DALLAS LOVE FIELD

2023 Day-Night Average Sound Level Contours

HMMH Report No. 307412.05

May 2024

Prepared for:

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QUALITY CONTROL PLAN

Revision No. 1
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QC CHECKLISTS TO UTILIZE / PROJECT MILESTONE			
☒	AEDT QAQC	Project milestone / schedule for checklist	Vincent Ma review 4/12/2024
☒	Develop Noise Model Inputs Memorandum	Project milestone / schedule for checklist	Nastasja von Conta review 3/21/2024
☒	Internal Review of Noise Model Inputs Memorandum	Project milestone / schedule for checklist	Robert Mentzer review 3/22/2024
☒	Noise Model Inputs Memorandum to Client for review/comments	Project milestone / schedule for checklist	Isaac Ellison review 3/25/2024
☒	Develop Draft Report/Tables	Project milestone / schedule for checklist	Nastasja von Conta review 4/18/2024
☒	1st Technical Review	Project milestone / schedule for checklist	Robert Mentzer review 4/19/2024
☒	2nd Round Review	Project milestone / schedule for checklist	Sarah Yenson review 4/22/2024
☒	Draft to Client	Project milestone / schedule for checklist	4/23/2024
☒	Respond to /Resolve comments	Project milestone / schedule for checklist	5/9/2024
☒	Review Final Report	Project milestone / schedule for checklist	5/10/2024
☒	Final Report Delivery	Project milestone / schedule for checklist	5/10/2024

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1 Summary

This report, prepared by Harris Miller Miller & Hanson Inc (HMMH) under contract to the City of Dallas, presents the analysis of the 2023 noise conditions at Dallas Love Field (DAL) in Dallas, Texas.

The development of the 2023 Day-Night Average Sound Level (DNL, or Ldn) contours used the current version (Version 3f) of the Federal Aviation Administration's (FAA) Aviation Environmental Design Tool (AEDT) and HMMH's proprietary AEDT data pre-processor, which converted every useable 2023 radar track into inputs for the AEDT noise model, ensuring that the modeling reflects runway closures, deviations from flight patterns, changes in flight schedules, and deviations from average runway use. This process resulted in the modeling of 241,167 operations to develop the 2023 DNL contours.

In 2023, the estimated number of people exposed to DNL exceeding the federal guideline of DNL 65 dB is 10,802 people, a decrease of approximately 8 percent compared to 2019 (11,792 people exposed to DNL 65 dB or greater). The 2023-estimated number of people within the DNL 65 dB or greater contour is 35 percent smaller than the number of people within the DNL 65 or greater contour in 2006 (16,798 people exposed to DNL 65 dB or greater). Analysis of the noise contours indicates that the total area contained within the DNL 65 dB noise contours increased from 3.95 square miles in 2019 to 4.04 square miles in 2023, which is 0.58 square miles smaller than the 2006 DNL contour area (4.62 square miles).

The rest of this report includes information on the Dallas Voluntary Noise Program (Section 1.1) and describes noise and land use compatibility guidelines (Section 2), the noise modeling process (Section 3), the noise modeling inputs (Section 4), the resulting contours and population assessment (Section 5), and noise terminology and aircraft noise effects (Appendix A).

1.1 The Dallas Love Field Voluntary Noise Program

Dallas Love Field is in a noise-sensitive area of the city near residential neighborhoods, which are essential in providing economic, social, and cultural stability for the City of Dallas. It is important that the airport operates in a manner that allows it to fulfill its vital role of attracting business to Dallas, while protecting and preserving the quality of life in the surrounding neighborhoods. To balance these needs, the City of Dallas has adopted policies that not only recognize Dallas Love Field's importance to the Dallas community but also establish a noise reduction goal through its Voluntary Noise Program (VNP) to reduce the impact of the airport's operations on the neighborhoods.

An integral part of the overall approach to noise control at Dallas Love Field is communication between the various parties involved in developing, monitoring, and improving the program. The City of Dallas Department of Aviation achieves this goal in several ways, such as providing this report on a periodic basis, providing access to the Casper noise monitoring system, and continued participation in the Dallas Love Field Environmental Advisory Committee (LFEAC).

The LFEAC was established to provide a forum for discussion among airport neighbors, airport operators, and Federal and City aviation representatives on issues related to aircraft noise at Dallas Love Field. Members of the committee meet quarterly to review airport operations, propose changes in operations, evaluate the effectiveness of the noise program, and propose potential adjustments and improvements to the noise control program. As of January 2024, the LFEAC has been combined with the Good Neighbor Program, holding joint meetings to present airport updates, information for the local community, project updates, operational and environmental data.

The Department of Aviation utilizes a permanent noise and operations monitoring system (Casper) for Dallas Love Field. This system provides a variety of important capabilities, including: (1) investigation of noise complaints, (2) monitoring of the noise control program, and (3) preparation of various reports. The Department of Aviation provides monthly updates on runway closures and construction activities, and reports on airport operations by group and by runway.[1]

The Department of Aviation for the City of Dallas developed a VNP in 1981 for Dallas Love Field. It consists of the following voluntary measures:

- Nighttime Preferential Runway (Runway 13R/31L) for all jet aircraft and any aircraft weighing over 12,500 pounds, between the hours of 9:00 p.m. and 6:00 a.m.
- Noise departure procedure (Trinity Departure) for night operations on Runway 13R for all turbojet aircraft and aircraft weighing over 12,500 pounds.
- Channelization of helicopter tracks: Four prescribed helicopter flight tracks and altitude restrictions.
- Aircraft use optimal take-off profile.
- Construction of high-speed exits for runway 13R/31L.
- Continuation of five pre-existing voluntary procedures: This category includes arrival and departure measures that were in effect prior to the 1981 study.
- Establishment of a system to monitor and manage the noise program.
- Review noise program on a regular basis.

The VNP also included two mandatory restrictions which are allowed because they were “grandfathered” under the 1990 Airport Noise and Capacity Act (ANCA).

- Ban all training flights at night and restrict touch-and-go activity during busy periods.
- Prohibition of aircraft engine maintenance run-ups between the hours of midnight and 6:00 a.m. Expanded to a voluntary moratorium between 10:00 p.m. and midnight.

Pilots are instructed to observe all ATC instructions. At no time is operational safety to be compromised.

In 2022, the Department of Aviation began a comprehensive review of the VNP and held a series of six stakeholder meetings to discuss stakeholder concerns, review the status of the current VNP, and to develop feasible additional noise recommendations to potentially pursue with FAA, as shown in **Figure 1**. The results of these meetings included retaining many of the existing measures and potentially adding additional measures to the program. The DOA presented this information to the Dallas City Council for consideration in November of 2023.

Meeting	Topic	Date
1	• Introductions • Project Overview (Agenda, goals, objective) • Part 150 - background • History of Love Field Noise Program & Contours Level Comparison • Overview of Airport responsibilities • Stakeholders Feedback	August 25, 2022 at 6pm - 8pm
2	• Potential Modifications to Voluntary Noise Program • Stakeholder Feedback	September 29, 2022 at 6pm - 8pm
3	• Results of Analysis of Program Review and Recommendation Elements	October 20, 2022 at 6pm - 8pm
4	• Review current VNP Measures and Feedback on Current Measures • Review Prior and New Stakeholders' Suggestions	January 12, 2023 at 6pm - 8pm
5	• Obtain and Review Additional Feedback on Stakeholders' Suggestions	February 28, 2023 at 6pm - 8pm
6	• Present Council Briefing Presentation Deck for Stakeholders' Review	April 2023 at 6pm- 8pm

Figure 1. Noise Stakeholder Meetings

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[1] https://www.dallas-lovefield.com/airport-info/environmental/voluntary-noise-abatement-program/presentations

2 Noise and Land Use Compatibility Guidelines

DNL estimates have two principal uses in a noise study:

1. To provide a basis for comparing existing noise conditions to the effects of noise abatement procedures and/or forecast changes in airport activity.
2. To provide a quantitative basis for identifying potential noise exposure.

Both functions require the application of objective criteria for evaluating noise exposure. Title 14 of the Code of Federal Regulations (CFR) Part 150 Appendix A provides land use compatibility guidelines as a function of DNL values. **Table 1** reproduces those guidelines, which represent a compilation of the results of extensive scientific research into noise-related activity interference and attitudinal response. However, reviewers should recognize the highly subjective nature of response to noise and that special circumstances can affect individuals' tolerance. For example, a high non-aircraft background noise level can reduce the significance of aircraft noise, such as in areas constantly exposed to relatively high levels of traffic noise. Alternatively, residents of areas with unusually low background levels may find relatively low levels of aircraft noise annoying. Responses may also be affected by expectation and experience. People may get used to a level of noise exposure that guidelines indicate may be unacceptable, and changes in exposure may generate a response that is far greater than that which the guidelines might suggest.

The cumulative nature of DNL means that the same level of noise exposure can be achieved in an essentially infinite number of ways. For example, a reduction in a small number of relatively noisy operations may be counterbalanced by a much greater increase in relatively quiet flights, resulting in no net change in DNL. Residents of the area may be highly annoyed by the increased frequency of operations despite the seeming maintenance of the noise status quo. With these cautions in mind, the Part 150 guidelines can be applied to the DNL contours to identify the potential types, degrees, and locations of noncompatible land use. Quantification of the land areas and populations involved can provide a numerical measure of exposure that allows a comparison of at least the gross effects of existing or forecast operations.

FAA land use compatibility guidelines, as set forth in 14 CFR Part 150, indicate that all land uses are normally compatible with aircraft noise at exposure levels below DNL 65 dB as shown in **Table 1**. Standards adopted by the U.S. Department of Housing and Urban Development (HUD)[2] formally support this limit by determining if residential sites are eligible for federal funding support. These standards, set forth in CFR Part 51, define areas with DNL exposure not exceeding 65 dB as acceptable for funding. Areas exposed to noise levels between DNL 65 and 75 dB are "normally unacceptable" and require special abatement measures and review. Those at DNL 75 dB and above are "unacceptable" except under very limited circumstances.

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[2] HUD's noise standards may be found in 24 CFR Part 51, Subpart B.

Table 1. 14 CFR Part 150 Noise / Land Use Compatibility Guidelines

Source: 14 CFR Part 150, Appendix A, Table 1

	Yearly Day-Night Average Sound Level, DNL, in Decibels (Key and notes on following page)					
Land Use	**<65**	**65-70**	**70-75**	**75-80**	**80-85**	**>85**
Residential Use						
Residential other than mobile homes and transient lodgings	Y	N(1)	N(1)	N	N	N
Mobile home park	Y	N	N	N	N	N
Transient lodgings	Y	N(1)	N(1)	N(1)	N	N
Public Use						
Schools	Y	N(1)	N(1)	N	N	N
Hospitals and nursing homes	Y	25	30	N	N	N
Churches, auditoriums, and concert halls	Y	25	30	N	N	N
Governmental services	Y	Y	25	30	N	N
Transportation	Y	Y	Y(2)	Y(3)	Y(4)	Y(4)
Parking	Y	Y	Y(2)	Y(3)	Y(4)	N
Commercial Use						
Offices, business and professional	Y	Y	25	30	N	N
Wholesale and retail--building materials, hardware, and farm equipment	Y	Y	Y(2)	Y(3)	Y(4)	N
Retail trade--general	Y	Y	Y(2)	Y(3)	Y(4)	N
Utilities	Y	Y	Y(2)	Y(3)	Y(4)	N
Communication	Y	Y	25	30	N	N
Manufacturing and Production						
Manufacturing general	Y	Y	Y(2)	Y(3)	Y(4)	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	Y(6)	Y(7)	Y(8)	Y(8)	Y(8)
Livestock farming and breeding	Y	Y(6)	Y(7)	N	N	N
Mining and fishing, resource production and extraction	Y	Y	Y	Y	Y	Y
Recreational						
Outdoor sports arenas and spectator sports	Y	Y(5)	Y(5)	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts and camps	Y	Y	Y	N	N	N
Golf courses, riding stables, and water recreation	Y	Y	25	30	N	N

Key to Table 1:

SLUCM:	Standard Land Use Coding Manual.
Y(Yes):	Land use and related structures compatible without restrictions.
N(No):	Land use and related structures are not compatible and should be prohibited.
NLR:	Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.
25, 30, or 35:	Land use and related structures generally compatible; measures to achieve NLR of 25, 30, or 35 dB must be incorporated into design and construction of structure.

Notes for Table 1:

The designations contained in this table do not constitute a Federal determination that any use of land covered by the program is acceptable or unacceptable under Federal, State, or local law. The responsibility for determining the acceptable and permissible land uses and the relationship between specific properties and specific noise contours rests with the local authorities. FAA determinations under Part 150 are not intended to substitute federally determined land uses for those determined to be appropriate by local authorities in response to locally determined needs and values in achieving noise compatible land uses.

(1) Where the community determines that residential or school uses must be allowed, measures to achieve outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB and 30 dB should be incorporated into building codes and be considered in individual approvals. Normal residential construction can be expected to provide a NLR of 20 dB, thus, the reduction requirements are often started as 5, 10, or 15 dB over standard construction and normally assume mechanical ventilation and closed windows year-round. However, the use of NLR criteria will not eliminate outdoor noise problems.
(2) Measures to achieve NLR of 25 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.
(3) Measures to achieve NLR of 30 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.
(4) Measures to achieve NLR of 35 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.
(5) Land use compatible provided special sound reinforcement systems are installed.
(6) Residential buildings require an NLR of 25.
(7) Residential buildings require an NLR of 30
(8) Residential buildings not permitted.

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3 Noise Modeling Methodology

3.1 Approach to Aircraft Noise Exposure Modeling

The DNL contours for this study were prepared using the most recent release of AEDT, Version 3f.[3]

AEDT requires inputs in the following categories:

- Physical description of the airport layout
- Number and mix of aircraft operations
- Day-night split of operations (by aircraft type)
- Runway utilization rates
- Representative flight track descriptions and flight track utilization rates
- Meteorological conditions
- Terrain

HMMH's proprietary pre-processing software for AEDT prepared the operational and spatial noise model inputs for AEDT from radar flight data. Use of this methodology enables modeling of all radar track data for a given period. Further details on this software are provided in Section 3.2.

The AEDT aircraft database is continuously updated with new aircraft types as noise data becomes available. The AEDT 3f model includes data for most of the Boeing and Airbus fleet, as well as regional jet, corporate jet, and non-jet aircraft types. The model also includes data for over 20 types of helicopters, several of which were included in the development of the 2023 DNL contour for Dallas Love Field. The AEDT terrain feature accessed topographical data to adjust the distance between the aircraft and the receiver. Following FAA guidelines, long-term average weather conditions are included in the modeling, which allows for adjustments in aircraft performance and the inclusion of atmospheric absorption effects.

3.2 Noise Modeling Process

HMMH prepared the 2023 noise exposure contours using a proprietary AEDT pre-processor, which prepares each available aircraft flight track contained in the radar data set for input into AEDT. The AEDT model itself is used for all noise calculations. The pre-processor provides an organizational structure to model individual flight tracks in AEDT; it does not modify AEDT standard noise, performance, or aircraft substitution data, but rather selects the best standard data or FAA-approved non-standard data available to AEDT for each individual flight track.

The AEDT pre-processor takes maximum possible advantage of the available data from the airport's Noise Lab system[4] and AEDT's capabilities. It automates the process of preparing the AEDT inputs and models the full range of aircraft activity as precisely as possible, improving the precision of modeling by doing the following:

- For every identified aircraft operation, it directly converts the flight track recorded by Noise Lab to an AEDT track (rather than assigning all operations to a limited number of prototypical tracks).
- It models each ground track as it was flown in 2023, including deviations from the typical flight patterns due to weather, safety, or other reasons.
- It models each operation on the specific runway that was actually used (rather than applying a generalized distribution of broad ranges of aircraft types to an average of runway use).

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[3] Released December 13, 2023, https://aedt.faa.gov/3f_information.aspx.

[4] The Noise Lab system is provided by Casper Airport Solutions Inc.

- It models each operation at the time it occurred to accurately determine which operations incur the 10 dB weighting for nighttime operations when calculating DNL.
- On an operation-by-operation basis, it selects the specific airframe and engine combination to model by using the aircraft type designator and registration data associated with the flight plan and, if registration data is not available for commercial operations, the published composition of the individual operator's aircraft inventory.
- Based on the radar origin and destination data, it selects the stage length for each flight (a surrogate factor for aircraft weight) from the list of available stage lengths for each AEDT type.
- It accurately incorporates the effects of runway closures due to construction (e.g., during a nighttime closure, the modeling will only include tracks on the active runway).

The flight track data for 2023 used in the modeling were obtained from DAL's Noise Lab system and are all from the FAA's NextGen radar data feed.

