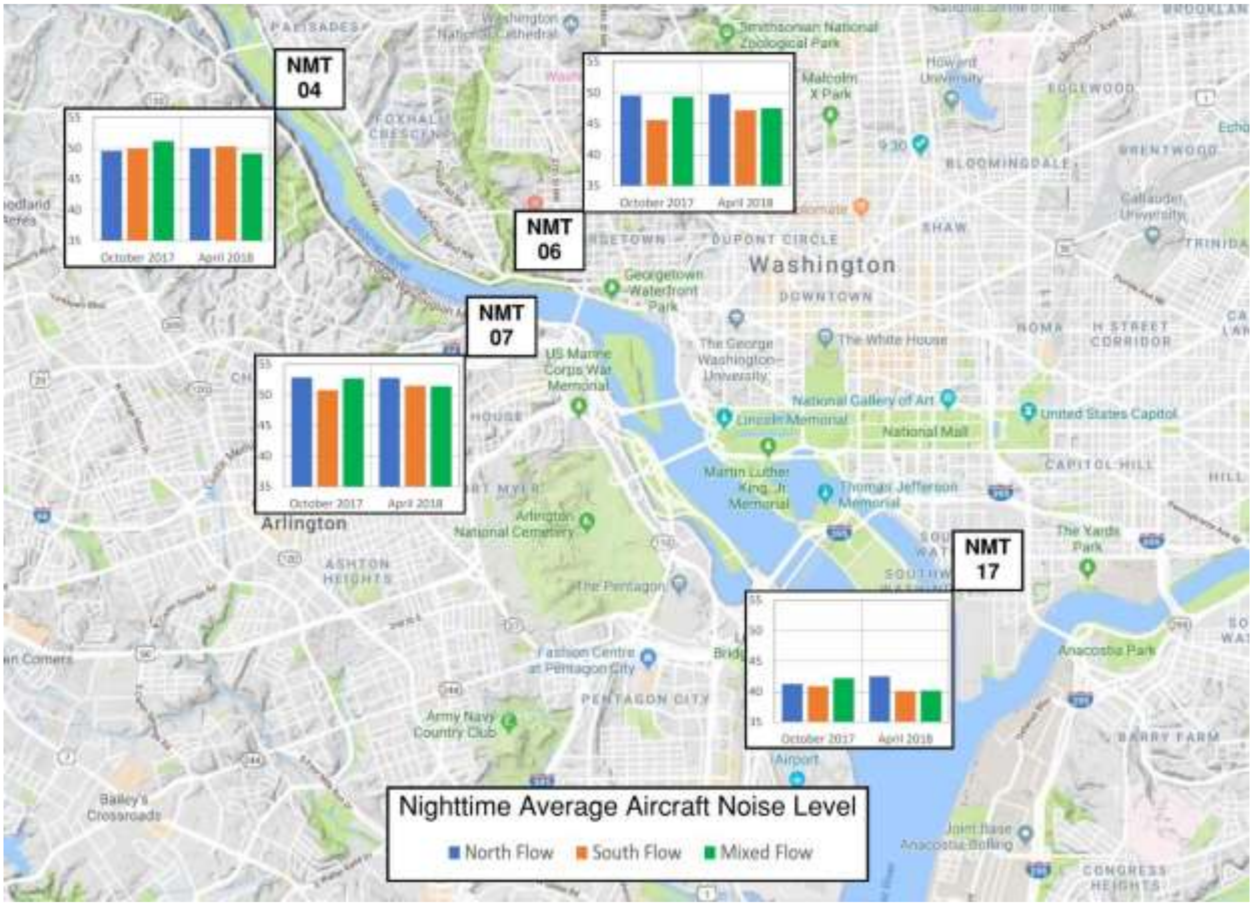

Figure 6-18: NMT Nighttime Average Aircraft Noise Level by Flow

7.0 Noise Complaint History

7.1 Operation of the MWAA Complaint System for DCA

This section describes the airport noise complaint system operated by the MWAA for aircraft to and from DCA. Noise complaint records compiled by MWAA from January 13, 2010 through December 1, 2015 were analyzed.

DOEE obtained a compilation of complaint records.[23] This compilation, in the form of an Excel workbook, includes a chronological list of 9,161 complaints over the six-year period, and includes the following information for most complaints:

- Airport (all DCA)
- Complainant city or District
- Complainant postal code
- Event date and time
- Nature of the concern
- Comments

The data was analyzed to identify and quantify unique household complaints, as many complaints appear to have been logged by the same person multiple times per day. It is important to identify discrete household complaints rather than multiple complaints by one household, as a more accurate representation of the total population submitting complaints is portrayed. Same-household complaints were identified by the following characteristics:

1. Same time of complaint: the complaint system logs complaints in one minute intervals; there were some instances where multiple complaints occurred in the same minute
2. Same postal code: If multiple complaints were logged at the same time, then the postal code of the complaints was reviewed
3. Same complaint text: The complainant has the ability to type in comments which get attached to a complaint. There were some instances where the comments were copy-and-pasted across multiple complaints.

Figure 7-1 shows the annual noise complaints reported by all communities surrounding DCA. A total of 3,802 (41.5%) are identified as redundant (same household) complaints and 5,359 (58.5%) are identified as non-redundant (unique household) complaints. Our analysis focuses only on non-redundant/unique household complaints, and the data presented in the following charts and figures only includes unique household complaints.

[23] Excel workbook from MWAA, 'Analysis MWAA complaints data 26JAN2016.xls', Created 12/2/2015 11:08 AM, Sandra Hoch.

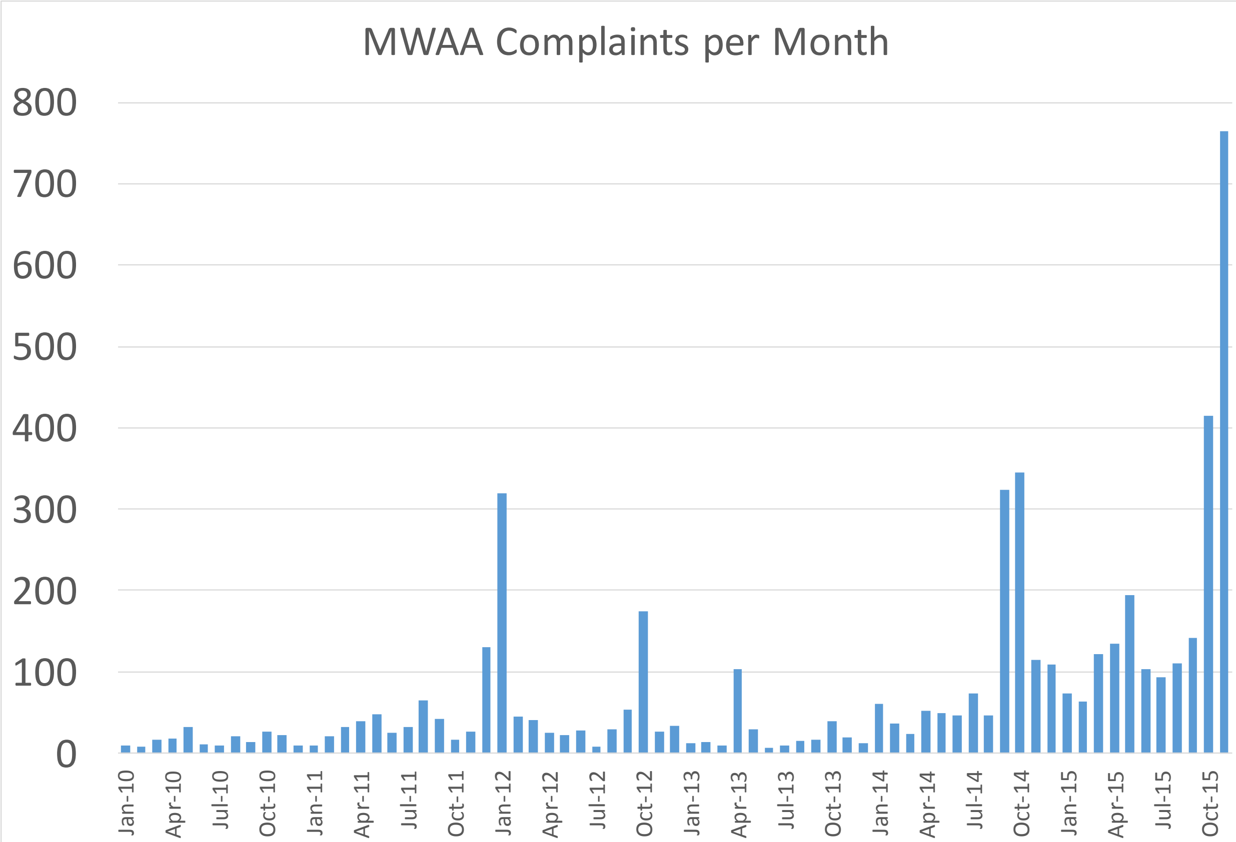

Figure 7-1: MWAA Unique Household Noise Complaints (Jan 2010 – Nov 2015)

There was a tremendous jump in the number of complaints for the last two months of 2015, as shown in Figure 7-2.

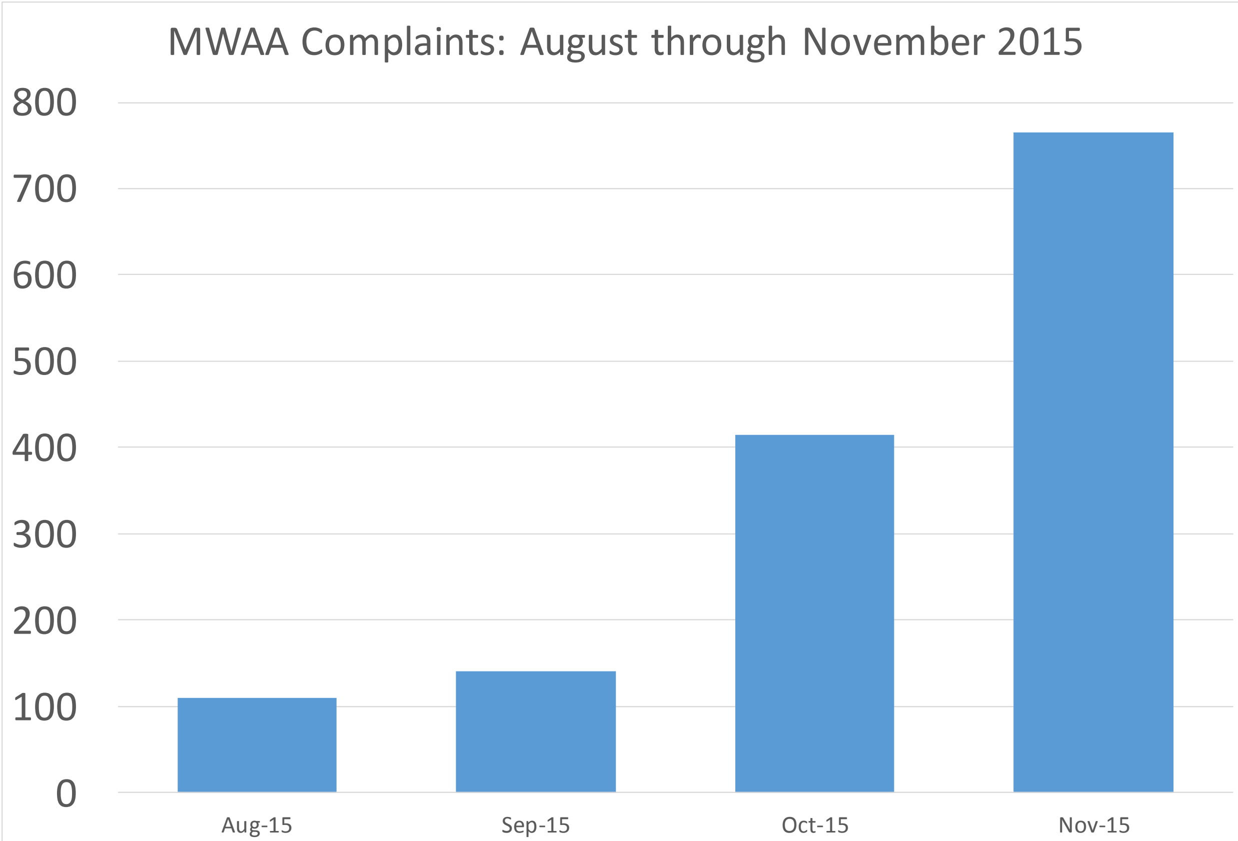

Figure 7-2: MWAA Noise Complaints (Aug 2015 – Nov 2015)

A review of the complaint statistics indicates that there may have been periods when complaints were not recorded. The complaint statistics were compared with the DNL analyses for each year from the MWAA annual aircraft noise reports.[24] Most monitoring locations show generally minor increases or decreases of DNL from month-to-month and year-to-year, with an attendant increase/decrease in total annual noise complaints, except for the years 2013 and 2014 which fall well below this trend. January, February, and March of 2013 reported total complaints of 12, 14 and 9 respectively; whereas, April reports 103 complaints up to April 22 and none for the remainder of the month.

The complaint volume beyond 2015 has remained elevated. In addition to the MWAA complaint records from this report, many complaints were received by the DOEE via email in 2017. These e-mail

[24] MWAA. (2010, September 30). *2010 Annual Aircraft Noise Report for Washington Dulles International Airport (IAD) and Ronald Reagan National Airport (DCA)*.
MWAA. (2011) *2011 Annual Aircraft Noise Report for Washington Dulles International Airport (IAD) and Ronald Reagan National Airport (DCA)*.
MWAA. *2012 Annual Aircraft Noise Report for Washington Dulles International Airport (IAD) and Ronald Reagan National Airport (DCA).*
MWAA. *2013 Annual Aircraft Noise Report for Washington Dulles International Airport (IAD) and Ronald Reagan National Airport (DCA).*
MWAA. *2014 Annual Aircraft Noise Report for Washington Dulles International Airport (IAD) and Ronald Reagan National Airport (DCA).*
MWAA. *2015 Annual Aircraft Noise Report, Ronald Reagan National Airport, Washington Dulles International Airport*.

complaints articulate many of the issues from the MWAA complaint forms discussed in the next section of this report.

7.2 The MWAA Complaint System

DCA's current noise complaint system was purchased from the Brüel & Kjær Corporation (B&K), and is the same as that used at many other major airports throughout the world. Complaints are submitted online[25] using the 'WebTrak'[26] public portal. This allows users to view dynamic aircraft activity around DCA delayed by one hour, and to identify individual flights by positioning the mouse over an aircraft as it moves. WebTrak also reports the embarkation and destination airport locations, aircraft speed and altitude, and displays the noise levels over the DCA noise monitors. Thus, aircraft en-route to other areas are identified by the embarkation and destination airports.

When filing a complaint, the complainant location and identification are entered on a form from the complaint website.[27] The form requests complaint details (e.g., noise concern, comments). The MWAA complaint Excel file includes summary information on worksheets 'Input & Constants', 'Multi-Year Analysis', 'Analysis of 2013 & 2014', 'Raw Data' and 'Summary table'. For this report, only the raw data was used.

The workbook contains information for all communities in the vicinity of DCA. A total of 72 zip code areas are tabulated for 34 municipalities, many distant from DC. Of primary interest to DC are local complaints and those of its neighbor to the west - Arlington County, Virginia. All following analyses and assessments are provided for DC, for Arlington and for all communities.

7.3 Complaint Records

For the 5,359 unique household complaints over the six-year period, 61 percent were from DC, 22 percent were from Arlington, and 17 percent were from other communities. Table 7-1 shows the totals for the three complaint groups.

Table 7-1: Compilation of 2010 – 2015 Complaints by MWAA

	Washington DC	Arlington	All other communities
Unique Household Complaints	3,214 (61%)	1,149 (22%)	906 (17%)

7.4 Nature of Concerns

The complaint form gave 33 choices for concerns that a complainant could choose. Concern reasons for unique household complaints were sorted from the raw complaint history for each of the three community areas analyzed. The results are presented in Table 7-2 for all six years analyzed.

[25] Reagan National. *Reagan National - Submit a Noise Complaint.* [Online]. Available: http://www.flyreagan.com/dca/reagan-national-submit-noise-complaint
[26] Bruel & Kjaer. *Webtrak.* [Online]. Available: http://webtrak5.bksv.com/dca
[27] Metropolitan Washington Airports Authority. *Noise Complaint Form*. [Online]. Available: https://complaints.bksv.com/dca

Table 7-2: Reasons for Unique Household Complaints by DCA Area, Jan 2010 – Dec. 1st, 2015

Concern Type	D.C.	Arlington	Other Areas	Total
APU (Noise)	-	2	-	2
Air Pollution	-	-	2	2
Aircraft Circling	-	2	-	2
Aircraft Off Course	98	83	**135**	316
Aircraft Too Low	74	**153**	66	293
Arrival Noise	1	-	1	2
Arrival Noise and Low Flying	3	1	1	5
Constant Noise	**554**	154	192	900
Departure Early Turn	-	4	-	4
Departure Noise	1	2	-	3
Departure Noise and Low Flying	-	4	3	7
Disturbed Rest/Relaxation/Sleep	**94**	42	15	151
Feared Plane would Crash	30	-	3	33
Flying After Hours	**170**	21	18	209
Helicopter Operations	3	30	3	36
Interference with Conversation	-	-	5	5
Interference with Conversation/TV	14	4	7	25
Noise at Wrong Time	**724**	72	49	845
Not Following the Recommended	2	7	1	10
Not Following the Recommended River Corridor	**361**	29	19	409
Other	**59**	26	15	100
Over Use of Runway	-	3	-	3
Question/Concern	-	1	-	1
Run-ups	1	2	1	4
Too Frequent	**82**	10	31	123
Too Loud	**295**	80	102	477
Too Low	**269**	16	25	310
Too Much Noise	**400**	377	188	965
Traffic Pattern	1	1	-	2
Unknown	-	3	-	3
Vibration-Caused Damage to My House	44	3	1	48
Vibrations	3	3	8	14
Total	**3283**	**1135**	**891**	**5309**

7.5 Time of Complaints

Twenty-five percent (25%) of all unique household complaints (1,340 of the 5,269) identified aircraft noise events occurring during the nighttime period of 10:00 p.m. to 7:00 a.m.

The days of the week for noise complaints were also reviewed and summarized in
Table 7-3. Unfortunately, the historical number of flights per day of the week was not available for 2010 – 2015 from the complaint file. However, this data is available from the MWAA noise data for NMT #6 in DC, so the percent of aircraft flyovers by day of the week for this area is included in the table below.

Table 7-3: Complaints by DCA Area, 2010 – 2015

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Percent complaints per day	11.4%	21.1%	19.9%	18.9%	12.0%	7.4%	9.4%
Annual percent operations (2016)	13.3%	14.9%	15.2%	15.5%	15.4%	15.5%	10.1%

7.6 Complaints and Operations History

We briefly reviewed the flight track history for 2010 – 2015 in an attempt to understand the noise complaint results. Of particular interest are any procedural changes towards the end of 2015 to explain the dramatic increase in noise complaints from DC and Arlington.

On March 10, 2011, the LAZIR RNAV departure serving RWYs 01 and 33 was published, defining a route of flight (north) up the Potomac River. LAZIR was seldom used in the first four years after its publication until technical and procedural solutions were found.

NMT #20 near the middle of Arlington is predominantly affected by low altitude RADAR vectoring of arrivals (east) and departures (west). Straight out departures from DCA RWYs 33/01 (NATIONAL SID) and instrument approaches to RWYs 15/19 which fly in the vicinity of NMT #4 and #5 were the traditional outbound and inbound approach procedures before 2015. As expected, DNL results for NMT #4 and #5 are similar, since they are nearby across the River from each other. The history shows somewhat erratic use of the LAZIR RNAV through 2010 and 2015. This is because the procedure was poorly designed and the aircraft flight management computers (FMC) would incur disconnects, so the air crews would not use it.[28]

The NATIONAL SID is a conventional navigation departure procedure that has been used at DCA for more than 20 years. When DCA is in a north-flow operation using RWYs 01 and 33, pilots on northerly departures are instructed to comply with a noise abatement procedure by remaining west of the Georgetown Reservoir, as well as remaining clear of P-56 areas.

On April 30, 2015, three new DCA RNAV departures were published for multiple runways, including RWYs 01 and 33. An additional six new RNAV departures were implemented June 25, 2015, serving all runways for DCA. This publication brought the total number of northbound RNAV departures serving RWYs 01 and 33 at DCA to nine. Each of these RNAV departures share the same initial routing for the respective runway transitions north up the river. Figure 7-3, from FAA records, shows the history of monthly departures from RWY 01/33.

[28] FAA, Ronald Reagan Washington National Airport (DCA) Area Navigation (RNAV) North-Flow Departure Development History and Analysis, August 17, 2016.

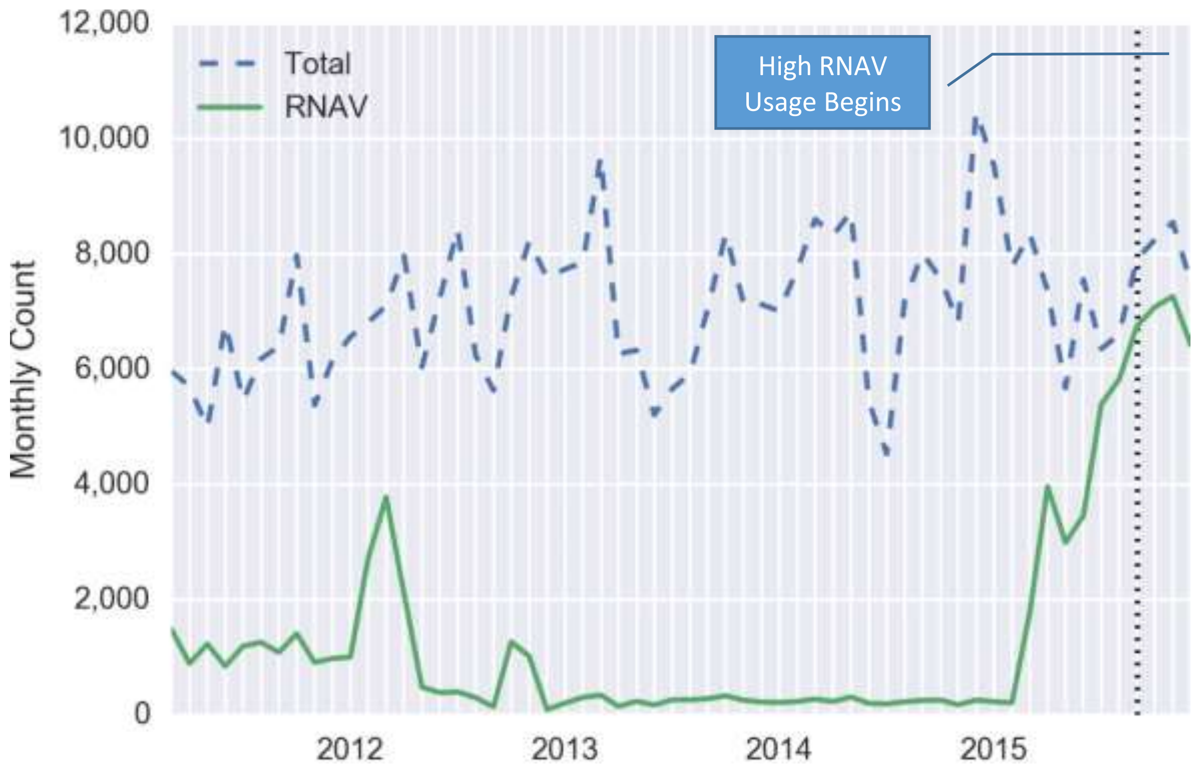

Figure 7-3: Monthly Departures from RWY 01/33 (Jan 2011 - Nov 2015)

The number of aircraft events monitored by NMT 6 increased by a significant amount over the six-year period. This is likely from the following factors:

- An increase in the volume of aircraft operations over the period, due to extended service areas.
- An increase in use of planes with larger airframes that increase noise, although this is somewhat ameliorated by the gradual replacement of noisier aircraft with newer and quieter aircraft. New generation aircraft A/C have been added to the fleet mix.
- Weather changes, landing from the "south," with aircraft being vectored at low altitude to the relocated instrument finals for RWY 19, SETOC, near NMT 7 / 6 from August to December 2015.

A summary of the yearly counts (March 1, 2011 through the end of 2015) is shown in Table 7-4 below.

Table 7-4: Total DCA Departures

Year	Total RWY 01/33	Conventional	RNAV
2011 (Mar. – Dec.)	60,957	49,711	11,246
2012	85,091	71,447	13,644
2013	84,312	81,344	2,968
2014	90,410	87,642	2,768
2015	91,403	40,070	51,333

7.7 Summary and Conclusions

The fundamental conclusions regarding complaint records from 2010 through 2015 are:

- MWAA complaints increased significantly in September and October of 2014, and then again in March of 2015, and then drastically increased for the final two months recorded (October and November of 2015).
- The primary reason for this increase may be the use of the RNAV departure procedures from DCA, which bring flights close to or over DC instead of the traditional NATIONAL SID departure, which led flights directly west of DC.
- MWAA complaint records extend from January 2010 through November 2015. Considerably more subsequent complaints (i.e., December 2015 and beyond) are expected because: 1) there was a very large increase in monthly complaints from the MWAA records, and 2) DC DOEE has received numerous complaints beyond 2015, primarily via email.
- MWAA complaint records appear to contain significant gaps, particularly in 2013.
- MWAA complaint records show that 42 percent of all complaints are redundant. This is likely due to multiple complaints from the same party.
- Monthly DNL records from NMTs in DC and Arlington show fairly constant noise exposure during the 2010 – 2014 period; DNL in DC increased in 2015 due to the new LAZIR departure procedure.

Appendix B is a summary of all complaint and NMT data.

8.0 Noise Modeling Analysis

8.1 Summary

This section provides the results of noise modeling of flights which occurred in 2010 and 2015-2016 to quantify the difference in aircraft noise levels in the northwest portion of DC (i.e., Georgetown and other communities) from flights to and from the DCA.

Noise modeling was conducted for eight days in 2010 and eight days in 2015-2016 to show the difference in aircraft noise levels as a result of the implementation of the NextGen program at DCA. The FAA-sponsored AEDT Version 2d was used for the noise modeling. This is the only computer model whose results are accepted by the FAA. Actual flight tracks obtained from the FAA's radar data (i.e., the National Offload Program) were modeled in the AEDT.

Exterior DNL values in DC, from DCA flyovers, vary from around 45 dBA to 65 dBA. An analysis of the flight tracks does show a shift in the northbound Runway 1 departure flight tracks to the east (i.e., away from Arlington, Virginia to over the Potomac River). A comparison of the 2015-16 DNL levels to the 2010 DNL noise levels showed increase in noise in and around Georgetown. There was a less than 5 dBA increase in noise; 5 dBA is the minimum increase in DNL noise exposure considered significant by the FAA for areas below an average annual DNL of 60 dBA. However, supplemental analysis of other parameters such as time above statistics and number (or frequency) of events may provide additional and more complete information on the DCA airplane noise exposure issues.

8.2 Modeling Procedure

8.2.1 Data Input

DC provided the raw radar files for aircraft using the DCA airport from 2010 to 2016. These files were obtained from the FAA's National Offload Program (NOP) radar files. Eight days in 2010 and eight days in 2015-2016 were selected for noise modeling. The year 2010 was chosen as it was the earliest NOP available and also because the "National" flight path was still being utilized by aircraft. The years 2015-2016 were chosen for the new flight paths because the implementation of NextGen had been completed by that time. These eight days were selected as representative days by utilizing the following methodology:

1. Obtaining the prevailing wind direction for every day in 2010 and every day in 2015 and 2016. The wind data was obtained from the National Weather Service. Aircraft generally must land and take off into the wind, so the wind direction determines which way an airport operates (i.e., north flow or south flow). North flow means aircraft land from the south and depart to the north; south flow means aircraft land from the north and depart to the south.

2. Select eight weekdays throughout the year representative of the average wind conditions at DCA. Based on the wind analysis, wind comes from the north 60% to 65% of the year and comes from the south 35% to 40% of the year (depending on the year). For each analysis year, five days had winds from the north (62.5%) and three days had winds from the south (37.5%). The selected days are shown in Table 8-1:

Table 8-1: Selected Days for Noise Modeling

Modeled Day	Prevailing Wind Direction
Wednesday, January 13, 2010	North
Thursday, March 25, 2010	South
Wednesday, April 28, 2010	North
Wednesday, June 16, 2010	South
Wednesday, July 21, 2010	North
Thursday, August 19, 2010	North
Wednesday, October 20, 2010	South
Tuesday, December 7, 2010	North
Tuesday, July 21, 2015	North
Wednesday, August 19, 2015	North
Thursday, October 9, 2015	South
Thursday, December 10, 2015	North
Wednesday, January 20, 2016	North
Tuesday, March 22, 2016	South
Thursday, April 28, 2016	North
Wednesday, June 1, 2016	South

Note: The data for Wednesday, April 28, 2010, is not included in the noise modeling as there was significant delayed vectoring and other atypical flight track/operations that day which is not characteristic of typical conditions at DCA.

3. The validity of the NOP data was then verified for the selected days, the data filtered, and files prepared for input into the FAA's AEDT to model noise exposure. The NOP file is a series of radar location records for each aircraft, noting the time, latitude, longitude, altitude (from transponder transmissions), aircraft identification and other information. The volume of information is considerable in that radar records are recorded every few seconds on each of the more than 800 flights per day to and from DCA. After processing the NOP data, a series of coordinates showing the precise latitude, longitude, altitude, and aircraft identification for each aircraft was generated for each analysis day, each runway, and each operation type (arrival or departure).

4. After the NOP data was translated, a computer program was written to translate the sequence of three-dimensional aircraft locations (a vector) into the XML (Extensible Markup Language) format required for input to the AEDT.

   While the AEDT software has numerous bugs, which were submitted to the software authors, the NOP data was successfully translated into the AEDT to model the noise exposure for 16 days. The flight tracks (from the NOP data), aircraft type, altitude, and departure/arrival time of each flight were modeled in the AEDT.

   Only departures and arrivals north of DCA were modeled, as this is the area of DC most affected by the flight path/NextGen airspace changes.

8.3 Data Output

After the noise model for each analysis day was created, a series of calculation outputs were then set up (i.e., noise metrics). The primary noise metrics modeled include:

- DNL: The DNL noise exposure metric integrates the level and duration of noise over a day and penalizes nighttime noise by 10 dBA to account for increased sensitivity to nighttime noise. DNL is explained in detail in Appendix A.

- TA: The time above level is a metric that summarizes the total amount of time aircraft noise is above a specified threshold (e.g., 65 and 75 dBA).

- NA: The number above metric summarizes the number of events (i.e., flyovers) that exceed a specified threshold.

