Western-Pacific Region
Los Angeles, CA 90009

National Park Service
Fort Collins, CO 80525

Baseline Ambient Sound Levels in *Death Valley National Park*

Final Report
DOT-VNTSC-NPS-11-19
July 2011

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE July 2011	3. REPORT TYPE AND DATES COVERED Final Report

4. TITLE AND SUBTITLE Baseline Ambient Sound Levels in Death Valley National Park	5. FUNDING NUMBERS VX-82/JM938
6. AUTHOR(S) Cynthia Lee and John MacDonald	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Research and Innovative Technology Administration John A. Volpe National Transportation Systems Center Environmental Measurement and Modeling Division, RVT-41 Acoustics Facility Cambridge, MA 02142-1093	8. PERFORMING ORGANIZATION REPORT NUMBER DOT-VNTSC-NPS-11-19
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Aviation Administration Western-Pacific Regional Office Washington, DC 20591	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
NPS Program Manager: Lelaina Marin (NPS Natural Sounds and Night Skies Division); FAA Program Manager: Keith Lusk (AWP, Western-Pacific Regional Office, Special Programs Staff)

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Federal Aviation Administration (FAA), with the cooperation of the National Park Service (NPS) and assistance of the U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) is developing Air Tour Management Plans (ATMP) for all national parks with commercial air tours, with the exception of the Grand Canyon National Park (GCNP), tribal lands within or abutting the GCNP, air tour operations flying over or near the Lake Mead National Recreation Area solely as a transportation route to conduct an air tour over GCNP, Rocky Mountain National Park, and national park units located in Alaska. An important area of technical support is the determination of representative baseline ambient sound levels for the study parks. During the summer (April - May 2008), the Volpe Center conducted baseline ambient sound level measurements in Death Valley National Park. Approximately one month of acoustical and meteorological data were measured at seven sites. This document summarizes the results of the noise measurement study.

14. SUBJECT TERMS Aircraft noise, air tours, ambient, acoustic zones, noise impact, noise, Air Tour Management Plan, ATMP, National Park	15. NUMBER OF PAGES 128
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

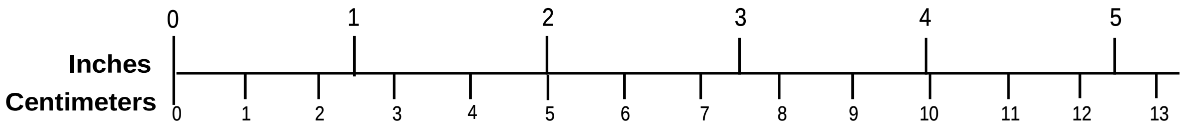
Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

Page left blank intentionally.

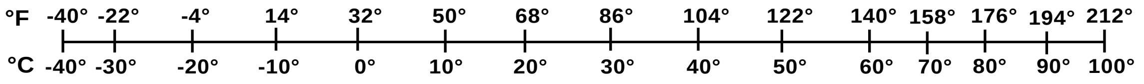
METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC			METRIC TO ENGLISH		
LENGTH (APPROXIMATE)			**LENGTH** (APPROXIMATE)		
1 inch (in)	=	2.5 centimeters (cm)	1 millimeter (mm)	=	0.04 inch (in)
1 foot (ft)	=	30 centimeters (cm)	1 centimeter (cm)	=	0.4 inch (in)
1 yard (yd)	=	0.9 meter (m)	1 meter (m)	=	3.3 feet (ft)
1 mile (mi)	=	1.6 kilometers (km)	1 meter (m)	=	1.1 yards (yd)
			1 kilometer (km)	=	0.6 mile (mi)
AREA (APPROXIMATE)			**AREA** (APPROXIMATE)		
1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)	1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)	1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)	1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)	10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)			
MASS - WEIGHT (APPROXIMATE)			**MASS - WEIGHT** (APPROXIMATE)		
1 ounce (oz)	=	28 grams (gm)	1 gram (gm)	=	0.036 ounce (oz)
1 pound (lb)	=	0.45 kilogram (kg)	1 kilogram (kg)	=	2.2 pounds (lb)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)	1 tonne (t)	=	1,000 kilograms (kg)
				=	1.1 short tons
VOLUME (APPROXIMATE)			**VOLUME** (APPROXIMATE)		
1 teaspoon (tsp)	=	5 milliliters (ml)	1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 tablespoon (tbsp)	=	15 milliliters (ml)	1 liter (l)	=	2.1 pints (pt)
1 fluid ounce (fl oz)	=	30 milliliters (ml)	1 liter (l)	=	1.06 quarts (qt)
1 cup (c)	=	0.24 liter (l)	1 liter (l)	=	0.26 gallon (gal)
1 pint (pt)	=	0.47 liter (l)			
1 quart (qt)	=	0.96 liter (l)			
1 gallon (gal)	=	3.8 liters (l)			
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)	1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)	1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)
TEMPERATURE (EXACT)			**TEMPERATURE** (EXACT)		
[(x-32)(5/9)] °F	=	y °C	[(9/5) y + 32] °C	=	x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