4 Noise Modeling Inputs

4.1 Airfield Layout and Runway Geometry

Dallas Love Field (DAL) is located approximately 7 miles northwest of downtown Dallas, TX. The Airport has two parallel runways (13L/31R and 13R/31L). **Figure 2** shows the Airport Diagram, and **Table 2** provides the runway specifications required for modeling. Each end of the runways is designated by a number that, with the addition of a trailing “0”, reflects the magnetic heading of the runway to the nearest 10 degrees, as seen by the pilot. Thus, the two parallel runways, 13L/31R and 13R/31L, are oriented on approximate magnetic headings of 130 degrees and 310 degrees and are 7,752 feet long by 150 feet wide and 8,800 feet long by 150 feet wide, respectively. The parallel runways are distinguished from each other with letter endings “L” meaning left and “R” meaning right, as seen by the pilot. Runway length, runway width, instrumentation, and declared distances may affect which aircraft might use a particular runway and under what conditions, and therefore how often a runway would be used relative to the other runways at the airport.

Table 2. Runway Data

Source: FAA Airport Master Record 5010 and IAPs on https://skyvector.com/files/tpp/2102/pdf/00106IL31L.PDF

Runway	Latitude	Longitude	Elevation ft. (MSL)	Width (ft.)	Length ft.	Glide Slope	Displaced Approach Threshold (Feet)	Threshold Crossing Height (ft)
13L	32.857273	-96.856799	476.9	150	7,752	3.00	399	57
13R	32.851317	-96.863451	476.4	150	8,800	3.00	489	52
31L	32.834029	-96.843416	476.4	150	8,800	3.08	0	55
31R	32.842043	-96.839152	486.9	150	7,752	3.00	0	55
HP[5]	32.849059	-96.845502	487	-	-	-	-	-

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[5] Notional helipad location defined for noise modeling purposes.

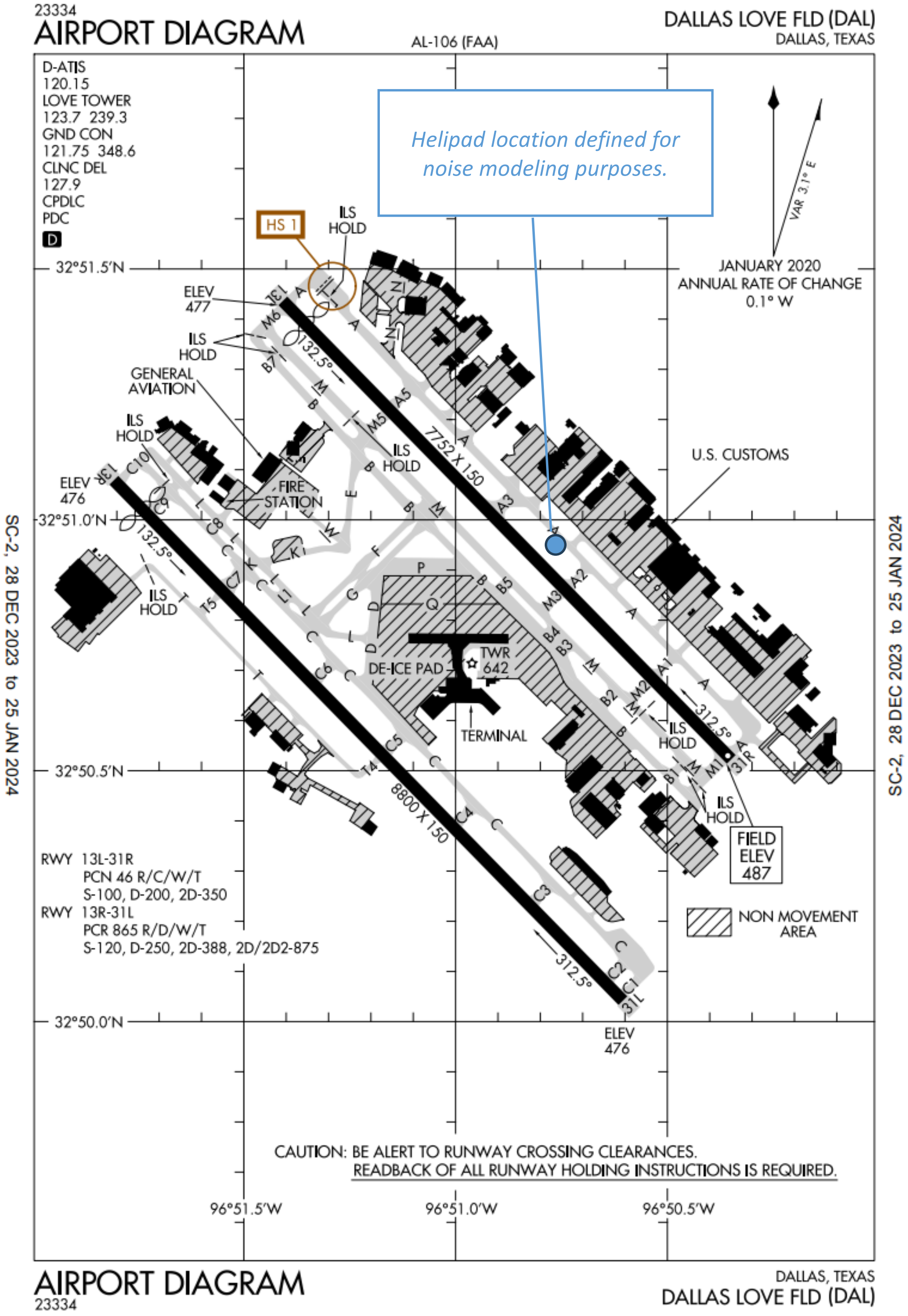


Figure 2. Existing Airport Diagram

Source: FAA, December 2023

4.2 Aircraft Operations

The 2023 DNL noise contours reflect all operations that occurred during the entire calendar year. Operations totals were obtained from the FAA Operations Network (OPSNET) (otherwise known as the tower counts) and are shown in **Table 3**. The FAA classifies operations in the following four categories:

- **Air Carrier** – Operations by aircraft capable of holding 60 seats or more and flying using a three-letter company designator.
- **Air Taxi** – Operations by aircraft of fewer than 60 seats and flying using a three-letter company designator or the prefix "Tango" (T).
- **General Aviation – Civil** (non-military) aircraft operations flying without a three-letter company destination or the prefix "Tango" (T).
- **Military** – all classes of military operations.

As described in Section 3.2, the Casper data source provided aircraft flight tracks from Noise Lab and identified individual operations as arrivals or departures by operator, aircraft type, and time of day. HMMH supplemented the Casper data with data from the FAA's Aircraft Registration Database where necessary to further identify aircraft types for noise modeling purposes. The pre-processor software assigned each flight to one of the FAA tower count categories to allow for the scaling of the data to match the FAA tower count totals. The number of modeled flight tracks and the FAA operations count totals differ for the following reasons:

- The pre-processor filters the flight track data and only uses tracks/operations that have a runway assignment, a valid aircraft type designation, and contain sufficient flight track points to define the aircraft's flight path and altitude profile; and
- Most military operations are not identified in the dataset.

HMMH imported 241,204 individual flight tracks/operations, of which 241,167 were usable for modeling. The aircraft operations format for entering data into AEDT includes day and night arrivals and departure operations (as appropriate) expressed in terms of an annual average day (AAD). The AAD operations are determined by dividing the annual operations by 365 days, as listed in **Table 3**.

There was missing data from September 17 to September 19, 2023, due to issues with the FAA data feed. To compensate for this data gap, an estimation approach was implemented, scaling the missing information according to FAA tower count. Arrivals and departures were balanced by aircraft type and FAA tower category, and then scaled up to the OPSNET count of 251,988 operations, which are modeled for the 2023 annual contour. The average annual daily operations by aircraft type, operation mode, and time of day are detailed in **Table 4** below.

Table 3. Average Annual Daily Aircraft Operations for 2023

Source: FAA OPSNET, Casper data, HMMH analysis 2024

Aircraft Category	2023 Operations	
	2023 FAA OPSNET	2023 Average Annual Day Modeled Operations
Air Carrier	149,744	411.21
Air Taxi	53,016	145.25
General Aviation	48,492	133.92
Military	736	0.00
Total	**251,988**	**690.38**

***Note**: Military operations are scaled into AC and GA depending on weight class. Because 47.1% of the 736 military operations reported for DAL for 2023 in the FAA's Traffic Flow Management System Counts (TFMSC) report were by air carrier size aircraft, that proportion of the military OPSNET operations were added to the air carrier total. The remaining 52.9% were absorbed into the GA category.*

Table 4. Modeled Average Daily Aircraft Operations for 2023

Source: Casper data, HMMH analysis 2024

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
Air Carrier	**Jet**	717200	0.76	0.11	0.86	0.02	1.75
		737300	0.04	0.02	0.03	0.03	0.12
		737400	0.07	0.02	0.06	0.03	0.18
		737700	90.09	14.04	89.75	14.37	208.25
		737800	47.75	7.98	46.90	8.83	111.46
		757300	-	<0.01	-	<0.01	0.01
		767300	0.01	-	<0.01	0.01	0.02
		727EM2	0.05	0.04	0.05	0.04	0.19
		7378MAX	32.40	6.15	32.01	6.54	77.11
		757PW	0.16	0.10	0.14	0.12	0.52
		767CF6	0.01	-	0.01	<0.01	0.02
		A319-131	4.03	1.08	4.57	0.54	10.22
		A320-211	0.29	0.17	0.30	0.16	0.91
		A320-270N	<0.01	-	-	<0.01	0.01
		A321-232	<0.01	-	<0.01	-	0.01
		CRJ9-ER	<0.01	-	<0.01	-	0.01
		DC93LW	0.01	0.02	0.02	0.01	0.07
		EMB190	0.01	0.01	0.02	<0.01	0.04
		EMB195	<0.01	-	-	<0.01	0.01
		MD81	<0.01	<0.01	0.01	-	0.01
		MD82	<0.01	<0.01	0.01	-	0.01
		MD83	0.09	0.06	0.12	0.03	0.30
	Turbine propeller	CVR580	<0.01	-	<0.01	-	0.01
Air Carrier Subtotal			175.79	29.81	174.87	30.73	411.21
Air Taxi	**Jet**	BD-700-1A10	0.86	0.04	0.87	0.03	1.80
		BD-700-1A11	0.43	0.04	0.45	0.02	0.93
		CIT3	0.07	0.03	0.07	0.02	0.19
		CL600	10.02	0.60	10.11	0.51	21.24
		CL601	1.29	0.04	1.29	0.05	2.67
		CAN500	0.01	0.02	0.02	0.02	0.07
		CAN510	0.83	0.05	0.85	0.03	1.77
		CAN525C	1.13	0.11	1.13	0.11	2.47
		CAN55B	7.53	0.49	7.24	0.78	16.04
		CAN560U	0.40	0.11	0.44	0.06	1.02
		CAN560XL	4.26	0.52	4.30	0.48	9.56
		CAN680	8.15	0.54	8.21	0.49	17.38
		CAN750	4.23	0.19	4.21	0.21	8.84
		ECLIPSE500	0.02	<0.01	0.02	<0.01	0.04
		EMB145	1.41	0.12	1.52	0.01	3.07
		EMB14L	11.21	0.85	12.00	0.05	24.11
		FAL20	0.03	0.02	0.04	0.01	0.10
		FAL900EX	0.49	0.03	0.50	0.02	1.04
		G650ER	0.40	<0.01	0.38	0.03	0.82
		GIIB	<0.01	-	<0.01	-	0.01
		GIV	1.64	0.09	1.67	0.06	3.47
		GV	0.56	0.05	0.56	0.05	1.21
		IA1125	0.06	<0.01	0.05	<0.01	0.12
		LEAR35	2.73	0.53	2.76	0.50	6.52
		MU3001	0.76	0.10	0.80	0.06	1.73
	Turbine propeller	1900D	0.01	<0.01	0.01	<0.01	0.03
		CAN208	1.62	1.77	1.86	1.53	6.78
		DHC6	2.05	0.83	2.14	0.73	5.75
		EMB120	<0.01	<0.01	<0.01	<0.01	0.03

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		HS748A	0.19	<0.01	0.19	<0.01	0.39
	Piston propeller	BEC58P	0.01	0.75	0.56	0.20	1.52
		CAN172	0.03	-	0.03	<0.01	0.06
		CAN182	0.02	-	0.02	-	0.04
		CAN206	0.04	-	0.04	-	0.08
		COMSEP	0.01	-	0.01	-	0.02
		GASEPF	-	-	-	-	<0.01
		GASEPV	<0.01	-	<0.01	-	<0.01
		PA30	0.09	-	0.09	<0.01	0.18
	Helicopter	B206B3	0.15	0.09	0.16	0.08	0.48
		B407	0.51	0.27	0.47	0.31	1.55
		B429	0.18	0.10	0.18	0.09	0.55
		B430	<0.01	-	<0.01	<0.01	0.01
		EC130	0.39	0.31	0.36	0.35	1.41
		S76	0.03	0.03	0.04	0.02	0.12
		SA350D	<0.01	<0.01	<0.01	<0.01	0.02
Air Taxi Subtotal			63.89	8.74	65.67	6.96	145.25
General Aviation	**Jet**	737500	<0.01	-	<0.01	-	<0.01
		737700	0.02	<0.01	0.02	-	0.04
		737800	<0.01	-	<0.01	-	<0.01
		757PW	0.02	0.05	0.06	0.01	0.14
		7673ER	<0.01	-	-	<0.01	<0.01
		BD-700-1A10	1.18	0.15	1.24	0.08	2.66
		BD-700-1A11	0.38	0.07	0.43	0.02	0.91
		CIT3	1.51	0.16	1.55	0.11	3.33
		CL600	5.20	0.49	5.36	0.33	11.37
		CL601	3.19	0.18	3.22	0.15	6.73
		CAN500	0.08	<0.01	0.08	0.01	0.18
		CAN510	1.46	0.05	1.46	0.05	3.03
		CAN525C	4.63	0.18	4.62	0.18	9.61
		CAN55B	2.67	0.11	2.67	0.11	5.57
		CAN560E	0.10	-	0.10	-	0.21
		CAN560U	1.67	0.11	1.69	0.10	3.57
		CAN560XL	3.31	0.17	3.35	0.12	6.95
		CAN680	3.02	0.14	3.03	0.14	6.33
		CAN750	3.68	0.24	3.77	0.15	7.84
		CRJ9-ER	<0.01	-	<0.01	-	0.01
		ECLIPSE500	0.42	0.02	0.42	0.02	0.88
		EMB145	0.77	0.03	0.79	0.02	1.61
		EMB14L	0.06	-	0.06	<0.01	0.12
		EMB190	<0.01	-	<0.01	-	0.01
		FAL20	0.04	<0.01	0.04	-	0.08
		FAL900EX	2.45	0.17	2.48	0.14	5.24
		G650ER	0.70	0.06	0.73	0.03	1.53
		GII	0.04	<0.01	0.04	<0.01	0.09
		GIIB	0.02	<0.01	0.02	-	0.05
		GIV	1.97	0.18	2.03	0.12	4.30
		GV	2.84	0.26	2.90	0.20	6.20
		IA1125	0.59	0.02	0.59	0.02	1.23
		LEAR35	4.82	0.28	4.80	0.31	10.21
		MD81	<0.01	-	<0.01	<0.01	0.01
		MU3001	0.95	0.07	0.89	0.13	2.03
	Turbine propeller	CAN208	2.90	0.20	2.82	0.28	6.21
		CAN441	0.15	-	0.15	<0.01	0.31
		DHC6	4.95	0.20	4.60	0.55	10.30

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		HS748A	0.01	-	0.01	-	0.03
		PA42	<0.01	-	<0.01	-	<0.01
	Piston propeller	BEC58P	0.67	0.04	0.68	0.02	1.41
		CAN172	0.19	0.04	0.18	0.05	0.46
		CAN182	0.16	0.01	0.16	0.02	0.36
		CAN206	0.05	-	0.05	-	0.10
		CAN20T	0.01	-	0.01	-	0.03
		COMSEP	1.27	0.07	1.27	0.06	2.66
		GASEPF	0.24	0.02	0.24	0.02	0.53
		GASEPV	1.23	0.07	1.20	0.10	2.60
		PA30	0.03	0.01	0.04	<0.01	0.09
	Helicopter	A109	0.02	-	0.02	-	0.04
		B206B3	0.19	0.10	0.18	0.11	0.58
		B206L	0.11	-	0.11	<0.01	0.22
		B407	1.25	0.18	1.19	0.24	2.86
		B429	0.57	0.20	0.55	0.21	1.53
		B430	0.03	-	0.03	-	0.06
		EC130	0.24	0.26	0.25	0.26	1.02
		H500D	0.02	-	0.02	-	0.04
		R44	0.01	-	0.01	-	0.02
		S76	0.16	0.02	0.17	0.01	0.36
		SA350D	0.01	-	0.01	-	0.03
		SA365N	<0.01	-	<0.01	-	<0.01
General Aviation Subtotal			62.32	4.64	62.44	4.52	133.92
Grand Total			302.00	43.19	302.98	42.21	690.38

***Note**: Military operations are scaled into AC and GA depending on weight class. Because 47.1% of the 736 military operations reported for DAL for 2023 in the FAA's TFMSC report were by air carrier size aircraft, that proportion of the military OPSNET operations were added to the air carrier total. The remaining 52.9% were absorbed into the GA category.*

4.2.1 Aircraft Sound Exposure Levels

Sound Exposure Level (SEL) represents noise exposure due to a single noise event such as an aircraft overflight while accounting for both the sound level and duration of the event. A noise "footprint" for a given type of aircraft can be generated by simulating an event that combines a single arrival with a single departure and calculating the SEL over the affected area. This results in SEL contours that can be compared for different aircraft types to show their relative influence in the overall noise level at an airport. **Appendix A** provides a more detailed explanation of SEL.