- Equivalent Noise Level (L_{eq}): The average noise level over a stated period (e.g., $L_{eq(day)}$) would be the average noise level during the daytime hours of 7 am to 10 pm.

The calculation outputs are summarized in Table 8-2 below:

Table 8-2: Calculation Outputs/Noise Metrics

Output/Metric	Description
DNL	24-hour average noise level
TA-50	Time above 50 dBA
TA-55	Time above 55 dBA
TA-60	Time above 60 dBA
TA-65	Time above 65 dBA
TA-70	Time above 70 dBA
NA-50	Number of events above 50 dBA
NA-55	Number of events above 55 dBA
NA-60	Number of events above 60 dBA
NA-65	Number of events above 65 dBA
NA-70	Number of events above 70 dBA
$L_{eq(day)}$	Average noise level during the daytime hours
$L_{eq(night)}$	Average noise level during the nighttime hours

All of the above metrics were calculated at 18 discrete location points in the northwest DC environs. The DNL metric was calculated at the 18 location points as well as over a grid of points spaced 0.1 nautical miles apart, beginning southwest of DCA and ending northeast of DC. This grid calculation allows for the creation of noise contours (i.e., a series of noise zones created by connecting grid points of equal noise level).

The 18 location points are provided in Table 8-3 and shown in Figure 8-1.

Table 8-3: Noise Modeling Location Analysis Points

Number	Name/Code	Latitude	Longitude
1	FOX_CRESC_1	38.92331	-77.0889
2	FOX_CRESC_2	38.91937	-77.0921
3	FOX_CRESC_3	38.92431	-77.0925
4	5063_SHERIER PL	38.92431	-77.1017
5	2316_BENTON	38.92038	-77.0808
6	2901_M_ST	38.90581	-77.0585
7	DEXTER_ST	38.92553	-77.0889
8	NMT_4	38.92717	-77.1081
9	NMT_6	38.90957	-77.0695
10	NMT_A	38.91143	-77.0886
11	NMT_B	38.91584	-77.0760
12	NMT_C	38.91313	-77.0901
13	NMT_D	38.90991	-77.0752
14	FRENCH_MAT	38.90954	-77.0621
15	4850_RES	38.91667	-77.0976
16	4920_ASHBY	38.92002	-77.0976
17	G_DAY	38.90833	-77.0869
18	GWU_NEW_H	38.89994	-77.0528

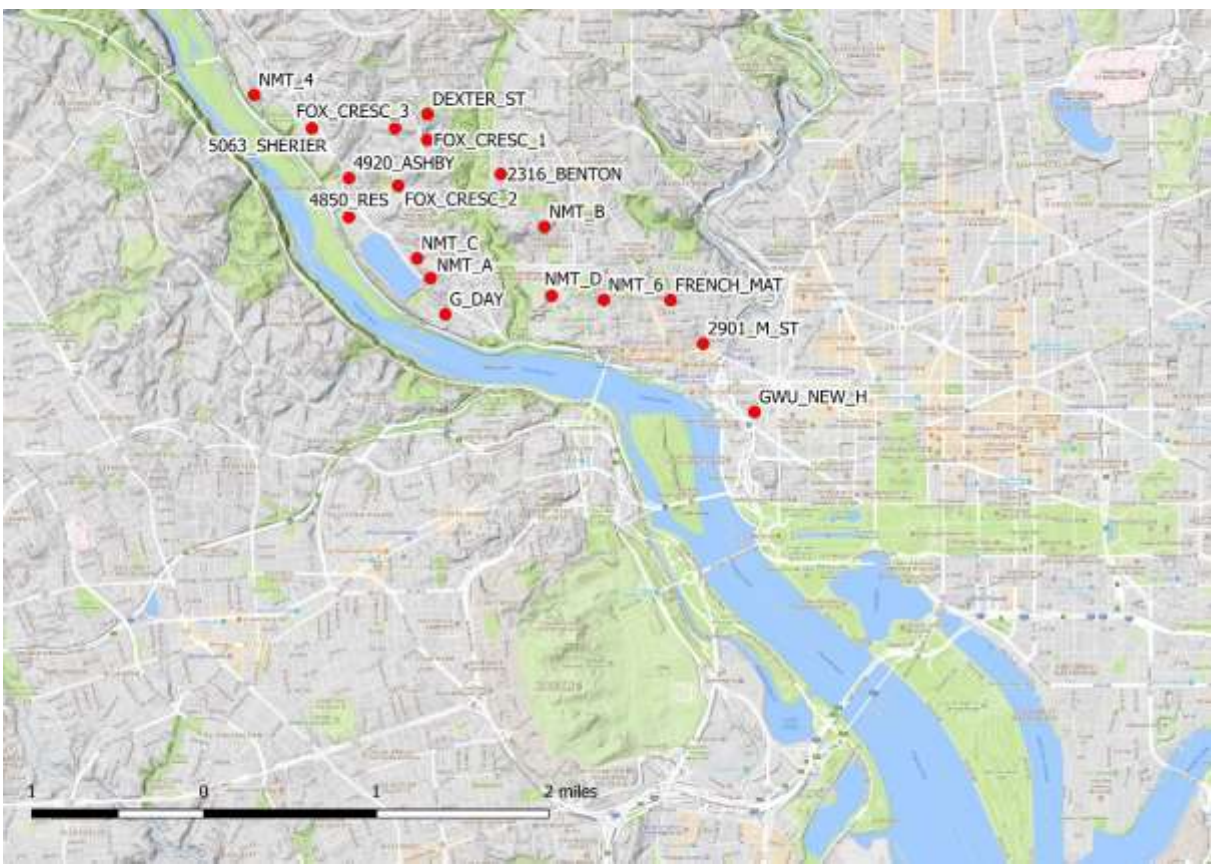

Figure 8-1: DC Noise Modeling Analysis Points

8.4 Noise Modeling Results

8.4.1 Operation Data

For the 16 days modeled, Table 8-4 provides statistical information on the number of arrivals, departures, aircraft types, etc.

Table 8-4: Noise Modeling, Operations Data

Operational Data	2010	2015-2016
Total Arrivals	943	1430
Total Departures	2241	2394
Top Aircraft Modeled (Percent of Total Operations)		
Airbus A319-100 Series	17%	11%
Airbus A320-200 Series	3%	5%
Airbus A321-200 Series	0%	1%
Boeing 717-200 Series	2%	1%
Boeing 737-400 Series	4%	0%
Boeing 737-700 Series	8%	20%
Boeing 757-200 Series	2%	1%
Boeing MD-82	1%	0%
Boeing MD-83	1%	0%
Boeing MD-90	4%	4%
Bombardier Challenger 600	4%	0%
Bombardier CRJ-900	18%	25%
DeHavilland DHC-8-100	1%	1%
Dornier 228-200 Series	1%	0%
Embraer ERJ145	12%	3%
Embraer ERJ170-LR	21%	19%
Embraer ERJ190	1%	9%
Hawker HS748-2B	1%	0%

8.4.2 Flight Tracks

Flight track graphics for the modeled days were created to compare the 2010 flight tracks (pre-NextGen) to the 2015-2016 flight tracks (post-NextGen). Figure 8-2 through Figure 8-5 show the historic flight tracks. Note the two heat maps show the density of flight tracks, with the warmer (red) color indicating a higher concentration of flight tracks (i.e., the majority of the planes are flying in the red section of the heat map).

As shown in the figures, the arrival flight tracks have not changed significantly from 2010 to 2015-16, with the exception that there are fewer arrivals over Arlington (directly west of Georgetown).

The departure flight tracks show a concentration of departures over the Potomac River in 2015-2016, whereas in 2010 flight tracks were more evenly dispersed over Arlington and the River.

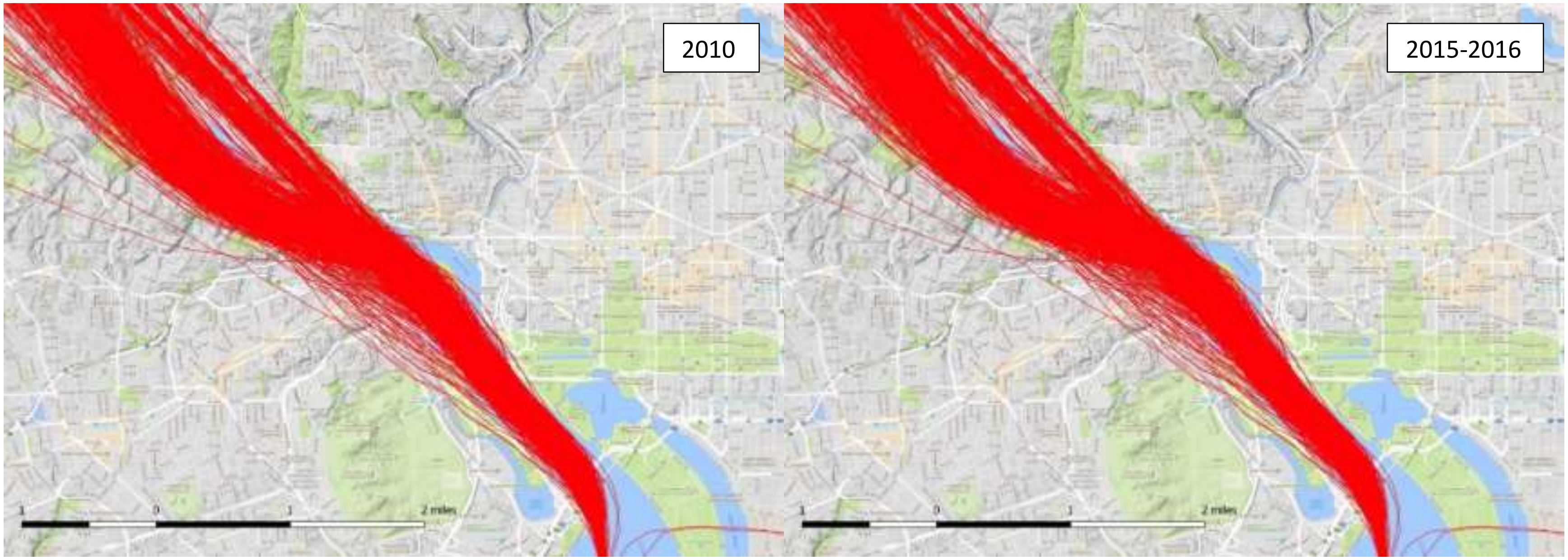

Figure 8-2: Arrival Tracks from the North (Runway 19)

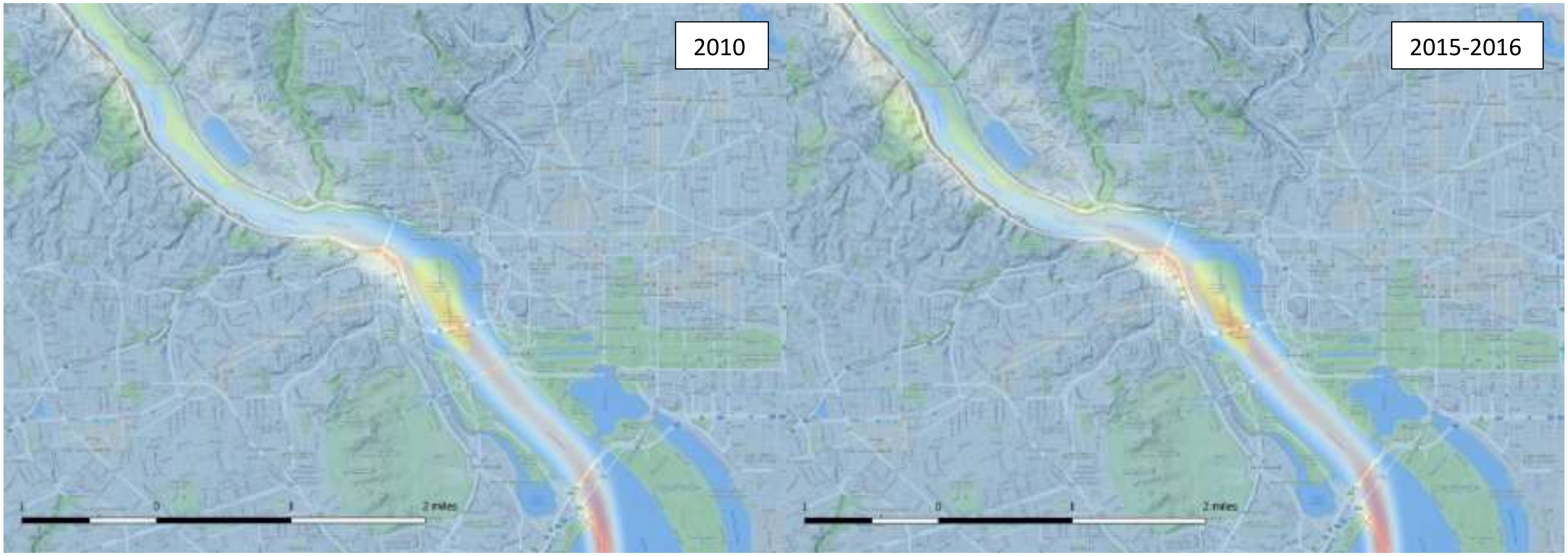

Figure 8-3: Arrival Flight Track Density from North (Runway 19)
Note: Warmer (red) colors indicate a higher density of flight tracks.

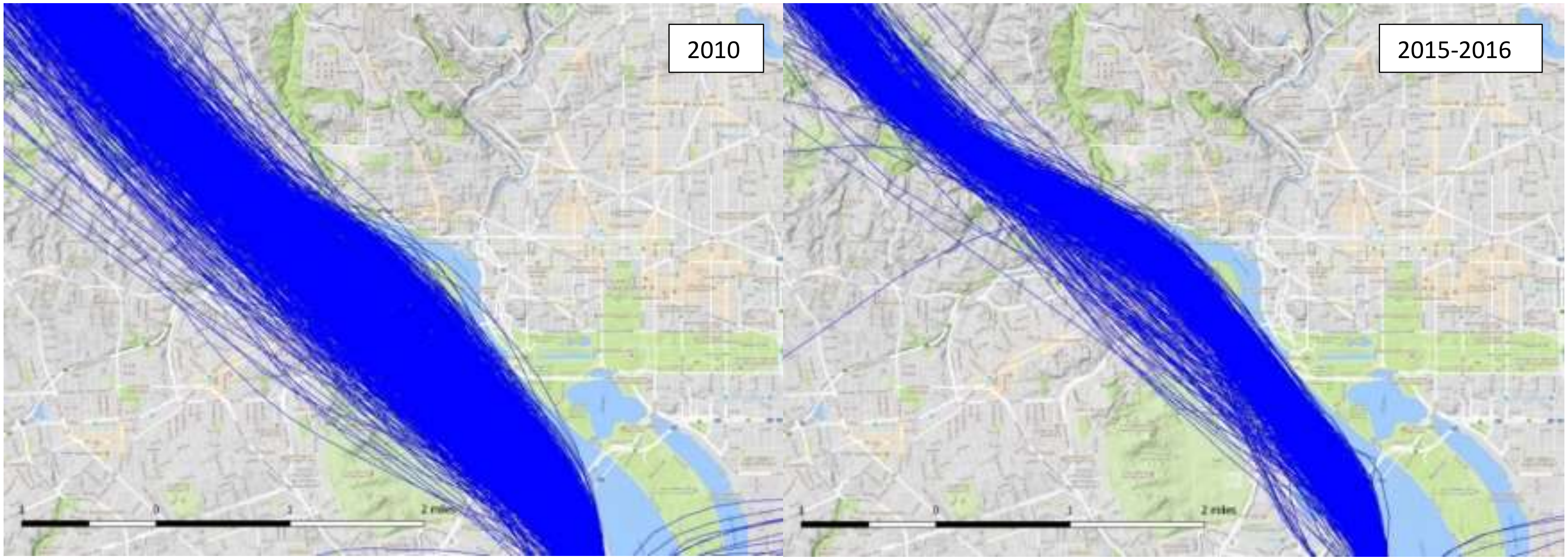

Figure 8-4: Departure Flight Tracks to North (Runway 1)

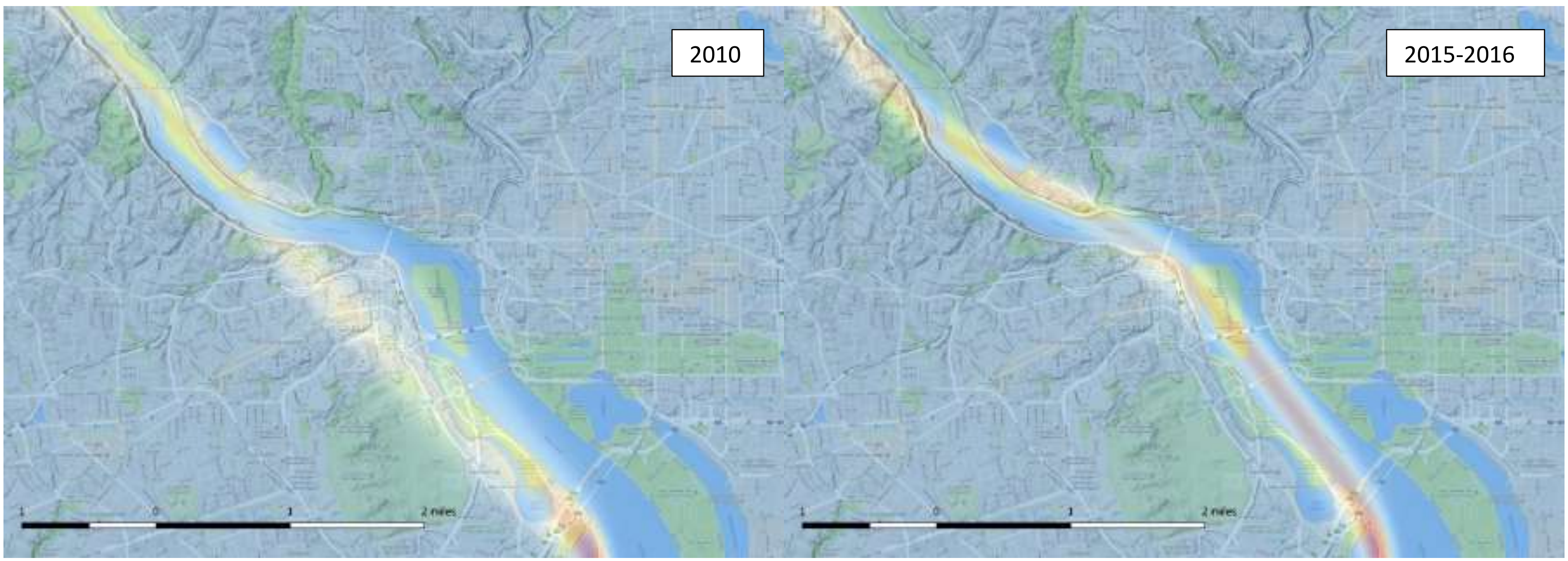

Figure 8-5: Departure Flight Track Density to North (Runway 1) Heat Map

Note: Warmer (red) colors indicate a higher density of flight tracks.

8.5 DNL Noise Exposure

8.5.1 DNL Contours

Figure 8-6 and Figure 8-7 present the calculated DNL noise contours for all days modeled in 2010 and 2015-2016. As noted previously, these contours are based upon the actual flight tracks and aircraft type flown for the 16 days modeled. The contours presented are the average DNL noise level for the 7 days modeled in 2010 and the average DNL for the 8 days modeled in 2015-2016 (i.e., the average annual day recognized by the FAA). The results were not included for Wednesday, April 28, 2010, as it was found that there was significant delayed vectoring and other atypical flight track/operations that day which is not characteristic of typical conditions at DCA.

Noise contour maps for each operation type were also created. The three operation types are as follows:

- North Flow: Departures to the North, arrivals from the South
- South Flow: Departures to the South, arrivals from the North
- Mixed: Each operation type occurred at least 25% of the day (e.g., started with North Flow and transitioned to South Flow at some point during the day)

Figure 8-9 through Figure 8-14 show the various DNL contour maps by operation type. It should be noted that the noise levels shown in the contour maps do not generally correspond well with the measurement data (both NMT and CSDA's measured data). Specifically, the modeled DNL north flow noise levels are similar to (or sometimes lower than) the South Flow modeled DNL noise levels in Georgetown; however, the measurement data indicates that North Flow noise levels are 1 to 4 dBA higher than South Flow noise levels. It is unclear as to the cause of this discrepancy; however, it could be due to the departure and arrival profiles used by the AEDT (e.g., possibly the AEDT assumes steeper takeoffs than actual, different thrust settings, etc.). Ultimately, this is an issue that the authors of the software will need to investigate.

Figure 8-8 provides a graphic which shows the difference in noise level between 2015-2016 and 2010 for all areas where the 2015-2016 noise exposure is at or above DNL 45 dBA (as the FAA does not consider noise levels below DNL 45 dBA to be significant). An important criterion for this assessment is from the FAA Order 1050.1F, which defines an environmental noise impact as shown in Table 8-5:

Table 8-5: FAA Noise Significance Criteria

Annual Average DNL Noise Level (dBA)	Significance Criteria
65+	1.5 dBA increase
60 to 65	3 dBA increase
45 to 60	5 dBA increase

DC's communities and Georgetown lie in or below the third category (DNL 45 dBA to 60 dBA). Therefore, the criterion for significant impact according to the FAA is an increased DNL of at least 5 dBA in an area where the later DNL (i.e., 2015-16) aircraft noise exposure is at least 45 dBA. No areas in DC meet this 5 dBA threshold.