ACKNOWLEDGEMENTS

The authors of this report wish to express their sincere gratitude to all who helped make this a successful study. The Federal Aviation Administration (FAA), Western-Pacific Regional Office, and National Park Service (NPS), Natural Sounds Office, proved invaluable coordination and support. We would also like to thank David Ek and his entire team at Death Valley National Park for their expertise and assistance during site selection and deployment. Finally, thanks to Ericka Pilcher (NPS Natural Sounds and Night Skies Division), Bob Samiljan (Computer Services Corporation) and Chris Scarpone (Volpe Center), who also participated in the field measurement effort.

Page left blank intentionally.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA), with the cooperation of the National Park Service (NPS) and assistance of the U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) is developing Air Tour Management Plans (ATMP) for all national parks with commercial air tours, with the exception of the Grand Canyon National Park (GCNP), tribal lands within or abutting the GCNP, air tour operations flying over or near the Lake Mead National Recreation Area solely as a transportation route to conduct an air tour over GCNP, Rocky Mountain National Park, and national park units located in Alaska.

An important area of technical support is the determination of representative baseline ambient sound levels for the study parks. The baseline ambient data will be used to establish a foundation from which potential noise impacts can be assessed. The collection of ambient sound level data also provides valuable information about a park's acoustic conditions for use in developing soundscape management plans.

This document summarizes the noise measurement study undertaken to provide data for the baseline ambient noise environment in Death Valley National Park (Death Valley). As shown in Figure 1, Death Valley is located northeast of Los Angeles, California along the border of the State of Nevada.