Figure 3 through Figure 5 display SEL contours for the most common aircraft types in use in 2023 at DAL. Larger aircraft generally affect a larger area, as would be expected. However, the introduction of newer engine technology has resulted in lower SELs. For example, the departure portion of the SEL contour for the larger Embraer 145 affects a much smaller area than the CRJ 200. These figures also include the percentage of operations represented by each aircraft type. The overall influence of an aircraft type combines its SEL footprint with its share of operations.

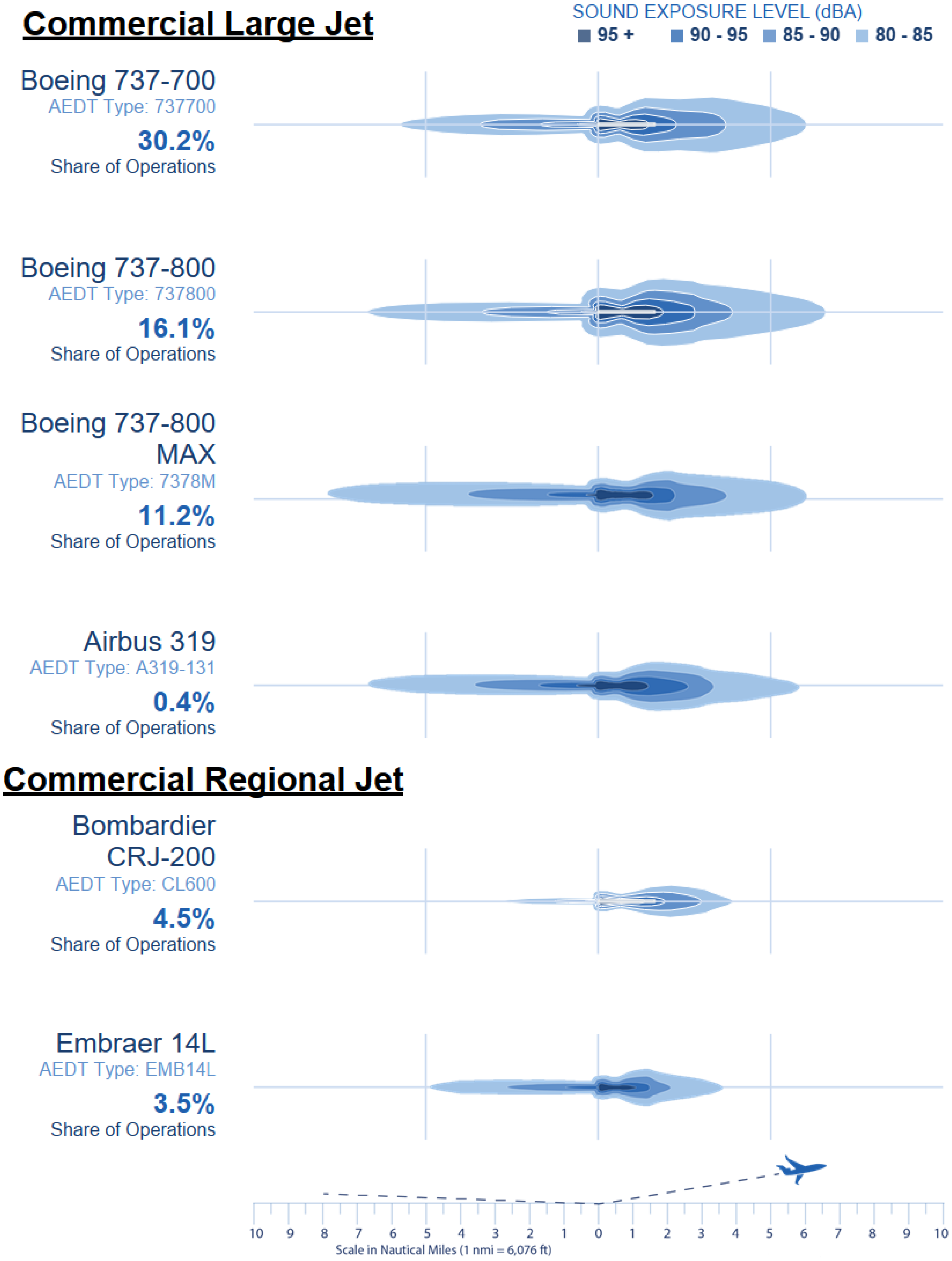


Figure 3. SEL Contours - Commercial Aircraft

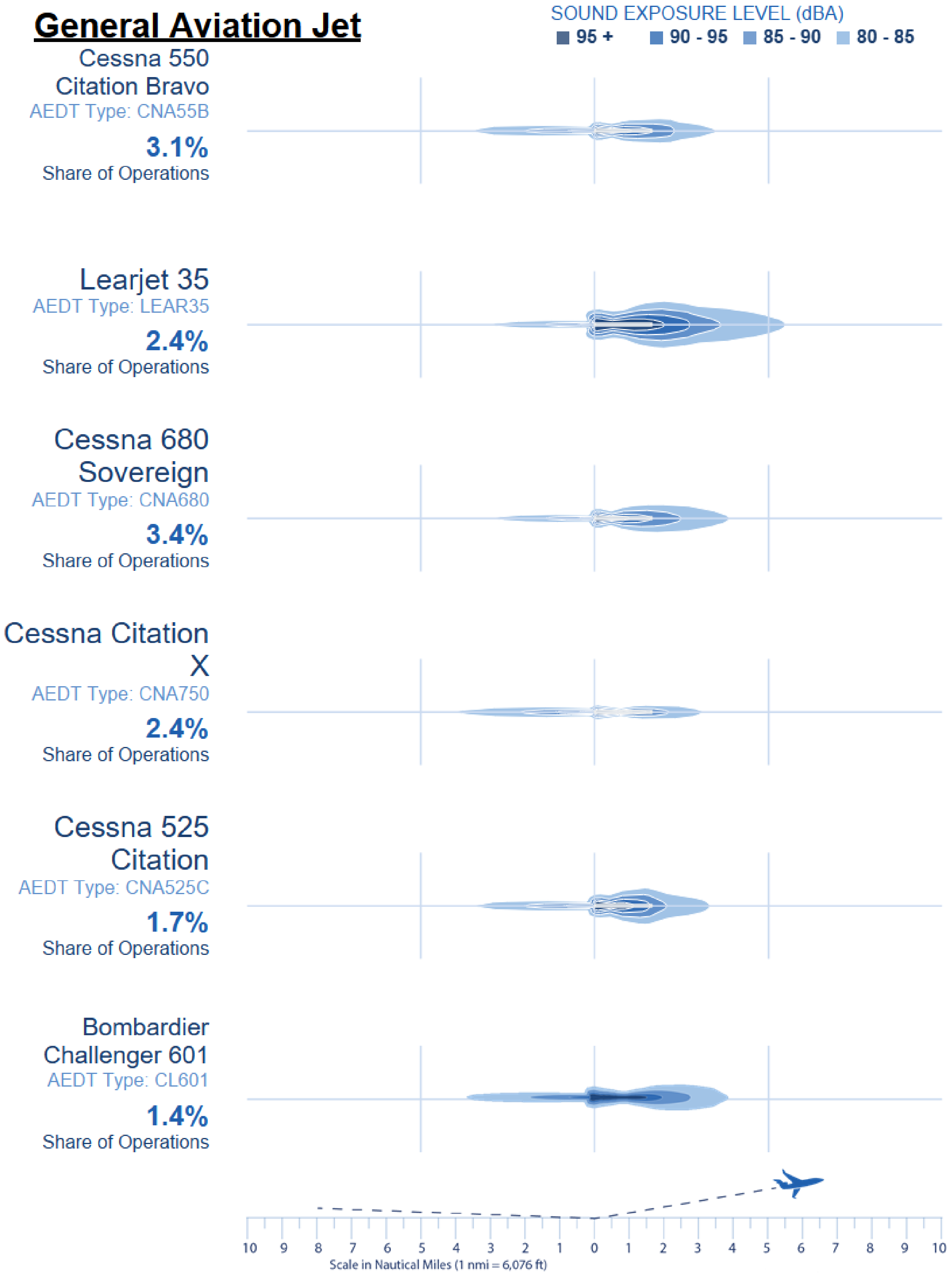


Figure 4. SEL Contours - General Aviation Jets

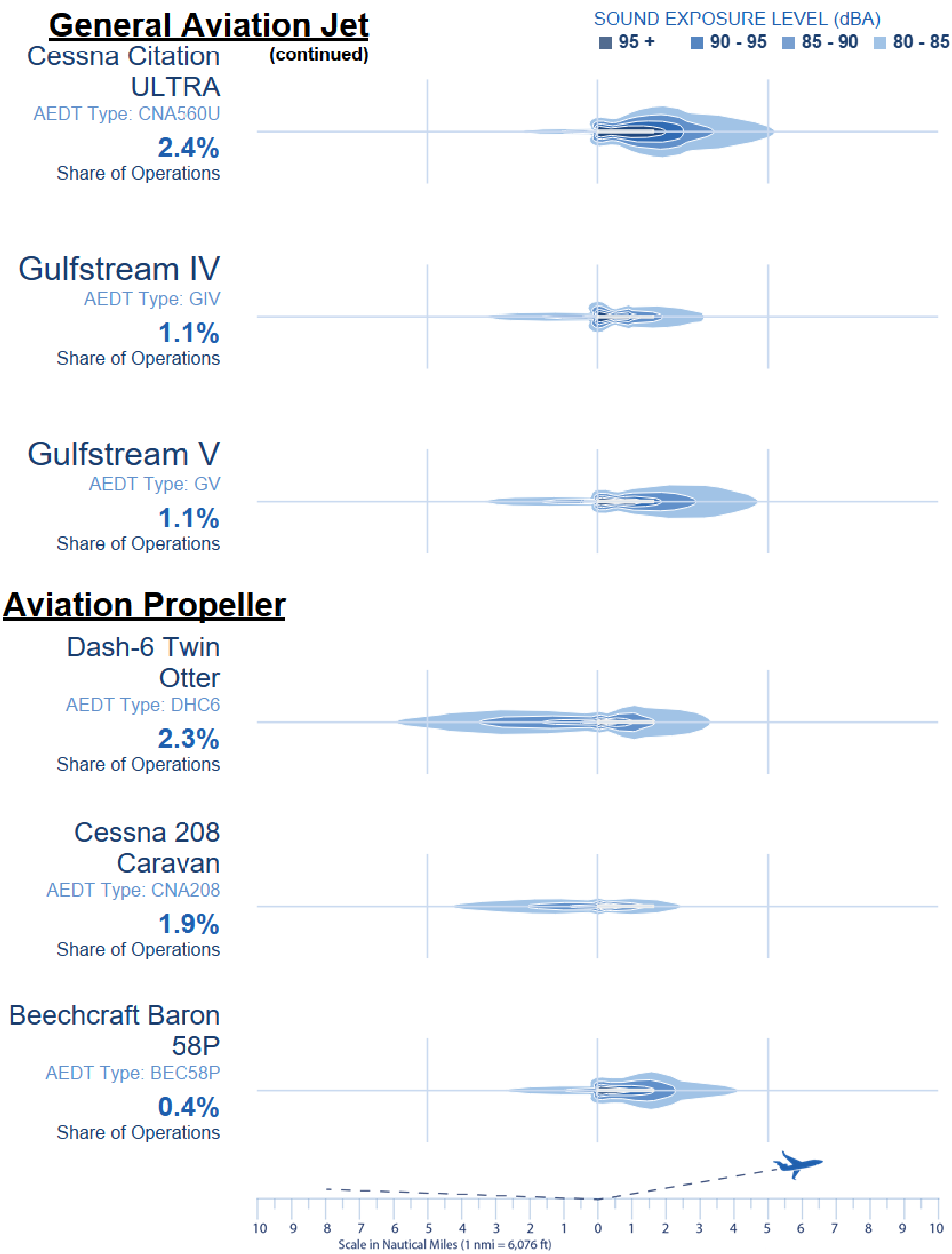


Figure 5. SEL Contours - General Aviation Jets (cont'd) and Propellers

4.3 Runway Utilization

The primary factor affecting runway use at airports is weather, specifically the wind direction and wind speed. Additional factors that may affect runway use include the position of the terminal or GA facilities to the runways. The calculation of runway utilization involves aggregating all operations on a particular runway and then dividing this total by the sum of operations across all runways. **Table 5** summarizes the runway utilization for the average annual day conditions modeled for 2023.

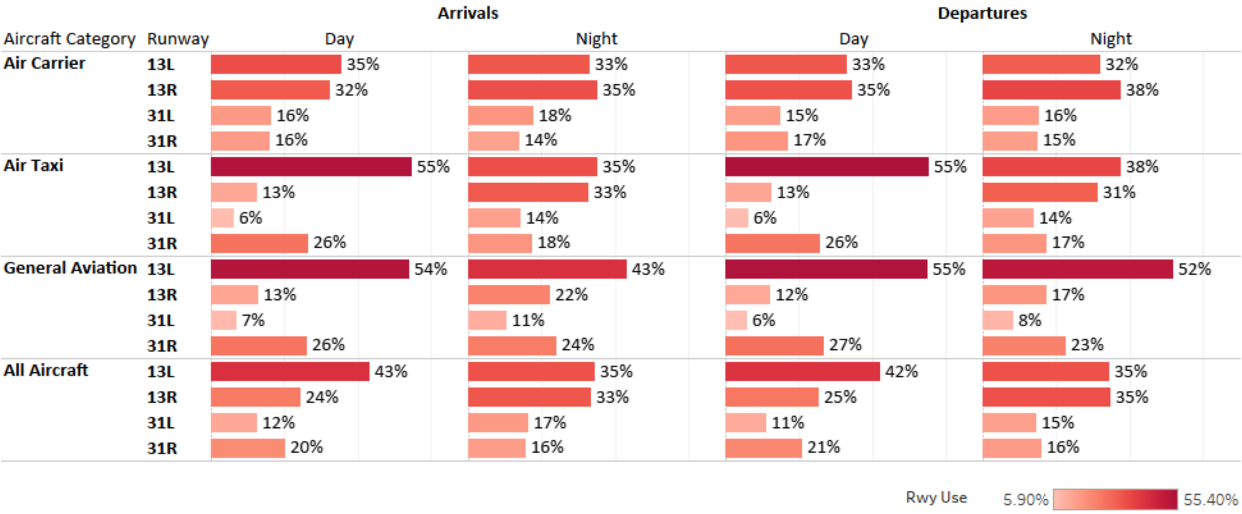
Figure 6 displays the data in **Table 5** graphically by aircraft category. This helps to visualize the usage of each category on the runways. Separate utilization percentages for each aircraft category and for all aircraft are given, and in general show 68 percent of operations in south flow (use of Runways 13L/13R) and 32 percent in north flow (use of Runways 31R/31L). In south and north flow operations during 2023, air carrier operations are almost equally split between the pair runways. Air taxi operations mainly occurred on Runway 13L/31R during the day and Runway 13R, 31L, 13L during the night. General aviation favored Runway 13L/31R for both daytime and nighttime operations. There were no extended runway closures in 2023.

In analyzing runway utilization trends between 2020 and 2023, notable shifts were observed in aircraft operations across various categories and flow directions. The share of south flow operations is up from 65 percent, and the share of north flow operations is down from 35 percent in 2020. For all aircraft operations in 2023, Runway 13L exhibited increased utilization during nighttime hours compared to 2020. Conversely, Runway 13R saw a decrease in both day and night departures, suggesting a redistribution of flight operations. Use of the voluntary noise abatement runway (13R/31L) at night (10pm to 7am), is down from 68 percent in 2020 to 48 percent in 2023.