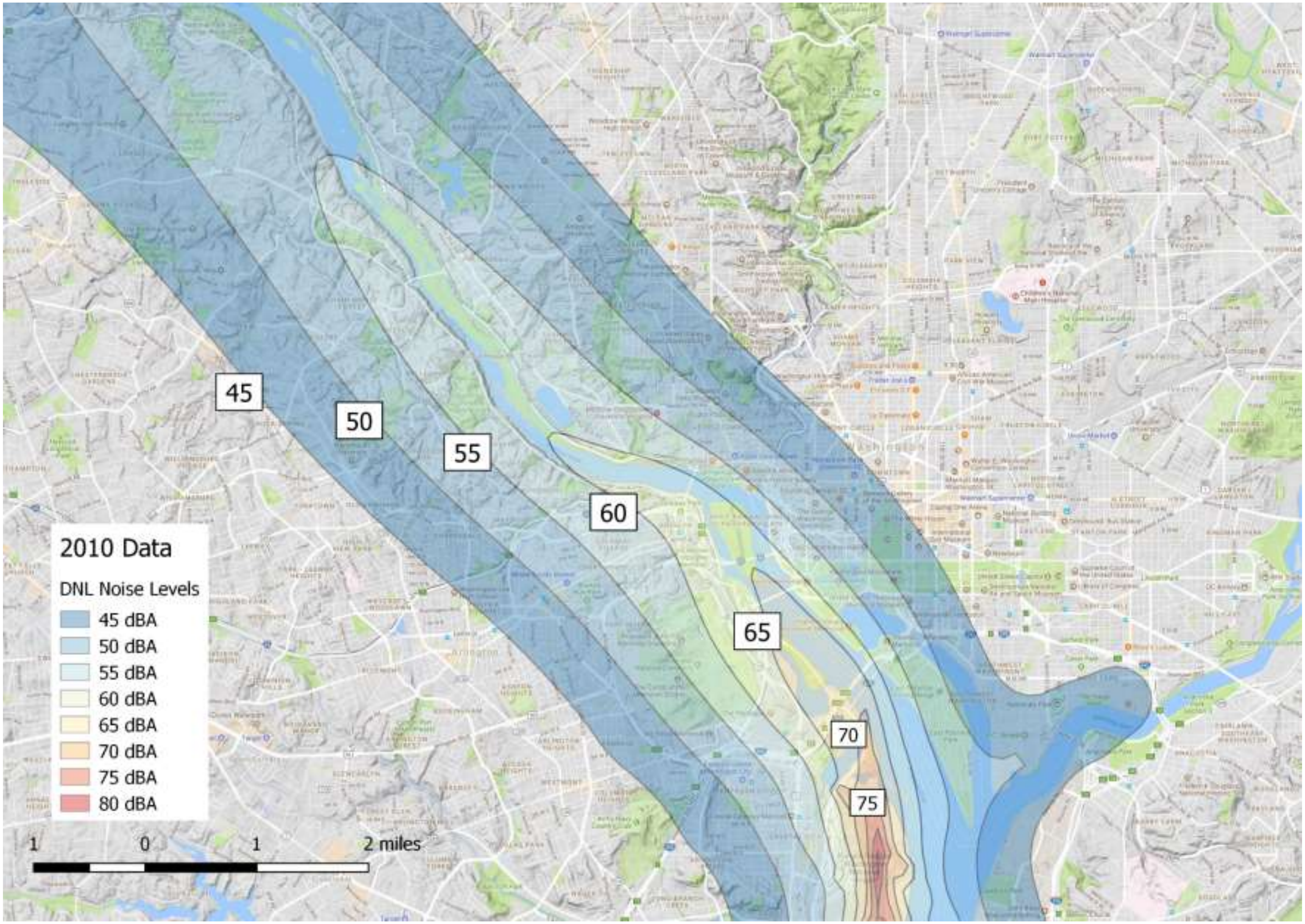

Figure 8-6: 2010 DNL Noise Contours

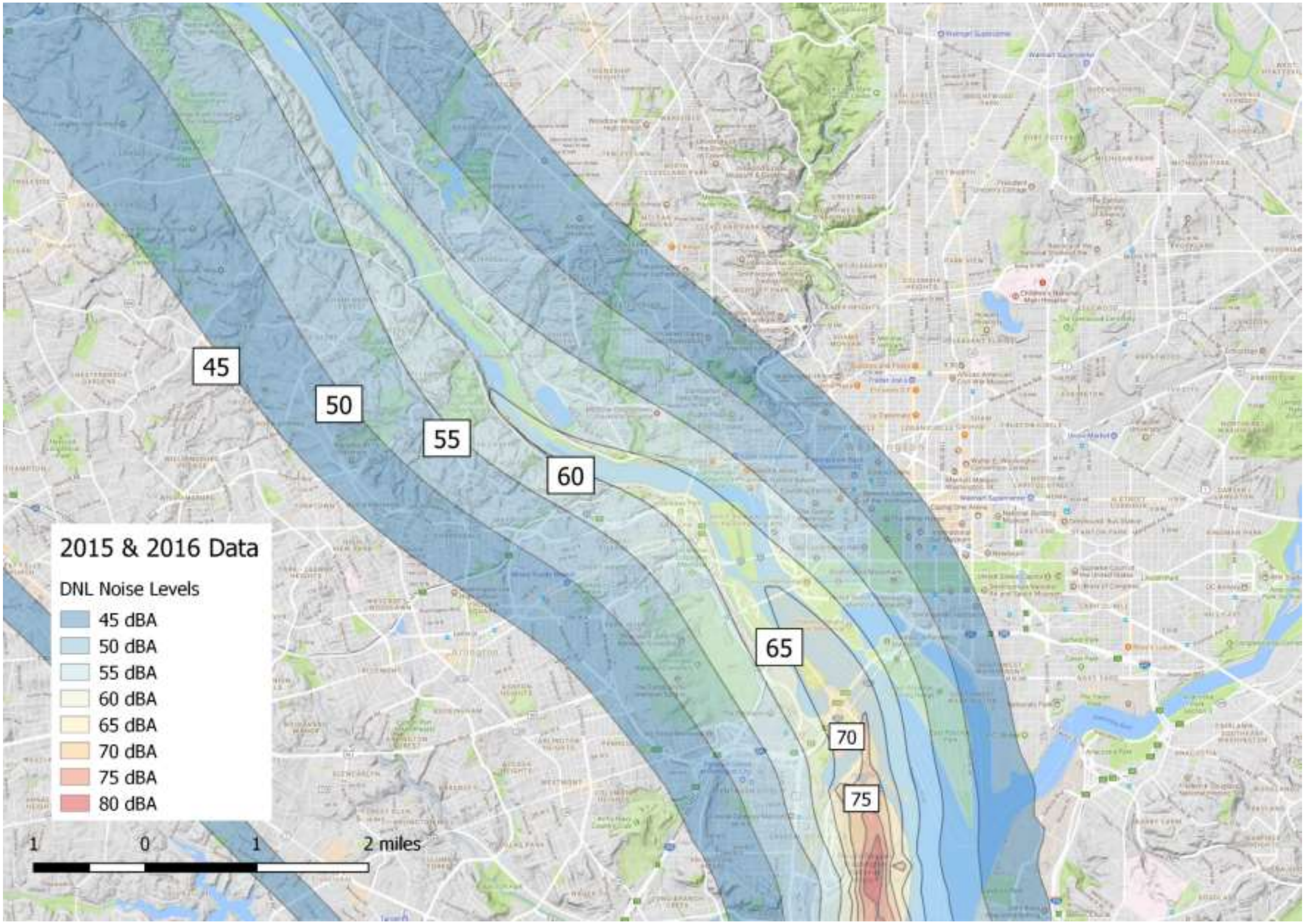

Figure 8-7: 2015-2016 DNL Noise Contours

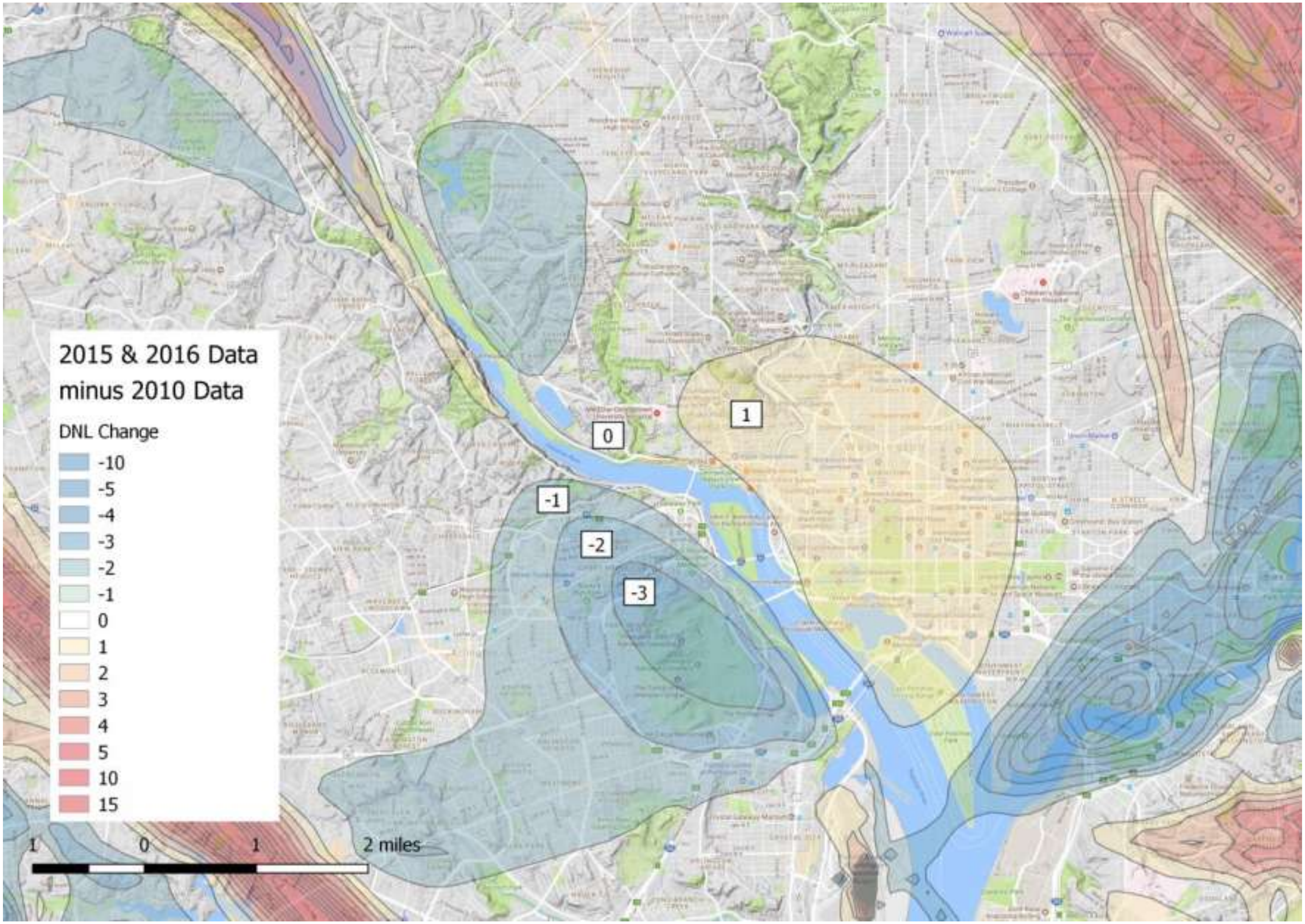

Figure 8-8: Difference in DNL Noise Exposure between 2015-2016 and 2010

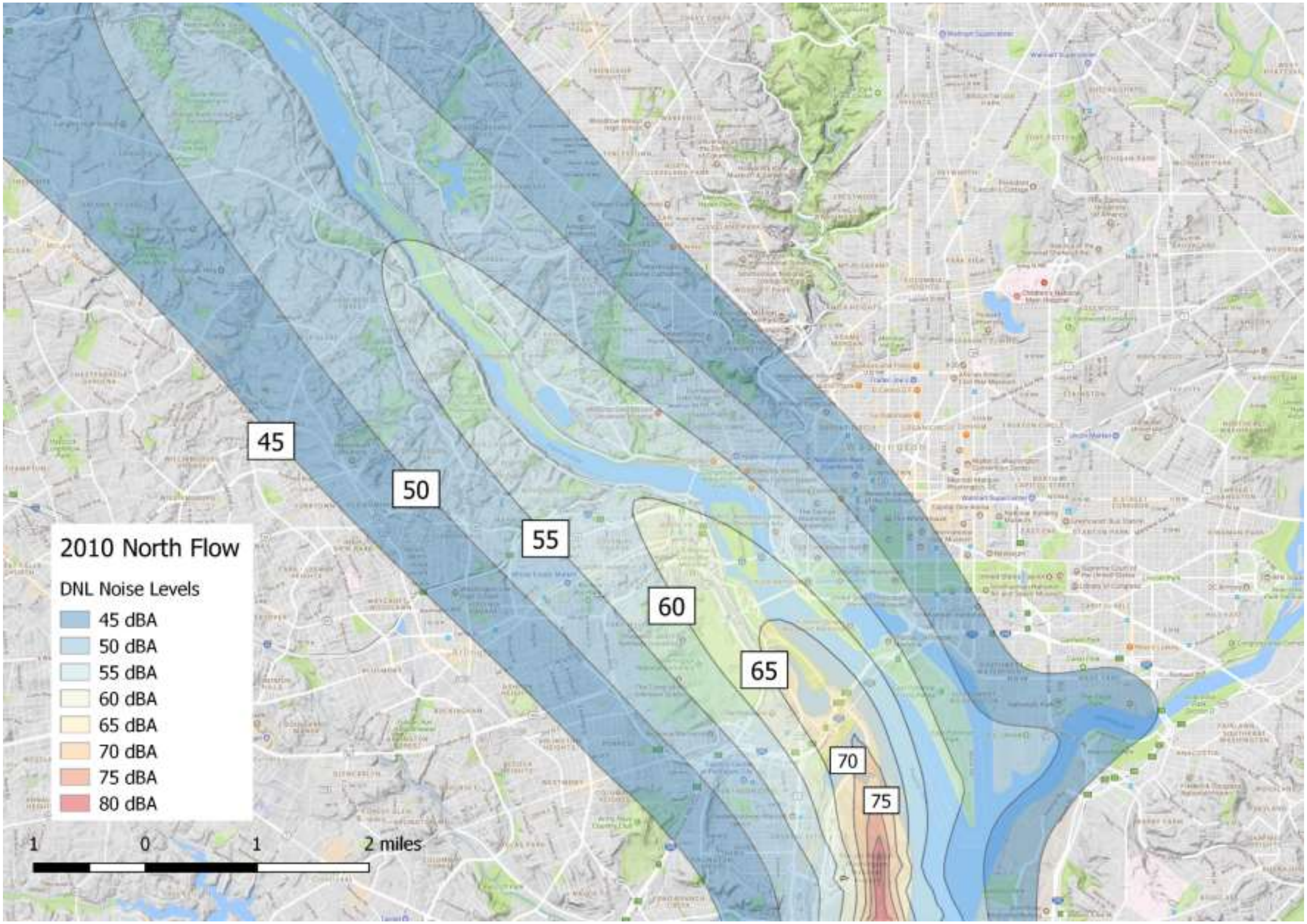

Figure 8-9: 2010 DNL North Flow Noise Contours

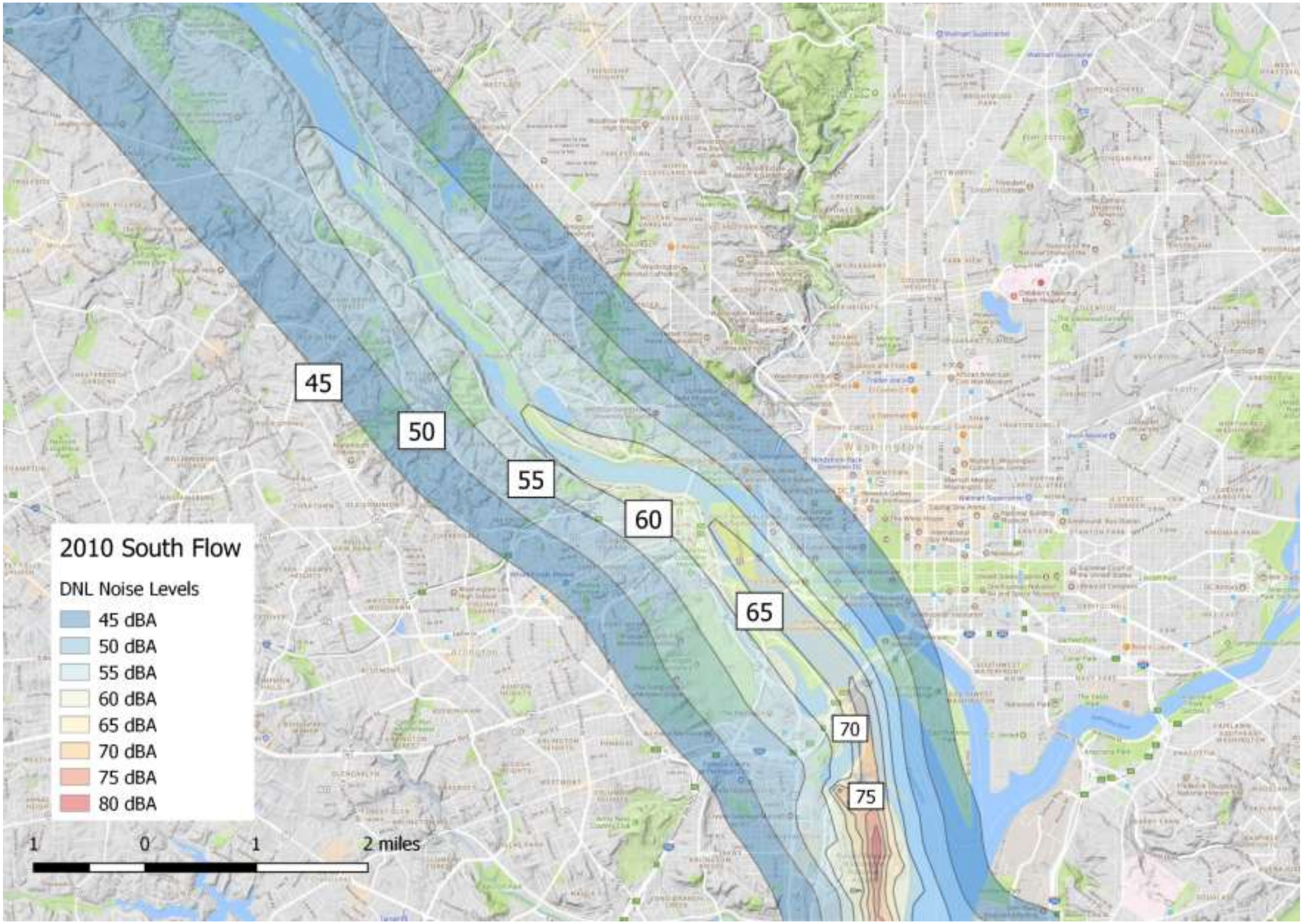

Figure 8-10: 2010 South Flow DNL Noise Contours

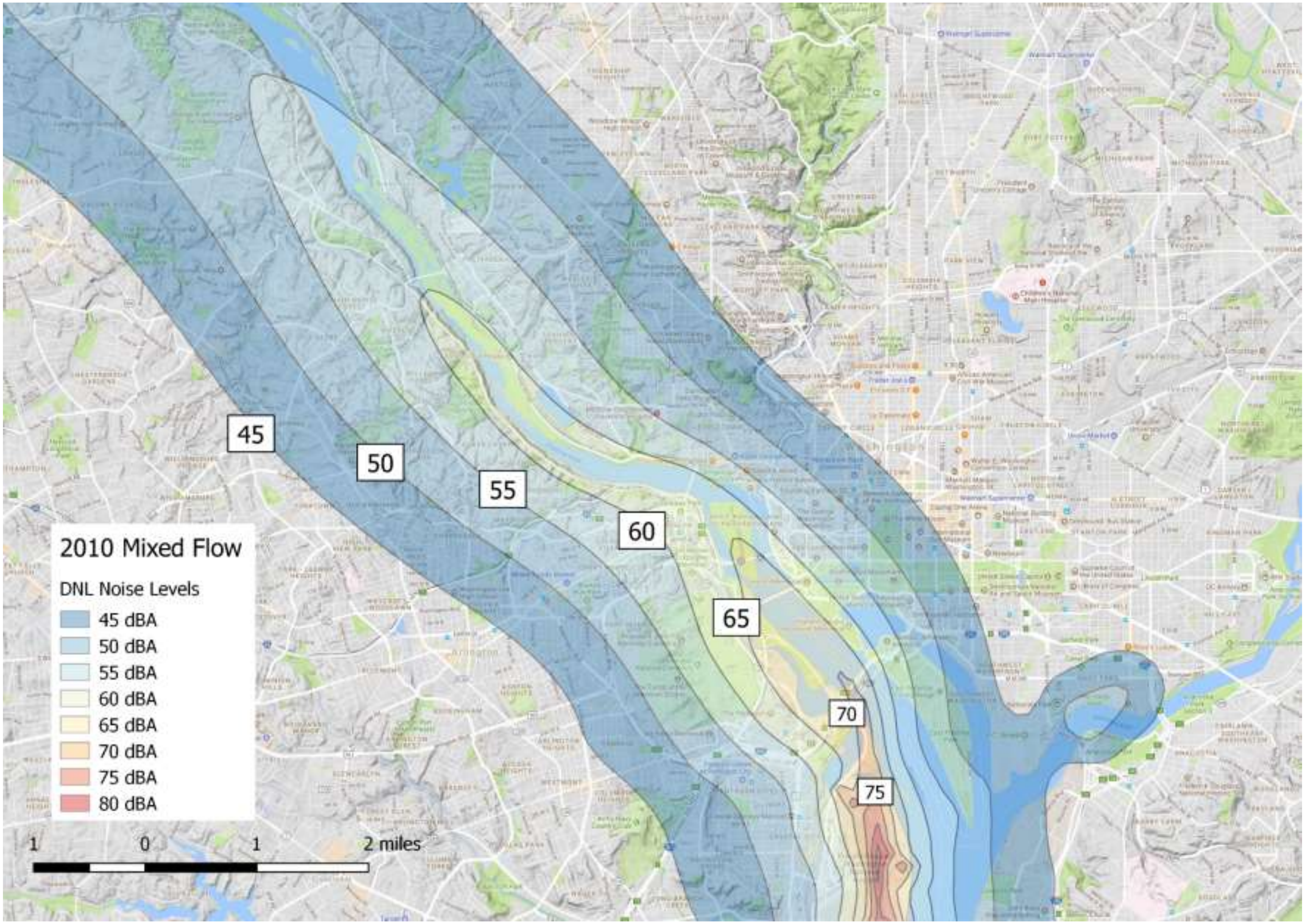

Figure 8-11: 2010 Mixed Flow DNL Noise Contours

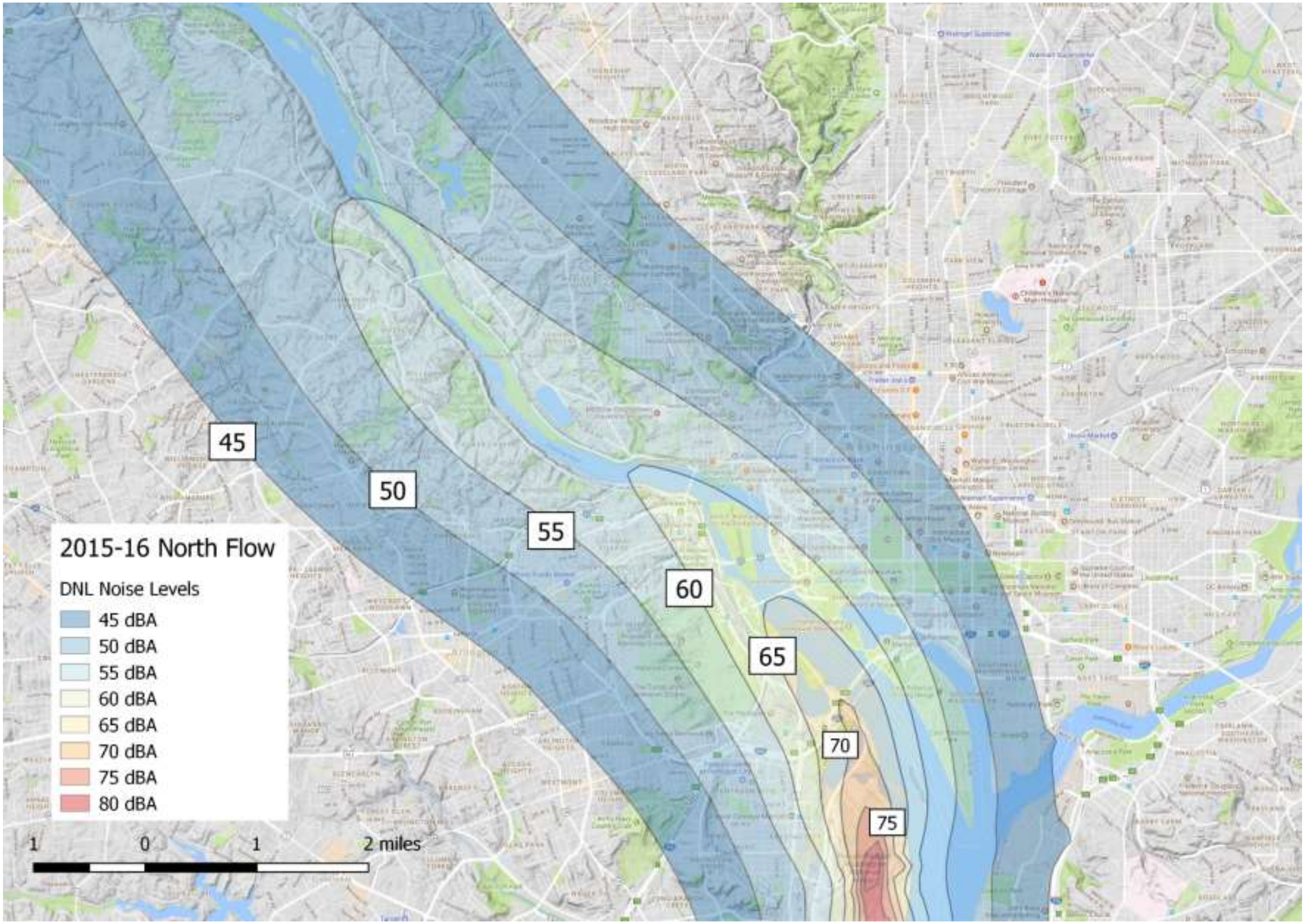

Figure 8-12: 2015-2016 North Flow DNL Noise Contours

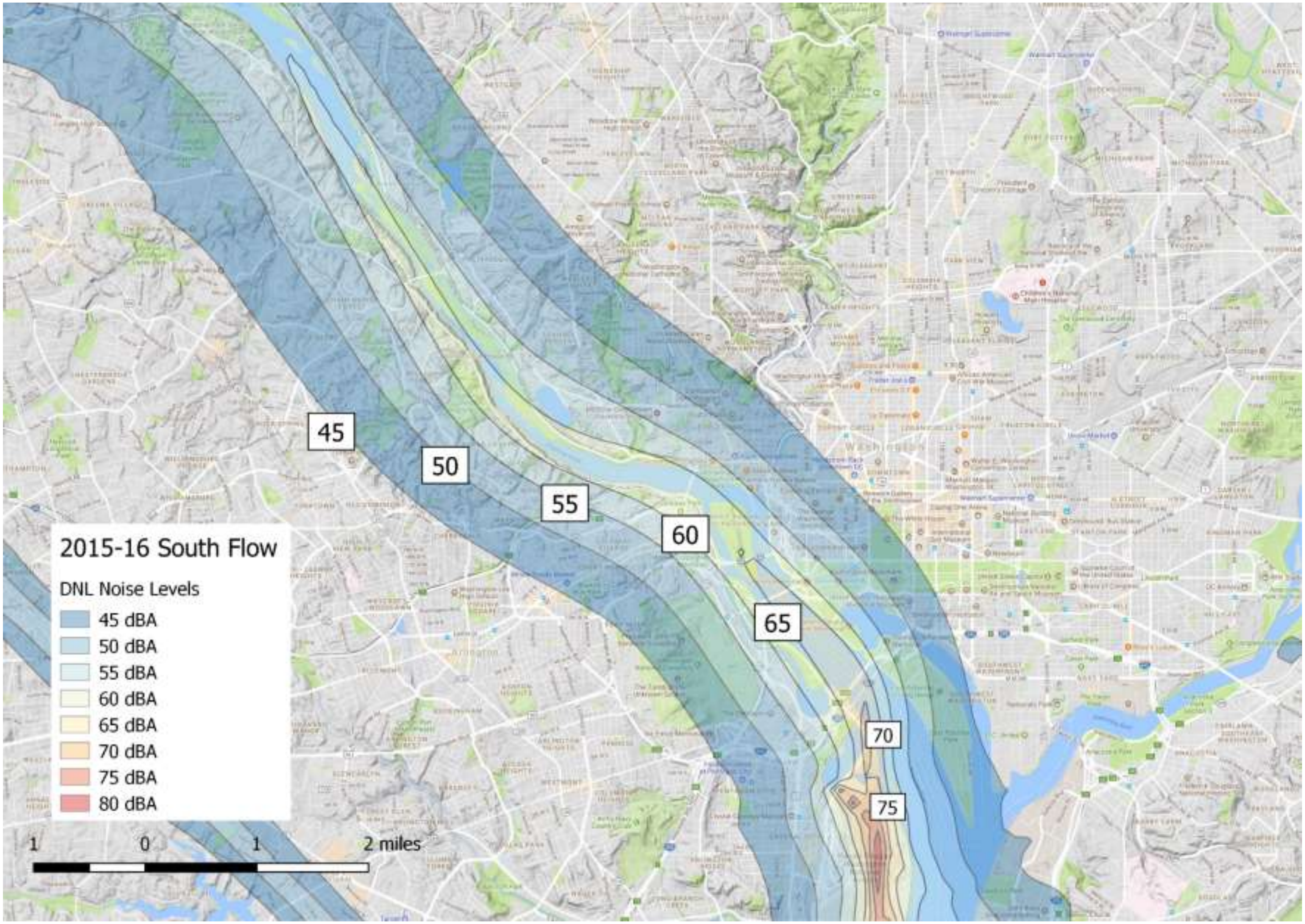

Figure 8-13: 2015-2016 South Flow DNL Noise Contours

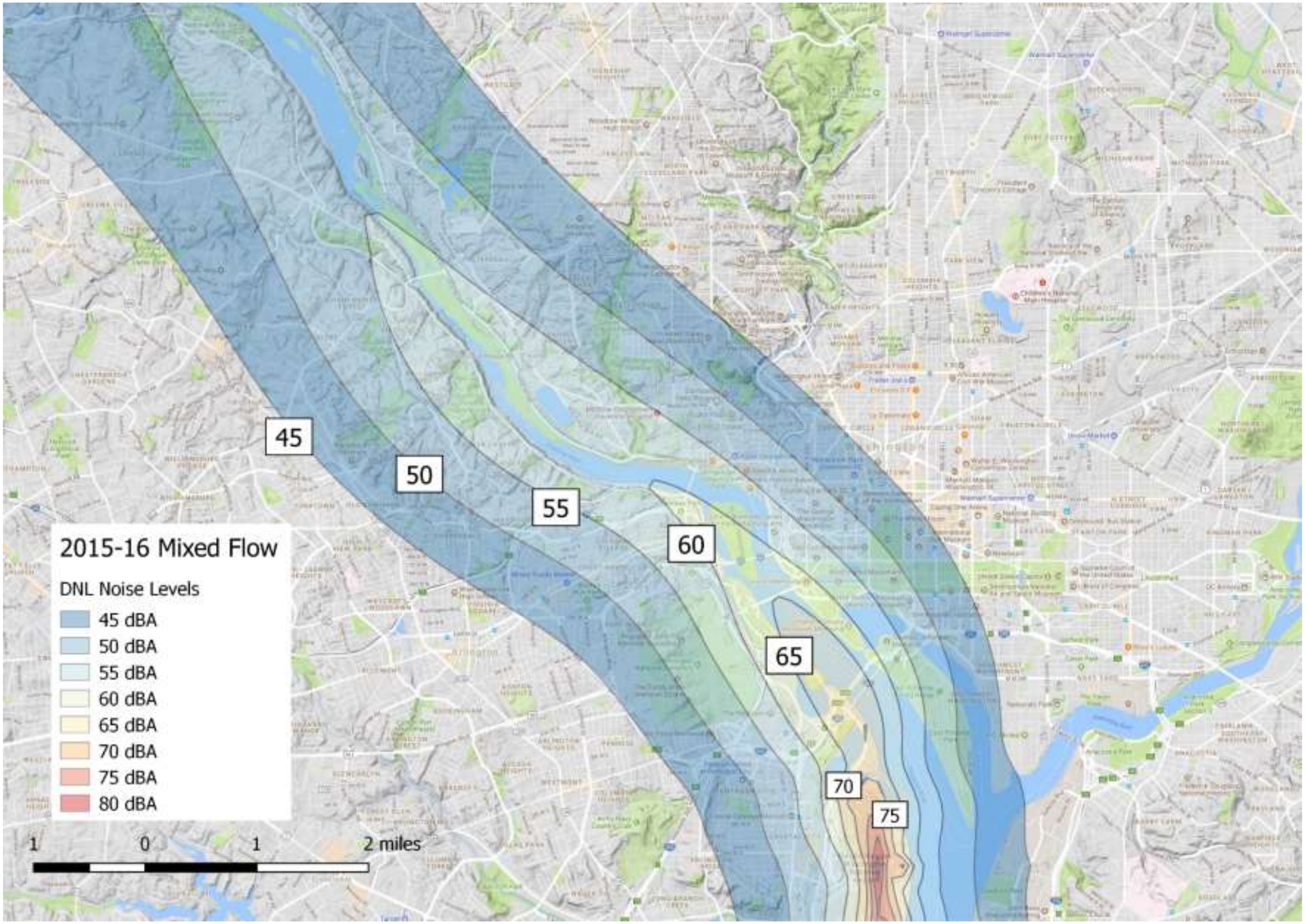

Figure 8-14: 2015-2016 Mixed Flow DNL Noise Levels

8.5.2 DNL at Location Points

Table 8-6 summarizes the calculated DNL noise level at the 18 locations points.

Table 8-6: Average DNL Noise Levels at Location Points (dBA)

Number	Name/Code	2010	2015-2016	Delta (2015-16 minus 2010)
1	FOX_CRESC_1	54.3	54.2	-0.1
2	FOX_CRESC_2	57.2	56.9	-0.3
3	FOX_CRESC_3	55.1	54.7	-0.4
4	5063_SHERIDAN	57.9	57.0	-0.9
5	2316_BENTON	52.7	53.6	0.7
6	2901_M_ST	53.0	55.0	2.0
7	DEXTER_ST	53.3	53.2	-0.1
8	NMT_4	58.2	57.5	-0.7
9	NMT_6	54.8	56.5	1.7
10	NMT_A	59.4	59.4	0.0
11	NMT_B	53.2	54.7	1.5
12	NMT_C	59.0	59.0	0.0
13	NMT_D	56.7	57.9	1.2
14	FRENCH_MAT	52.0	54.1	2.1
15	4850_RES	58.5	57.6	-0.9
16	4920_ASH	57.5	56.4	-1.1
17	G_DAY	59.5	59.6	0.1
18	GWU_NEW_H	53.0	54.8	1.8

Note: Data from 4-28-2010 is not averaged into the above DNL values.

Again, it is important to note that the calculated noise levels presented above may not be 100% reliable, due to the discrepancies found between North versus South Flow DNL (discussed in the previous section).

8.6 Comparison of Modeling results to MWAA Measurement Data

As a check on the accuracy of the noise modeling, the calculated noise levels were compared to MWAA's noise monitoring terminal data. This comparison is shown in Table 8-7.

Table 8-7: Comparison of AEDT Modeling results to MWAA NMT Measurement Data

	Loc. 8: NMT-4			Loc 9: NMT-6		
Date	MWAA Measured Aircraft DNL, dBA	AEDT Calculated DNL, dBA	Difference DNL, dBA	MWAA Measured Aircraft DNL, dBA	AEDT Calculated DNL, dBA	Difference DNL, dBA
20100113	53.3	57.1	-3.8	49.9	56.3	-6.4
20100325	56.9	57.2	-0.3	52.2	51.6	0.6
20100428	55.7	59.3	-3.6	n/a	57.0	n/a
20100616	55.9	59.1	-3.2	56.8	55.0	1.8
20100721	56.7	58.1	-1.4	56.0	53.7	2.3
20100819	57.3	61.0	-3.7	55.3	55.1	0.2
20101020	58.1	57.0	1.1	56.0	55.9	0.1
20101207	55.2	56.1	-0.8	53.1	54.4	-1.3
2010 Average Noise Level	56.3	58.4		54.7	55.1	
2010 Average Difference			-2.0			-0.4
2010 Standard Deviation			1.9			2.9
20150721	58.1	57.4	0.7	58.7	58.7	0.0
20150819	58.4	56.5	2.0	54.8	52.5	2.3
20151009	57.2	58.8	-1.6	56.1	56.8	-0.7
20151210	60.7	57.4	3.3	59.7	54.8	5.0
20160120	56.5	56.5	0.0	57.2	56.4	0.8
20160322	58.4	57.4	1.0	n/a	56.6	n/a
20160428	58.3	57.8	0.5	59.1	59.1	0.0
20160601	59.3	57.9	1.4	56.3	51.6	4.8
2015/2016 Average Noise Level	58.5	57.5		57.7	56.5	
2015/2016 Average Difference			0.9			1.7
2015/2016 Standard Deviation			1.4			2.3

Note: There are some uncertainties with the 2010 MWAA noise monitor data due to the equipment being used at that time. n/a signifies MWAA monitor data was not available.

8.7 TA Level

The time that aircraft flyovers are above various noise levels were calculated for both 2010 and 2015-16. We have calculated TA levels for the three operating conditions at DCA (North Flow, South Flow, and Mixed). Figure 8-15 through Figure 8-17 show the TA 65 dBA contour maps for 2010. Figure 8-18 through Figure 8-20 shows the TA 65 dBA contour maps for 2015-2016.

Unlike the DNL metric, there are no formal criteria for TA levels. However, the DoD has issued a document outlining the use of supplemental noise metrics such as the TA Level.[29] Per the DoD document, the TA metric is useful for describing the noise environment at schools and other noise sensitive environments. Further, the EPA's Levels document (EPA Report 550) stipulates that speech communication begins to be impacted when background noise levels exceed 60 dBA.[30]

[29] DoD Noise Working Group. Technical Bulletin: Using Supplemental Noise Metrics and Analysis Tools. December 2009.
[30] U.S. Environmental Protection Agency. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. EPA Report 550/9-74-004. March 1974.