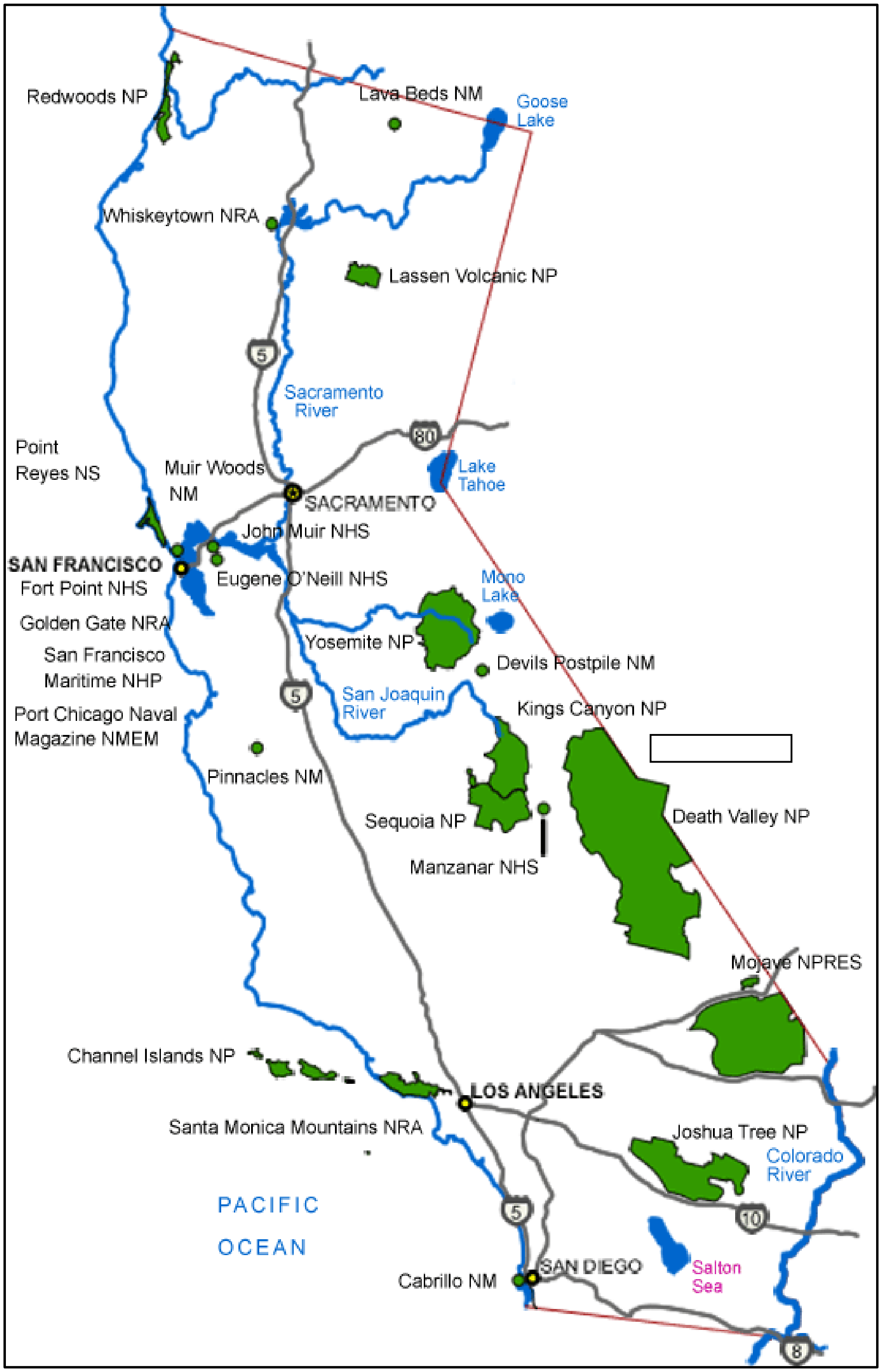


Figure 1. Location of Death Valley National Park. [1]

The Volpe Center performed acoustical monitoring during April - May 2008 to measure baseline ambient data that will be used to represent the summer season for Death Valley. Approximately one month of acoustical and meteorological data were measured at seven sites throughout Death Valley. These sites were selected during a meeting which took place at NPS Headquarters between Death Valley NPS, FAA personnel, and the Volpe Center (with FAA Western-Pacific Region personnel and NPS Natural Sounds Program Office personnel participating via phone).

The primary goal of the site selection process was to identify the minimum number of field-measurement sites, which would allow for characterization of the baseline ambient sound levels throughout the entire park. This was accomplished by identifying acoustically representative regions for which data could be collected and stratified, i.e., "acoustic zones." These data could then be applied to other regions in the park possessing similar attributes, which will affect acoustics, such as land cover, wind conditions, and wildlife habitats.

Because the vegetative land cover within a park is one of the key attributes affecting the acoustics as land cover directly affects how sounds propagate from a source to a receiver, Geographic Information System (GIS) data for land cover were used in the development of the initial acoustic zones. Death Valley's shrubland cover 90 percent of the park (see Figure 2). The remaining three land cover types are primarily bare rock/sand/clay (9 percent), evergreen forest (1 percent) and developed areas (less than 1 percent). This establishes four initial acoustic zones.