Table 5. 2023 Runway Use

Source: Casper data, HMMH analysis 2024

Aircraft Category	Flow Direction	Runway	Arrivals		Departures	
			Day	Night	Day	Night
Air Carrier	South flow	13L	35.4%	33.2%	33.2%	31.9%
		13R	32.4%	35.1%	34.6%	37.6%
	North flow	31R	15.9%	14.0%	17.2%	15.0%
		31L	16.3%	17.8%	15.0%	15.5%
	Total		**100.0%**	**100.0%**	**100.0%**	**100.0%**
Air Taxi	South flow	13L	54.8%	35.4%	55.4%	37.5%
		13R	12.5%	32.7%	12.6%	31.2%
	North flow	31R	26.3%	17.6%	25.9%	17.4%
		31L	6.4%	14.4%	6.2%	13.9%
	Total		**100.0%**	**100.0%**	**100.0%**	**100.0%**
General Aviation	South flow	13L	54.0%	43.1%	54.9%	52.0%
		13R	12.9%	22.4%	12.2%	17.3%
	North flow	31R	26.0%	24.0%	26.9%	22.5%
		31L	7.1%	10.6%	5.9%	8.2%
	Total		**100.0%**	**100.0%**	**100.0%**	**100.0%**
All Aircraft	South flow	13L	43.2%	34.6%	42.4%	34.6%
		13R	24.3%	33.4%	25.4%	34.8%
	North flow	31R	20.1%	15.6%	21.0%	16.0%
		31L	12.4%	16.5%	11.3%	14.6%
	Total		**100.0%**	**100.0%**	**100.0%**	**100.0%**



		Arrivals		Departures	
Aircraft Category	Runway	Day	Night	Day	Night
Air Carrier	**13L**	35%	33%	33%	32%
	13R	32%	35%	35%	38%
	31L	16%	18%	15%	16%
	31R	16%	14%	17%	15%
Air Taxi	**13L**	55%	35%	55%	38%
	13R	13%	33%	13%	31%
	31L	6%	14%	6%	14%
	31R	26%	18%	26%	17%
General Aviation	**13L**	54%	43%	55%	52%
	13R	13%	22%	12%	17%
	31L	7%	11%	6%	8%
	31R	26%	24%	27%	23%
All Aircraft	**13L**	43%	35%	42%	35%
	13R	24%	33%	25%	35%
	31L	12%	17%	11%	15%
	31R	20%	16%	21%	16%

Figure 6. 2023 Runway Use

Figure 7 through **Figure 10** show geographic views of the runway use percentages[6] for all aircraft operations. This helps to visualize the effect of specific operation types on surrounding areas.

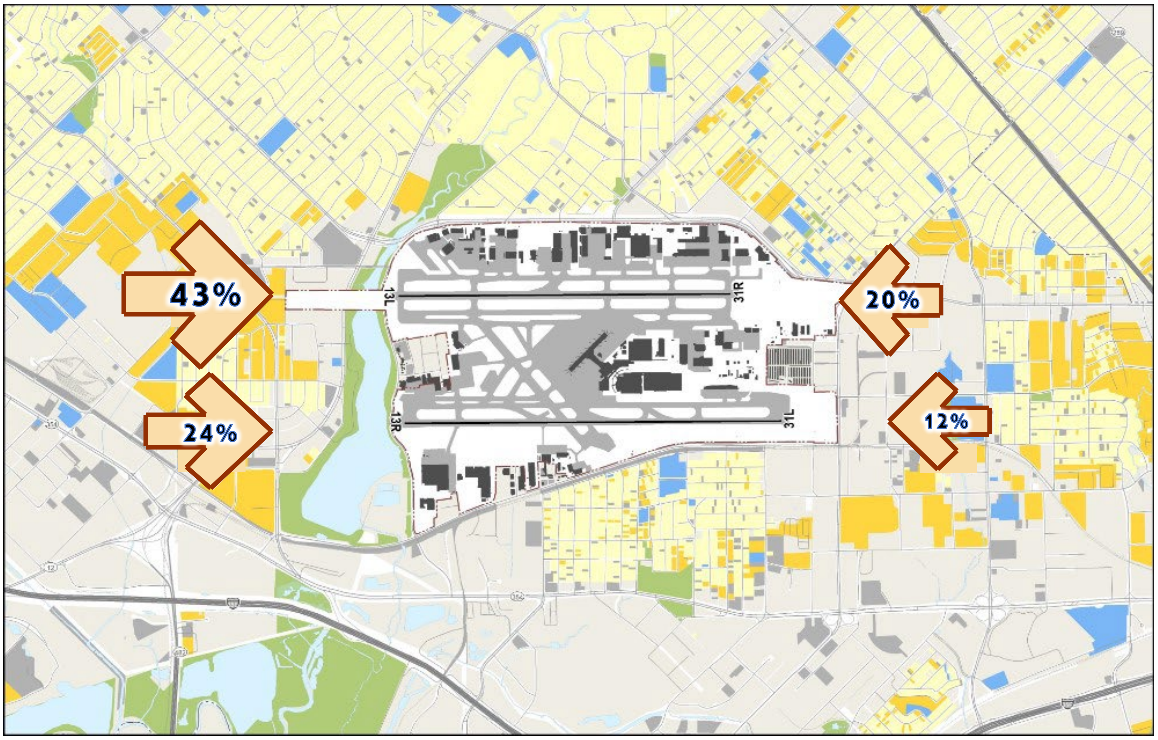


Figure 7. Runway Use: Daytime Arrivals

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[6] Runway utilization numbers may not add up to 100% due to rounding.

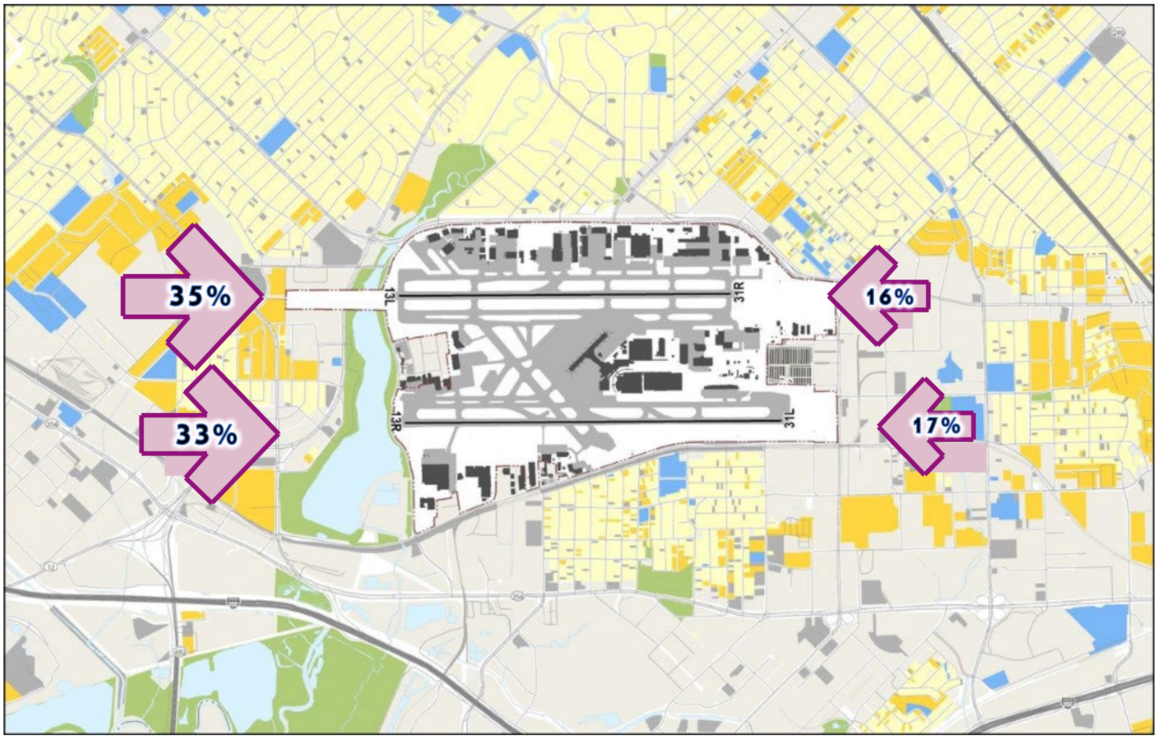

Figure 8. Runway Use: Nighttime Arrivals

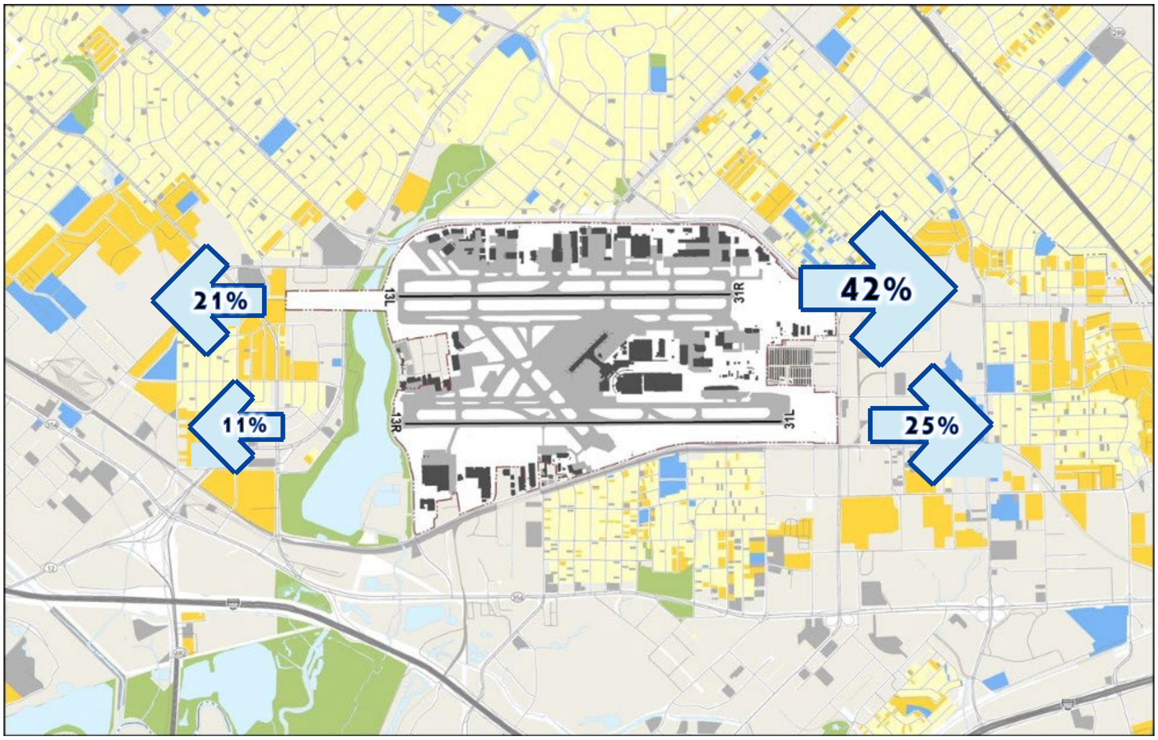

Figure 9. Runway Use: Daytime Departures

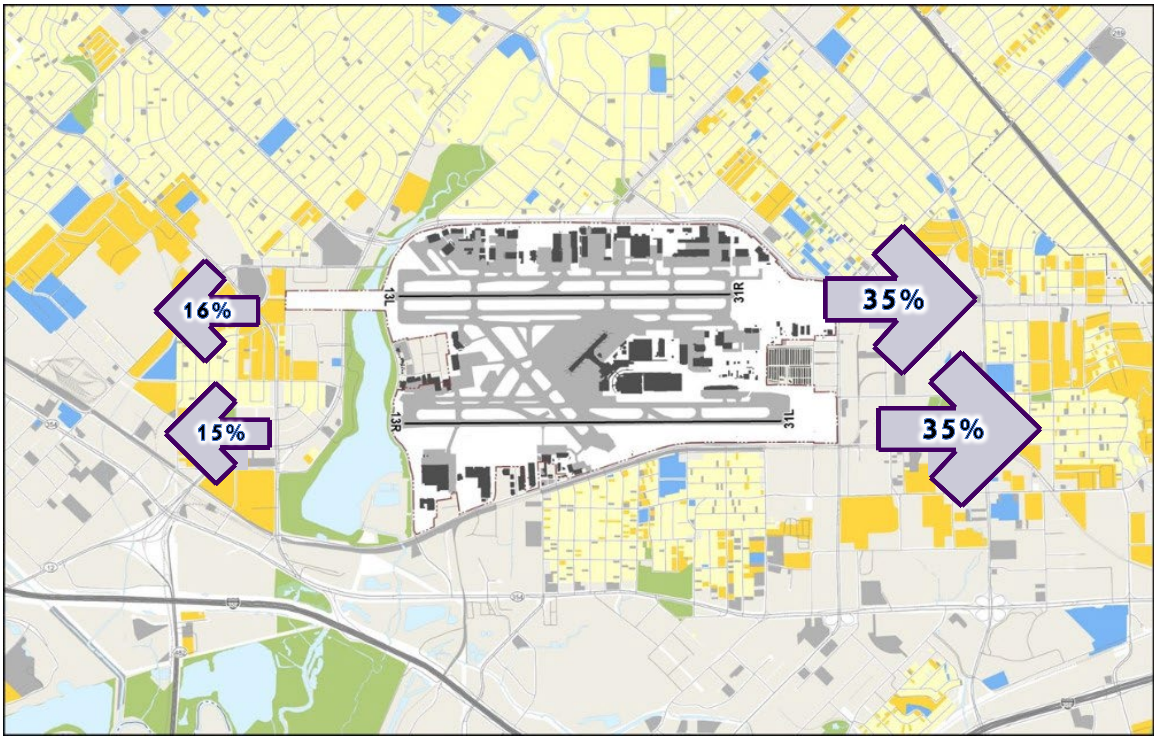

Figure 10. Runway Use: Nighttime Departures

Runway 13R/31L is the Nighttime Preferential Runway for all jet aircraft and any aircraft weighing over 12,500 pounds between the hours of 9:00 p.m. and 6:00 a.m. at DAL. **Table 6** provides percentages by runway of jet arrivals and jet departures that occurred between 9 p.m. and 6 a.m. for 2023. The data shows that slightly less than half of the operations during this time use the preferred runway, with about 48 percent of jet operations occurring on either Runway 13R or 31L.

Table 6. Jet Operations by Runway between 9 p.m. and 6 a.m.

Source: Casper data, HMMH 2024 analysis

Runway	Arrivals	Departures	Total
13L	22.1%	12.4%	34.5%
31R	10.7%	6.8%	17.5%
13R	18.7%	13.5%	32.2%
31L	9.6%	6.2%	15.8%
Total	61.2%	38.8%	100.0%

4.4 Flight Track Geometry

As described in Section3.2, the AEDT preprocessor was used to develop AEDT tracks from radar flight data, thereby modeling every available radar flight record as an AEDT flight track. **Figure 11** and **Figure 12** provide samples of the radar-based AEDT model tracks. A total of 241,167 individual tracks were modeled. **Figure 11** presents a sample of north flow model tracks and **Figure 12** presents a sample of south flow model tracks, representing approximately a ten percent sampling of all modeled flight tracks.

The flight tracks in these views are predominantly in line with the runways. As seen in Section 5, this is reflected in the shape of the noise contours, which vary in length due to operations volume on particular runways but remain centered on the extended runway centerlines. In the top left corner of **Figure 12**, tracks are shown arriving from the north and turning onto runway heading. These arrivals cannot align with the runway farther from the airport due to airspace conflict with Dallas – Fort Worth Airport to the west. However, these tracks align with the runway far enough from the airport that this does not affect the shape of the noise contours.