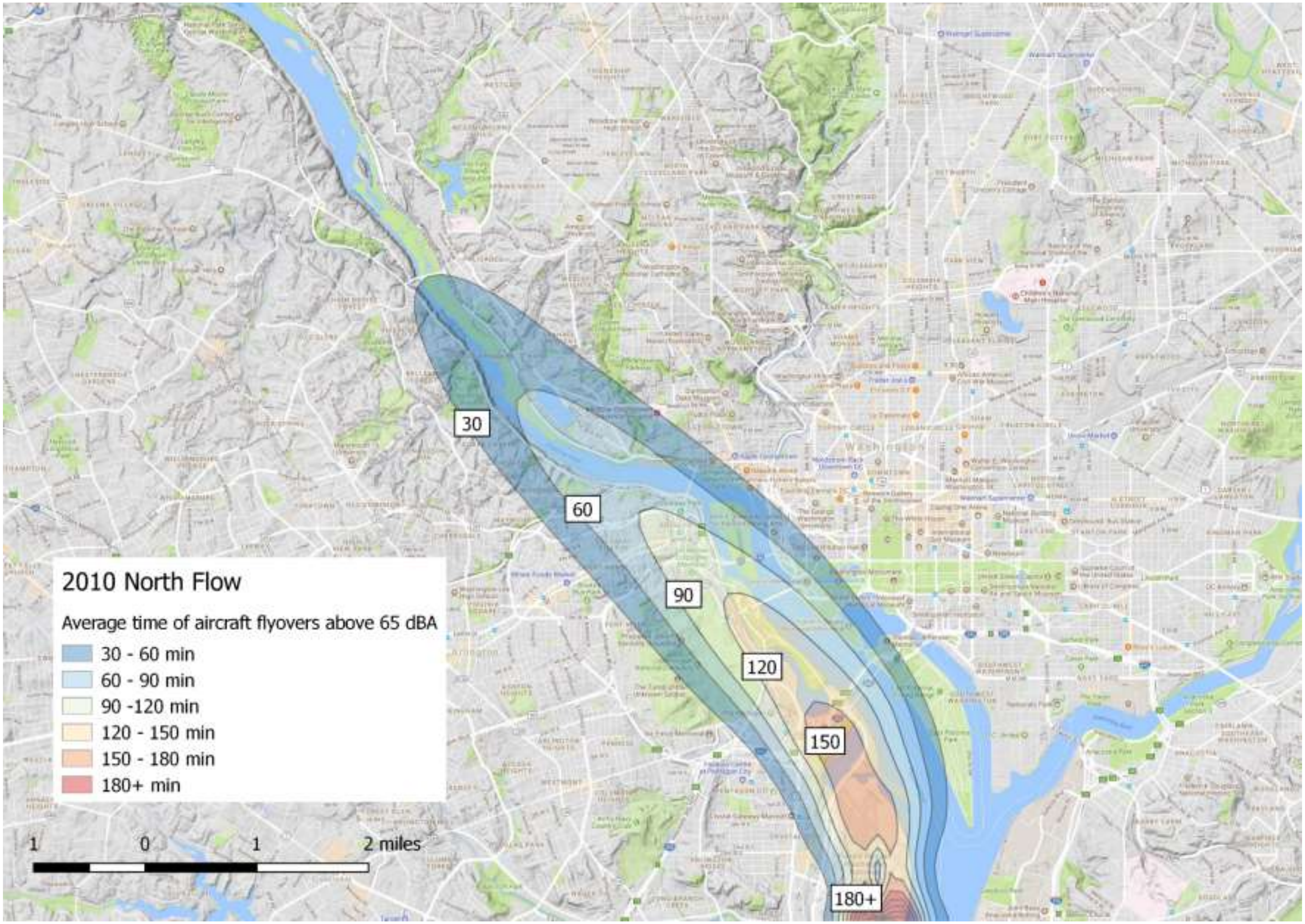

Figure 8-15: 2010 North Flow Time Above 65 dBA

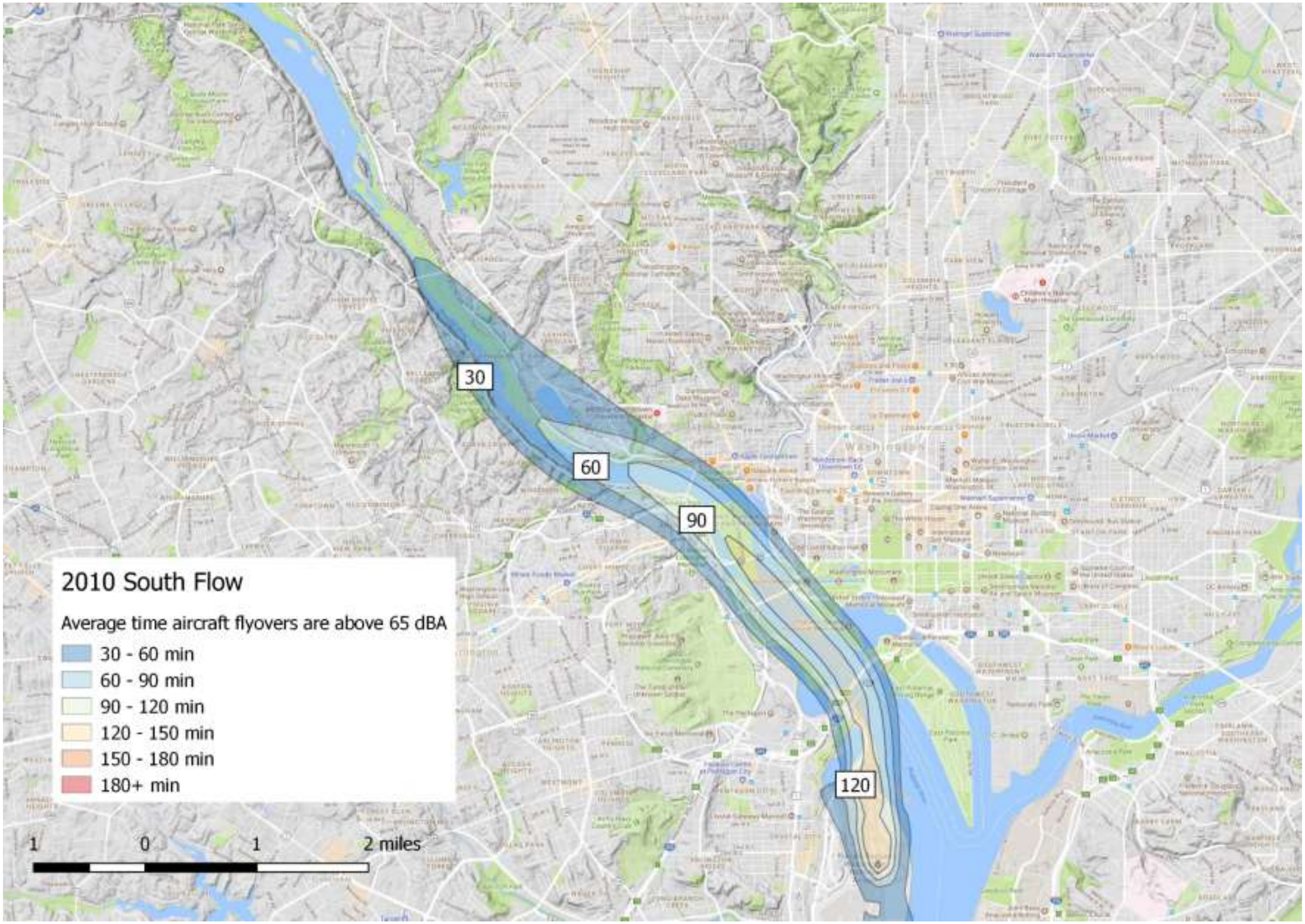

Figure 8-16: 2010 South Flow Time Above 65 dBA

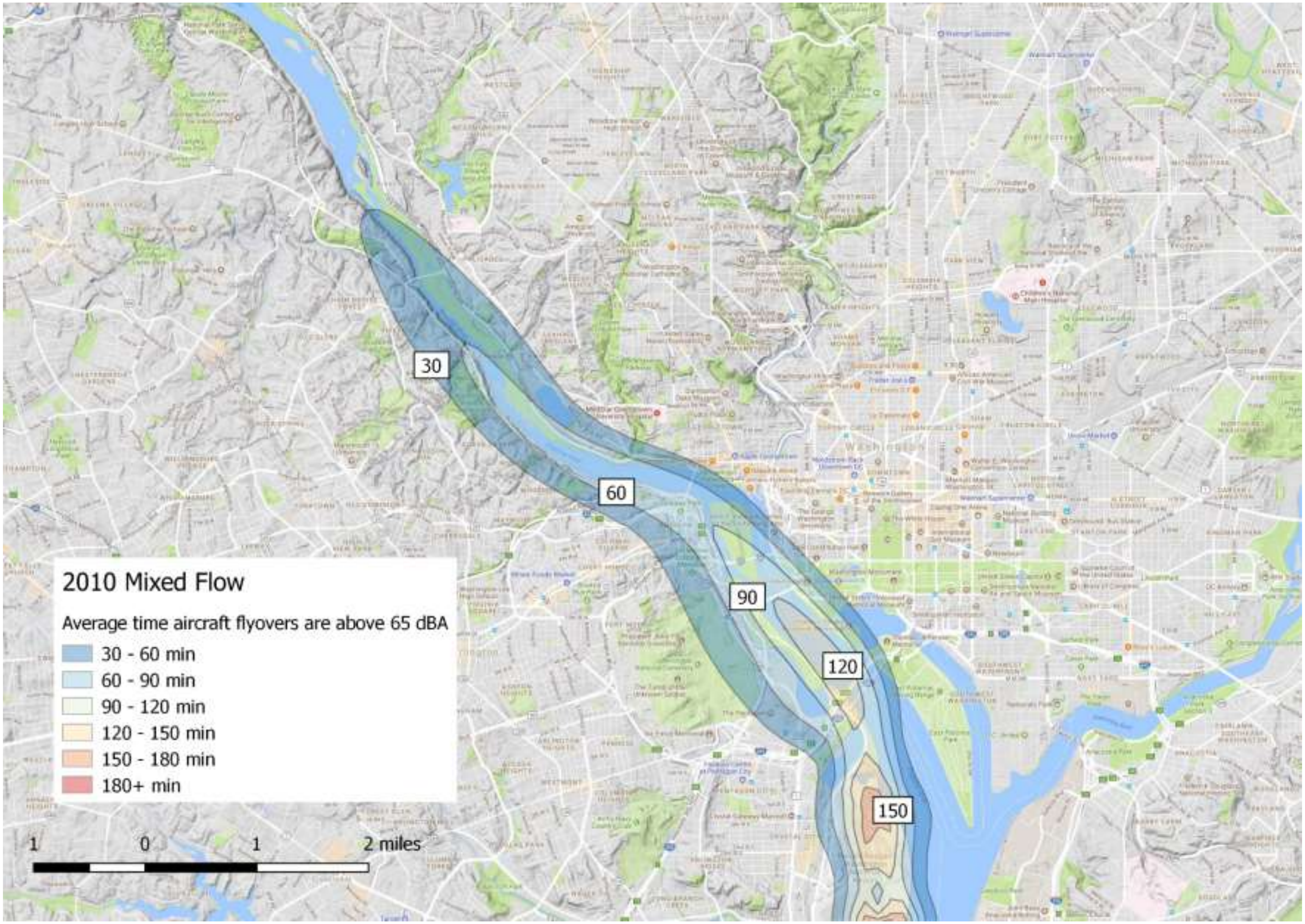

Figure 8-17: 2010 Mixed Flow Time Above 65 dBA

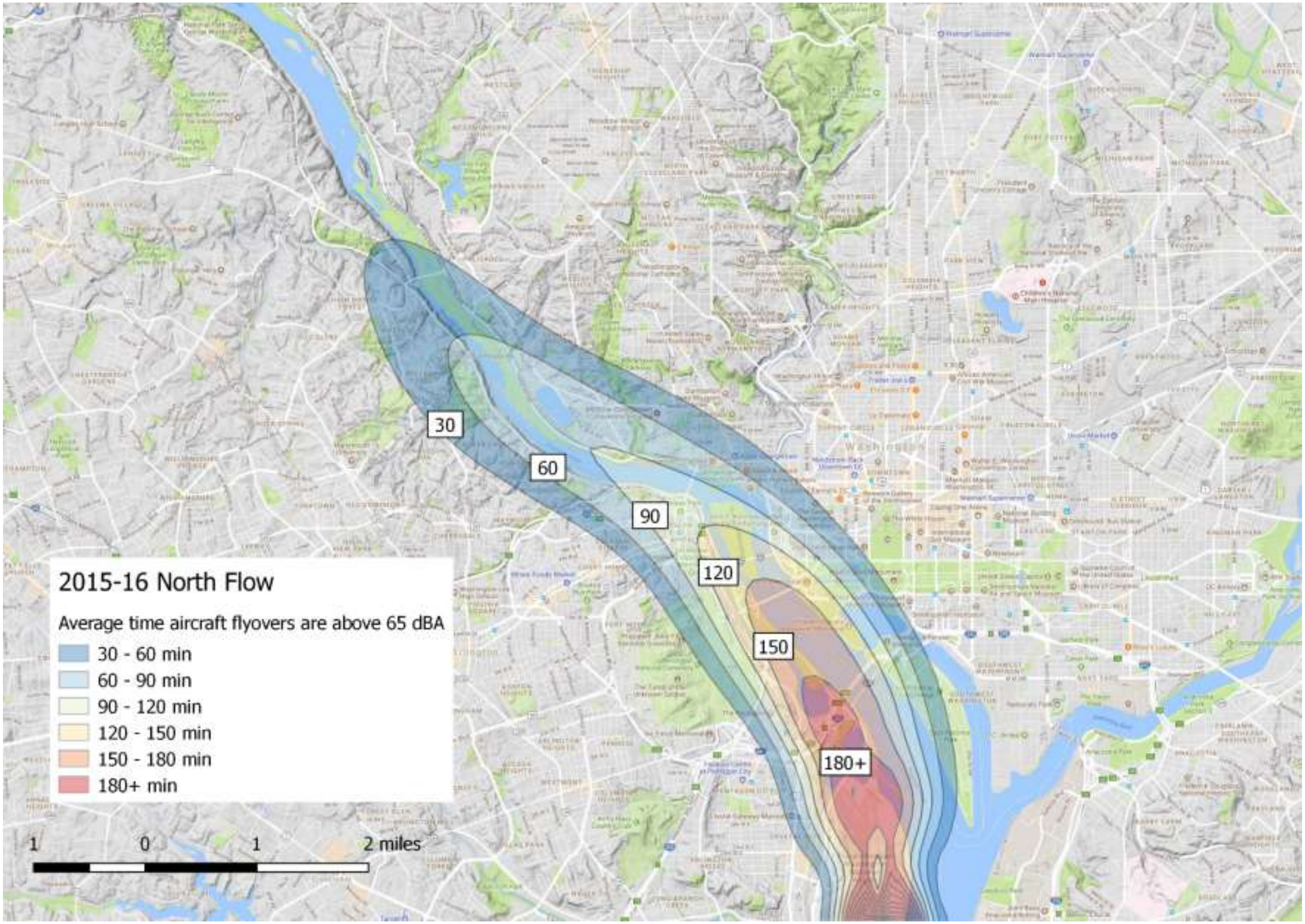

Figure 8-18: 2015-2016 North Flow Time Above 65 dBA

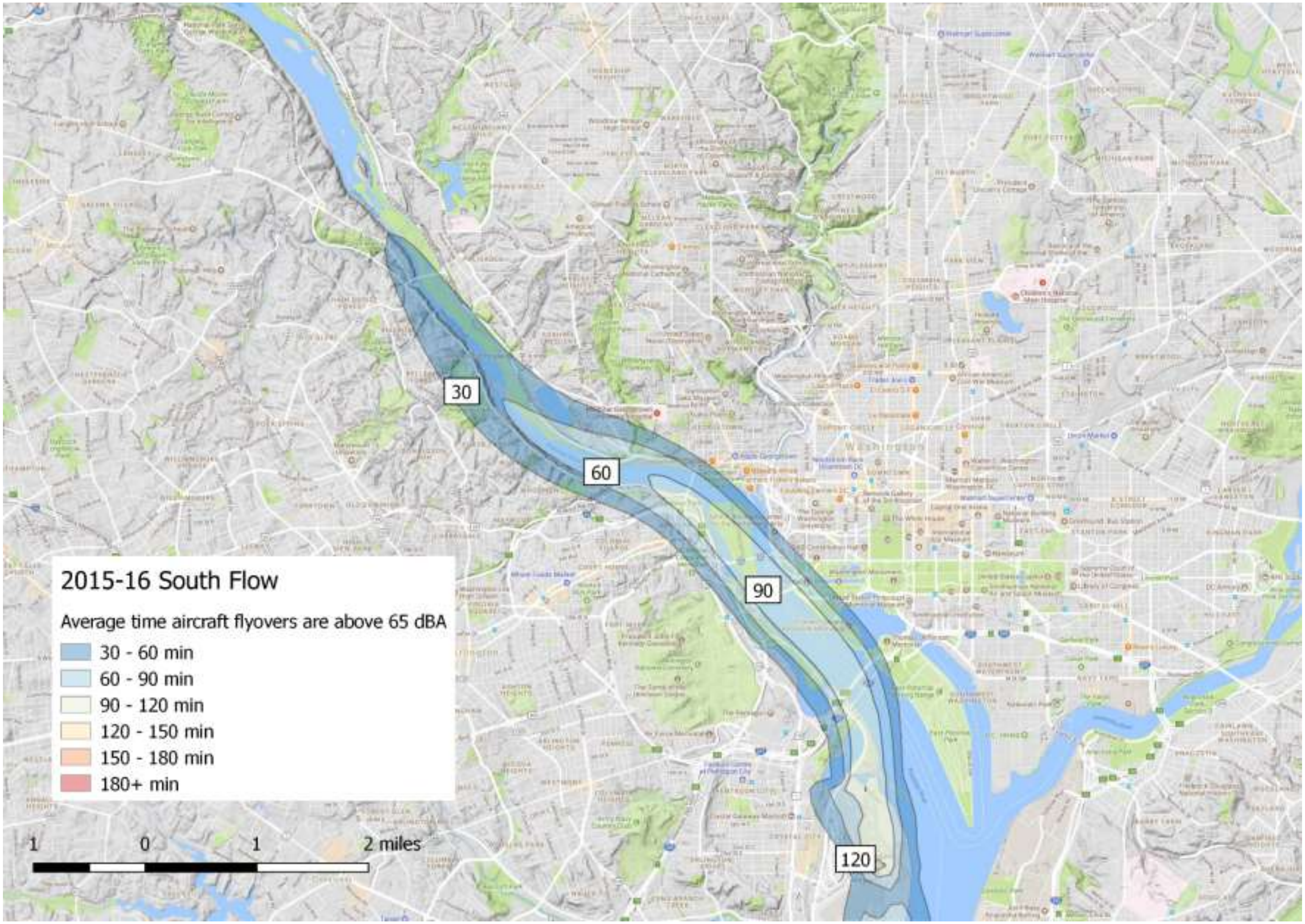

Figure 8-19: 2015-2016 South Flow Time Above 65 dBA

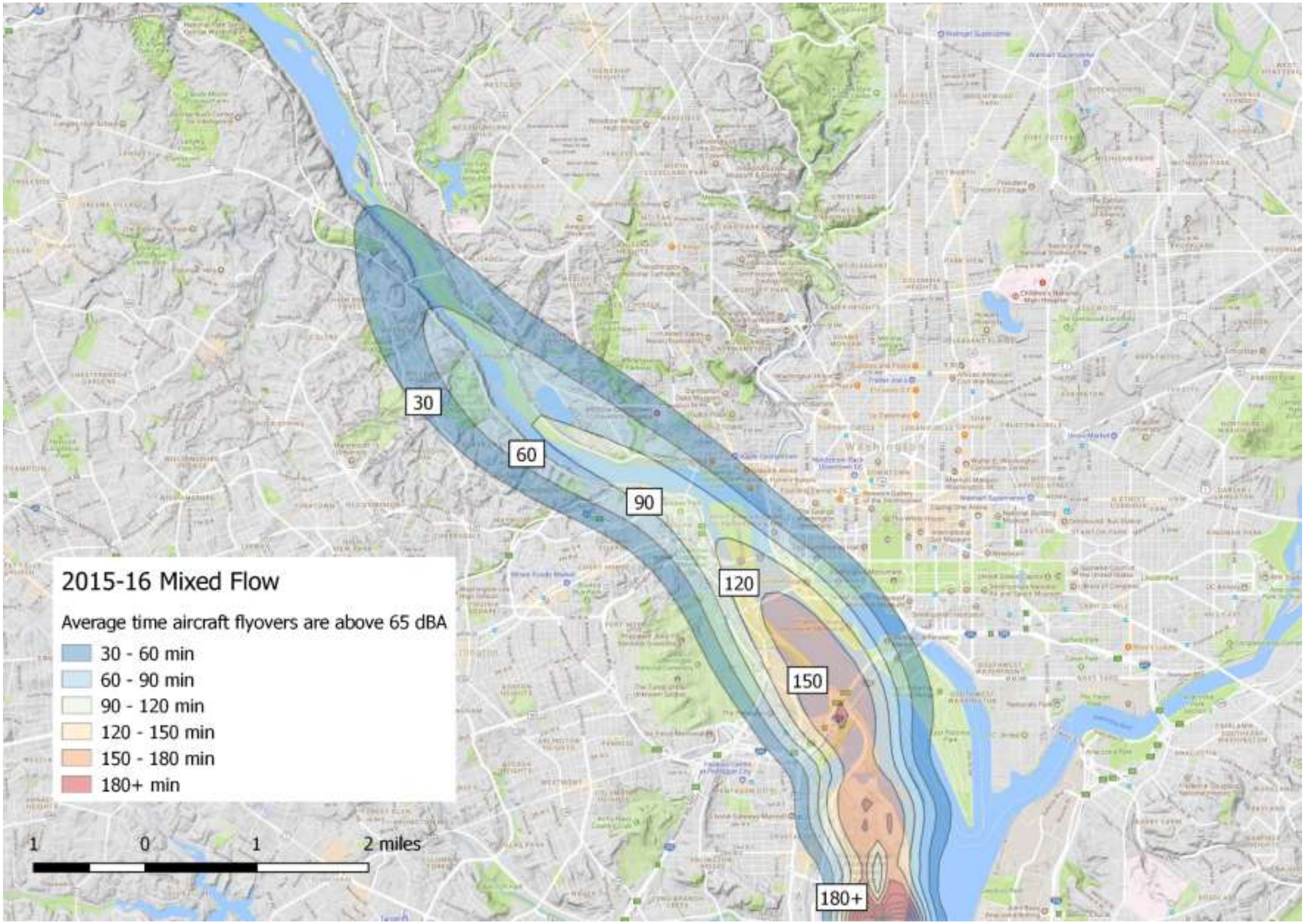

Figure 8-20: 2015-2016 Mixed Flow Time Above 65 dBA

Table 8-8 provides a summary of Time Above levels at various location points.

Table 8-8: Average Time Above dBA Level at Location Points (minutes)

		2010					2015-2016					Delta (2015-2016 minus 2010)				
Number	Name/Code	50 dBA	55 dBA	60 dBA	65 dBA	70 dBA	50 dBA	55 dBA	60 dBA	65 dBA	70 dBA	50 dBA	55 dBA	60 dBA	65 dBA	70 dBA
1	FOX_CRESC_1	270.9	134.8	53.9	9.4	1.0	322.9	163.8	63.2	10.4	0.0	52.0	29.0	9.3	1.1	-0.9
2	FOX_CRESC_2	344.3	193.4	90.4	30.8	4.1	414.7	228.1	107.0	35.5	3.4	70.4	34.7	16.5	4.8	-0.6
3	FOX_CRESC_3	292.3	150	63.6	13.7	1.3	350.8	178.6	72.4	13.4	0.1	58.5	28.6	8.8	-0.3	-1.3
4	5063_SHERID.	355.4	209.6	102.8	33.5	4.6	436.3	254.9	118.8	34.0	2.6	80.9	45.3	16.0	0.4	-2.0
5	2316_BENTON	230.4	107.6	36.1	4.6	0.5	280.9	136.8	50.0	8.3	0.0	50.5	29.2	13.9	3.6	-0.5
6	2901_M_ST	240.9	106.3	34.3	7.1	0.7	305.9	153.9	61.0	20.1	1.3	65.1	47.6	26.7	12.9	0.7
7	DEXTER_ST	243.5	117.5	41.5	5.8	0.6	292.6	144.6	47.9	4.4	0.0	49.1	27.1	6.4	-1.4	-0.6
8	NMT_4	361.8	217	110.1	35.4	4.8	447.0	269.9	136.5	40.9	4.0	85.2	52.9	26.5	5.4	-0.7
9	NMT_6	296.9	150.6	56.1	13.5	1.3	355.0	197.8	85.6	28.4	4.4	58.2	47.2	29.5	14.9	3.1
10	NMT_A	394.3	243.7	132.2	52.9	10.6	466.2	292.1	164.4	69.4	14.8	18.6	14.6	12.3	7.3	2.7
11	NMT_B	255	116	41.8	6.4	0.7	309.4	150.6	60.9	16.3	0.2	71.8	48.4	32.2	16.5	4.2
12	NMT_C	387.5	236.4	124.7	48.3	9.0	460.8	284.0	153.2	60.6	12.9	54.4	34.6	19.2	9.9	-0.6
13	NMT_D	342.7	191.6	84.9	26.7	3.4	401.4	237.8	118.8	42.2	8.5	73.2	47.6	28.6	12.3	3.8
14	FRENCH_MAT	219.5	89.3	27.5	4.5	0.5	278.7	130.2	49.9	14.7	0.2	58.7	46.1	34.0	15.5	5.1

8.8 Number of Events Above

The number of flyover events above a predetermined threshold was calculated for both 2010 and 2015-16. We have calculated NA counts for the three operating conditions at DCA (North Flow, South Flow, and Mixed). Figure 8-21 through Figure 8-23 show the NA 65 dBA contour maps for 2010. Figure 8-24 through Figure 8-26 shows the NA contour maps for 2015-2016.

Note there are no formal criteria, unlike the DNL metric, for NA counts. However, based on the DoD supplemental metric document, the NA metric allows the public to easily relate the NA metric to their everyday experience and more easily understand changes to their noise environment. The use of the NA-65 metric (i.e., the number of events above 65 dBA) allows the quantification of the number of times per day speech may be interrupted outdoors.