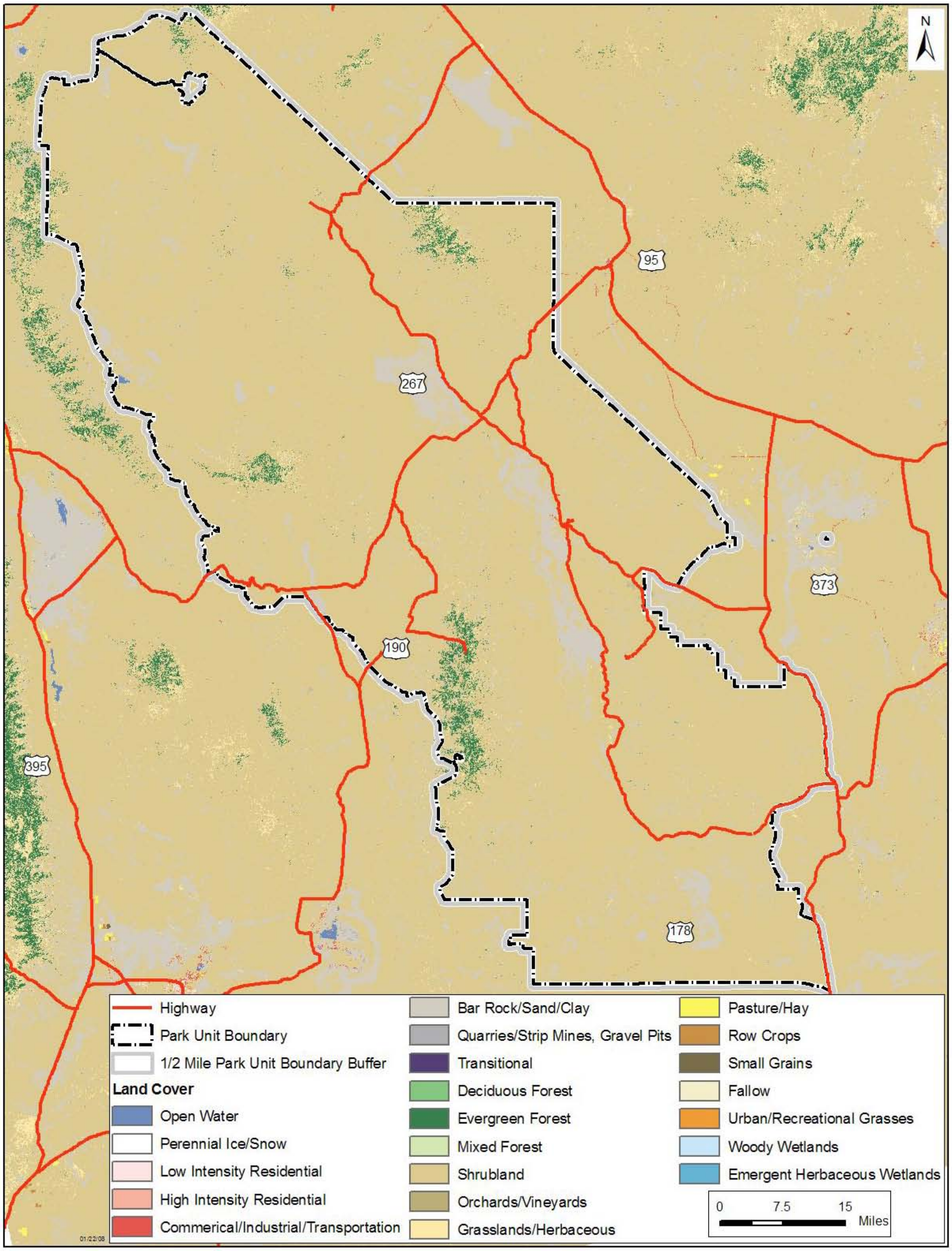


Figure 2. National Land Cover Database (NLCD) land cover types for Death Valley.

Based on the land cover data and the meeting discussion, three final acoustic zones were developed:

- Shrubland (90% of area)
- Barren (9% of area)
- Forested (1% of area)
- Developed (less than 1% of area)

With the goal of site selection to ensure at least one measurement location within each of the acoustic zones, Table 1 and Figure 3 display the locations of the final acoustic zones and measurement sites (see also additional discussion in Section 2).

Table 1. Summary of measurement sites for Death Valley.

Site ID	Site Name	National Land Cover Database Classification	Acoustic Zone	Latitude (decimal degrees)	Longitude (decimal degrees)	Altitude (ft)	# Days of Data
DV1	Scotty's Castle	Developed	Developed	37.03271°	117.34097°	3,020	20 days
DV2	Fall Canyon	Bare Rock/Sand/Clay	Barren	36.82576°	117.17743°	1,025	30 days
DV3	Badwater Basin	Bare Rock/Sand/Clay	Barren	36.24768°	116.88197°	-261	29 days
DV4	Saratoga Spring	Shrubland	Shrubland	35.68490°	116.42400°	195	29 days
DV5	Panamint Dunes	Shrubland	Shrubland	36.39832°	117.41119°	1,537	28 days
DV6	Charcoal Kilns	Evergreen Forest/ Mixed Forest	Forested	36.24635°	117.07715°	6,920	28 days
DV7	Eureka Dunes	Shrubland	Shrubland	37.10390°	117.68548°	2,881	28 days