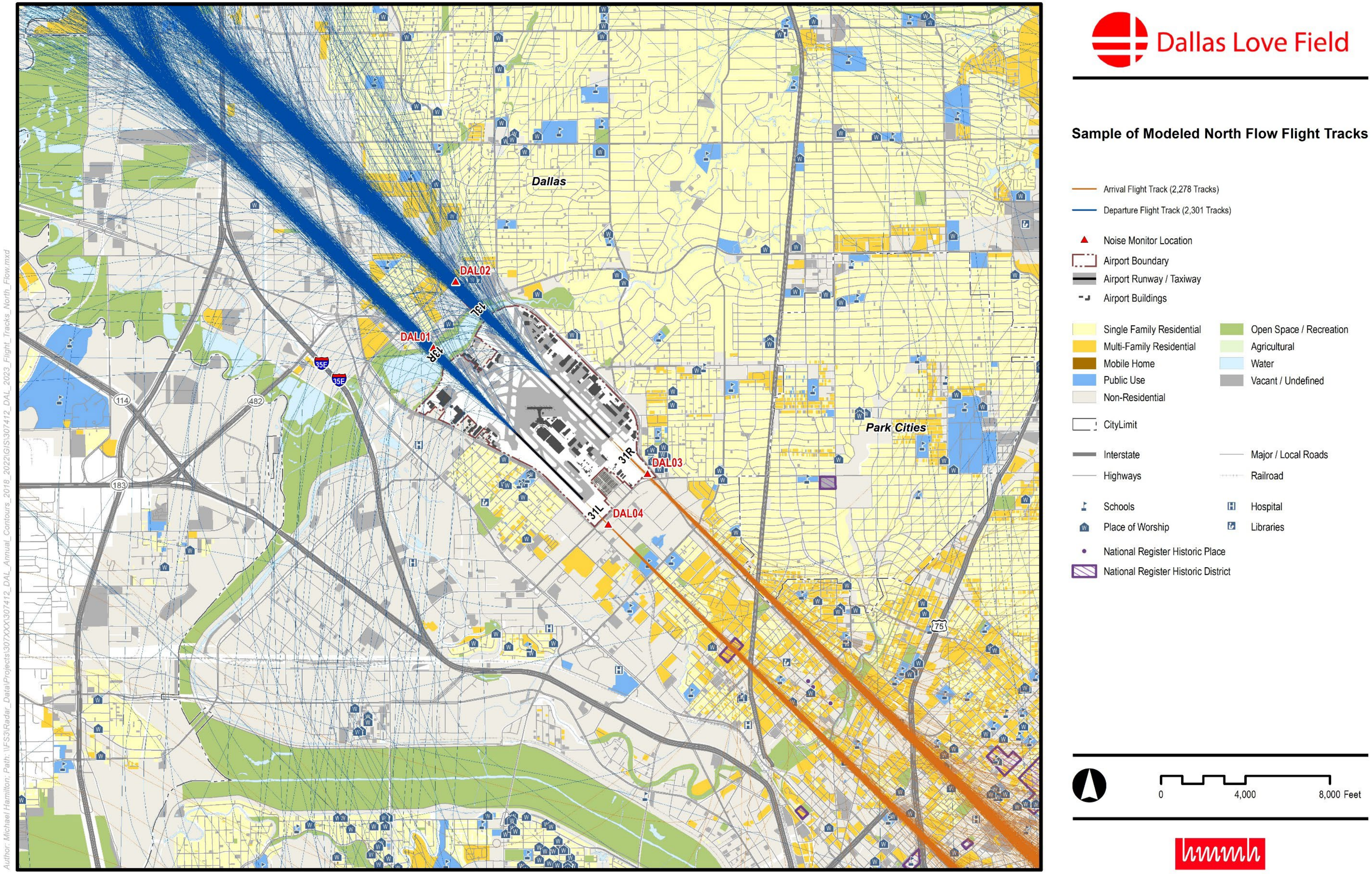

Figure 11. Sample of Modeled North Flow Tracks

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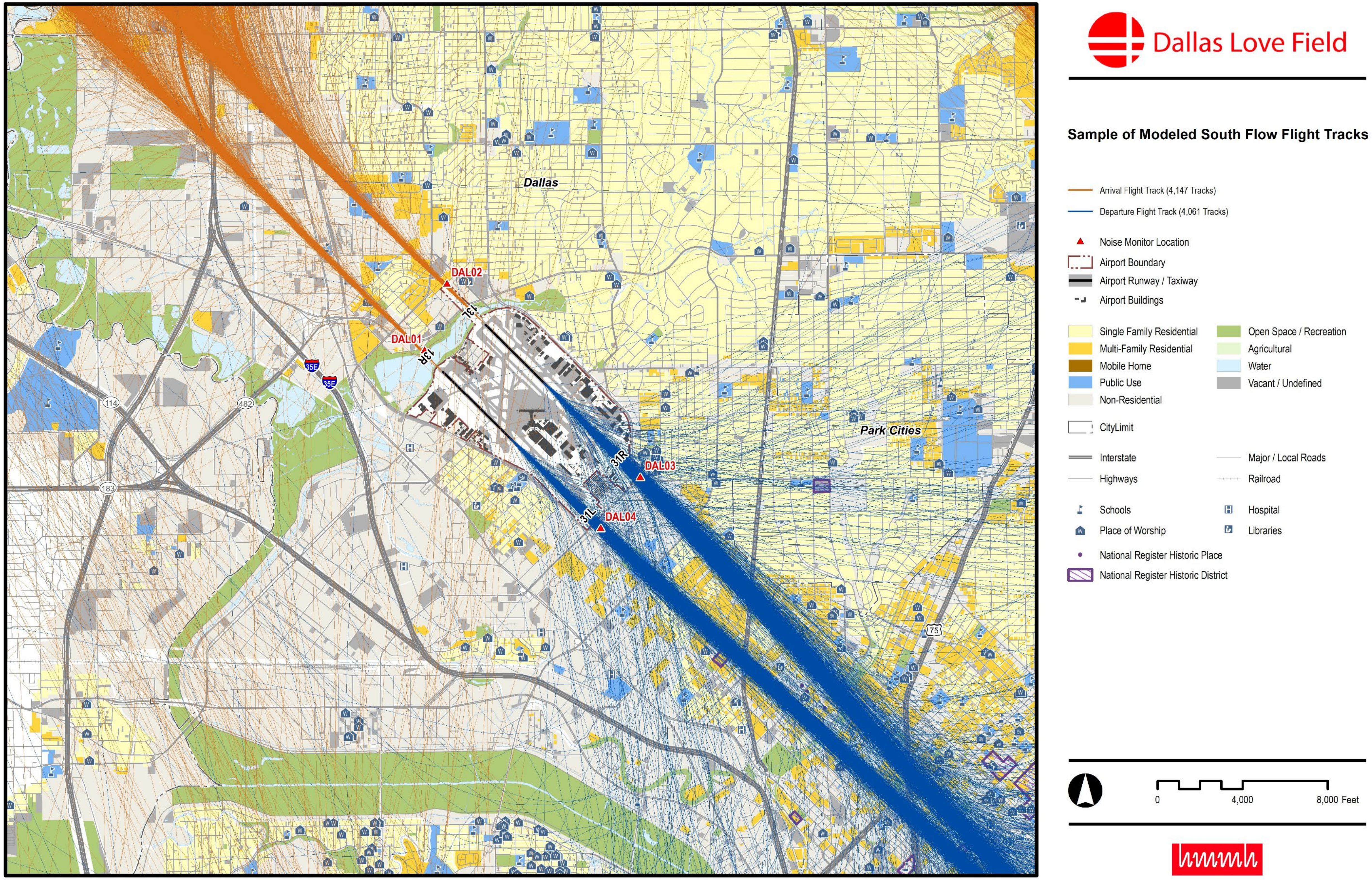

Author: Michael Hamilton; Path: \\FS3\Radar_Data\Projects\307XXX\307412_DAL_Annual_Contours_2018_2022\GIS\307412_DAL_2023_Flight_Tracks_South_Flow.mxd

Figure 12. Sample of Modeled South Flow Tracks

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4.5 Departure Stage Length

AEDT uses an aircraft's weight to determine takeoff performance criteria such as thrust and climb rate, which in turn affect the sound exposure level at locations on the ground. A substantial component of aircraft weight is fuel load. The fuel load of a departing aircraft varies primarily with the distance to its destination, which is referred to in AEDT as the stage length; in noise analyses, stage length serves as a proxy for aircraft weight. The AEDT noise and performance database includes a set of departure profiles for each aircraft type, covering each stage length category that the aircraft is likely to fly. In preparing the AEDT study, the preprocessor assigns a stage length to each departing flight based on the destination airport on the flight plan. The program calculates the great circle distance between the two airports and finds the stage length category corresponding to this distance, which determines the most appropriate departure profile available in the AEDT database. AEDT does not have profiles for all stage lengths available for all aircraft. In cases where the stage length (as determined by the distance calculation) is not available, the maximum stage length profile for that aircraft is selected. The preprocessor also checks the length of the takeoff roll in the given profile against the length of the runway being used; if the profile's takeoff roll is longer, then the maximum stage length available without overrunning the runway is selected.

Table 7 presents the ten categories for departure stage length used in AEDT and the respective number of departures modeled for 2023. 58 percent of departures from DAL were stage length 1 operations in 2023. This includes destinations such as El Paso and Saint Louis. Stage length 2 departures would include Las Vegas and Atlanta, while stage length 3 would reach most coastal cities including Los Angeles and Baltimore. Fewer than 1 percent of departures were stage length 4 or higher.

Table 7. Modeled 2023 Departure Stage Length Operations

Source: FAA AEDT 3f Technical Manual, HMMH analysis 2024

Stage Length Number	Trip Length (Nmi)	2023 Daily Departure Operations			
		Day	Night	Total	Total (%)
D-1	0 - 500	177.56	23.91	201.47	58%
D-2	500 - 1,000	93.03	12.80	105.83	31%
D-3	1,000 - 1,500	32.04	5.43	37.47	11%
D-4	1,500 - 2,500	0.16	0.02	0.18	0%
D-5	2,500 - 3,500	0.05	0.00	0.05	0%
D-6	3,500 - 4,500	0.10	0.03	0.13	0%
D-7	4,500 - 5,500	0.04	0.01	0.05	0%
D-8	5,500 - 6,500	0.00	0.00	0	0%
D-9	6,500 - 7,500	0.00	0.00	0	0%
D-10	7,500 - 8,500	0.00	0.00	0	0%
D-11	Greater than 8,500	0.00	0.00	0	0%
D-M	Max range at MTOW	0.00	<0.01	0	0%
	Total	**302.98**	**42.1**	**345.19**	**100%**

4.6 Meteorological Conditions

AEDT has several settings that affect aircraft performance profiles and sound propagation based on meteorological data. Meteorological settings include average annual temperature, barometric pressure, and relative humidity at the airport. AEDT holds the following values for annual average weather conditions at DAL as used for this project:

- Temperature: 67.26° F
- Pressure: 998.75 millibars
- Sea-level Pressure: 1016.27 millibars
- Relative Humidity 60.39%
- Dew Point: 53.05° F
- Wind Speed: 8.1 Knots

4.7 Terrain

Terrain data describes the elevation of the ground surrounding the airport and on airport property. If the AEDT user selects the use of terrain data, AEDT uses terrain data to adjust the ground level under the flight paths. The terrain data does not affect the aircraft's performance or noise levels but does affect the vertical distance between the aircraft and a "receiver" on the ground. This in turn affects noise propagation assumptions about how noise propagates over ground.

Terrain data was obtained from the United States Geological Survey (USGS) National Map Viewer[7] and used with the terrain feature of AEDT in generating the noise contours for the DAL 2023 Contour Analysis.

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[7] GridFloat USGS data in 1/3 arc second (about 33 feet) increments.

5 Noise Modeling Results and Land Use Exposure

5.1 Land Use

Figure 13 displays the land use in the area surrounding Dallas Love Field. The land use is differentiated into three residential categories (Single Family Residential, Multi-Family Residential and Mobile Home) and six non-residential categories (Public Use, Non-Residential, Open Space / Recreation, Agricultural, Water, and Vacant / Undefined). Residential areas are predominantly located to the north, east, and southeast of the airport with smaller groups of homes immediately to the northwest of the airfield and immediately adjacent to the airport on the west side. **Figure 13** also identifies locations of noise sensitive sites such as schools, places of worship, hospitals, and libraries within the surrounding area. All land use data was obtained through the City of Dallas GIS Services Division.

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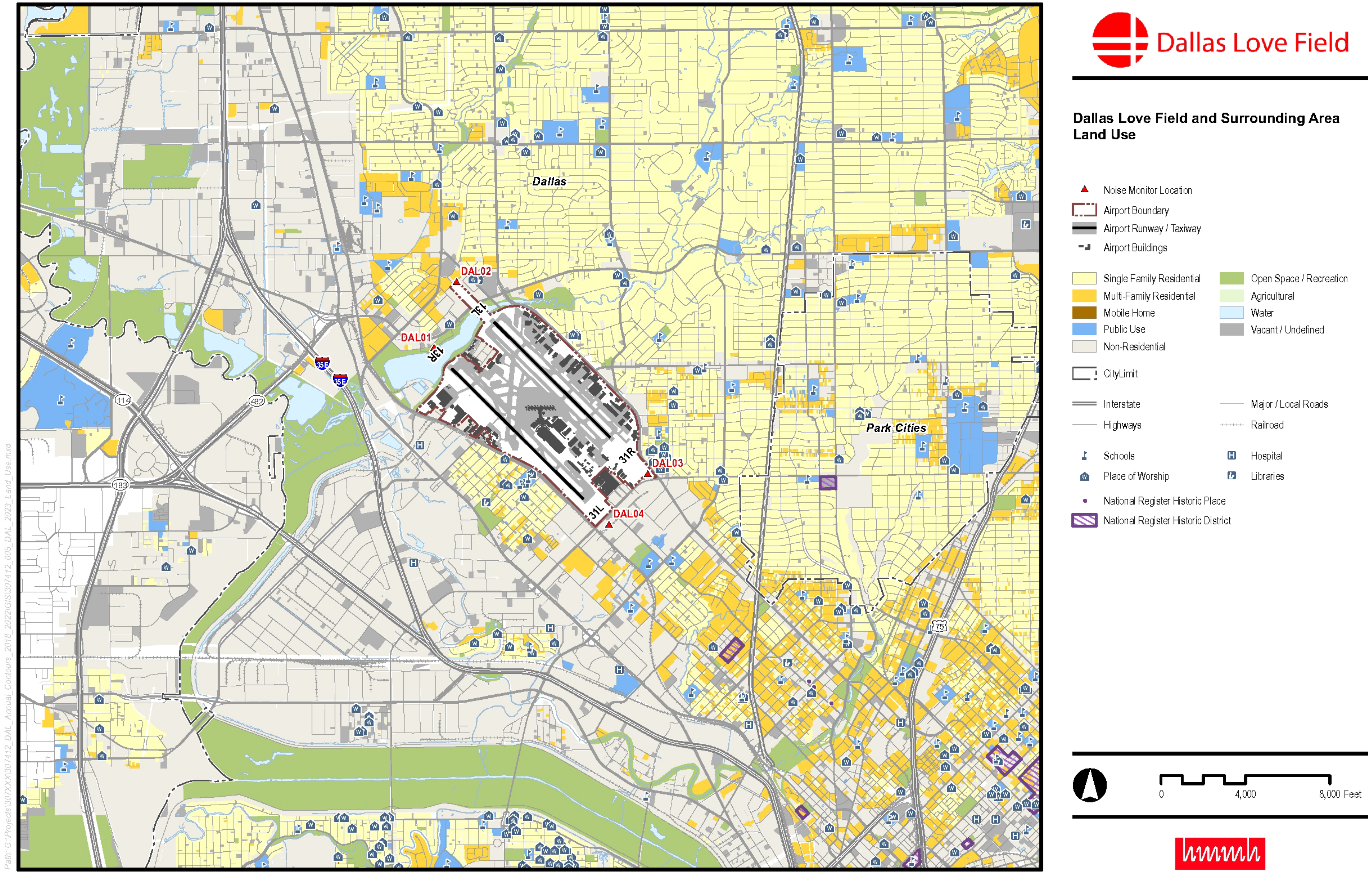

Figure 13. Dallas Love Field and Surrounding Area Land Use

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5.2 DNL Noise Contours

5.2.1 2023 Noise Contours

Figure 14 presents the 2023 DNL contours, 60 dB through 75 dB in five-dB intervals, overlaid on the land use base map provided in Section 5.1. The shape of the DNL contours is a function of the number of operations, the type of operation, the period during which the operations occurred, and, to some degree, the aircraft/engine combination. Arrival operations influence contour shapes in a different manner than departure operations do. The extended regions along the extended runway centerlines are due to both arrivals and departures, whereas the wider bulges at the runway ends and sides are primarily the result of sideline noise associated with departures.

The DNL 65 dB contour extends from the airfield as follows:

- To the northwest, the DNL 65 dB contour extends beyond the Calvary Hill Cemetery and Francisco ‘Pancho’ Medrano Middle School due to operations on Runway 13L/31R, and to Lombardy Lane due to operations on Runway 13R/31L.
- To the southeast, the DNL 65 dB contour extends near to the Dallas North Tollway along Lemmon Avenue due to operations on Runway 13L/31R, and past Maple Springs Boulevard due to operations on Runway 13R/31L.
- To the southwest along the sideline of Runway 13R/31L, the DNL 65 dB contour remains primarily within airport property except towards the end of Runway 31L where sideline noise extends to Thurston Drive (Maple Avenue).
- To the northeast along the sideline of Runway 13L/31R, the DNL 65 dB contour remains almost entirely within airport property except towards the end of Runway 31R where sideline noise extends several blocks along Thedford Avenue and Savage Street.