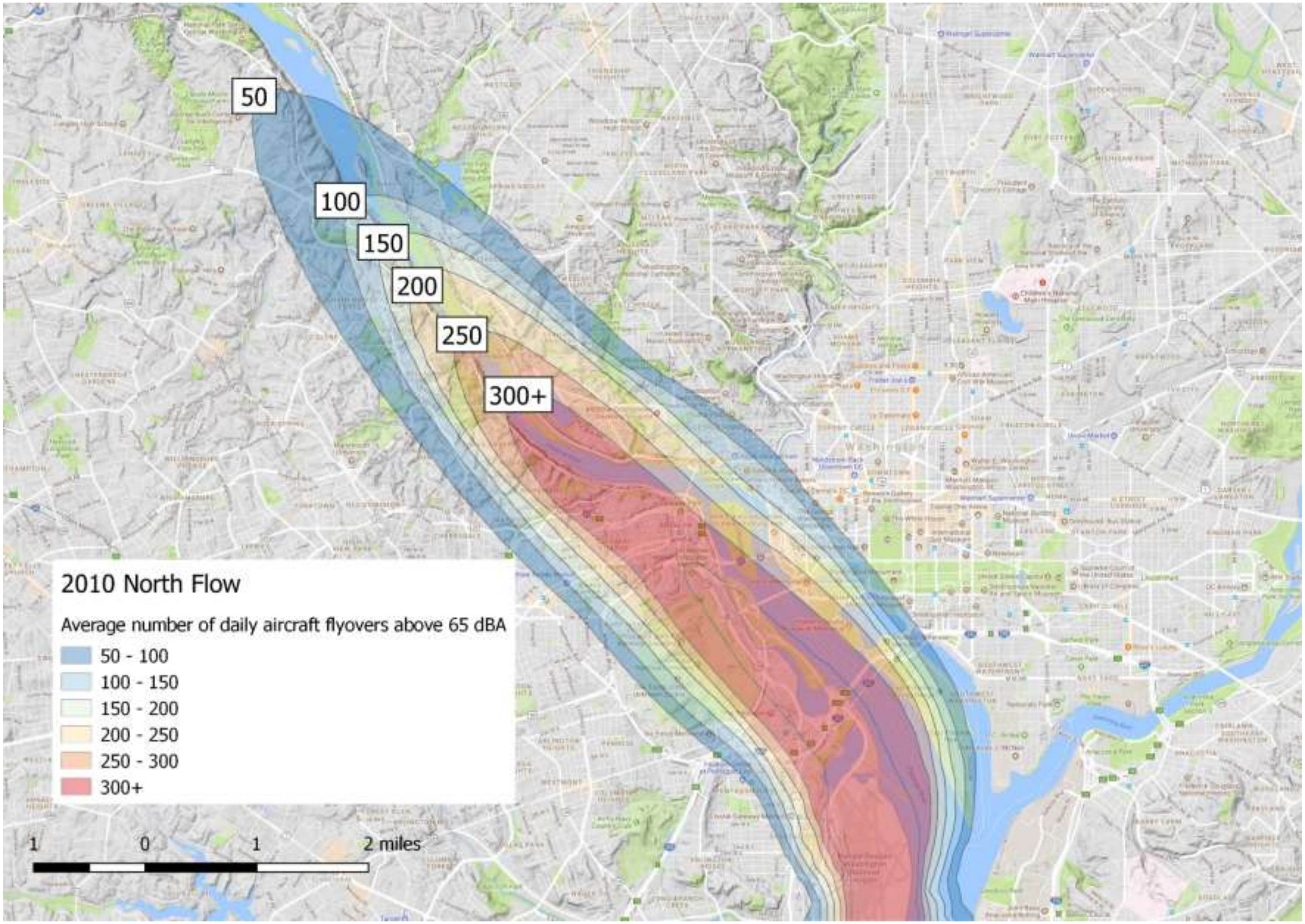

Figure 8-21: 2010 North Flow Number of Flights Above 65 dBA

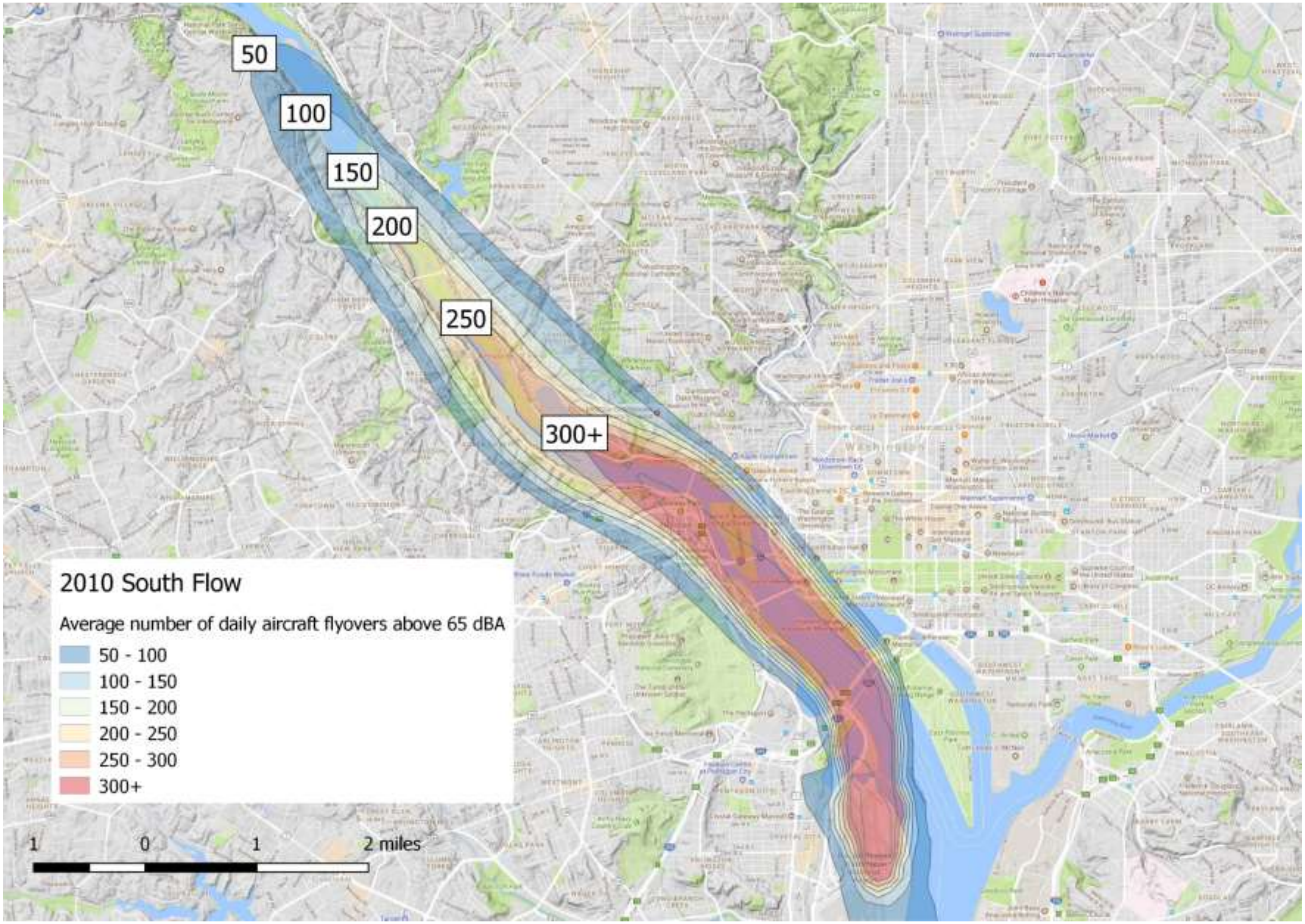

Figure 8-22: 2010 South Flow Number of Flights Above 65 dBA

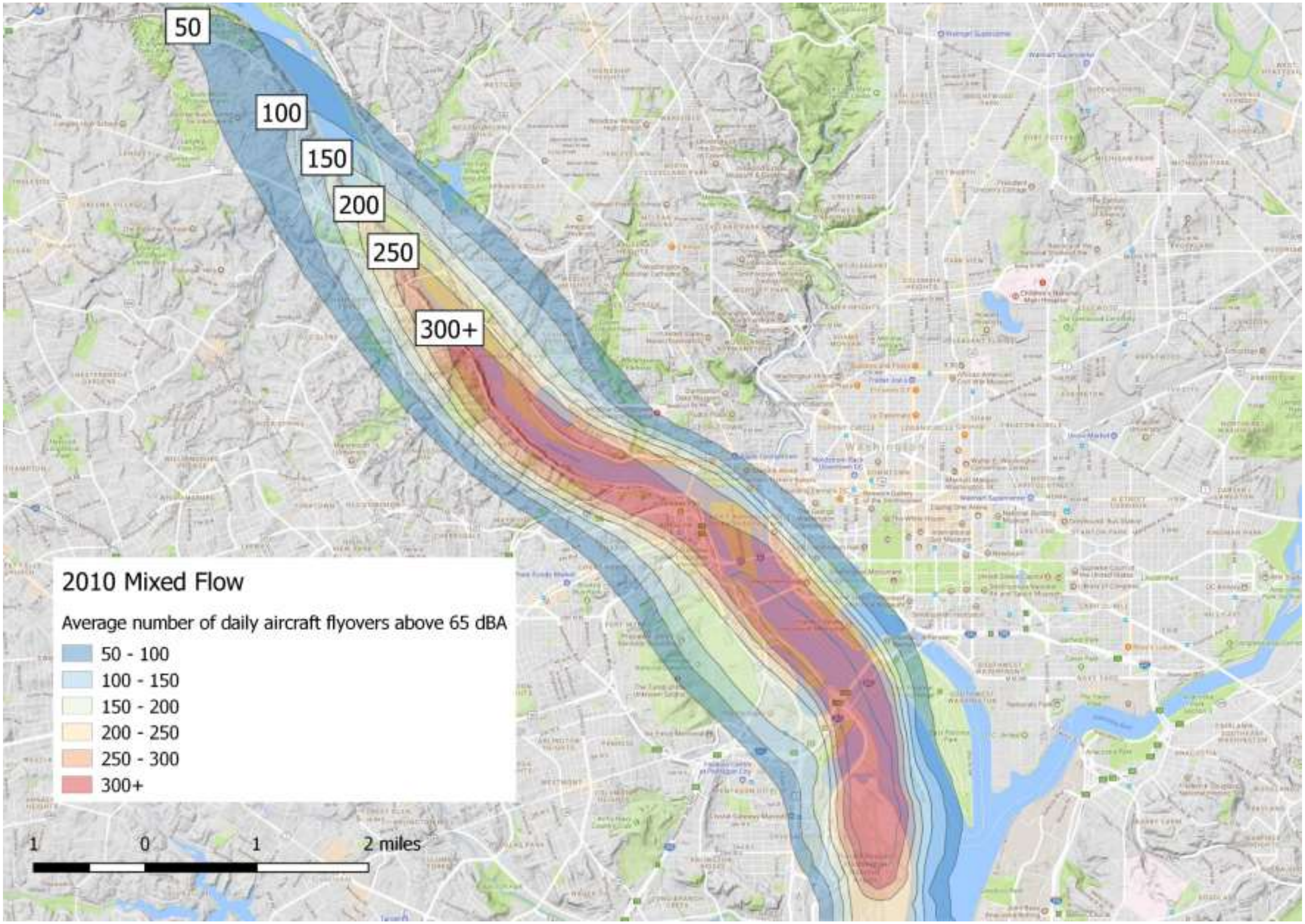

Figure 8-23: 2010 Mixed Flow Number of Flights Above 65 dBA

475 Sansome Street Suite 800 San Francisco, CA 94111 415.693.9800 www.csdadesigngroup.com
San Francisco • Los Angeles

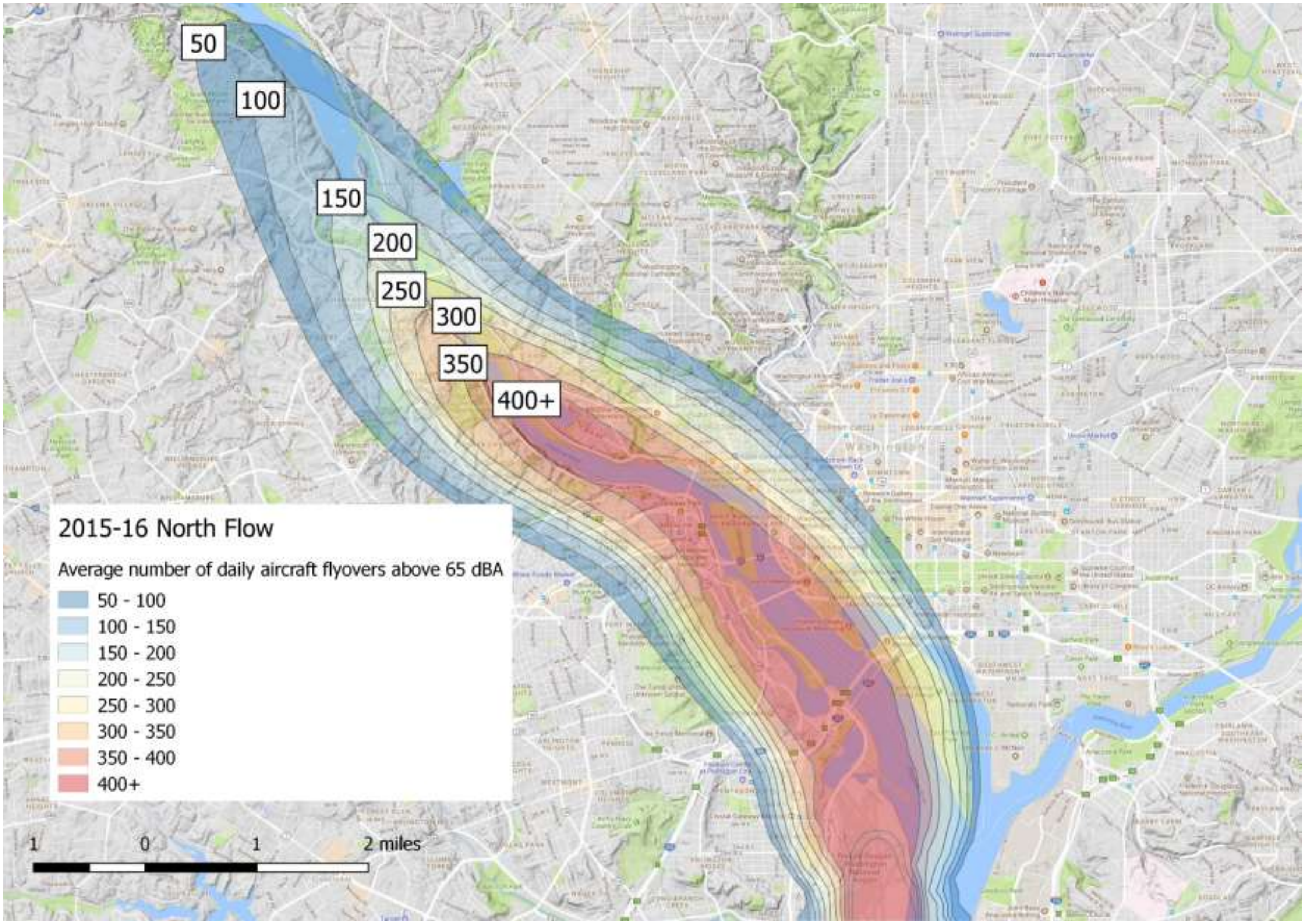

Figure 8-24: 2015-2016 North Flow Number of Flights Above 65 dBA

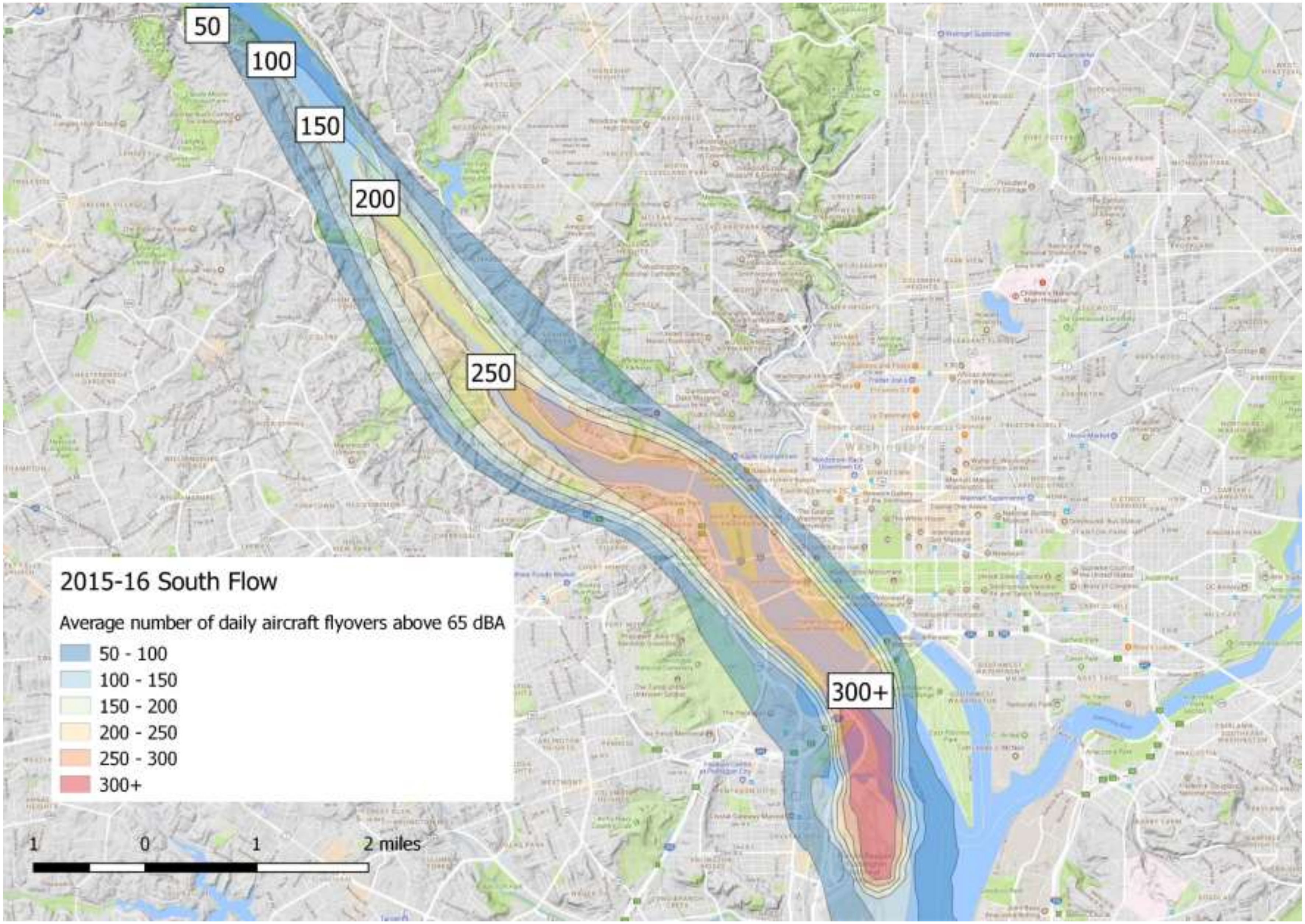

Figure 8-25: 2015-2016 South Flow Number of Flights Above 65 dBA

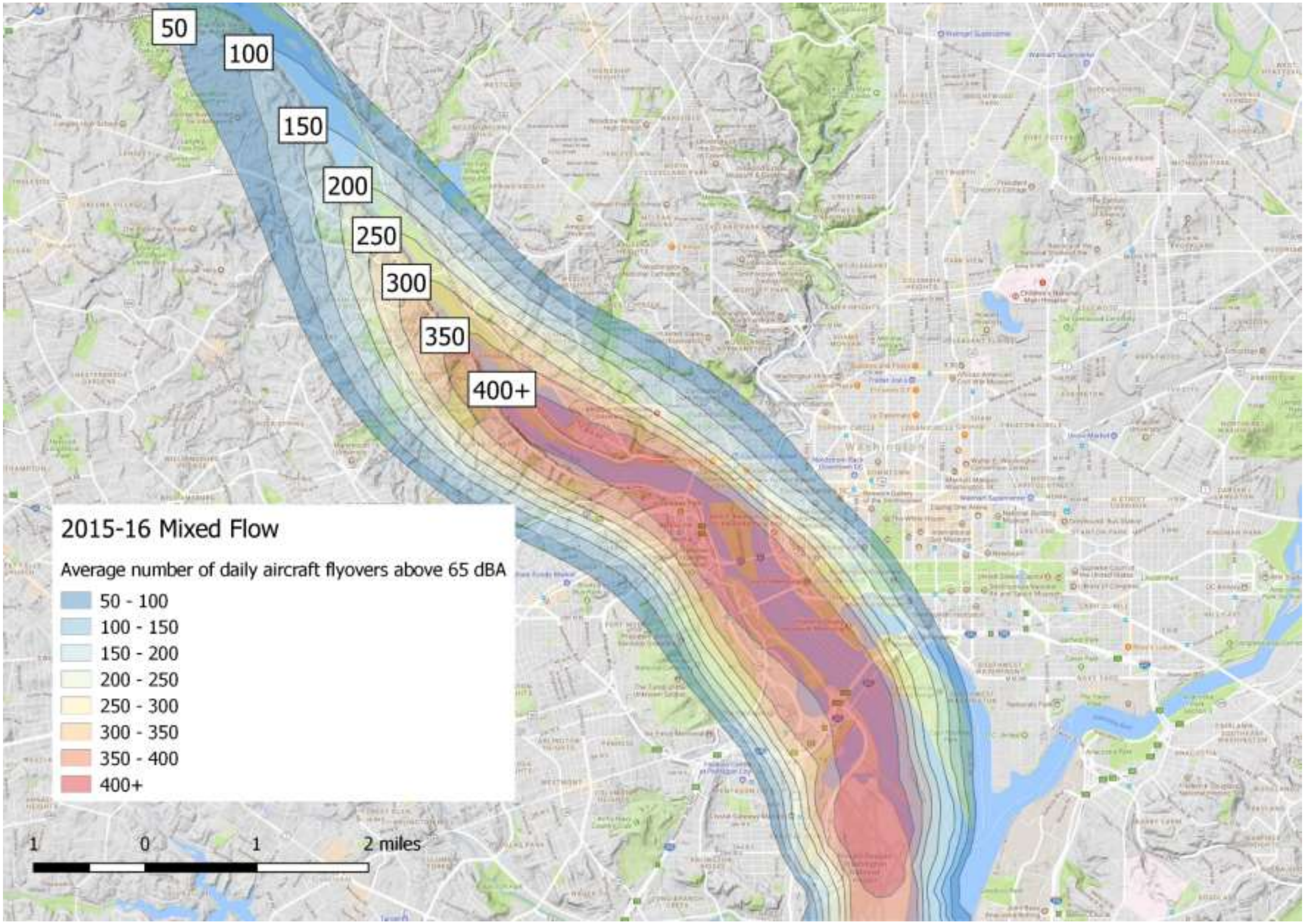

Figure 8-26: 2015-2016 Mixed Flow Number of Flights Above 65 dBA

The number of events (flyovers) above various noise levels were calculated for both 2010 and 2015-16 at 14 different location points. The average number of events above level for each year is presented in Table 8-9.

Table 8-9: Average Number of Events Above dBA Level at Location Points

		2010					2015-2016					Delta (2015-2016 minus 2010)				
Number	Name/Code	50 dBA	55 dBA	60 dBA	65 dBA	70 dBA	50 dBA	55 dBA	60 dBA	65 dBA	70 dBA	50 dBA	55 dBA	60 dBA	65 dBA	70 dBA
1	FOX_CRESC_1	347.3	268.9	199.5	72.0	8.6	387.6	310.8	225.4	88.6	0.3	40.4	41.9	25.9	16.6	-8.4
2	FOX_CRESC_2	358.6	344.6	278.3	180.8	47.0	410.1	394.9	311.6	205.0	53.4	51.5	50.3	33.4	24.3	6.4
3	FOX_CRESC_3	352.9	301.4	218.5	102.3	12.8	402.1	331.4	253.5	104.4	1.1	49.3	30.0	35.0	2.1	-11.6
4	5063_SHERID.	359.8	350.6	320.5	204.8	50.9	410.6	407.1	367.0	204.1	40.3	50.9	56.5	46.5	-0.6	-10.6
5	2316_BENTON	320.4	230.8	155.0	33.0	3.1	369.4	295.6	192.6	78.3	0.0	49.0	64.9	37.6	45.3	-3.1
6	2901_M_ST	346.3	277.0	146.9	56.3	5.0	409.6	383.0	237.8	130.9	26.3	63.4	106.0	90.9	74.6	21.3
7	DEXTER_ST	331.6	245.3	172.8	43.1	4.6	365.9	290.9	201.9	58.9	0.0	34.3	45.6	29.1	15.8	-4.6
8	NMT_4	360.1	353.0	333.0	221.5	48.3	410.8	408.6	394.6	257.5	54.9	50.6	55.6	61.6	36.0	6.6
9	NMT_6	356.6	321.3	220.6	87.0	10.8	410.3	404.3	336.1	158.1	60.4	53.6	83.0	115.5	71.1	49.6
10	NMT_A	361.0	359.6	351.1	273.8	113.6	410.9	409.5	406.6	363.4	150.6	49.9	49.9	55.5	89.6	37.0
11	NMT_B	346.9	257.9	163.1	53.5	5.4	404.9	345.4	239.8	134.5	7.5	58.0	87.5	76.6	81.0	2.1
12	NMT_C	361.0	358.5	345.6	253.4	98.6	410.8	409.3	402.6	324.8	132.9	49.8	50.8	57.0	71.4	34.3
13	NMT_D	360.3	346.1	283.1	160.5	38.8	410.8	408.1	385.9	243.0	99.3	50.5	62.0	102.8	82.5	60.5
14	FRENCH_MAT	340.3	243.3	128.3	44.1	3.5	408.1	351.9	206.8	119.6	5.4	67.9	108.6	78.5	75.5	1.9

8.9 Equivalent Day and Night Levels

To show the difference in aircraft noise level between daytime and nighttime, the average daytime equivalent levels ($L_{eq(day)}$) and nighttime equivalent levels ($L_{eq(night)}$) were calculated for both 2010 and 2015-16. Figures 8-27 through 8-32 show the 2010 ($L_{eq(day)}$) and ($L_{eq(night)}$), separated by flow type. Figures 8-33 through 8-38 show the 2015-16 ($L_{eq(day)}$) and ($L_{eq(night)}$), also separated by flow type.