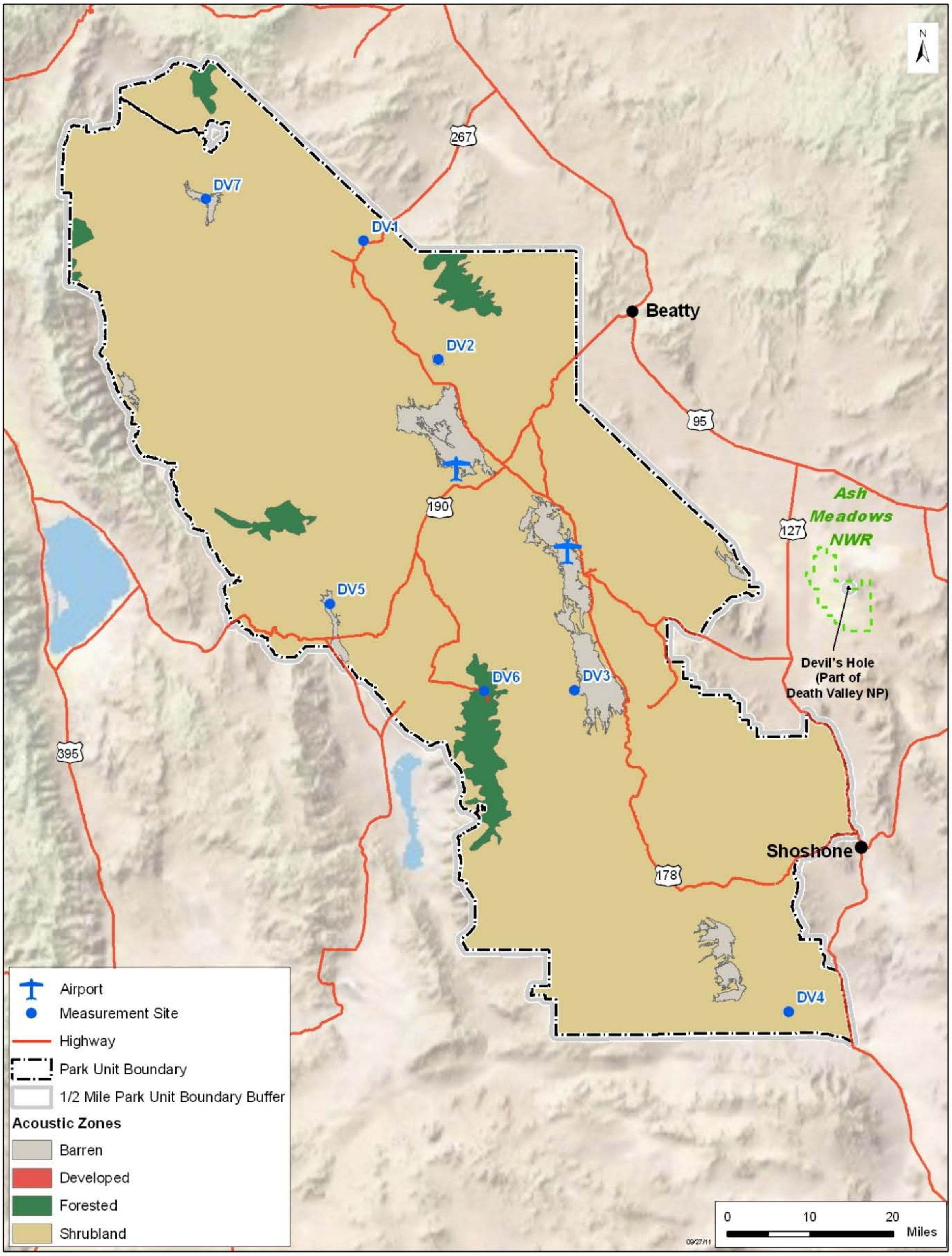


Figure 3. Final acoustic zones and measurement sites for Death Valley.

The following types of data were collected:

- *Acoustical*:
    - Continuous, one-second, A-weighted sound levels and their associated one-third octave-band un-weighted spectrum from 20 to 20,000 Hz;
    - Continuous digital audio recordings
- *Meteorological*: Continuous, one-second wind speed and direction data; and
- *Observer Logs*: During site visits, a field observer would perform short-term documentation of the acoustic environment at the site. Events audible within the acoustic environment were categorized into one of three primary acoustic states, based on the following hierarchal order: (1) Aircraft intrusions; (2) Human intrusions; and (3) Natural sounds. Aircraft intrusions include air tour, commercial, general aviation, military, and other aircraft sounds. Examples of non-aircraft (human) intrusions include hikers, campers, talking, motor vehicles, etc. The natural category was documented when no aircraft or other human-made sounds could be heard.

In addition, FAA and NPS have agreed that impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur – typically daytime hours. Daytime (as used in this report) will refer to the time period 7 am to 7 pm; nighttime will refer to the time period 7 pm to 7 am. For Death Valley ATMP analysis, only daytime data (measured during the time period of 7 am to 7 pm) will be used.