There are residential areas within the DNL 65 dB contour to the northwest of Runways 13L and 13R, to the west of Runway 13R/31L, southeast of Runway 31L, and east of Runway 31R. There are also six schools and eleven places of worship within the DNL 65 dB contour:

- Francisco 'Pancho' Medrano Middle School,
- Jose 'Joe' May Elementary School,
- Maple Lawn Elementary School,
- Obadiah Knight Elementary School,
- Thomas J. Rusk Middle School,
- Our Lady of Perpetual Help School,
- Bethany Missionary Baptist Church,
- Cristo Rey Presbyterian Church,
- Iglesia Pentecostal Roca De Poder,
- Macedonia Missionary Church,
- New Jerusalem AME Church,
- North Park CME Church,
- North Temple Baptist Church,
- Our Lady of Perpetual Help Catholic Church,
- Services of Hope,
- St Luke Missionary Baptist Church,
- The Greater North Park Church of God in Christ

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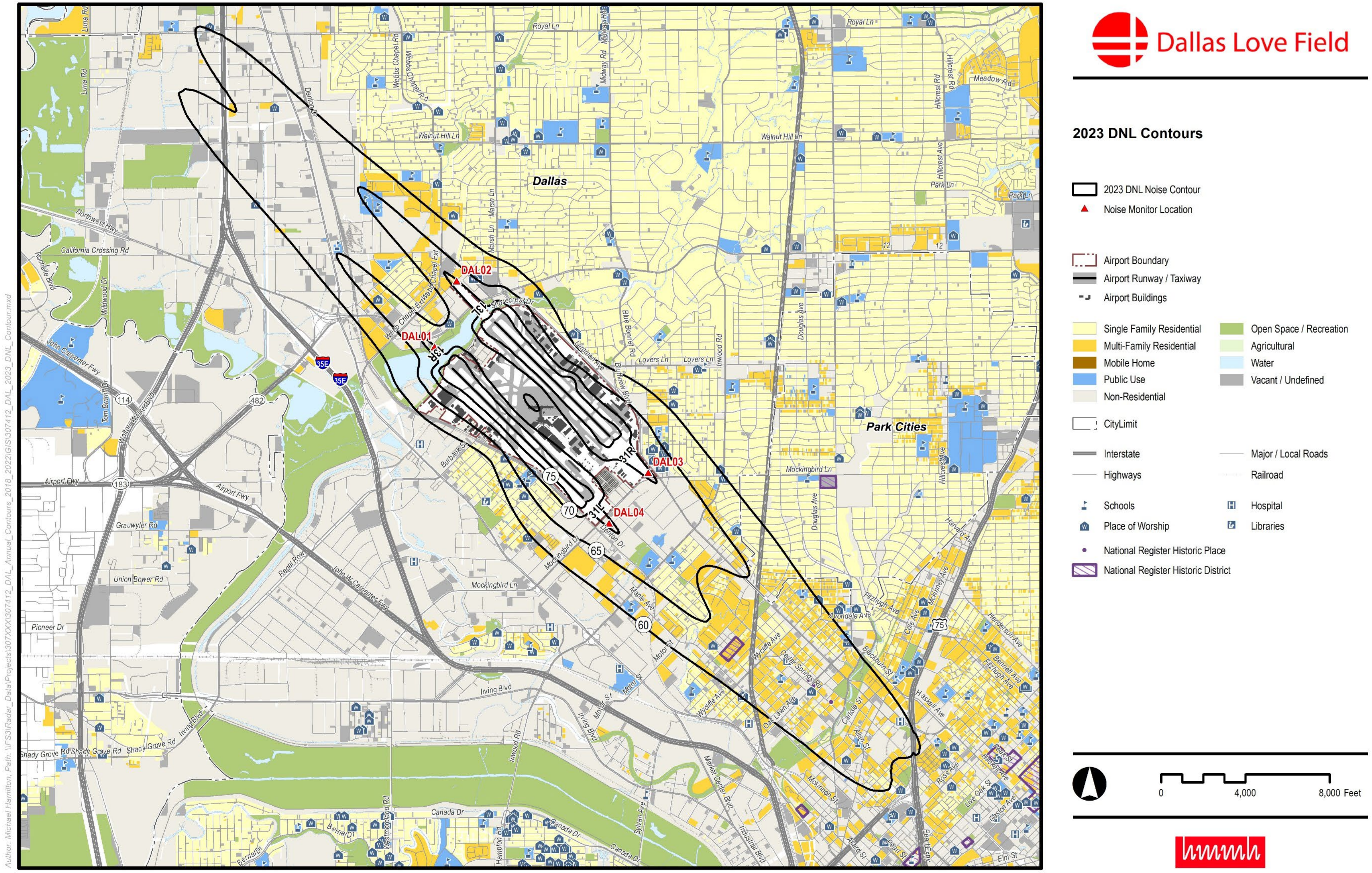

Figure 14. Dallas Love Field 2023 Noise Contour

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5.3 Comparison of the 2019, 2020, and 2023 Noise Contours

Figure 15 shows a comparison of the 2023 DNL contours to the 2019 and 2020 DNL contours for the DNL 60 dB through DNL 75 dB range. Changes in these contours over the years can be influenced by several factors, including the effects of the global pandemic on air travel, the number and type of aircraft operations particularly during nighttime, and changes in the runway utilization.

The total AAD aircraft operations have changed between the years. In 2020, there was a reduction in operations compared to 2019, due to reduced air travel during COVID-19 pandemic. The reduction in the modeled AAD for all aircraft categories contributed to the smaller noise contour due to fewer flights. The increase in operations in 2023 suggests a recovery and growth beyond pre-2020 levels. The total modeled AAD is higher than in previous years, with a notable increase in air carrier operations, which suggests that increased traffic contributes to the larger noise contour.

The percentage of arrivals and departures for different runways has changed over the years. For example, in 2019, there was heavier use of the 13R and 31R runways, while in 2023, the use is more evenly distributed among all runways. This can influence where and how noise is dispersed around the airport and is one of the primary causes of differing contour shapes. Shifts in runway usage patterns can be due to changes in air traffic management, noise abatement procedures, or other operational considerations. Nighttime operations can have a significant impact on noise contours due to the added nighttime weighting, and changes in the proportions of night arrivals and departures can affect the size and shape of the contours. For example, a reduction in nighttime flights on certain runways or overall can result in a smaller noise contour. Implementation of noise abatement procedures and operational restrictions, such as preferential runway use or altered flight paths, can also impact the noise contours.

The type of aircraft can affect the noise footprint. Newer aircraft models might be quieter, influencing the reduction of noise contours. The contours for each year are the result of complex interactions between these factors, reflecting the cumulative effect of airport operations.

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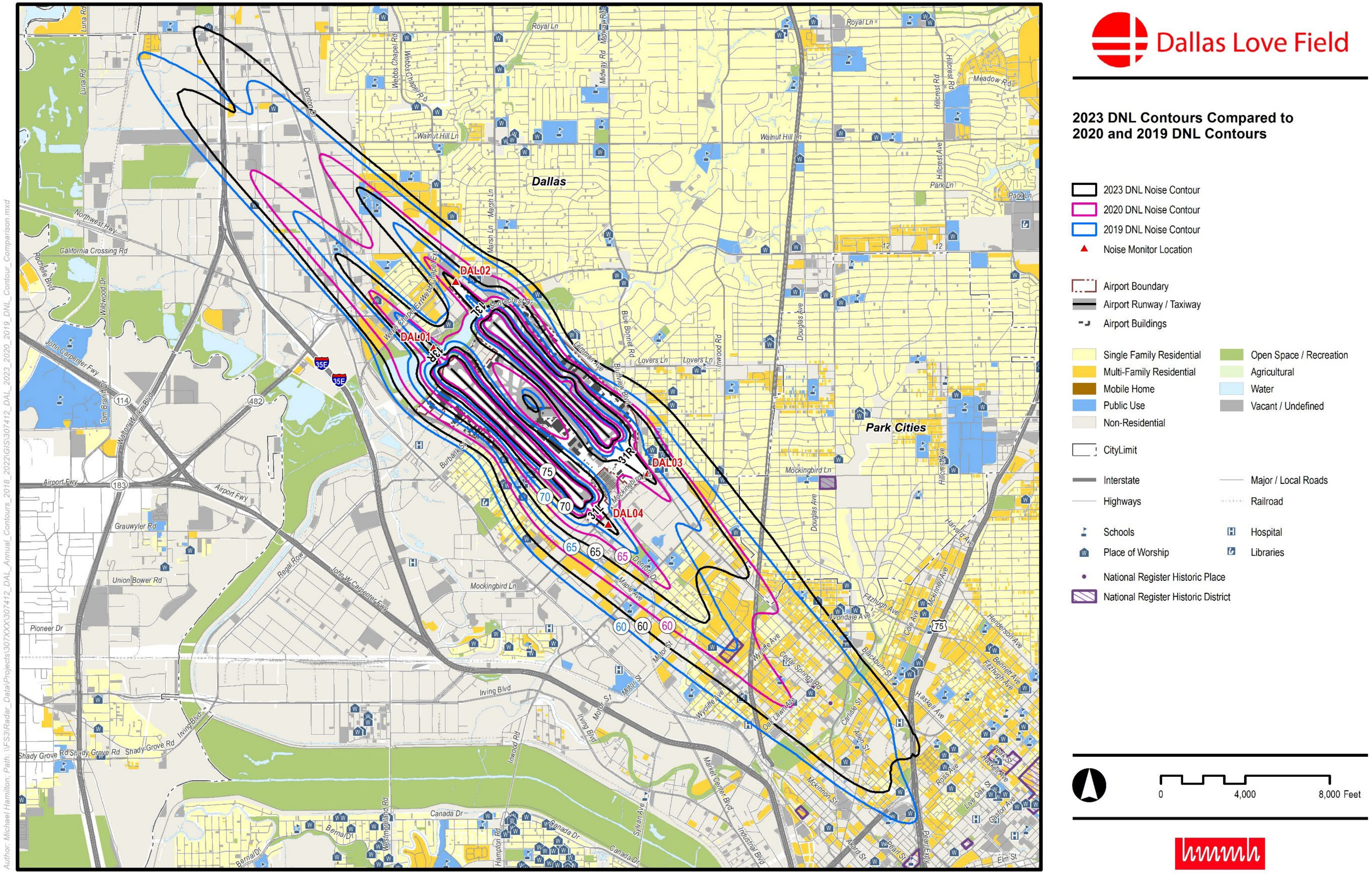

Figure 15. 2023 DNL Contours Compared to 2019 and 2020 DNL Contours

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5.4 Noise Monitor Location Results

DNL levels were computed and averaged over the associated operational period, resulting in an average measured DNL value. The Noise Lab system matches noise events to aircraft operations and supplied the aircraft-only noise event data. DNL values from aircraft operations were modeled at each of these sites using AEDT and are reported in **Table 8.** The measured values are provided for comparison. Measured and modeled values are generally within 1 dB. A permanent noise monitor installation is depicted in **Figure 16**.

Table 8. Modeled DNL at Noise Monitor Locations

Source: HMMH, DAL Noise Office

Noise Monitor Location			Day-Night Average Sound Level (DNL) dBA	Day-Night Average Sound Level (DNL) dBA	Periods Offline
Site	Latitude	Longitude	Modeled (AEDT)	Measured	
DAL01	32.853960	-96.866067	71.1	70.2	96 days (June 15 - Sept 18)
DAL02	32.862532	-96.862499	70.9	70.7	46 days (August 9 - Sept 18)
DAL03	32.837125	-96.833364	70.8	70.7	159 days (Jan 1 - Jan 16, Feb 21 - July 10)
DAL04	32.830612	-96.839535	70.9	70.3	16 days (Jan 1 - Jan 16)

Figure 16. DAL01 Permanent Noise Monitor Installation

5.5 Exposed Population and Land Area

The estimated area within the noise contours is listed in **Table 9**, and the exposed population, based on U.S. Census Data, is summarized in **Table 10**. The exposed population for 2023 is 35 percent smaller than the exposed population in 2006.

Table 9. Estimated Area within Noise Contours

Source: HMMH, 2024

DNL Noise Level (dBA)	Estimated Land Area Exposed to Given Noise Exposure Level (square miles)		
	2006	2019	2023
60-65	5.71	6.75	6.68
>65	4.62	3.95	4.04
65-70	2.68	2.65	2.74
70-75	1.08	0.76	0.76
>75	0.86	0.54	0.54
Note*: Airport property is included in total (1.93 sq. mi.)*			

Table 10. Estimated Population within Noise Exposure Area

Source: HMMH, 2024

DNL Noise Level (dBA)	Estimated Number of People Exposed to Given Noise Exposure Level		
	2006	2019	2023
60-65	42,603	52,538	59,019
>65	16,798	11,792	10, 802
65-70	15,858	11,489	10,549
70-75	936	303	253
>75	4	0	0
Note*: Data from the 2020 U.S. Census was utilized for 2023. For earlier years, the most recent U.S. Census data available at that time was used.*			

Appendix A. Noise Terminology

Noise is a complex physical quantity. The properties, measurement, and presentation of noise involve specialized terminology that can be difficult to understand. Throughout this appendix, we use graphics and everyday comparisons to communicate noise-related quantities and effects in reasonably simple terms. To provide a basic reference on these technical issues, this chapter introduces fundamentals of noise terminology, the effects of noise on human activity, and weather and distance effects.

Introduction to Noise Terminology

Analyses of potential impacts from changes in aircraft noise levels rely largely on a measure of cumulative noise exposure over an entire calendar year, expressed in terms of a metric called the Day-Night Average Sound Level (DNL/Ldn). However, DNL does not provide the only metric for measuring noise. A variety of metrics, which are further described in subsequent sub-sections, are used to describe noise, including:

- Sound Pressure Level, SPL, and the Decibel, dB
- A-Weighted Decibel, dBA
- Maximum A-Weighted Sound Level, Lmax
- Time Above, TA
- Sound Exposure Level, SEL
- Equivalent A-Weighted Sound Level, Leq
- Day-Night Average Sound Level, DNL/Ldn

Sound Pressure Level, SPL, and the Decibel, dB

All sounds come from a sound source—a musical instrument, a voice speaking, an airplane passing overhead. It takes energy to produce sound. The sound energy produced by any sound source travels through the air in sound waves—tiny, quick oscillations of pressure just above and just below atmospheric pressure. The ear senses these pressure variations and —with much processing in our brain—translates them into sound.

Our ears are sensitive to a wide range of sound pressures. The loudest sounds that we can hear without pain contain about one million times more energy than the quietest sounds we can detect. To allow us to perceive sound over this very wide range, our ear/brain “auditory system” compresses our response in a complex manner, represented by a term called sound pressure level (SPL), which we express in units called decibels (dB). Mathematically, SPL is a logarithmic quantity based on the ratio of two sound pressures, the numerator being the pressure of the sound source of interest (P_{source}), and the denominator being a reference pressure ($P_{reference}$).[8]

$$\text{Sound Pressure Level (SPL)} = 20 * Log\left(\frac{P_{source}}{P_{reference}}\right) dB$$

The logarithmic conversion of sound pressure to SPL means that the quietest sound that we can hear (the reference pressure) has a sound pressure level of about 0 dB, while the loudest sounds that we hear without pain have sound pressure levels of about 120 dB. Most sounds in our day-to-day environment have sound pressure levels from about 40 to 100 dB.[9]

Because decibels are logarithmic quantities, we cannot use common arithmetic to combine them. For example, if two sound sources each produce 100 dB operating individually, when they operate simultaneously, they produce

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[8] The reference pressure is approximately the quietest sound that a healthy young adult can hear.

[9] The logarithmic ratio used in its calculation means that SPL changes relatively quickly at low sound pressures and more slowly at high pressures. This relationship matches human detection of changes in pressure. We are much more sensitive to changes in level when the SPL is low (for example, hearing a baby crying in a distant bedroom), than we are to changes in level when the SPL is high (for example, when listening to highly amplified music).

103 dB—not the 200 dB we might expect. Increasing to four equal sources operating simultaneously will add another 3 dB of noise, resulting in a total SPL of 106 dB. For every doubling of the number of equal sources, the SPL goes up another 3 dB.

If one noise source is much louder than another is, the louder source masks the quieter one and the two sources together produce virtually the same SPL as the louder source alone. For example, a 100 dB and 80 dB sources produce approximately 100 dB of noise when operating together.

Two useful "rules of thumb" related to SPL are worth noting: (1) humans generally perceive a six to 10 dB increase in SPL to be about a doubling of loudness,[10] and (2) changes in SPL of less than about 3 dB for a particular sound are not readily detectable outside of a laboratory environment.

A-Weighted Decibel

An important characteristic of sound is its frequency, or pitch. This is the per-second oscillation rate of the sound pressure variation at our ear, expressed in units known as Hertz (Hz).