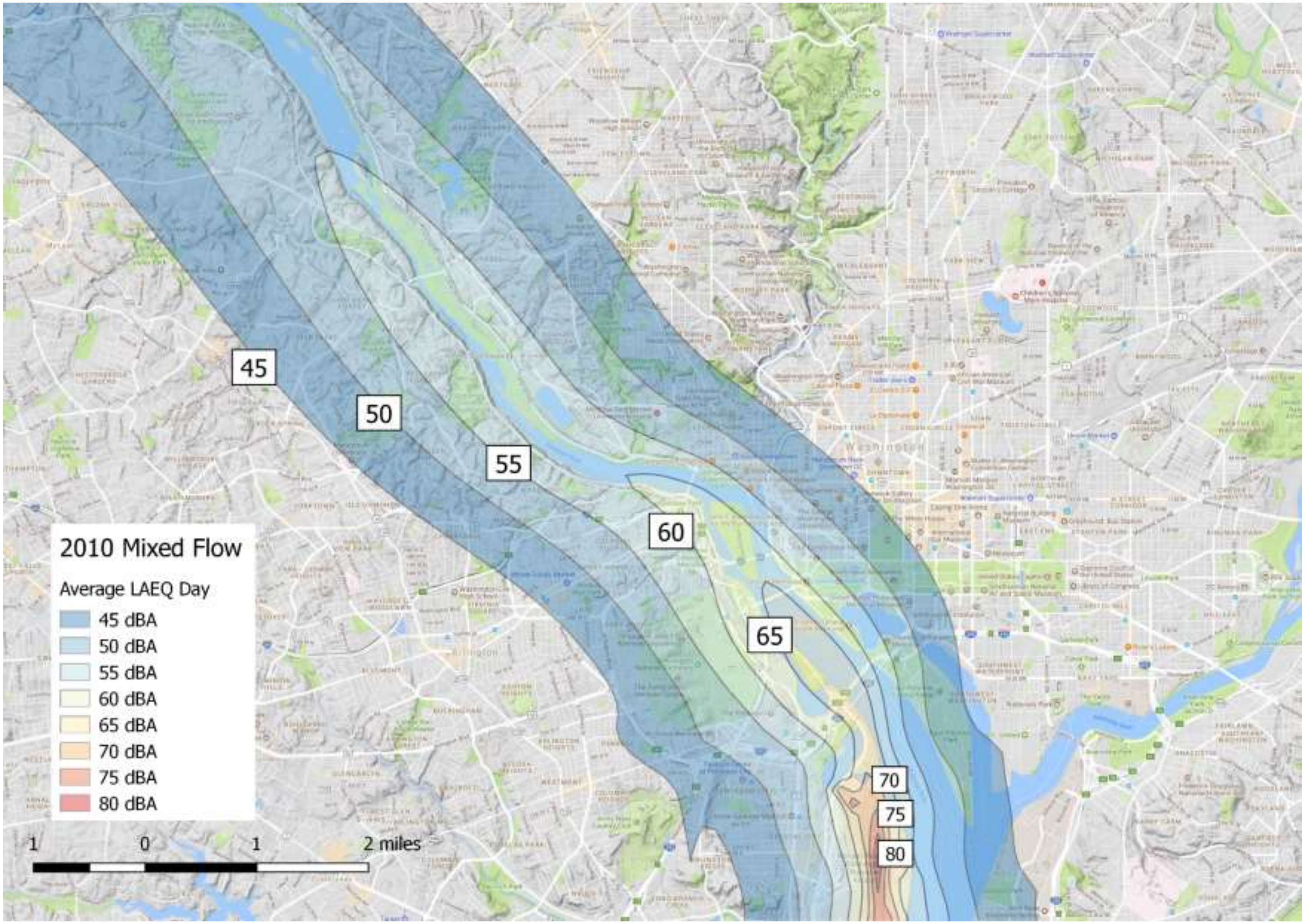

Figure 8-27: 2010 Average Daytime Equivalent Level Mixed Flow

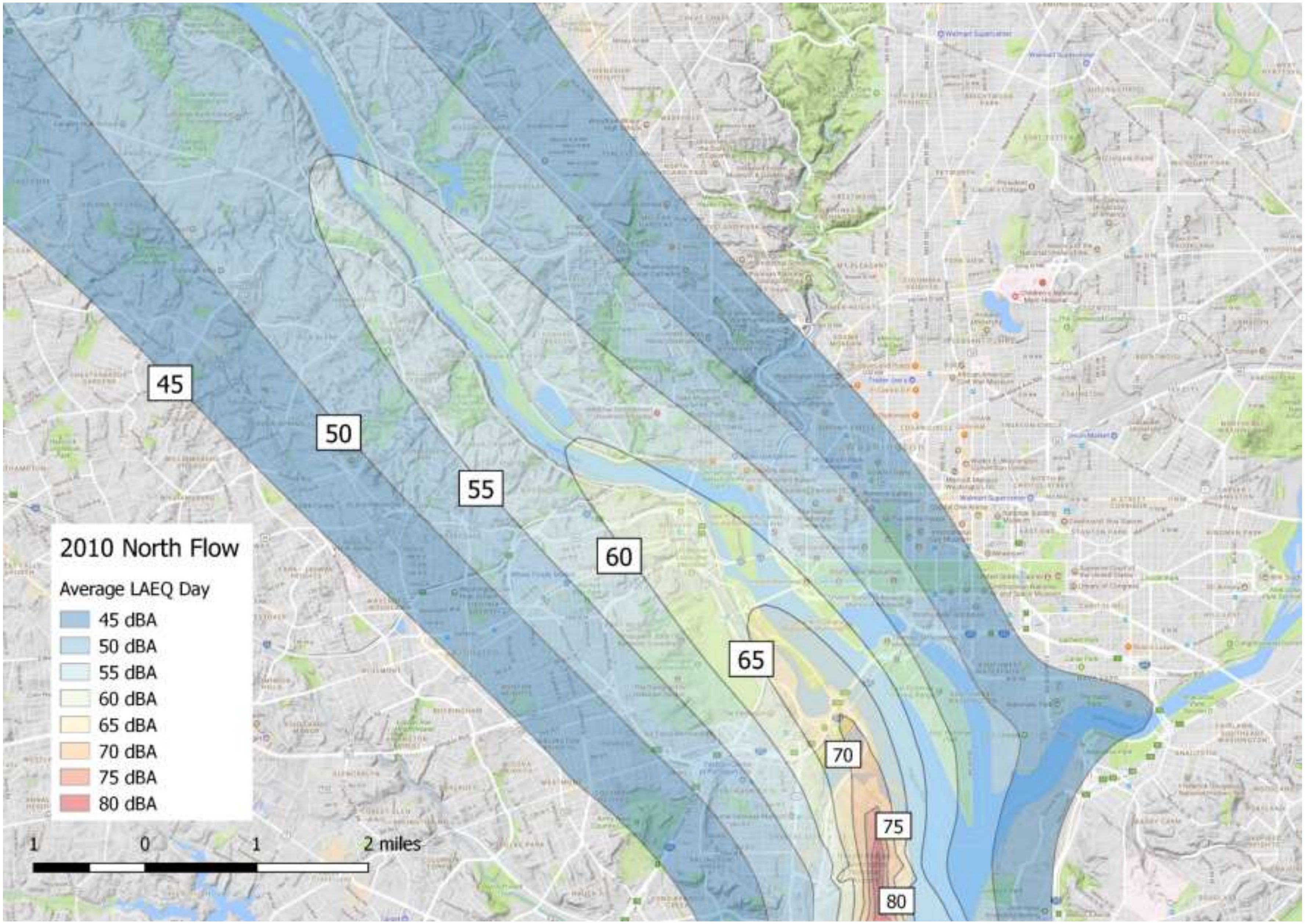

Figure 8-28: 2010 Average Daytime Equivalent Level North Flow

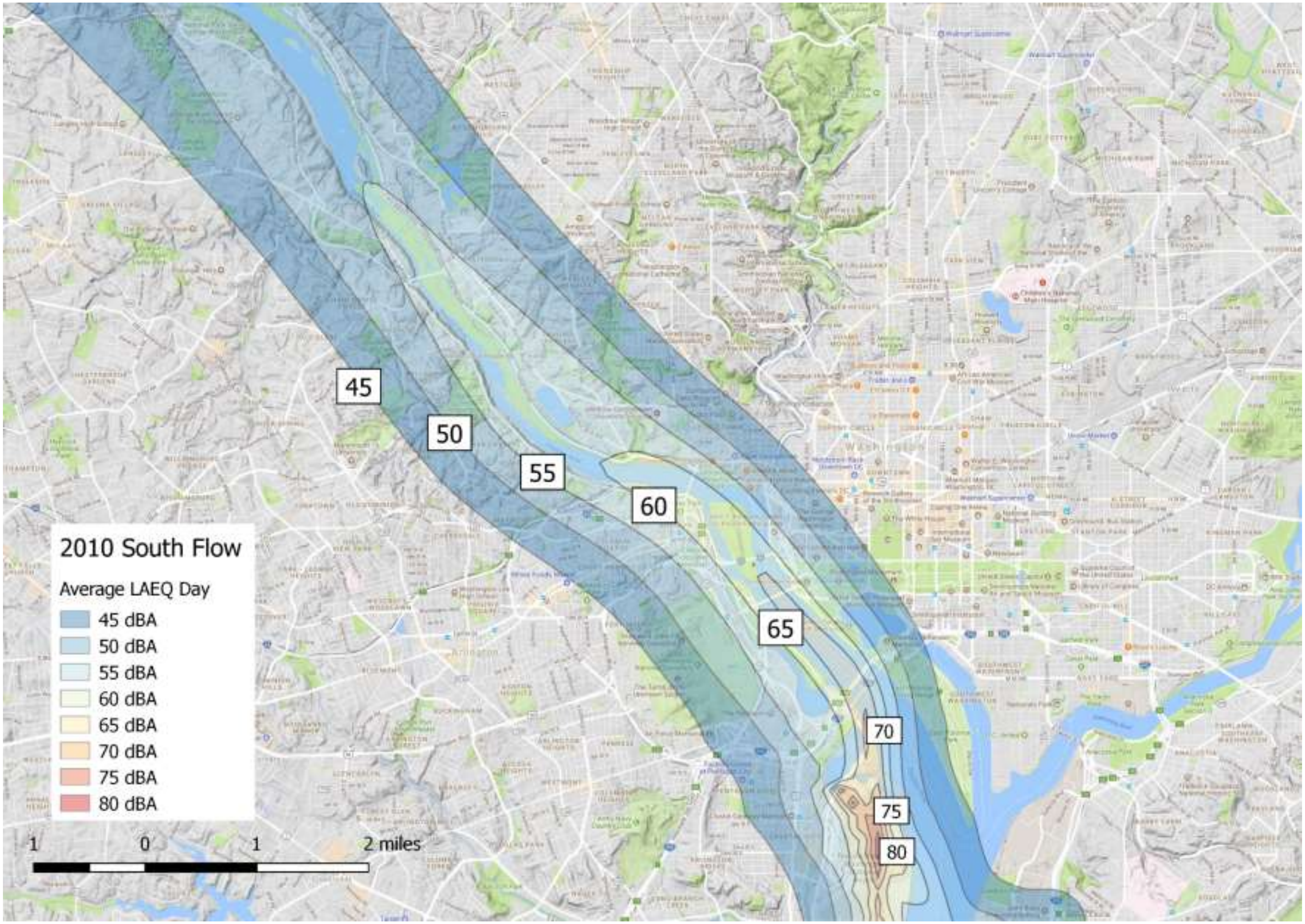

Figure 8-29: 2010 Average Daytime Equivalent Level South Flow

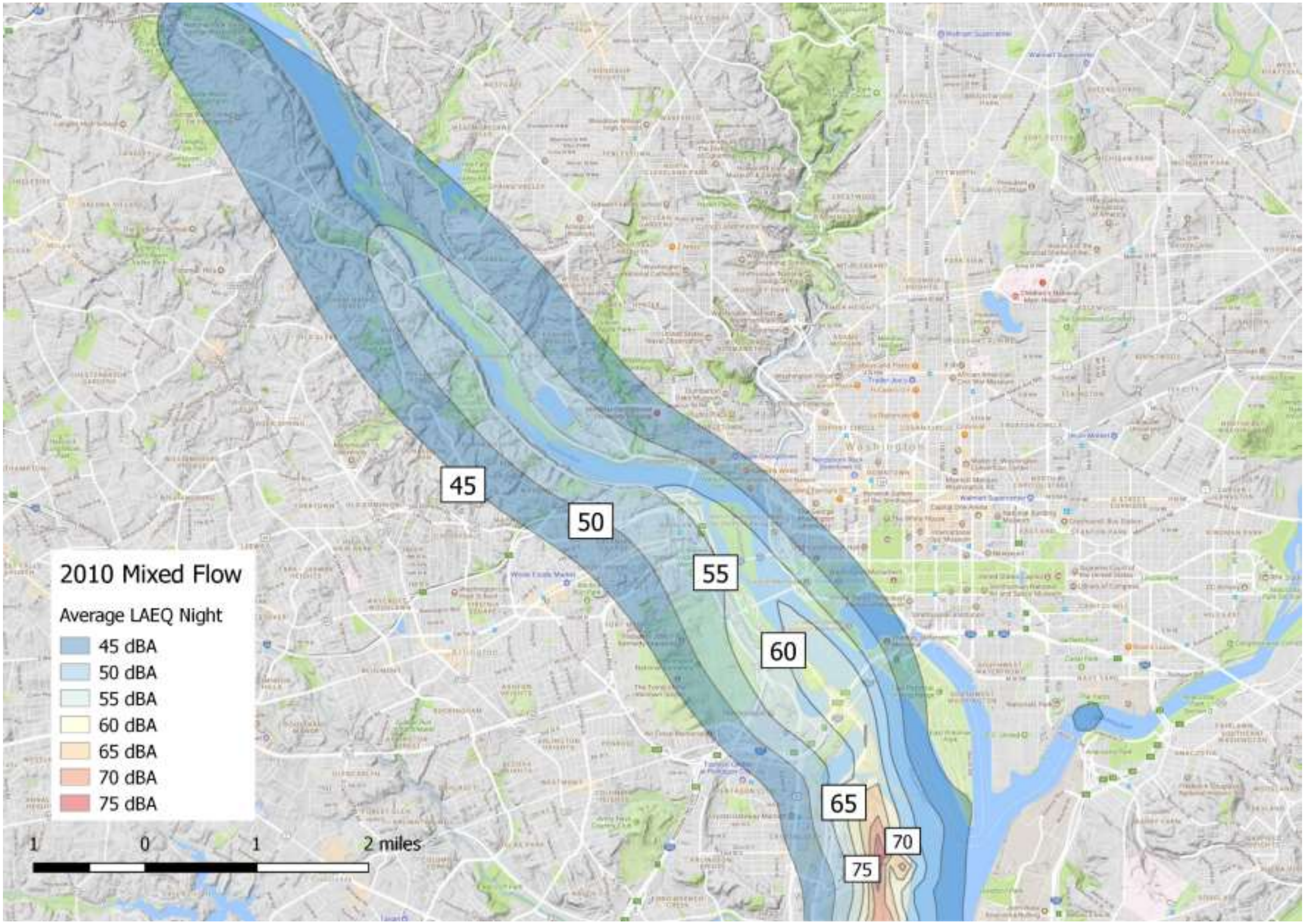

Figure 8-30: 2010 Average Nighttime Equivalent Level Mixed Flow

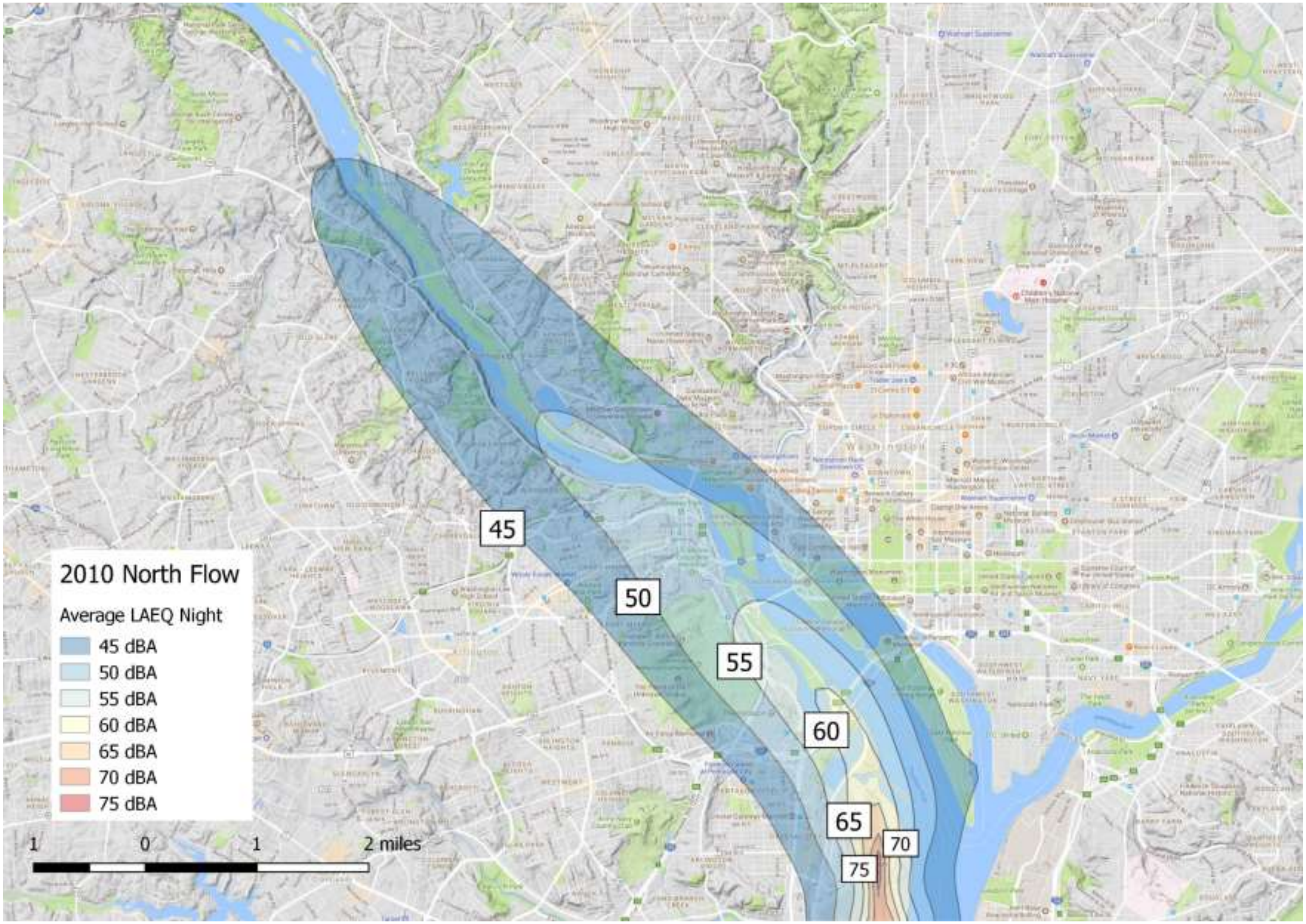

Figure 8-31: 2010 Average Nighttime Equivalent Level North Flow

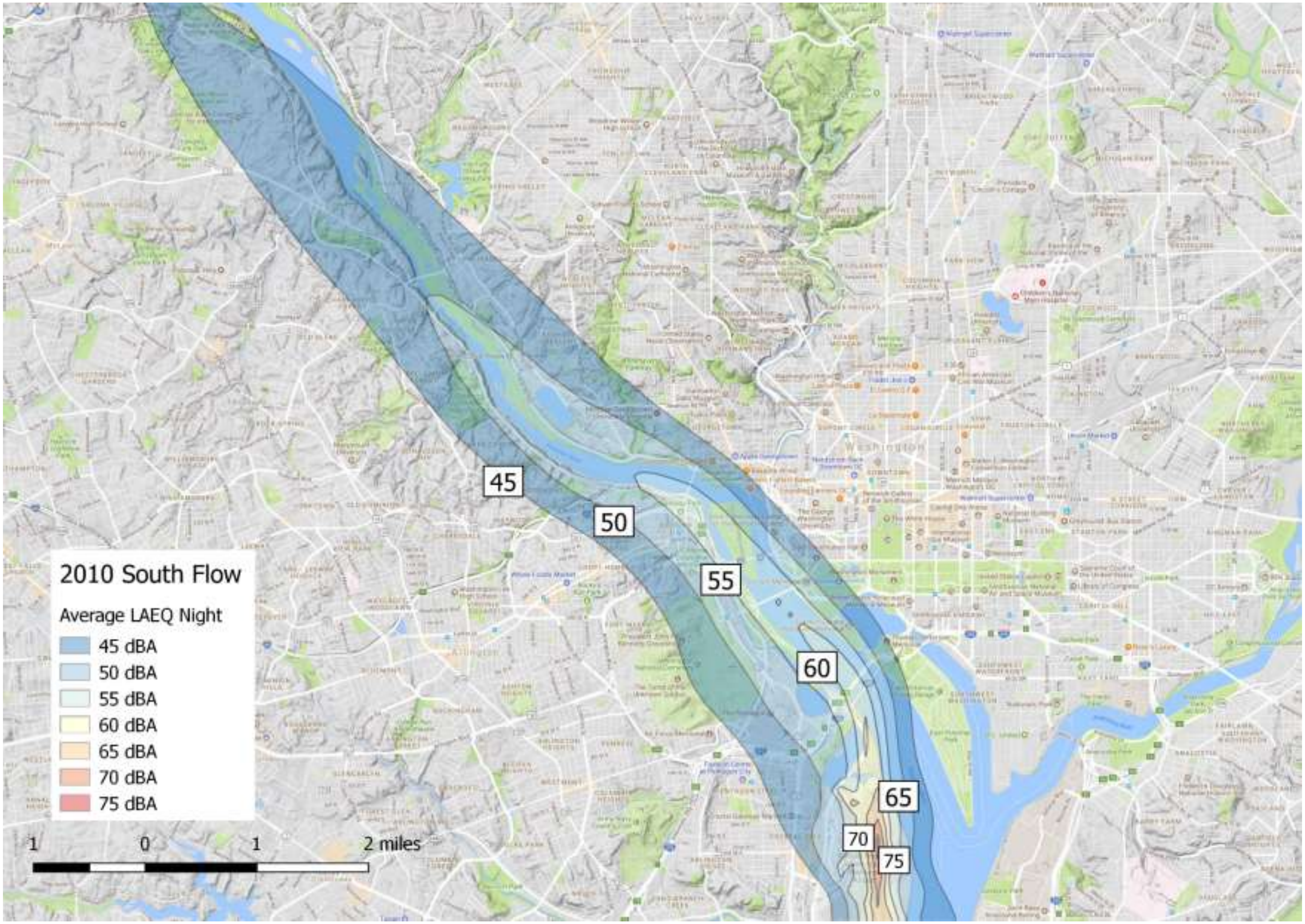

Figure 8-32: 2010 Average Nighttime Equivalent Level South Flow

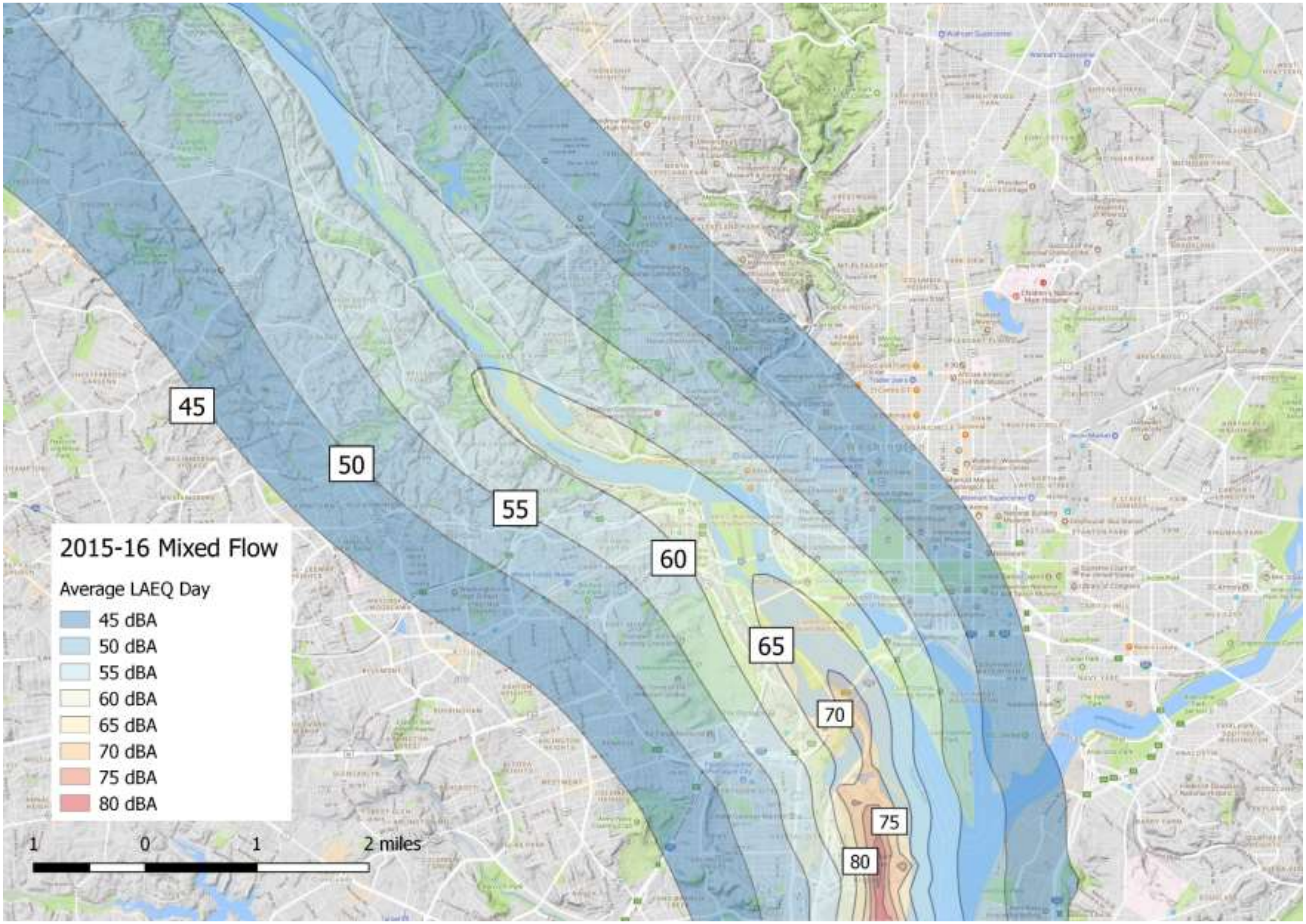

Figure 8-33: 2015-2016 Average Daytime Equivalent Level Mixed Flow

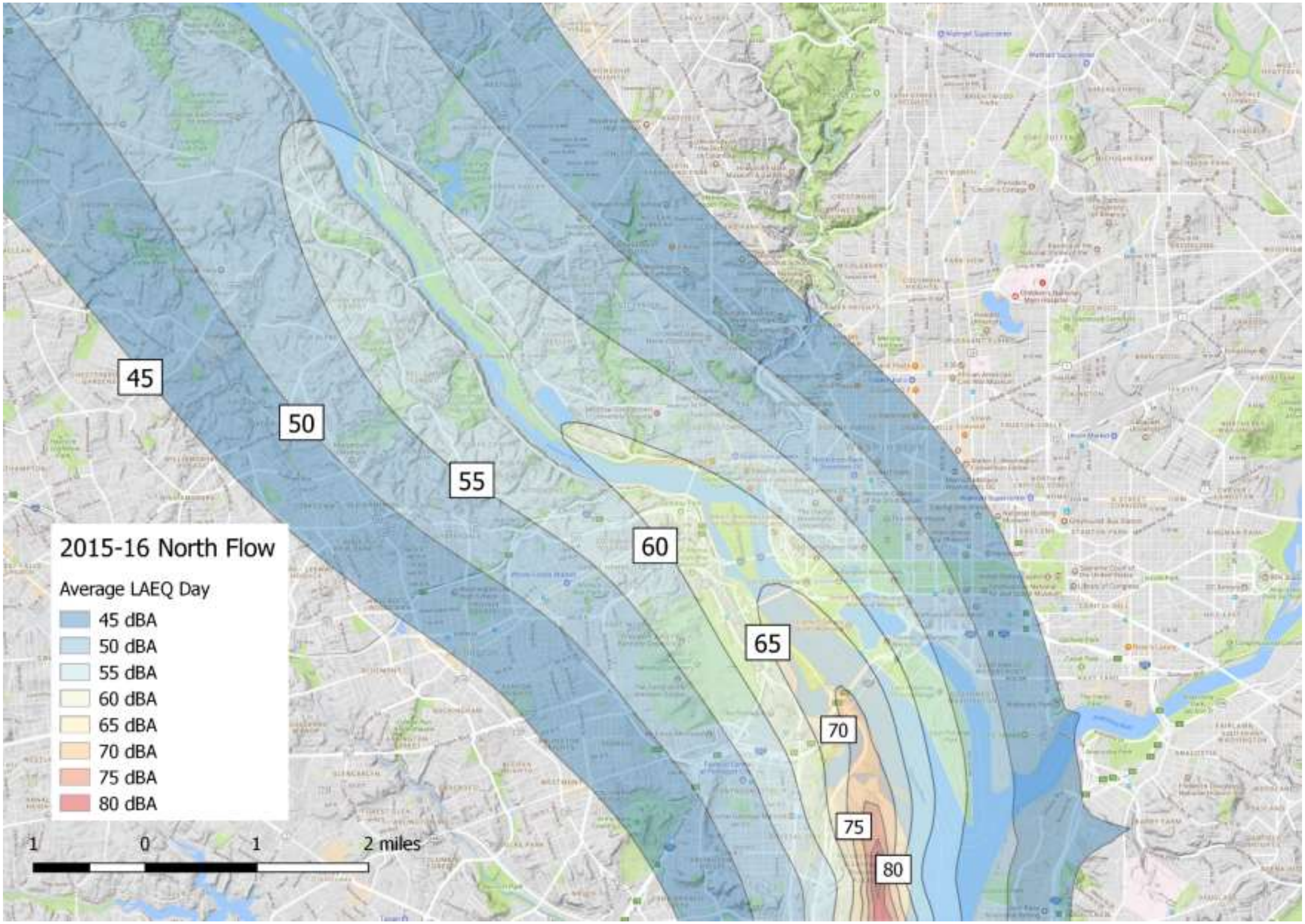

Figure 8-34: 2015-2016 Average Daytime Equivalent Level North Flow

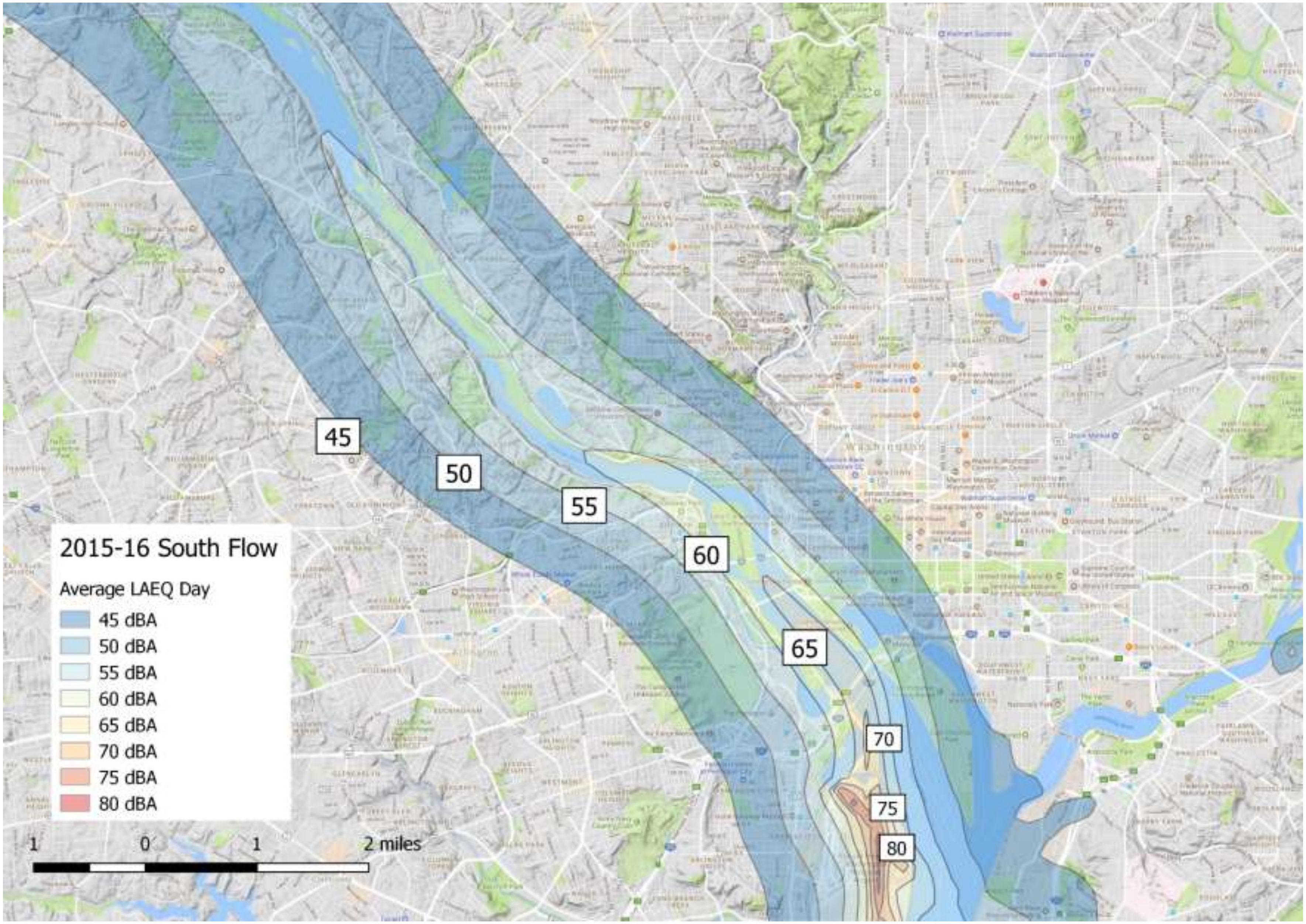

Figure 8-35: 2015-2016 Average Daytime Equivalent Level South Flow

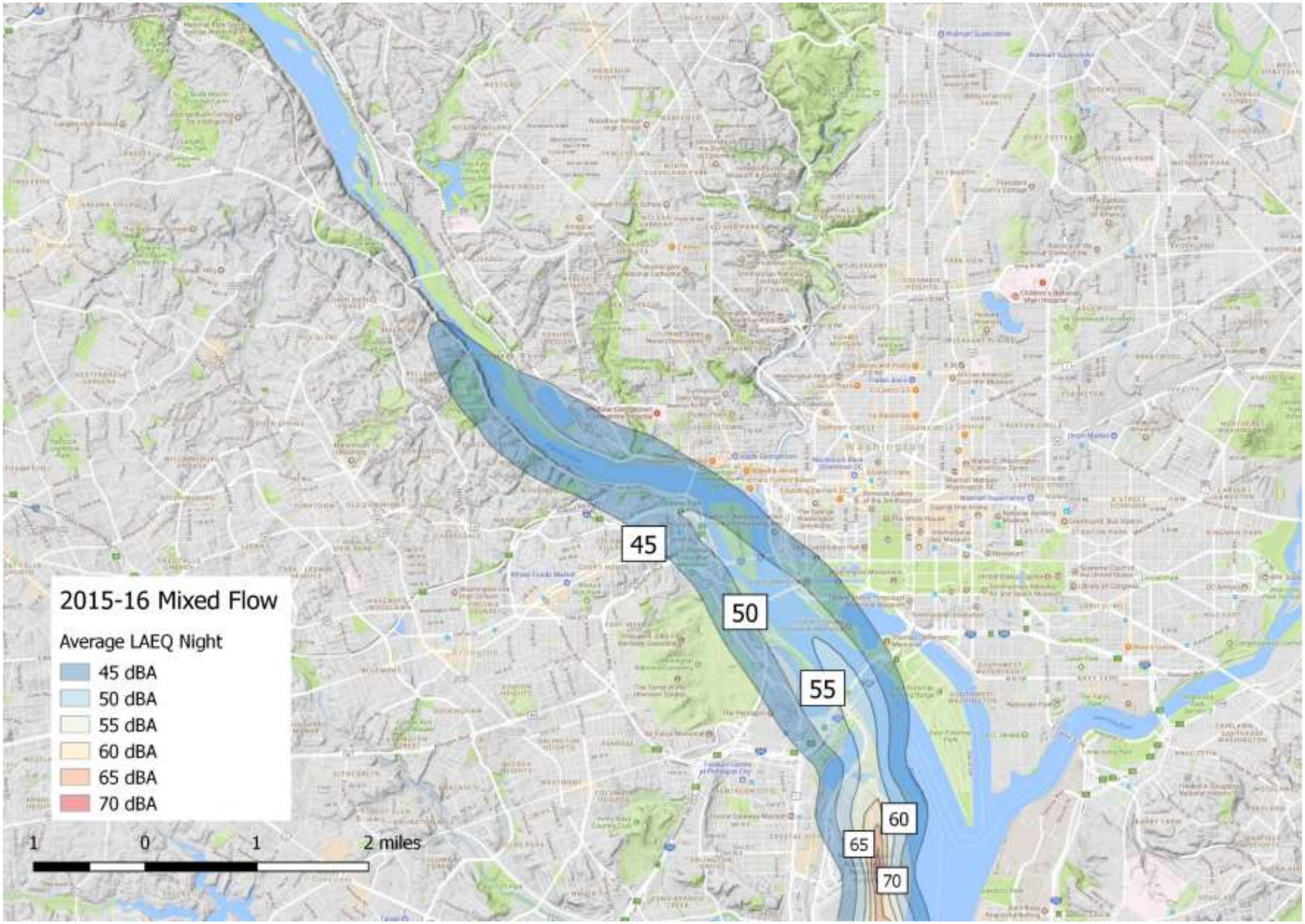

Figure 8-36: 2015-2016 Average Nighttime Equivalent Level Mixed Flow

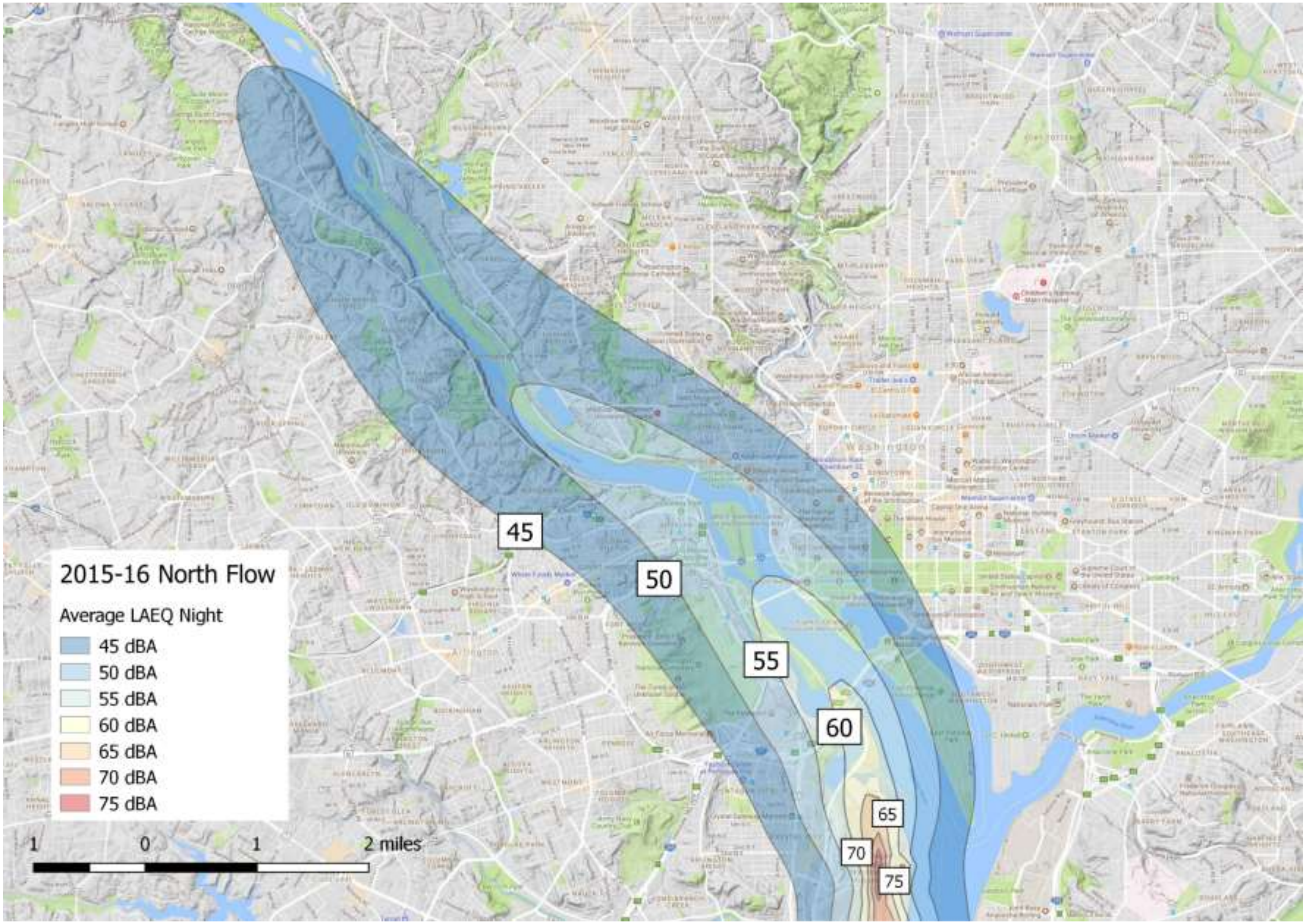

Figure 8-37: 2015-2016 Average Nighttime Equivalent Level North Flow

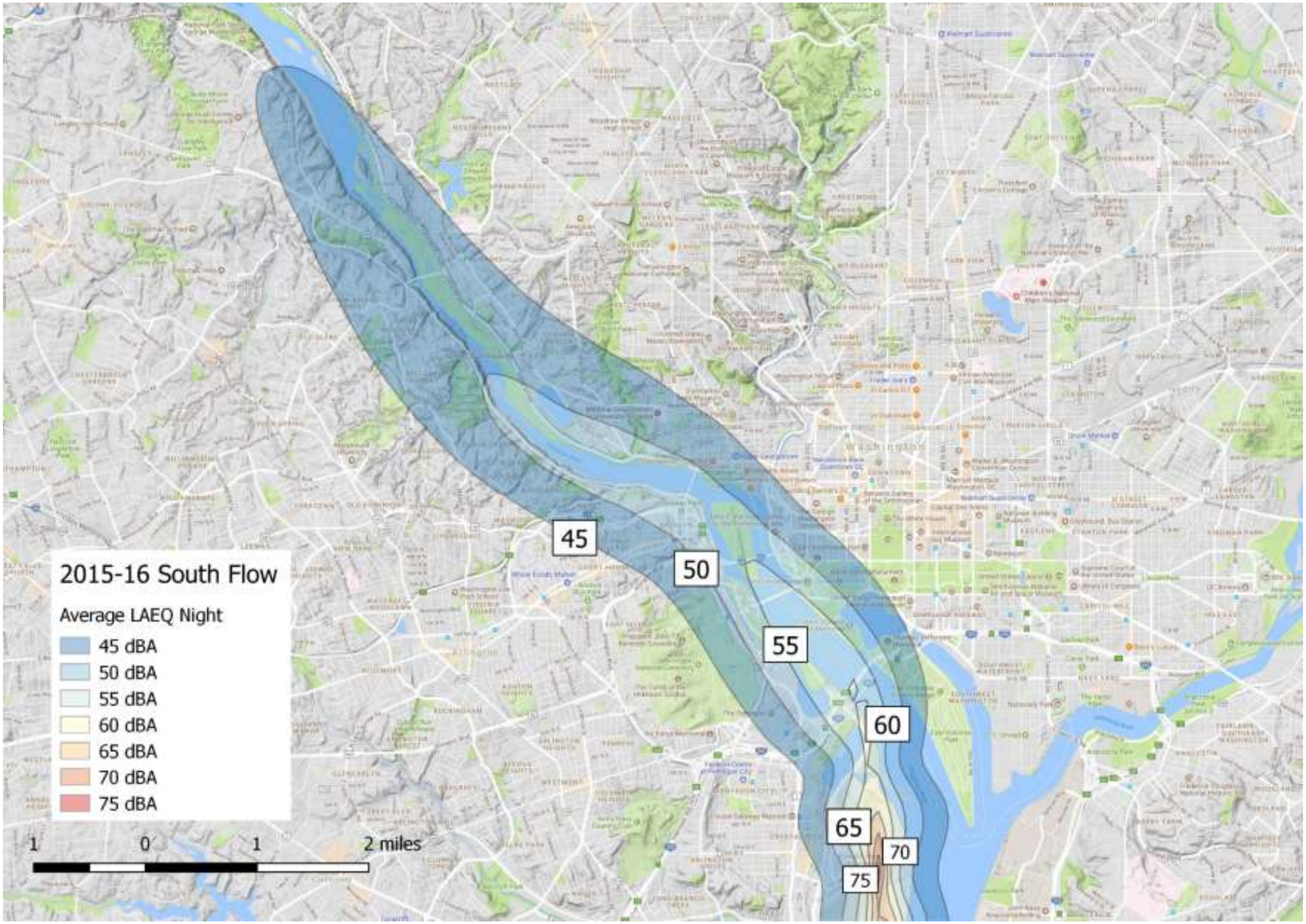

Figure 8-38: 2015-2016 Average Nighttime Equivalent Level South Flow

Tables 8-10 and 8-11 summarize the results at the 18 different location points:

Table 8-10: Average Equivalent Daytime Levels ($L_{eq(day)}$)

Number	Name/Code	2010	2015-2016	Delta (2015-16 minus 2010)
1	FOX_CRESC_1	53.5	54.1	0.6
2	FOX_CRESC_2	56.3	57.0	0.7
3	FOX_CRESC_3	54.2	54.7	0.5
5	5063_SHERIDAN	56.7	57.1	0.4
5	2316_BENTON	52.0	53.3	1.3
6	2901_M_ST	52.4	54.7	2.3
7	DEXTER_ST	52.5	53.1	0.6
8	NMT_4	57.0	57.7	0.7
9	NMT_6	54.2	56.2	2.0
10	NMT_A	58.4	59.4	1.0
11	NMT_B	52.7	54.4	1.7
12	NMT_C	58.0	59.0	1.0
13	NMT_D	56.1	57.7	1.6
14	FRENCH_MAT	51.6	53.8	2.2
15	4850_RES	58.1	58.9	0.8
16	4920_ASHBY	57.4	58.0	0.6
17	G_DAY	59.3	60.1	0.8
18	GWU_NEW_H	54.4	56.8	2.4

Note: The data for Wednesday, April 28, 2010, is not included in the noise modeling as there was significant delayed vectoring and other atypical flight track/operations that day which is not characteristic of typical conditions at DCA.

Table 8-11: Average Equivalent Nighttime Levels ($L_{eq(night)}$)

Number	Name/Code	2010	2015-2016	Delta (2015-16 minus 2010)
1	FOX_CRESC_1	44.0	44.7	0.7
2	FOX_CRESC_2	47.3	47.1	-0.2
3	FOX_CRESC_3	45.0	45.0	0.0
4	5063_SHERIDAN	48.2	46.8	-1.4
5	2316_BENTON	42.2	44.2	2.0
6	2901_M_ST	42.4	45.8	3.4
7	DEXTER_ST	43.0	43.7	0.7
8	NMT_4	48.6	47.0	-1.6
9	NMT_6	44.4	47.1	2.7
10	NMT_A	49.7	49.5	-0.2
11	NMT_B	42.8	45.4	2.6
12	NMT_C	49.3	49.1	-0.2
13	NMT_D	46.6	48.3	1.7
14	FRENCH_MAT	41.4	44.9	3.5
15	4850_RES	50.3	48.9	-1.4
16	4920_ASHBY	49.2	47.9	-1.3
17	G_DAY	51.4	50.3	-1.1
18	GWU_NEW_H	44.9	47.8	2.9

Note: The data for Wednesday, April 28, 2010, is not included in the noise modeling as there was significant delayed vectoring and other atypical flight track/operations that day which is not characteristic of typical conditions at DCA.

Again, it is important to note that the calculated noise levels presented above may not be 100% reliable, due to the discrepancies found between North versus South Flow DNL (discussed in Section 8.4).

9.0 Conclusions and Recommendations

9.1 Conclusions

The following are the basic findings from our investigations:

- The DCA 2004 Part 150 study recommended the relocation of the north departure route east to be aligned with the center of the Potomac River. In 2008, the FAA's ROA for the Part 150 study disallowed the implementation of this "over the river" flight path change, as FAA regulations (Order 7100.9D and 8260.44A) stipulate that new procedures can only be developed to enhance safety or efficiency (and not be solely for noise abatement).
- Review of the CATEX filed by the FAA to qualify the LAZIR route improperly employed an FAA Order 1050.1E exclusion. The CATEX filed by the FAA to qualify the LAZIR route, i.e, "§ 311p: Establishment of new procedures that routinely route aircraft over non-noise sensitive areas," was improper because LAZIR routed aircraft over "noise sensitive areas."
- FAA noise modeling results in 2010 indicated that the new route would create a "significant" (more than DNL 5 dBA) increase in noise exposure over the National Mall on the east side of the Potomac River to include Hains Point, the Tidal Basin, the Jefferson and Lincoln Memorials, and many other memorials, as well as large increases for the historic communities in DC (see Figure 4-3). Noise modeling results indicated an increase in noise exposure over DC communities.
- The environmental review of the LAZIR route was inadequate in that it did not conform to NEPA, NHPA, Section 4(f), or FAA Order 1050.1E requirements.
- The environmental process to establish the new 2013 Metroplex routes failed to develop or present noise contours or noise zones over the newly affected areas.
- The FAA failed to fully disclose the 2013 Metroplex noise assessment results of the NIRS modeling.
- There was a failure to comply with FAA Order 1050.1E / F, NEPA, NHPA, and Section 4(f) to assess the effects of the new LAZIR route on historic neighborhoods, national historic landmarks, national parks, and monuments on the east side of the Potomac River.
- Noise modeling and MWAA's noise monitoring terminal measurement data confirmed an eastward shift of the DCA airplane noise environment.
- Noise measurements conducted in three Georgetown schools indicated that the ANSI classroom acoustical standards were exceeded on numerous occasions; based on the currently available research, excessive aircraft noise impacts student learning and achievement. Although not measured, we would expect there to be exceedances at other Georgetown-Palisades area schools.
- Nighttime aircraft noise levels inside of northwest DC residences are higher enough to awaken between 12 to 33% of the population.
- Approximately 400 flights per day from DCA produce noise levels in northwest DC which is at or above 65 dBA, the level at which speech communication begins to be impaired.
- Noise measurements and analysis indicated that North Flow (departure) noise is significantly louder than South Flow (arrival) noise, and North Flow noise is the primary determinant of the overall DNL noise level.

9.2 Recommendations

9.2.1 New Procedures or Alternate Procedures

We recommend consideration of the following ATC alternatives:

- Alternative #1 – Amend Runway transition track for Runways 01/33: Figure 9-1 shows two alternative departure paths as well as the existing RWY 01 departure path; these alternatives paths are similar to the NATIONAL SID track. These two proposed flight paths were presented by DC and the FAA and are termed "RWY 01 Alternative" for the DC proposal and "RWY 01 FAA WP395 Alternative," respectively. The DC proposal was drafted by the FAA and presented by DC representatives from Wards 2 and 3 to the DCA Working Group in 2016; the FAA proposal was presented to the DCA Working Group in May of 2017.

  For the DC proposal, the current coded RNAV route for RWY 01 is VI – CF (FB) which would be retained. The ADAXE waypoint would be relocated to the west side of the Key Bridge, 38-54-13.03N / 077-05-10.25W. At the mid-span of the 14th Street Bridge (or earlier if feasible), aircraft would turn northwest to a new heading of 308 (True Course)/317 (Magnetic Course) away from P-56 to the new ADAXE waypoint. After this, aircraft would head to BEBLE, and then north to the COVTO waypoint joining the remaining common route.

  The change in flight track would give greater avoidance from P-56 and predictability for compliance. The relocation of waypoints would also return the flight track back to the western shoreline and closely mimic the NATIONAL SID (conventional) track.

  The FAA proposal is similar to the DC proposal, except the ADAXE waypoint is relocated to North Rossyln (WP 395) near the river.

  An analysis of expected noise reduction has been conducted using the AEDT noise model. The results of this analysis at the selected DC location points are shown in Table 9-1. In general, noise reduction of up to DNL 2.3 dBA is expected with the DC proposal and up to 1.5 dBA with the FAA proposal (this assumes no change in fleet mix, total number of aircraft operations, etc.).

  NOTE: Prototype development of this alternative, or any variation of waypoints / track, should be conducted with the FAA (Potomac TRACON), in a work group forum with "all stakeholders," for open and full disclosure.

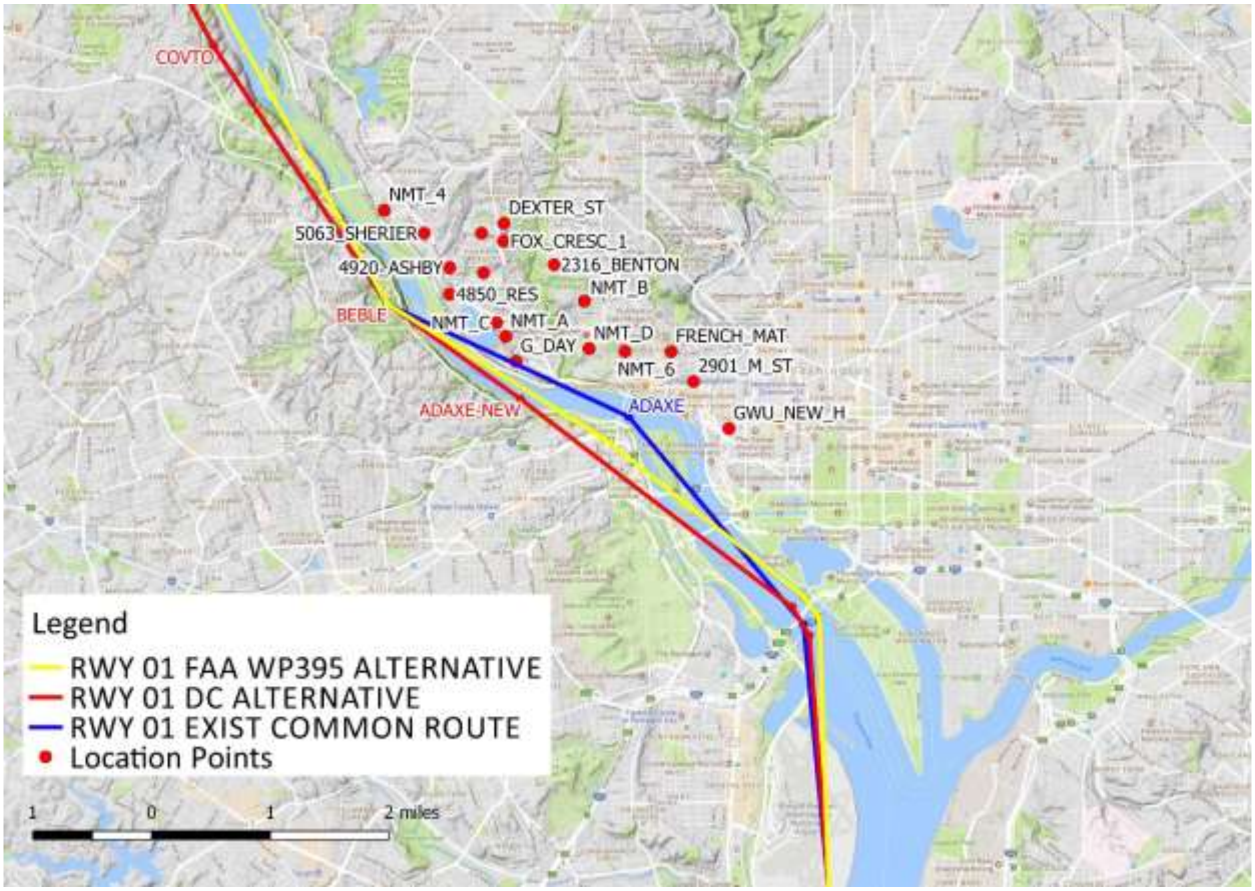

Figure 9-1: RWY 01 Departure Alternatives

Table 9-1: DNL Noise Reduction from Runway 01 Alternative Departure Route

Location No.	Location	Latitude (deg)	Longitude (deg)	Noise Reduction w/ DC Alternative (dBA)	Noise Reduction w/ FAA Alternative (dBA)
1	FOX_CRESC_1	38.92331	-77.0889	1.0	0.5
2	FOX_CRESC_2	38.91937	-77.0921	0.8	0.4
3	FOX_CRESC_3	38.92431	-77.0925	0.8	0.4
4	5063_SHERIDAN	38.92431	-77.1017	0.3	0.1
5	2316_BENTON	38.92038	-77.0808	1.4	0.9
6	2901_M_ST	38.90581	-77.0585	2.3	1.3
7	DEXTER_ST	38.92553	-77.0889	0.9	0.5
8	NMT_4	38.92717	-77.1081	0.1	-0.1
9	NMT_6	38.90957	-77.0695	2.3	1.5
10	NMT_A	38.91143	-77.0886	0.5	0.4
11	NMT_B	38.91584	-77.076	1.7	1.1
12	NMT_C	38.91313	-77.0901	0.5	0.5
13	NMT_D	38.90991	-77.0752	1.9	1.2
14	FRENCH_MAT	38.90954	-77.0621	2.2	1.2
15	4850_RES	38.91667	-77.0976	0.1	0.1
16	4920_ASHBY	38.92002	-77.0976	0.2	0.1
17	G_DAY	38.90833	-77.0869	0.2	0.2
18	GWU_NEW_H	38.89994	-77.0528	2.4	1.1
	AVERAGE NOISE REDUCTION			**1.0**	**0.5**

- Alternative #2 – TOP Altitude: Raising the TOP Altitude of northbound RNAV departures from DCA from 5,000 feet to at least 8,000 feet (or higher) would enhance initial fuel burn and reduce emission and noise impacts over the flight track as westbound RNAV departures from BWI have a minimum TOP Altitude of 14,000. Reducing the probability of level-offs would give an improved climb profile with predictable altitudes. A test of a B-737-300 series showed that the difference between a continuous climb to 6,000 feet and one with a level step at 3,000 feet for two minutes is an extra production of 344 kilograms of CO_2. (British Airways, www.nats.co.uk.)

- Alternative #3 – Crossing Altitudes: An added feature to Alternative # 2 would be the addition of "waypoint crossing altitudes" and change of speed restrictions. Aligned with the higher "TOP Altitude" an optimized climb profile could be created that would insure higher altitudes (above) those communities aligned with the Potomac River throughout the full departure flight track.

  A similar request was made at the November 3, 2016, MWAA Community Work Group meeting and was identified as "Recommendation #6, North Flow Departures," for tracking. MWAA's, 2016 Annual Aircraft Noise Report, page 31, shows that almost a year later the status of "Recommendation #6" is *"pending"* over a year later.

- Alternative #4 – Amend Runway usage: The CWG should seek clarification from MWAA as to the scope and intent of their "Nighttime Hours Program (Noise Rule, FAA Order 8400.9)." Having departures use Runway 01, prior to 7 am (wind calm), departing north for approximately ten miles, then turning southwest for another ten to twenty miles is not efficient. The same departure could have departed Runway 19, "to generally position aircraft over the Potomac and Anacostia Rivers" for "noise abatement" and flight track efficiency.

The balancing of departure runway usage, by ATC, should also be part of this alternative with MWAA oversight. When the prevailing wind is less than five knots, during Nighttime hours, "South Flow" or a balance of North/South Flow should become Standard Operating Practice (SOP) for the airport. Using this "Preferential Runway" usage could result in an average annual DNL reduction of 1 to 3 dBA, for communities in DC. This alternative can be completed in the near term because it does not require any change in instrument procedures.

- Alternative #5 – Low Altitude vectoring to final: Vectoring to the RIVER VISUAL RWY 19 (GREYZ), inside of the DCA 10 DME, should not be the standard arrival route or Standard Operating Policy (SOP). Low altitude (2,000' – 3,000') vectoring creates an unstable approach and constant thrust adjustments, which creates noise and added emissions over noise sensitive residential areas, while negating the benefits of RNAV, Optimized Profile Descent (OPD). This issue was also mentioned as an action item in the DCA Part 150, 2004.

- Alternative #6 – Airport Terminal Information Service (ATIS): ATIS is a continuous broadcast of aeronautical information for a specific airport and is used as a briefing tool for the airlines and aircrews to use in flight planning. The ATIS broadcast information such as weather, runway usage, instrument approaches in use, and special notes of construction or taxiway usage. Prior to contacting the air traffic control tower or radar facility, pilots have information, which will reduce controller workload and radio communication. The recorded information is updated usually five minutes before the hour or as significant change (weather) affects the airport and is identified by a new alpha letter ("A"). This allows the air traffic controller to verify that the pilot has current information.

  The same issues addressed in Alternative #4 should be applied to arrival traffic. The DC Metroplex established new RNAV STARs to the airport from the north, FRDMM and TRUPS. Both of these procedures contain a descent profile known as OPD. The OPD utilizes the ability of the aircraft descent from high altitude using the fully automated on-board Flight Management System (FMS). Both of these arrivals are connected to the RNAV (RNP) RWY 19 Instrument Approach Procedure (IAP) that provides guidance during most / low weather conditions to the runway, versus the River VISUAL.

  This method of arrival is preferential to the airlines (all hours – using ATIS) and provides for the reduction of operational cost, controller / cockpit workload, communication, noise, and emissions. This alternative can be completed in the short term.

  The continued primary use of vectoring, RIVER VISUAL, negates the FAA and industry investment while increasing the environmental impact on DC. The same methodology can be applied to arrival aircraft from the south.

- Alternative #7 – Reduce the number of RNAV SIDs: Reduce the number of RNAV SIDs (northbound) with transitions from Runways 01 / 33 / 04, from nine down to two (west / east).

This alternative can be achieved, short term, through the MWAA CWG working in collaboration with the FAA, Potomac TRACON and Industry (airline representatives). This will provide a common and predictable transition leg for all departures, and will likely result in some noise reduction at the National Mall, Tidal Basin, Hains Point, Georgetown, and Northwest DC. This action will reduce publication maintenance costs throughout the procedural line of business, reduce ATC workload and automation demands, while offering relief to the surrounding areas and reducing operating cost to Industry.

The FAA issues arrival and departure procedures for compliance with the region's prohibited airspace restrictions. However, the operational hours and philosophies of MWAA and the FAA have not included proactive noise abatement (voluntary) or noise mitigation programs for the surrounding noise sensitive communities. Instead, they have relocated air traffic from commercial Arlington, Virginia, to DC using only predicted model noise levels.

The relocation of air traffic procedural tracks that route flights over noise sensitive residential areas and publicly owned parks, and recreational areas, as well as a historic site of national significance, appears to have taken place without appropriate environmental review procedures, as required by FAA Order 1050.1E concerning the use of publicly owned land, national parks and recreation areas, as well as historic districts, national landmarks, and national monuments.

9.2.2 Airport / FAA Work Groups

MWAA currently sponsors a collaborative “Community Noise Working Group” comprised of FAA, industry, and adjoining / surrounding community representatives. After a review of historic meeting minutes, presentations, and summaries, it appears that major role player for technical expertise is the FAA. Because of this, an FAA bias would always be an issue or draw back that would not best serve the CWG in its deliberation of technical (procedural) proposals. MWAA should consider the support of an independent “Subject Matter Expert” (SME). This SME would act, on-call, as technical support to the Work Group as needed.

MWAA sponsors monthly meetings of the CWG. A review of several meeting summaries reveals that the community representatives have made many “Recommendations” for changes. However, to date the FAA has taken final action on only one of those recommendations regarding moving southern departures away from Old Town Alexandria. Some recommendations state: *“An FAA PBN working group kick-off is expected by early fall 2017 and will include local community outreach. A procedure publication goal is 18-24 months.”* This could be problem solved, short term, by working with Potomac TRACON.

9.2.3 MWAA / Consultant / FAA (New Part 150)

The last 14 CFR Part 150 Noise Compatibility Study was submitted, by MWAA, to the FAA in 2004. While EAs were done relative to the Runway Safety Areas (RSAs), they did not assess the full impacts of changes brought about by air traffic changes over the last ten years and their impacts on the noise sensitive National Parks, National Monuments and “Historic Districts in the District of Columbia”.

In the regard, MWAA should collaborate with the Airports Division (FAA) on conducting a new land use compatibility study as outlined in 14 CFR Part 150, Appendix A. This action would display MWAA’s awareness and dedication to solving and /or lessening, of the impacts of aircraft noise on the surrounding communities.

Changes to the DCA airport operations have become an increasing burden on DC and national parks along the eastern river shoreline. Residents have reported a moderate to heavy increase in aviation generated noise. Further frustration has also developed from an incomplete or less than "*user friendly"* complaint reporting system. A noise analysis showing an increase of 3 dBA in the 60 dBA to 65 dBA contour should be grounds for mitigation of noise planning. (FAA Order 1050.1F, §11.6)

DC representatives to the DCA CWG, should consider joining with other members of the group in all efforts needed to assist MWAA in successful completion of an updated/new Part 150 Study. Current issues regarding airport and aircraft noise impacts could be explored and resolved though their pro-active participation and provide guidance and protection for at least five years of airport future planning.

9.2.4 Noise Mitigation

As described in the preceding issues an airport noise analysis can provide the information need as to the source and solution. Each runway should be evaluated independently for noise sources / impacts on and off the airport. (FAA Orders 1050.11, 8400.9, 7050.1A)

The FAA and aircraft operators may not always adhere to noise mitigation measures set forth by MWAA due to traffic and weather conditions. The scope and intent of MWAA's operational practices should be quantified and clarified for compliance by all user stakeholders.

MWAA generates a quarterly report that displays flight tracks and attempts to disclose and inform the public of efforts to monitor compliance with the purported noise abatement procedures at the airport. Utilizing the vast sorting and arranging of records that ANOMS has, a more complete compilation of data can be made available, e.g. number of departures per runway. The CWG should ask for meaningful data relevant to those residents north and south of the airport.

Appendix A – Acoustic Properties, Perception, Noise Measures, Metrics and Day-Night Average Sound Level (DNL)

Airborne sound is a rapid fluctuation of air pressure and local air velocity. Sound levels are measured and expressed in decibels (dB) with 0 dB roughly equal to the threshold of hearing.

Because we perceive both the level and frequency of sound in a non-linear way, the decibel scale is used to describe sound levels. The frequency scale is also measured in logarithmic increments. Decibels, measuring sound energy, combine logarithmically. A doubling of sound energy (for instance, from two identical automobiles passing simultaneously) creates a 3-dB increase (i.e., the resultant sound level is the sound level from a single passing automobile plus 3 dB); a doubling of sound energy is not perceived as twice as loud. The rules for decibel addition are:

- If two sound levels are within 1 dB of each other, their sum is the highest value plus 3 dB.
- If two sound levels are within 2 to 4 dB of each other, their sum is the highest value plus 2 dB.
- If two sound levels are within 5 to 9 dB of each other, their sum is the highest value plus 1 dB.
- If two sound levels are greater than 9 dB apart, the contribution of the lower value is negligible and the sum is simply the higher value.

The human ear can perceive a tremendous frequency range (about 20 Hz to 12 kHz) and a range of acoustic energy from the threshold of hearing to a loud rock concert (about 0 dB to 120 dB).

The frequency of a sound is a measure of the pressure fluctuations per second measured in units of hertz (Hz). Most sounds do not consist of a single frequency, but are comprised of a broad band of frequencies differing in level. The characterization of sound level magnitude with respect to frequency is the sound spectrum. A sound spectrum is often described in octave bands which divide the audible human frequency range (i.e., from 20 to 12,500 Hz) into segments.

Sound has the properties of both waves and fluid. Wave properties include diffraction, or bending, around structures or other barriers, frequency variable absorption in the air and on materials, and phase effects at specific frequencies amplifying and attenuating sound with the geometry of the surroundings.

Sound propagates fundamentally per the “Inverse square law” with additional attenuation or (under special circumstances) amplification from other factors. The inverse square law states that the intensity of a physical quantity attenuates at a rate proportional to the square of the distance from the source. A common description of the inverse square law is the spreading of water waves emanating for a pebble dropped into a pond. Applying the logarithmic scale for decibels used in acoustics, a point source following the inverse square law attenuates 6 dB per distance doubling.

Air absorption further attenuates sound rapidly reducing higher frequency sound above 500 Hz. Natural and man-made barriers further attenuate, or reduce, sound propagation through diffraction, or bending. As with absorption in the atmosphere or by local features, higher frequency sound is more rapidly attenuated. Wind also moderately amplifies sound downwind and attenuates it upwind. Certain atmospheric conditions such as temperature inversion and wind shear also have significant diffraction effects which tend to focus sound areas while attenuating it in others.

Therefore, sound levels are expected to vary from moment to moment, hour to hour, and day to day. The greater the distance from the sound source, the greater the variation in measurement results over time.

Noise is simply unwanted sound, and therefore depends on the attitude of the listener as well as the level and character of the sound[31]. Three aspects of community noise are important in determining subjective response[32]:

- Level (i.e., magnitude or loudness) of the sound.
- The frequency composition or spectrum of the sound.
- The variation in sound level with time.

Many rating methods exist to analyze sound of different spectra and duration. The simplest method is generally used so that measurements may be made and noise impacts readily assessed using basic acoustical instrumentation. This method evaluates all frequencies by using a single weighting filter that progressively de-emphasizes frequency components below 1000 Hz and above 5000 Hz. This weighting is called A-weighting and is applied by an electrical filter in all U.S. and international standard sound level meters.

Noise exposure is a measure of noise over a period of time, whereas noise level is a single value at an instant in time. Although a single sound level may adequately describe community noise at any instant in time, community noise levels vary continuously. Most community noise is produced by many distant noise sources which produce a relatively steady background noise having no identifiable source. These distant sources change gradually throughout the day and include traffic, wind in trees, and distant industrial activities. Superimposed on this slowly varying background is a succession of identifiable noise events of brief duration. These include nearby activities such as single vehicle passbys or aircraft flyovers which cause the community noise level to vary from instant to instant.

A single number called the equivalent sound level or L_{eq} is used to describe noise varying over a period. The L_{eq} is the average noise exposure level over a period (i.e., the total sound energy divided by the duration). It is the constant sound level which would contain the same acoustic energy as the varying sound level, during the same time period. The L_{eq} is useful in describing noise over a period with a single numerical value. Discrete short duration transient noise events, such as aircraft flyovers, may be described by their maximum A-weighted noise level or by their Sound Exposure Level (SEL). The SEL value is the preferred descriptor because measured results may be more reliably repeated and because the duration of the transient event is incorporated into the measure (thereby better relating to subjective response). Maximum levels of transient events vary with instantaneous propagation conditions while a total energy measure, like SEL, is more stable. The SEL of a transient event is a measure of the acoustic energy normalized to a constant duration of one second.