When analyzing the total noise of any source, acousticians often break the noise into frequency components (or bands) to consider the "low," "medium," and "high" frequency components. This breakdown is important for two reasons:

- Our ear is better equipped to hear mid and high frequencies and is least sensitive to lower frequencies. Thus, we find mid- and high-frequency noise more annoying.
- Engineering solutions to noise problems differ with frequency content. Low-frequency noise is generally harder to control.

The normal frequency range of hearing for most people extends from a low of about 20 Hz to a high of about 10,000 to 15,000 Hz. Most people respond to sound most readily when the predominant frequency is in the range of normal conversation – typically around 1,000 to 2,000 Hz. The acoustical community has defined several filters, which approximate this sensitivity of our ear and thus help us to judge the relative loudness of various sounds made up of many different frequencies.

The so-called "A" filter ("A-weighting") generally does the best job of matching human response to most environmental noise sources, including natural sounds and sound from common transportation sources. "A-weighted decibels" are abbreviated "dBA." Because of the correlation with our hearing, the U. S. Environmental Protection Agency (EPA) and nearly every other federal and state agency have adopted A-weighted decibels as the metric for use in describing environmental and transportation noise.

Figure A-1 depicts A-weighting adjustments to sound from approximately 20 Hz to 10,000 Hz.

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[10] A "10 dB per doubling" rule of thumb is the most often used approximation.

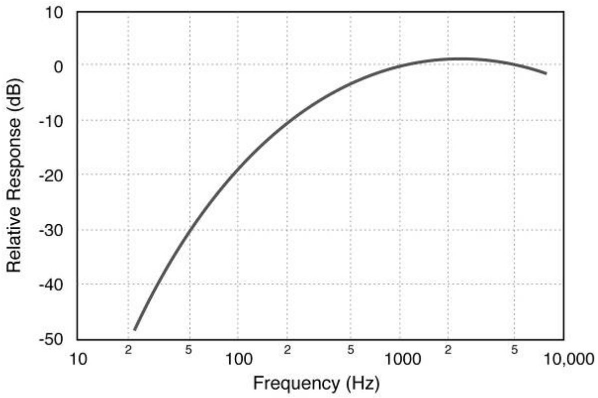

Figure A-1. A-Weighting Frequency Response

Source: Extract from Harris, Cyril M., Editor, "Handbook of Acoustical Measurements and Control," McGraw-Hill, Inc., 1991, pg. 5.13; HMMH

As the figure shows, A-weighting significantly de-emphasizes noise content at lower and higher frequencies where we do not hear as well, and has little effect, or is nearly "flat," in for mid-range frequencies between 1,000 and 5,000 Hz. All sound pressure levels presented in this document are A-weighted unless otherwise specified.

Figure A-2 depicts representative A-weighted sound levels for a variety of common sounds.

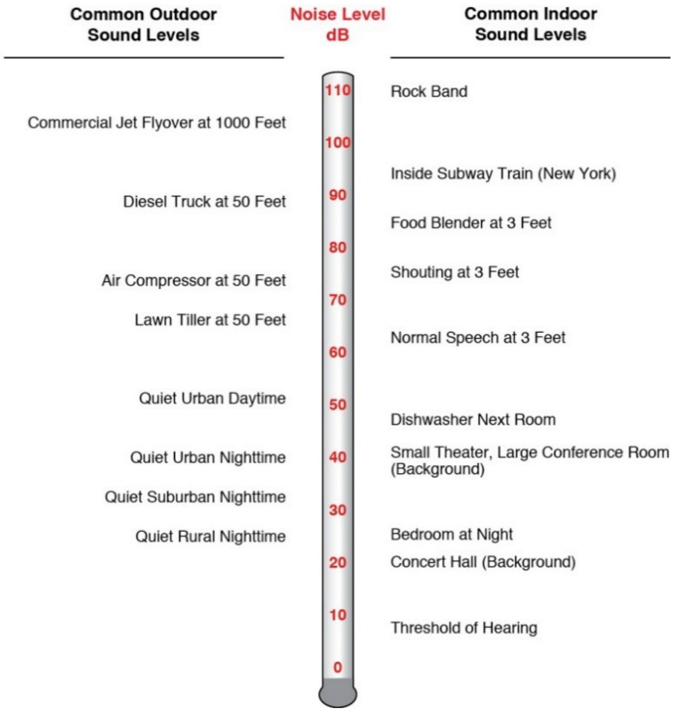

Figure A-2. A-Weighted Sound Levels for Common Sounds

Maximum A-Weighted Sound Level, Lmax

An additional dimension to environmental noise is that A-weighted levels vary with time. For example, the sound level increases as a car or aircraft approaches, then falls and blends into the background as the aircraft recedes into the distance. The background or ambient level continues to vary in the absence of a distinctive source, for example due to birds chirping, insects buzzing, leaves rustling, etc. It is often convenient to describe a particular noise event (such as a vehicle passing by, a dog barking, etc.) by its maximum sound level, abbreviated as Lmax.

Figure A-3 depicts this general concept for a hypothetical noise event with an Lmax of approximately 102 dB.

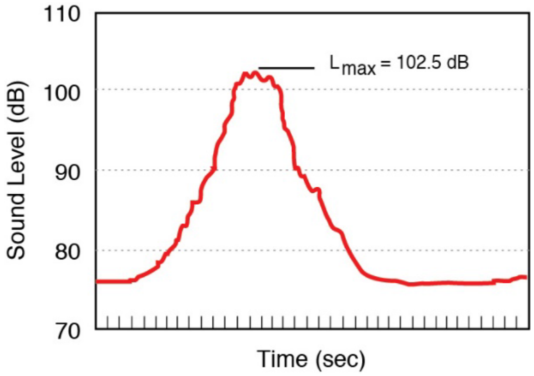

Figure A-3. Variation in A-Weighted Sound Level over Time and Maximum Noise Level

Source: HMMH

While the maximum level is easy to understand, it suffers from a serious drawback when used to describe the relative noisiness of an event such as an aircraft flyover; i.e., it describes only one dimension of the event and provides no information on the event's overall, or cumulative, noise exposure. In fact, two events with identical maximum levels may produce very different total exposures. One may be of very short duration, while the other may continue for an extended period and be judged much more annoying. The next section introduces a measure that accounts for this concept of a noise "dose," or the cumulative exposure associated with an individual noise event such as an aircraft flyover.

Sound Exposure Level, SEL

The most commonly used measure of cumulative noise exposure for an individual noise event, such as an aircraft flyover, is the Sound Exposure Level, or SEL. SEL is a summation of the A-weighted sound energy over the entire duration of a noise event. SEL expresses the accumulated energy in terms of the one-second-long steady-state sound level that would contain the same amount of energy as the actual time-varying level.

SEL provides a basis for comparing noise events that generally match our impression of their overall "noisiness," including the effects of both duration and level. The higher the SEL, the more annoying a noise event is likely to be. In simple terms, SEL compresses the energy for the noise event into a single second. **Figure A-4** depicts this compression, for the same hypothetical event shown in **Figure A-3**. Note that the SEL is higher than the Lmax.

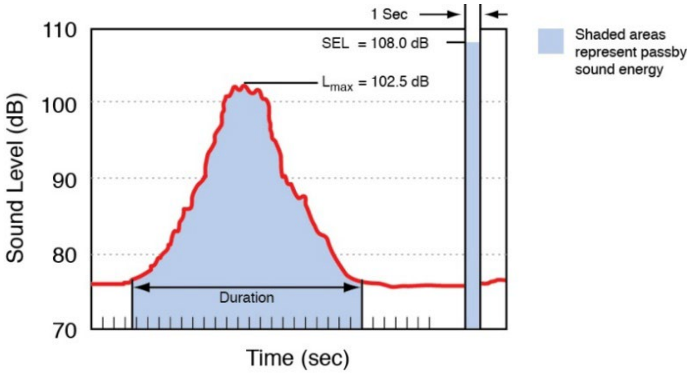

Figure A-4. Graphical Depiction of Sound Exposure Level

Source: HMMH

The compression of energy into one second means that a given noise event's SEL will almost always will be a higher value than its Lmax. For most aircraft flyovers, SEL is roughly 5 to 12 dB higher than Lmax. Adjustment for duration means that relatively slow and quiet propeller aircraft can have the same or higher SEL than faster, louder jets, which produce shorter duration events.

Equivalent A-Weighted Sound Level, Leq

The Equivalent Sound Level, abbreviated Leq, is a measure of the exposure resulting from the accumulation of sound levels over a particular period of interest; e.g., one hour, an eight-hour school day, nighttime, or a full 24-hour day. Leq plots for consecutive hours can help illustrate how the noise dose rises and falls over a day or how a few loud aircraft significantly affect some hours.

Leq may be thought of as the constant sound level over the period of interest that would contain as much sound energy as the actual varying level. It is a way of assigning a single number to a time-varying sound level. **Figure A-5** illustrates this concept for the same hypothetical event shown in **Figure A-3** and **Figure A-4**. Note that the Leq is lower than either the Lmax or SEL.

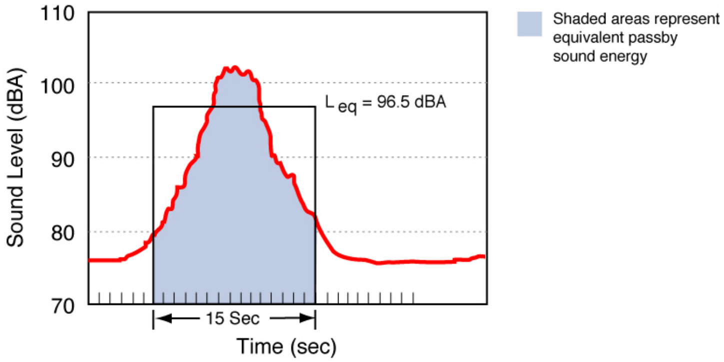

Figure A-5. Example of a 15-Second Equivalent Sound Level

Source: HMMH

Day-Night Average Sound Level, DNL or L_{dn}

The FAA requires that airports use a measure of noise exposure that is slightly more complicated than Leq to describe cumulative noise exposure – the Day-Night Average Sound Level, DNL.

The U.S. Environmental Protection Agency identified DNL as the most appropriate means of evaluating airport noise based on the following considerations:[11]

- The measure should be applicable to the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods.
- The measure should correlate well with known effects of the noise environment and on individuals and the public.
- The measure should be simple, practical, and accurate. In principle, it should be useful for planning as well as for enforcement or monitoring purposes.
- The required measurement equipment, with standard characteristics, should be commercially available.
- The measure should be closely related to existing methods currently in use.
- The single measure of noise at a given location should be predictable, within an acceptable tolerance, from knowledge of the physical events producing the noise.
- The measure should lend itself to small, simple monitors, which can be left unattended in public areas for long periods.

Most federal agencies dealing with noise have formally adopted DNL. The Federal Interagency Committee on Noise (FICON) reaffirmed the appropriateness of DNL in 1992. The FICON summary report stated: “There are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric.”

In simple terms, DNL is the 24-hour Leq with one adjustment; all noises occurring at night (defined as 10 p.m. through 7 a.m.) are increased by 10 dB to reflect the added intrusiveness of nighttime noise events when background noise levels decrease. In calculating aircraft exposure, this 10 dB increase is mathematically identical to counting each nighttime aircraft noise event ten times.

DNL can be measured or estimated. Measurements are practical only for obtaining DNL values for limited numbers of points, and, in the absence of a permanently installed monitoring system, only for relatively short periods. Most airport noise studies use computer-generated DNL estimates depicted as equal-exposure noise contours (much as topographic maps have contours of equal elevation).

The annual DNL is mathematically identical to the DNL for the average annual day; i.e., a day on which the number of operations is equal to the annual total divided by 365 (366 in a leap year). **Figure A-6** graphically depicts the manner in which the nighttime adjustment applies in calculating DNL. **Figure A-7** presents representative outdoor DNL values measured at various U.S. locations.

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[11] "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U. S. EPA Report No. 550/9-74-004, March 1974.

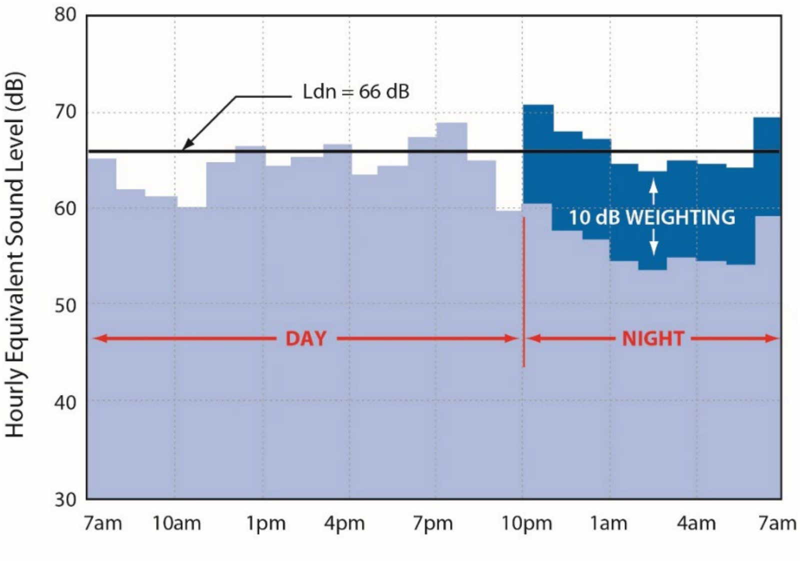

Figure A-6. Example of a Day-Night Average Sound Level Calculation

Source: HMMH

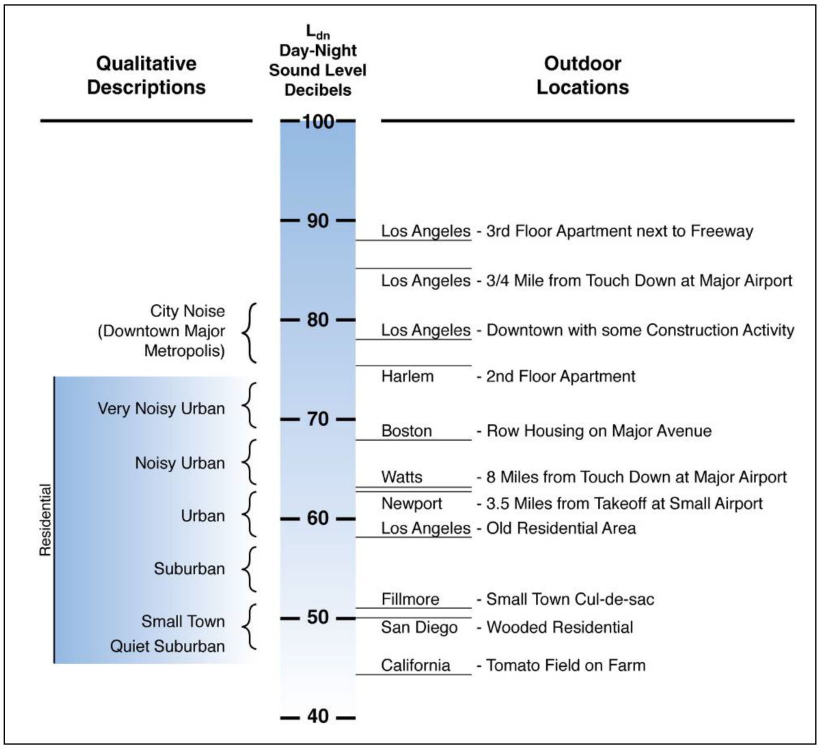

Figure A-7. Examples of Measured Day-Night Average Sound Levels, DNL

Source: U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," March 1974, p.14.

Aircraft Noise Effects on Human Activity

Aircraft noise can be an annoyance and a nuisance. It can interfere with conversation and listening to television, disrupt classroom activities in schools, and disrupt sleep. Relating these effects to specific noise metrics helps in the understanding of how and why people react to their environment.

Speech Interference

One potential effect of aircraft noise is its tendency to mask speech, making it difficult to carry on a normal conversation. The sound level of speech decreases as the distance between a talker and listener increases. As the background sound level increases, it becomes harder to hear speech.

Figure A-8 presents typical distances between talker and listener for satisfactory outdoor conversations, in the presence of different steady A-weighted background noise levels for raised, normal, and relaxed voice effort. As the background level increases, the talker must raise his/her voice, or the individuals must get closer together to continue talking.