---

[31] American National Standards Institute. *ANSI/ANSI-ASA S12.9-2005, Part 4, Quantities and Procedures for Description and measurement of Environmental Sound – Part 4: Noise* Assessment *and Prediction of Long-term Community Response*

[32] Department of Defense Noise Working Group. Technical Bulletin: Using Supplemental Noise Metrics and Analysis Tools. December 2009.

SEL values may be summed on an energy basis to compute L_{eq} values over any period. This is useful in modeling noise in areas exposed to numerous transient noise events, such as communities around airports or shooting ranges. Hourly L_{eq} values are called Hourly Noise Levels (i.e., HNL values).
In determining the daily measure of community noise, it is important to account for the difference in human response to daytime and nighttime noise. During the nighttime, exterior background noise levels are generally lower than in the daytime. Most household noise also decreases at night, and exterior noise intrusions become more noticeable. People are more sensitive to noise at night than during other periods of the day.

Day-night average sound level (DNL" is the only noise exposure standard adopted by the Environmental Protection Agency (EPA) and also the only standard used by the FAA and every other government agency for community noise annoyance. It is applied for aircraft noise, highway noise, industrial noise and all other noise sources assessed under the National Environmental Policy Act (NEPA). The DNL is also the only noise metric for which there is a scientific and comprehensive assessment of the degree of community noise annoyance.

DNL was adopted as the noise standard by the EPA[33] in 1974 after extensive compilation of psychoacoustic research, principally by Theodore Schultz, Bolt Beranek & Newman. It was found to agree more closely than many other noise metrics in adverse response to transportation noise. DNL sums the A-weighted over a continuous 24-hour period after biasing nighttime noise (10:00 pm to 7:00 am) to account for increased sensitivity to noise during this period. Numerically, DNL is expressed as a daily average by dividing the 24-hour weighted sum by the duration of the day; thus, a numeric DNL value may be compared to typical measured noise levels.

The DNL metric represents a compromise between 1) many subjective factors affecting noise annoyance, and 2) the ability to feasibility measure and comprehend the measure. Acoustic properties such as sharpness, fluctuation strength, roughness, impulsiveness, and tonality are not specifically incorporated into the measure. Incorporating these factors requires detailed spectral analyses, very rapid measurement, and detailed computer processing for each noise event. However, the DNL metric is oft criticized. Government inter-agencies have formed committees three times to review and assess the validity of the DNL metric. Following is a brief discussion of those activities.

In 1979, the Federal Interagency Committee on Urban Noise (FICUN) was formed to develop Federal policy and guidance on noise. The FICUN issued its report, "Guidelines for Considering Noise in Land Use Planning and Control"[34], June 1980, stating that standard residential construction was compatible for noise exposure up to a DNL of 65 dB. The FAA has adopted the 65 dB standard as the basis for mitigating noise exposure to residents around airports; specifically, some homes may be eligible for sound insulation under the FAR Part 150 program.

In 1991, the FAA and EPA initiated the Federal Interagency Committee on Noise (FICON) to review technical and policy issues related to assessment of noise impacts around airports[35]. With respect to

---

[33] U.S. Environmental Protection Agency. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. EPA Report 550/9-74-004. March 1974.

[34] Federal Interagency Committee on Urban Noise. (1980, June). *Guidelines for Considering Noise in Land Use Planning and Control*.

[35] Federal Interagency Committee on Noise. (1992, August). *Federal Agency Review of Selected Airport Noise Analysis Issues.*

DNL, the FICON found that there are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric. It further recommended continuing the use of the DNL metric as the principal means for describing long-term noise exposure of civil and military aircraft operations. The FICON conducted several studies including a reassessment of the original noise annoyance curve. This is shown in Figure A-1.

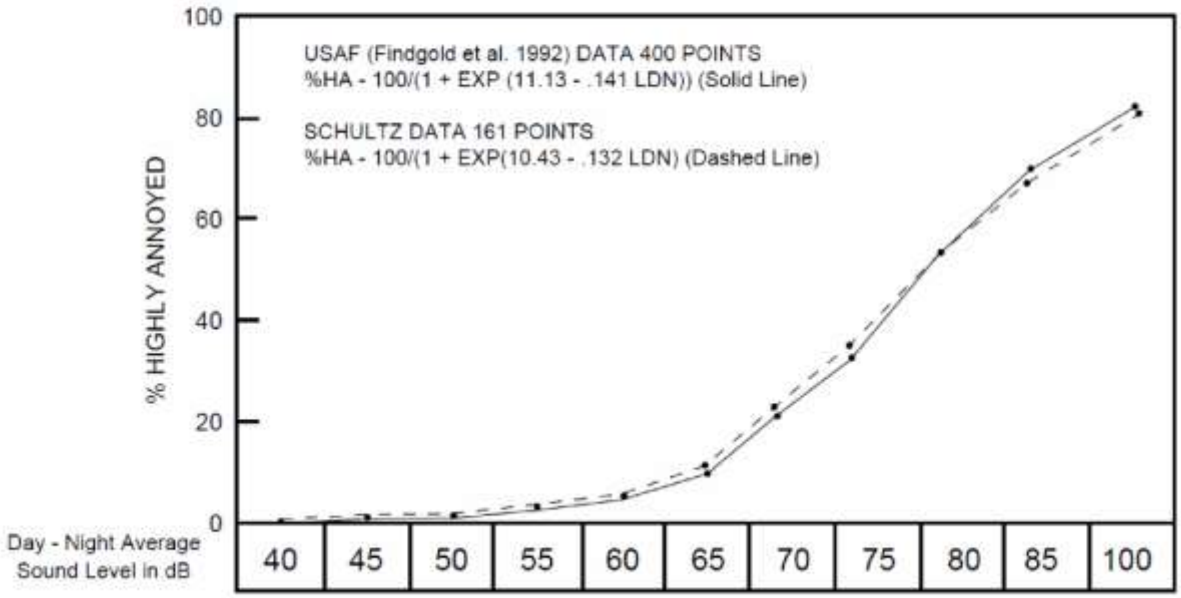

Figure A-1: Comparison of logistic fits to original 161 data points of Schultz (1978) and USAF analysis with 400 points (data provided by USAF Armstrong Laboratory).

In 1993, the Federal Interagency Committee on Aviation Noise (FICAN) was formed based on the FICON report's policy recommendation to form a standard interagency committee for facilitating research on methodology development and on the impact of aircraft noise. The FICAN recommended that FAA and other Federal agencies use the yearly day-night average sound level metric as the primary measure of noise impacts on people and land uses. This cumulative metric is the Federal standard because it:

- Correlates well with the results of attitudinal surveys of residential noise impact;
- Increases with the duration of noise events, which is important to people's reaction;
- Considers the number of noise events of the full 24 hours in a day, which also is important to people's reaction;
- Considers the increased sensitivity to noise at night by including a 10-dB nighttime penalty between 10:00 p.m. and 7:00 a.m. to compensate for sleep disturbance and other effects;
- Allows composite measurements of all sources of community noise; and
- Allows quantitative comparison of noise from various sources with a community.

All three committees were comprised of members from various government agencies including the EPA, FAA, HUD, DOD, VA, DOT, and NASA. Each of these federal organizations employs the DNL metric exclusively for assessing compatible land use and in assessing community noise annoyance.

Appendix B – DNL by NMT with Number of Non-Redundant Complaints

The table below shows the aircraft DNL from MWAA yearly reports at monitoring locations 4, 5, 6, 7, 17 and 20 by month. Also shown are the number of non-redundant complaints from DC, Arlington, VA and "other" locations with the total non-redundant complaints for that respective month.

Months	DNL-ac NMT#4	DNL-ac NMT#5	DNL-ac NMT#6	DNL-ac NMT#7	DNL-ac NMT#17	DNL-ac NMT#20	Wash, D.C.	Arlington, VA	Other	Total
Jan-10	54.1	52.5	50.5	54.8	54.8	44.8	3	1	5	9
Feb-10	50.7	48.3	50.2	56.2	56.2	30.4	1	2	5	8
Mar-10	55.1	53.6	51.3	55.1	55.1	37.7	5	5	6	16
Apr-10	54.7	53.3	52.2	57	57	47.7	4	4	10	18
May-10	54.6	54.6	52.6	54.1	54.1	45.4	6	8	18	32
Jun-10	54.4	53.9	55.2	54.7	54.7	44.8	1	0	10	11
Jul-10	54	54.4	59.3	55.8	55.8	46	1	5	3	9
Aug-10	54.1	52.9	51.4	53	53	48.3	7	6	8	21
Sep-10	53.7	-	52.2	52.6	52.6	42	3	7	3	13
Oct-10	54.6	-	54.3	54.8	54.8	45.4	10	10	6	26
Nov-10	56	-	53.5	55.2	55.2	46.1	2	15	5	22
Dec-10	53.8	-	52.9	57.3	57.3	38.6	0	2	7	9
Jan-11	53.7	56.7	51.4	58.8	-	38.3	1	3	6	10
Feb-11	54.3	60.4	51.8	58	-	41.9	1	5	15	21
Mar-11	55.2	63.3	58.7	59.8	-	48.1	4	14	14	32
Apr-11	55.6	57.4	54.8	60.5	64.1	46.8	4	17	19	40
May-11	55.4	55.1	54.9	60.1	61.2	50.7	8	19	21	48
Jun-11	54.9	54.3	52.9	61.1	54.5	47.4	7	9	9	25
Jul-11	53.9	54.5	53.9	59	52.1	46	10	15	7	32
Aug-11	53.5	52.8	53	59.8	57.9	45.9	6	26	33	65
Sep-11	52.9	54.1	50.3	58.7	50.3	45.3	12	7	23	42
Oct-11	54.8	55.2	51.8	59.6	58.3	44.3	3	2	11	16
Nov-11	55.2	54.6	52.7	59.4	57.2	40.9	5	8	13	26
Dec-11	55.9	56.7	51.9	60.1	57.8	47.9	4	113	14	131
Jan-12	54.6	52.8	51.4	57	57	43.7	3	310	7	320
Feb-12	54.7	54.4	51.9	56.9	56.9	41.6	1	35	9	45
Mar-12	54.9	54.5	53.1	57.9	57.9	40.8	4	14	23	41
Apr-12	55.5	53.5	53.8	58.7	58.7	42.8	5	8	12	25
May-12	59.6	55.6	51.6	56.9	56.9	49.9	7	3	12	22
Jun-12	55	54.5	48.3	56.7	56.7	41.6	8	10	10	28
Jul-12	53.7	54	48	56.6	56.6	45.1	1	4	3	8
Aug-12	55.3	55.1	50.6	55.8	55.8	42.4	3	3	24	30
Sep-12	57	54.6	53.3	55.7	55.7	46.5	30	2	22	54
Oct-12	54.4	54.6	49.6	55.9	55.9	-	149	6	20	175
Nov-12	55.7	54.4	50.3	56.5	56.5	45.2	15	4	7	26
Dec-12	54.9	54.3	49.2	57.1	57.1	39.9	11	5	18	34
Jan-13	54.5	53.2	50.1	57.9	57.9	45.5	2	3	7	12

Months	DNL-ac NMT#4	DNL-ac NMT#5	DNL-ac NMT#6	DNL-ac NMT#7	DNL-ac NMT#17	DNL-ac NMT#20	Wash, D.C.	Arlington, VA	Other	Total
Feb-13	54.7	54.1	50	56.6	56.6	42.1	2	8	4	14
Mar-13	55.3	53.1	52.2	55.3	55.3	44.6	2	5	2	9
Apr-13	54.8	54.1	50.1	55.6	55.6	44.9	92	2	9	103
May-13	57	54.5	53.3	-	-	46.7	15	6	8	29
Jun-13	54.5	55.1	48.6	55.7	55.7	44.2	2	1	4	7
Jul-13	55.1	54.3	48.3	56.4	56.4	48.1	3	5	1	9
Aug-13	55.3	54.8	48.9	57.3	57.3	43.3	0	4	11	15
Sep-13	55.7	54.5	49.3	55.1	55.1	43.2	0	8	8	16
Oct-13	55.3	54.4	50.7	64	64	43.8	15	8	17	40
Nov-13	55	53.3	50.7	58.9	58.9	44.8	3	9	7	19
Dec-13	54.6	54.1	49.4	56.6	56.6	39	5	6	1	12
Jan-14	53	52.5	47.6	57.7	57.7	38.1	52	7	1	60
Feb-14	52.5	51.2	46.1	56	56	37.7	32	3	1	36
Mar-14	52.5	51.6	47.3	-	-	39.2	12	6	5	23
Apr-14	54.4	54.1	49	56.1	56.1	46.3	37	12	3	52
May-14	54.9	55.2	51.7	55.9	55.9	46.5	24	9	16	49
Jun-14	54.4	54.6	53.2	55.9	55.9	45.3	36	5	5	46
Jul-14	55	56.3	57.8	56.1	56.1	43.4	56	7	11	74
Aug-14	54.4	55.8	47.8	53.9	53.9	42.3	29	9	8	46
Sep-14	54.3	54.4	49.9	60.5	60.5	45.2	297	17	9	323
Oct-14	54.1	54.6	49.5	55.3	55.3	44.2	332	5	8	345
Nov-14	53.4	54.3	52.4	54.3	54.3	-	112	1	2	115
Dec-14	53.8	53.2	48.9	56	56	-	97	7	5	109
Jan-15	-	-	-	-	-	-	59	15	0	74
Feb-15	55.9	55.9	51.9	60	53.5	39.6	52	9	3	64
Mar-15	57.4	57.9	57.3	61.1	55.2	41.4	98	10	14	122
Apr-15	58.5	59.4	58	61.5	55.8	44.9	90	26	19	135
May-15	58.5	59.4	57.3	61.2	55.2	43.9	94	73	27	194
Jun-15	58.2	58.6	56.6	62	54.8	41.9	48	33	22	103
Jul-15	58	58.9	56.9	60.8	54.8	42.7	52	12	29	93
Aug-15	58	58.8	57.2	60.8	54.3	43.7	33	14	63	110
Sep-15	58	58.8	57.5	61.1	54	44.7	61	24	56	141
Oct-15	58.2	59.1	57.8	61.5	55.2	44.9	362	10	43	415
Nov-15	57.9	58.4	57.9	61.2	55.3	44.2	663	63	39	765
Dec-15	57.8	58.6	57.7	60.8	54.8	43.2	90	0	0	90

Appendix C – Awakening Computation Procedure

Probability of awakening as a function of both the single-event indoor ASEL and the time since retiring.

One of the more consistent findings in the sleep literature is that the probability of an awakening due to a noise event increases as time in bed increases. Equation (2) quantifies the probability of awakening as a function of both the time since retiring (in minutes) and the indoor A-weighted sound exposure level in a sleeper's quarters (in decibels).

Probability of awakening:

$P_{A,single} = 1 / (1 + e^{-Z})$ $\quad$ $P_{A,Single} = 11 + e - Z$

where $Z = 7.594 + 0.04444L_{AE} + 0.0336T_{retire}$. L_{AE} is predicted or measured and limited as described above and T_{retire} is the time in minutes since retiring.

Method for calculating the probability of awakening at least once to the sound from distributions of single noise events.

For the *i*th single event that creates an ASEL of level L_i during any time period or sub-time period, *j*, the probability of *NOT* awakening, $P_{NotA,i}$, is given by:

$P_{NotA,j} = (1 – P_{A,j})$

where $P_{A,i}$ is the probability of being awakened by the *i*th event given by the first equation.

For a distribution of events during a stated time period or sub-time period, *j*, the probability of not awakening is given by:
$P_{NotA} = \prod_{(i=1,k)} (1 – P_{A,j})^{Ni}$

where $P_{A,i}$ is the probability of awakening from the *i*th single event as given by the first equation, Ni is the fractional number of events producing an ASEL equal to the *i*th ASEL, K is the total number of distinct ASELs, and the symbol ∏ indicates the product of the $(1 – PA,i)^{Ni}$ terms.

For whole-night calculations the following steps are recommended:

Divide the nine-hour night into three three-hour time segments, and determine the distribution of noise events for each of the three time segments.

Find the probability of not being awakened for each of the time periods using the distributions assembled in Step 1.

The procedure for computing awakenings, set forth in the ANSI standard, was developed from research data on aircraft flyover awakenings from the following independent studies:

1. Anderson, G.S. and Miller, N.P. (2007). "Alternative analysis of sleep-awakening data," *Noise Control Eng. J.* **55** (2), 224.1

2. Federal Interagency Committee on Noise, Federal Agency Review of Selected Airport Noise Analysis Issues, August 1992.

3. Fidell, S.; Pearsons, K.; Howe, R.; Silvati, L.; and Barber, D. "Field Study of Noise-Induced Sleep Disturbance," *J. Acoust. Soc. Am.* pp. **98**, 1025-1033, 1995.

4. Fidell, S.; Howe, R.; Tabachnick, B.; Pearsons, K.; and Sneddon, M. "Noise-induced sleep disturbance in residences near two civil airports," NASA Langley Research Center Contract No. NAS1-20101, NASA Contractor Report 198252, Hampton, VA. 1995.

5. Fidell, S.; Howe, R.; Tabachnick, B.; Pearsons, K.; Silvati, L.; Sneddon, M.; and Fletcher, E. (1997). "Field studies of habituation to change in nighttime aircraft noise and of sleep motility measurement methods," USAF Contract No. F41624-96-C-9003, BBN Report No. 8195. Wright-Patterson AFB, OH.

6. Ollerhead, J.B.; Jones, C.J.; Cadoux, R.E.; Woodley, A.; Atkinson, B.J.; Horne, J.A.; Pankhurst, F.; Reyner, L.; Hume, K.I.; Van, F.; Watson, A.; Diamond, I.D.; Egger, P.; Holmes, D.; and McKean, J. (1992). "Report of a field study of aircraft noise and sleep disturbance," London: Department of Safety, Environment and Engineering.

7. Pearsons, K.; Barber, D.; Tabachnick, B.; and Fidell, S."Analysis of the predictability of noise-induced sleep disturbance," *J. Acoust. Soc. Am.* **97**, 331-338. 1995.

8. Silva, G.E.; Goodwin, J.L.; Sherrill, D.L.; Arnold, J.L.; Bootzin, R.R.; Smith, T.; Walsleben, J.A.; Baldwin, C.M.; and Quan, S.F. "Relationship Between Reported and Measured Sleep Times: The Sleep Heart Health Study (SHHS)," *J. Clin. Sleep Med.* **3**(6), pp. 622-630. 2007.

9. Passchier-Vermeer, W.; Vos H.; Steenbekkers J.H.M.; van der Ploeg, F.D.; Groothuis-Oudshoorn, K. (2002). "Sleep disturbance and aircraft noise; exposure-effect relationships." Leiden, TNO PG, 2002a. TNO PG Report 2002.027.

10. Vos, J. (2007). "Sleep disturbance caused by impulse sounds," TNO The Netherlands Report TNO-DV 2007 A331.

11. Michaud, D.S.M.; Fidell, S; Pearsons, K.; Campbell, K.; and Keith, S.E. "Review of field studies of aircraft noise-induced sleep disturbance," *J. Acoust. Soc. Am.* **121**, pp. 32-41. 2007.

Appendix D – Typical NMT Report from a Newer Monitor

REAGAN NATIONAL

Detailed Noise Event Report

RMTID	START_DATE	START_TIME	LEQ	SEL	MAX_LEVEL	MAX_LEVEL_DATE_TIME	DURATION	CLASSIFICATION	OPERATION_TYPE	RUNWAY	AIRLINE	FLIGHT_NUMBER	AIRCRAFT_TYPE	TAIL_NUMBER	BEACON	AIRPORT ID	OTHER_PORT	OPERATOR_CATEGORY	AC CATEGORY	CORR ID
6	02/02/2015	19:04:10	58.1	73.9	63.6	02/02/2015 19:04:29	38	Aircraft		33	SWA	SWA164	B737	N409WN	7055	KDCA	KSTL	A	J	101452195
6	02/02/2015	19:08:18	69.6	83.1	73.7	02/02/2015 19:08:29	22	Aircraft		33	DAL	DAL2239	MD88	N997DL	531	KDCA	KATL	A	J	100005671
6	02/02/2015	19:19:52	59	76	64.1	02/02/2015 19:20:21	50	Aircraft		1	JBU	JBU1579	A320	N640JB	511	KDCA	KFLL	A	J	101452244
6	02/02/2015	19:21:13	57.5	73.8	61.8	02/02/2015 19:21:32	43	Aircraft		1	TCF	TCF3540	E170	N652PY	3666	KDCA	KORD	T	R	100016887
6	02/02/2015	19:26:53	61.3	75.3	66.2	02/02/2015 19:26:55	25	Aircraft		1	AWE	AWE2192	E190	N952UW	7063	KDCA	KLGA	A	R	101452245
6	02/02/2015	19:28:17	57.9	69.6	63.3	02/02/2015 19:28:26	15	Aircraft			RPA	RPA4356	E170	N429YX	5673	KDCA	KSTL	A	R	101452710
6	02/02/2015	19:29:10	61.2	74.4	65.1	02/02/2015 19:29:16	21	Aircraft		1	JBU	JBU749	E190	N236JB	2453	KDCA	KTPA	A	R	101452252
6	02/02/2015	19:30:10	57.7	72.9	61.8	02/02/2015 19:30:25	33	Aircraft		1	SWA	SWA328	B737	N259WN	2163	KDCA	KHOU	A	J	101452216
6	02/02/2015	19:35:30	59.7	70.1	62.2	02/02/2015 19:35:40	11	Aircraft		1	JBU	JBU790	E190	N279JB	6264	KDCA	KBOS	A	R	101452231
6	02/02/2015	19:36:56	59.1	72.2	63.8	02/02/2015 19:37:05	20	Aircraft		1	SWA	SWA3310	B737	N952WN	2165	KDCA	KMKE	A	J	101452219
6	02/02/2015	19:38:01	56.9	73.6	61.3	02/02/2015 19:38:26	47	Aircraft		33	AWE	AWE9177	A319	N826AW	7064	KDCA	KPIT	A	J	101452265
6	02/02/2015	19:40:21	59.5	72.3	61.1	02/02/2015 19:40:35	19	Aircraft		1	DAL	DAL832	B752	N694DL	2154	KDCA	KSLC	A	J	101452718
6	02/02/2015	19:43:23	59.3	74.2	65	02/02/2015 19:43:36	31	Aircraft		1	ASH	ASH3732	E170	N89304	2176	KDCA	KIAH	A	R	101452210
6	02/02/2015	19:50:13	55.7	72.2	59.3	02/02/2015 19:50:34	45	Aircraft		1	RPA	RPA4578	E170	N829MD	5363	KDCA	KRDU	A	R	101452725
6	02/02/2015	19:52:24	57.4	74.4	61.1	02/02/2015 19:52:48	50	Aircraft		1	SWA	SWA453	B737	N772SW	577	KDCA	KTPA	A	J	101452717
6	02/02/2015	20:01:54	60.5	67.5	63.5	02/02/2015 20:01:56	5	Aircraft		1	AWE	AWE1761	A319	N713UW	2105	KDCA	KPBI	A	J	100016861
6	02/02/2015	20:07:58	59.1	73.1	64.9	02/02/2015 20:08:12	25	Aircraft		1	DAL	DAL2339	MD88	N989DL	2124	KDCA	KATL	A	J	101452358
6	02/02/2015	20:10:12	59.5	66.5	61.4	02/02/2015 20:10:13	5	Aircraft		1	RPA	RPA4457	E170	N828MD	570	KDCA	KMEM	A	R	101452363
6	02/02/2015	20:13:29	54.4	64.4	57.6	02/02/2015 20:13:34	10	Aircraft		1	AWI	AWI4002	CRJ2	N442AW	7030	KDCA	KBHM	A	R	101452309
6	02/02/2015	20:14:08	60.2	75.6	64.8	02/02/2015 20:14:36	35	Aircraft		1	AWE	AWE1878	A319	N733UW	7015	KDCA	KMCO	A	J	101452364
6	02/02/2015	20:18:31	60.6	74.8	63.8	02/02/2015 20:18:43	26	Aircraft		1	AWE	AWE2194	E190	N953UW	2122	KDCA	KLGA	A	R	101452292
6	02/02/2015	20:20:34	57.3	72.9	62.3	02/02/2015 20:21:01	36	Aircraft		1	RPA	RPA4543	E170	N135HQ	2164	KDCA	KCMH	A	R	101452343
6	02/02/2015	20:24:58	55.7	62.7	58.2	02/02/2015 20:25:01	5	Aircraft		1	RPA	RPA8050	E170	N805MD	3602	KDCA	KMCI	A	R	101452236
6	02/02/2015	20:27:25	62.2	76.6	67	02/02/2015 20:27:41	28	Aircraft		1	AAL	AAL2206	B738	N907AN	2135	KDCA	KMIA	A	J	101452301
6	02/02/2015	20:35:34	52.5	63.6	56	02/02/2015 20:35:43	13	Aircraft		33	JIA	JIA5141	CRJ2	N245PS	7007	KDCA	KCAK	F	R	101452341
6	02/02/2015	20:40:15	57.6	72.7	60.1	02/02/2015 20:40:37	32	Aircraft		33	UAL	UAL2138	A320	N456UA	5631	KDCA	KORD	A	J	101452329
6	02/02/2015	20:41:09	56.2	70.1	62.2	02/02/2015 20:41:11	25	Aircraft		1	UAL	UAL508	A320	N452UA	2136	KDCA	KIAH	A	J	100016725
6	02/02/2015	20:42:44	56.4	64.8	58.2	02/02/2015 20:42:48	7	Aircraft		1	RPA	RPA4446	E170	N130HQ	3612	KDCA	KPIT	A	R	101452321
6	02/02/2015	20:53:31	52.6	63	55.8	02/02/2015 20:53:35	11	Aircraft		1	AWI	AWI38A	CL60	N471ZW	2474	KDCA	KSDF	A	R	101452287
6	02/02/2015	20:56:53	56.8	72.4	59.8	02/02/2015 20:57:10	37	Aircraft		1	SWA	SWA278	B737	N236WN	5602	KDCA	KDAL	A	J	101452335
6	02/02/2015	21:02:41	58.2	67.2	59.7	02/02/2015 21:02:45	8	Aircraft		1	RPA	RPA4464	E170	N111HQ	7077	KDCA	KMSY	A	R	101452367
6	02/02/2015	21:06:16	61.1	74.5	65.8	02/02/2015 21:06:35	22	Aircraft		1	AAL	AAL1295	B738	N832NN	7020	KDCA	KMIA	A	J	101452361
6	02/02/2015	21:08:27	56.4	69	58.5	02/02/2015 21:08:36	18	Aircraft		1	RPA	RPA4560	E170	N827MD	2110	KDCA	KCHS	A	R	101452368
6	02/02/2015	21:10:28	59.5	74.1	64.4	02/02/2015 21:10:41	29	Aircraft		1	SWA	SWA1161	B733	N376SW	5623	KDCA	KATL	A	J	101452375
6	02/02/2015	21:15:51	51.8	60.8	53.6	02/02/2015 21:15:58	8	Aircraft		1	AWI	AWI3895	CL60	N416AW	5630	KDCA	KGSO	A	R	101452369
6	02/02/2015	21:17:08	60	76.7	66.7	02/02/2015 21:17:30	47	Aircraft		1	AWE	AWE2130	A319	N768US	521	KDCA	KBOS	A	J	101452376
6	02/02/2015	21:19:40	58.3	72.3	62.9	02/02/2015 21:19:55	25	Aircraft		1	RPA	RPA4569	E170	N123HQ	7013	KDCA	KJAX	A	R	100016700
6	02/02/2015	21:21:54	56.6	63.6	58.6	02/02/2015 21:21:57	5	Aircraft		33	SWA	SWA2594	B737	N948WN	5601	KDCA	KCAK	A	J	101452269
6	02/02/2015	21:28:45	54.1	69.7	57.5	02/02/2015 21:29:09	36	Aircraft		1	TCF	TCF2395	E170	N654RW	2166	KDCA	KORD	T	R	101452267
6	02/02/2015	21:46:38	58.6	74.8	63.2	02/02/2015 21:47:08	42	Aircraft		1	JBU	JBU2323	E190	N307JB	5660	KDCA	KMCO	A	R	101452719
6	02/02/2015	22:00:26	60.6	75.8	65.7	02/02/2015 22:00:46	33	Aircraft		1	JBU	JBU1090	E190	N339JB	2475	KDCA	KBOS	A	R	100005673
6	02/02/2015	22:01:28	59	75.8	64.2	02/02/2015 22:01:51	48	Aircraft		1	AAL	AAL1029	B738	N830NN	5664	KDCA	KJFK	A	J	100001186
6	02/02/2015	22:09:43	55.5	69.7	60.8	02/02/2015 22:09:54	26	Aircraft					HELO		4305			U	H	100005672
6	02/02/2015	22:13:34	55	71.8	59.5	02/02/2015 22:13:49	47	Aircraft		1	RPA	RPA4598	E170	N121HQ	3631	KDCA	KPIT	A	R	101452409
6	02/02/2015	22:15:17	56.6	73.4	62	02/02/2015 22:15:41	47	Aircraft		1	RPA	RPA4445	E170	N146UQ	7065	KDCA	KDTW	A	R	101452408
6	02/02/2015	22:18:11	60.2	75.1	66.6	02/02/2015 22:18:35	31	Aircraft		1	SCX	SCX8990	B738	N809SY	5354	KDCA	KNGU	U	J	101452386
6	02/02/2015	22:18:49	57.9	66.9	59	02/02/2015 22:18:51	8	Aircraft					HELO		4305			U	H	100005672
6	02/02/2015	22:20:06	54.9	70.4	61.7	02/02/2015 22:20:27	35	Aircraft							5223			U	U	101452382
6	02/02/2015	22:21:32	57.1	66.2	59.2	02/02/2015 22:21:35	8	Aircraft		1	RPA	RPA4475	E170	N807MD	5662	KDCA	KBTV	A	R	100016751
6	02/02/2015	22:27:40	60.2	74.7	66.1	02/02/2015 22:27:57	28	Aircraft		1	RPA	RPA4449	E170	N801MA	534	KDCA	KPWM	A	R	101452392
6	02/02/2015	22:29:01	56.8	72.8	61.2	02/02/2015 22:29:21	40	Aircraft		1	RPA	RPA4602	E170	N812MD	572	KDCA	KMHT	A	R	101452399
6	02/02/2015	22:32:11	61.7	75	66.1	02/02/2015 22:32:15	21	Aircraft		1	JBU	JBU1098	E190	N247JB	5617	KDCA	KBDL	A	R	101452388