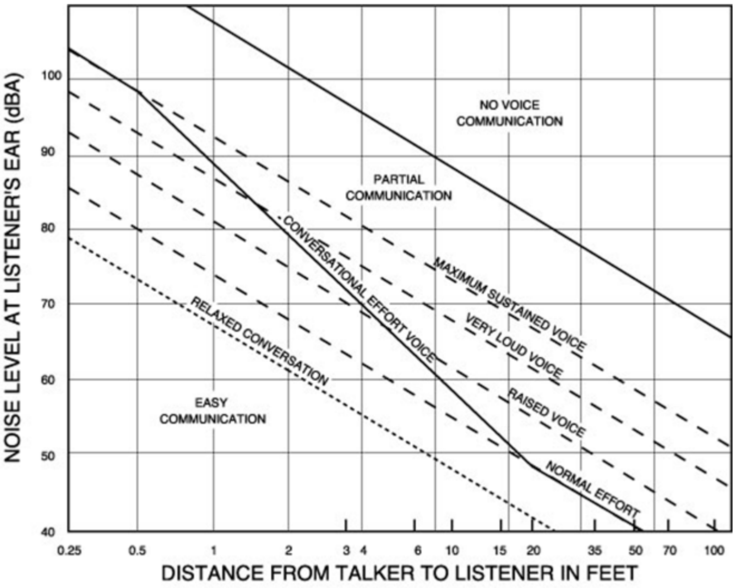

Figure A-8. Outdoor Speech Intelligibility

Source: U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," March 1974, p.D-5.

Satisfactory conversation does not always require hearing every word; 95% intelligibility is acceptable for many conversations. In relaxed conversation, however, we have higher expectations of hearing speech and generally require closer to 100% intelligibility. Any combination of talker-listener distances and background noise that falls below the bottom line in the figure (which roughly represents the upper boundary of 100% intelligibility) represents an ideal environment for outdoor speech communication. Indoor communication is generally acceptable in this region as well.

One implication of the relationships in **Figure A-8** is that for typical communication distances of 3 or 4 feet, acceptable outdoor conversations can be carried on in a normal voice as long as the background noise outdoors is less than about 65 dB. If the noise exceeds this level, as might occur when an aircraft passes overhead, intelligibility would be lost unless vocal effort were increased or communication distance were decreased.

Indoors, typical distances, voice levels, and intelligibility expectations generally require a background level less than 45 dB. With windows partly open, housing generally provides about 10 to 15 dB of interior-to-exterior noise level reduction. Thus, if the outdoor sound level is 60 dB or less, there is a reasonable chance that the resulting indoor sound level will afford acceptable interior conversation. With windows closed, 24 dB of attenuation is typical.

Sleep Interference

Research on sleep disruption from noise has led to widely varying observations. In part, this is because (1) sleep can be disturbed without awakening, (2) the deeper the sleep the more noise it takes to cause arousal, (3) the tendency to awaken increases with age, as well as other factors. **Figure A-9** shows a summary of findings on the topic.

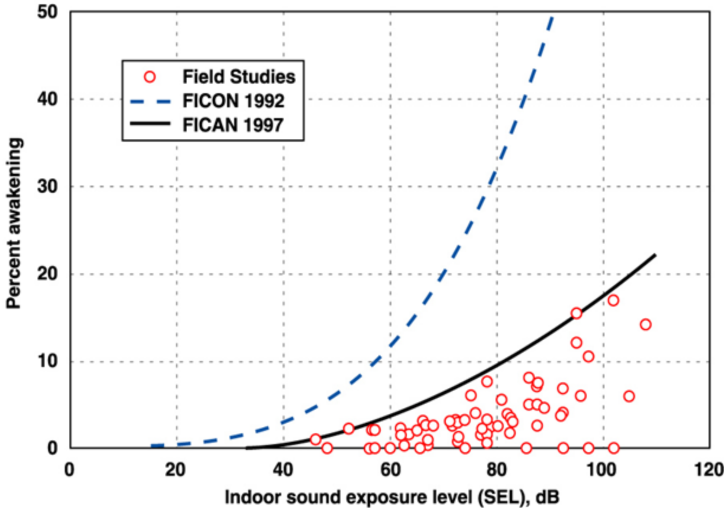

Figure A-9. Sleep Interference

Source: Federal Interagency Committee on Aircraft Noise (FICAN), "Effects of Aviation Noise on Awakenings from Sleep," June 1997, pg. 6

Figure A-9 uses indoor SEL as the measure of noise exposure; current research supports the use of this metric in assessing sleep disruption. An indoor SEL of 80 dBA results in a maximum of 10% awakening.[12]

Community Annoyance

Numerous psychoacoustic surveys provide substantial evidence that individual reactions to noise vary widely with noise exposure level. Since the early 1970s, researchers have determined (and subsequently confirmed) that aggregate community response is generally predictable and relates reasonably well to cumulative noise exposure such as DNL. **Figure A-10** depicts the widely recognized relationship between environmental noise and the percentage of people "highly annoyed," with annoyance being the key indicator of community response usually cited in this body of research.

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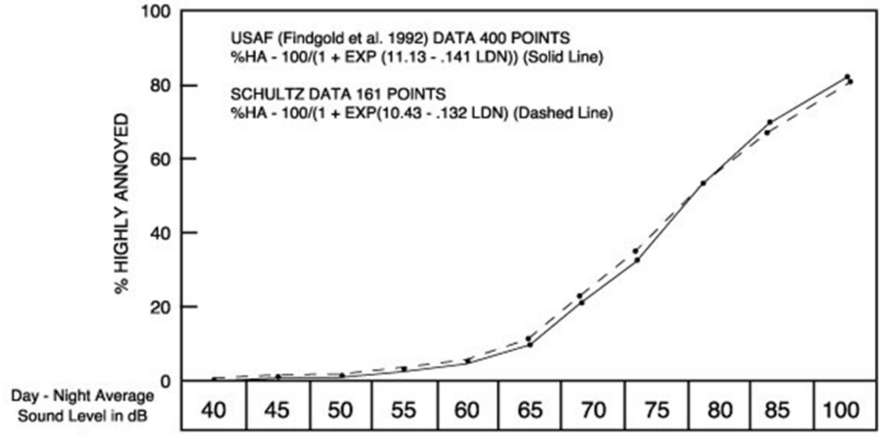
[12] The awakening data presented in Figure A-9 apply only to individual noise events. The American National Standards Institute (ANSI) has published a standard that provides a method for estimating the number of people awakened at least once from a full night of noise events: ANSI/ASA S12.9-2008 / Part 6, "Quantities and Procedures for Description and Measurement of Environmental Sound – Part 6: Methods for Estimation of Awakenings Associated with Outdoor Noise Events Heard in Homes." This method can use the information on single events computed by a program such as the FAA's Aviation Environmental Design Tool, to compute awakenings.



Calculated %HA Points											
	USAF	0.41	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
	SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81

Figure A-10. Percentage of People Highly Annoyed

Source: FICON, "Federal Agency Review of Selected Airport Noise Analysis Issues," September 1992

Separate work by the EPA has shown that overall community reaction to a noise environment is also dependent on DNL. **Figure A-11** depicts this relationship.

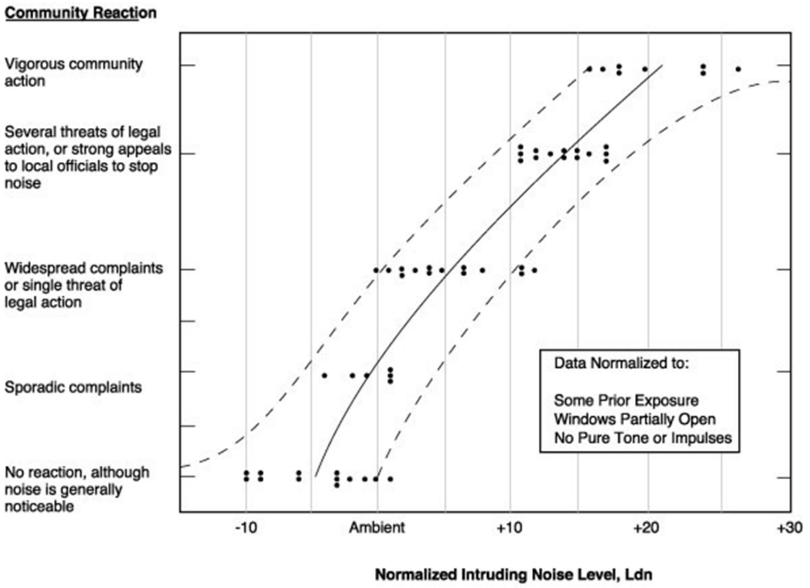


Figure A-11. Community Reaction as a Function of Outdoor DNL

Source: Wyle Laboratories, Community Noise, prepared for the U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C., December 1971, pg. 63

Data summarized in the figure suggest that little reaction would be expected for intrusive noise levels 5 dB below the ambient, while widespread complaints can be expected as intruding noise exceeds background levels by about 5 dB. Vigorous action is likely when levels exceed the background by 20 dB.

Noise Propagation

This section presents information sound-propagation effect due to weather, source-to-listener distance, and vegetation.

Weather-Related Effects

Weather (or atmospheric) conditions that can influence the propagation of sound include humidity, precipitation, temperature, wind, and turbulence (or gustiness). The effect of wind—turbulence in particular—is generally more important than the effects of other factors. Under calm wind conditions, the importance of temperature (in particular, vertical “gradients”) can increase, sometimes to very significant levels. Humidity generally has little significance relative to the other effects.

Influence of Humidity and Precipitation

Humidity and precipitation rarely affect sound propagation in a significant manner. Humidity can reduce propagation of high-frequency noise under calm wind conditions. This is called “atmospheric absorption.” In very cold conditions, listeners often observe that aircraft sound “tinny,” because the dry air increases the propagation of high-frequency sound. Rain, snow, and fog also have little, if any, noticeable effect on sound propagation. A substantial body of empirical data supports these conclusions.[13]

Influence of Temperature

The velocity of sound in the atmosphere depends on the air temperature.[14] As a result, if the temperature varies at different heights above the ground, sound will travel in curved paths rather than straight lines. During the day, temperature normally decreases with increasing height. Under such “temperature lapse" conditions, the atmosphere refracts ("bends") sound waves upwards and an acoustical shadow zone may exist at some distance from the noise source.

Under some weather conditions, an upper level of warmer air may trap a lower layer of cool air. Such a temperature inversion is most common in the evening, at night, and early in the morning when heat absorbed by the ground during the day radiates into the atmosphere.[15] The effect of an inversion is the opposite of lapse conditions. It causes sound propagating through the atmosphere to refract downward.

The downward refraction caused by temperature inversions often allows sound rays with originally upward-sloping paths to bypass obstructions and ground effects, increasing noise levels at greater distances. This type of effect is most prevalent at night, when temperature inversions are most common and when wind levels often are very low, limiting any confounding factors.[16] Under extreme conditions, one study found that noise from ground-borne aircraft might be amplified 15 to 20 dB by a temperature inversion. In a similar study, noise caused by an aircraft on the ground registered a higher level at an observer location 1.8 miles away than at a second observer location only 0.2 miles from the aircraft.[17]

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[13] Ingard, Uno. “A Review of the Influence of Meteorological Conditions on Sound Propagation,” *Journal of the Acoustical Society of America*, Vol. 25, No. 3, May 1953, p. 407.

[14] In dry air, the approximate velocity of sound can be obtained from the relationship:
$c = 331 + 0.6T_c$ (c in meters per second, T_c in degrees Celsius). Pierce, Allan D., *Acoustics: An Introduction to its Physical Principles and Applications.* McGraw-Hill. 1981. p. 29.

[15] Embleton, T.F.W., G.J. Thiessen, and J.E. Piercy, “Propagation in an inversion and reflections at the ground,” *Journal of the Acoustical Society of America*, Vol. 59, No. 2, February 1976, p. 278.

[16] Ingard, p. 407.

[17] Dickinson, P.J., “Temperature Inversion Effects on Aircraft Noise Propagation,” (Letters to the Editor) *Journal of Sound and Vibration.* Vol. 47, No. 3, 1976, p. 442.

Influence of Wind

Wind has a strong directional component that can lead to significant variation in propagation. In general, receivers that are downwind of a source will experience higher sound levels, and those that are upwind will experience lower sound levels. Wind perpendicular to the source-to-receiver path has no significant effect.

The refraction caused by wind direction and temperature gradients is additive.[18] One study suggests that for frequencies greater than 500 Hz, the combined effects of these two factors tends towards two extreme values: approximately 0 dB in conditions of downward refraction (temperature inversion or downwind propagation) and a reduction of 20 dB in upward refraction conditions (temperature lapse or upwind propagation). At lower frequencies, the effects of refraction due to wind and temperature gradients are less pronounced.[19]

Wind turbulence (or “gustiness”) can also affect sound propagation. Sound levels heard at remote receiver locations will fluctuate with gustiness. Also, gustiness can cause considerable attenuation of sound due to effects of eddies traveling with the wind. Attenuation due to eddies is essentially the same in all directions, with or against the flow of the wind, and can mask the refractive effects of the wind. [20]

Distance-Related Effects

People often ask how distance from an aircraft to a listener affects sound levels. Changes in distance may be associated with varying terrain, offsets to the side of a flight path, or aircraft altitude. The answer is a bit complex because distance affects the propagation of sound in several ways. The principal effect results from the fact that any emitted sound expands in a spherical fashion – like a balloon – as the distance from the source increases, resulting in the sound energy being spread out over a larger volume. With each doubling of distance, spherical spreading reduces instantaneous or maximum level by approximately six decibels and SEL by approximately 3 dB.

Vegetation-Related Effects

Sound can be scattered and absorbed as it travels through vegetation. This results in a decrease in sound levels. The literature on the effect of vegetation on sound propagation contains several approaches to calculating its effect. Though these approaches differ in some respects, they agree on the following:

- The vegetation must be dense and deep enough to block the line of sight.
- The noise reduction is greatest at high frequencies and least at low frequencies.

The International Standard ISO 9613-2[21] provides a useful example of the types of calculations employed in these methods. Originally developed for industrial noise sources, ISO 9613-2 is well-suited for the evaluation of ground-based aircraft noise sources under favorable meteorological conditions for sound propagation. ISO 9613-2’s methodology for calculating sound propagation includes geometric dispersion from acoustical point sources, atmospheric absorption, the effects of areas of hard and soft ground, screening due to barriers, and reflections. The attenuation provided by dense foliage varies by octave band and by distance as shown in Table A-1.

For propagation through less than 10 m of dense foliage, no attenuation is assumed. For propagation through 10 m to 20 m of dense foliage, the total attenuation is shown in the first row of

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[18] Piercy and Embleton, p. 1412. Note, in addition, that as a result of the scalar nature of temperature and the vector nature of wind, the following is true: under lapse conditions, the refractive effects of wind and temperature add in the upwind direction and cancel each other in the downwind direction. Under inversion conditions, the opposite is true.

[19] Piercy and Embleton, p. 1413.

[20] Ingard, pp. 409-410.

[21] International Organization for Standardization, Acoustics – Attenuation of sound during propagation outdoors – Part 2: General Method of calculation, International Standard ISO9613-2, Geneva, Switzerland (15 December 1996).

Table A-1. For distances between 20 m and 200 m, the total attenuation is computed by multiplying the distance of propagation through dense foliage by the dB/m values shown in the second row of

Table A-1. Dense Foliage Noise Attenuation

Source: ISO 9613-2, Table A.1

Propagation Distance	Nominal Midband Frequency (Hz)							
	63	125	250	500	1,000	2,000	4,000	8,000
10 m to 20 m (dB Attenuation)	0	0	1	1	1	1	2	3
20 m to 200 m (dB/m Attenuation)	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.12

ISO 9613-2 assumes a moderate downwind condition. The equations in the ISO Standard also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights. In either case, the sound is refracted downward. The radius of this curved path is assumed to be 5 km. With this curved sound path, only portions of the sound path may travel through the dense foliage, as illustrated by **Figure A-12**. Thus, the relative locations of the source and receiver, the dimensions of the volume of dense foliage, and the contours of the intervening terrain are essential to the estimation of the noise attenuation.

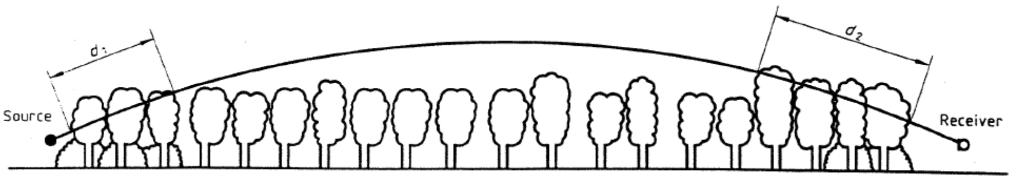

Figure A-12. Downward Refracting Sound Path

Source: ISO 9613-2

As illustrated in **Figure A-12**, the foliage only provides attenuation if the sound path passes through the foliage. For aircraft in the air, the sound will pass through little, if any foliage. Additionally, either the noise source or receiver must be near the foliage for it to have an effect.