In general, all data analyses were performed in terms of three metrics:

- T*he A-weighted equivalent sound level (L_{Aeq}) and its associated one-third octave-band spectrum (unweighted)*: Ten times the base-10 logarithm of the time-mean-square, instantaneous A-weighted sound pressure, during a stated time interval, divided by the squared reference sound pressure of 20 μPa, the threshold of human hearing;
- *The 50-percentile exceeded sound level (L_{50}) and its associated one-third octave-band spectrum (unweighted)*: A statistical descriptor describing the sound level exceeded 50 percent of a specific time period. For example, from a fifty-sample measurement period with the samples sorted from highest sound level to lowest sound level, the twenty-fifth sound level is the 50-percentile exceeded sound level; and
- *The 90-percentile exceeded sound level (L_{90}) and its associated one-third octave-band spectrum (unweighted)*: A statistical descriptor describing the sound level exceeded 90 percent of a specific time period. For example, from a fifty-sample measurement period with the samples sorted from highest sound level to lowest sound level, the forty-fifth sound level is the 90-percentile exceeded sound level.

Using the data in the acoustic observer logs to group the individual, one-second, sound level values, four different types of ambient for each of the three above metrics can be computed from the data. The following four types of "ambient" characterizations are generally used and considered sufficient by the FAA and NPS in environmental analyses related to transportation noise:

- *Existing Ambient*: The composite, all-inclusive sound associated with a given environment, excluding only the analysis system's electrical noise (i.e., aircraft-related sounds are included);
- *Existing Ambient Without Air Tours*: The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sound source of interest, in this case, commercial air tour aircraft;
- *Existing Ambient Without All Aircraft (for use in assessing cumulative impacts)*: The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sounds produced by the sound source of interest, in this case, all types of aircraft (e.g., commercial air tours, commercial jets, general aviation aircraft, military aircraft);[*] and
- *Natural Ambient*: The natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excluding all human and mechanical sounds.

Table 2 contains a summary of the ambient, sound level data measured at each measurement site. The table is arranged by acoustic zone, followed by measurement site number. The first four columns in the table are arranged as follows:

- *Acoustic Zone*: The acoustic and management zone in which the measurement site was located;
- *Site Name:* The name of the site;
- *Site ID*: The unique three-character ID representing the site "number"; and
- *Total # Days*: The total number of days measured.

The remaining columns define the ambient sound levels computed, as described in 5.7.[†] For the Existing Ambient, the L_{Aeq}, L_{50}, and L_{90} metrics are computed taking into account the data from all days of measurements. For the remaining ambients (Existing Ambient Without Air Tours, the Existing Ambient Without All Aircraft, and Natural Ambient), only the L_{50} metric is computed.

Table 3 contains a summary of the acoustic observer data logged at each measurement site. The first four columns in the table are arranged as follows:

- *Acoustic Zone*: The acoustic zone in which the measurement site was located;
- *Site Name:* The name of the site;
- *Site ID*: The unique three-character ID representing the site "number"; and
- *Level of Visitor-Use*: A designator indicating expected visitor use (with "high" indicating

---

[*] The definition of Existing Ambient Without All Aircraft used in this report is consistent with FAA's historical approach for cumulative impact analysis.

[†] As noted previously, because for most parks, the majority of air tour operations occur during the day, the FAA and NPS have agreed that the impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur. Accordingly, all ATMP analyses will be based on daytime ambient data. For Death Valley, only data measured during the time period of 7:00 a.m. to 7:00 p.m. were used. This time period reflects typical operating hours for air tour operators conducting air tours in Death Valley according to Flight Standards District Office personnel.

sites such as overlooks, "moderate" indicating short hikes, and "low" indicating minimal or no visitor use such as in the wilderness/backcountry) in the measurement site area.

The next four columns define the percentage of time that different noise sources were audible to the acoustic observer. The in-situ logging is performed during visits to the site itself; office listening is performed in the office using audio files that were collected at each site. Events audible within the acoustic environment were categorized into one of three primary acoustic states, based on the following hierarchal order: (1) Aircraft intrusions; (2) Human intrusions; and (3) Natural sounds. For aircraft intrusions, the acoustic observer would attempt to discern whether the aircraft was an air tour operation, or other operation (i.e., commercial, general aviation, or military) based on visual and auditory cues (e.g., type of aircraft and proximity to known air tour routes). Examples of non-aircraft (human) intrusions include hikers, campers, talking, motor vehicles, etc. The natural category was documented when no aircraft or other human-made sounds could be heard.

- *Fixed-Wing Aircraft and Helicopters*: The percentage of observer log time that typical air tour aircraft, fixed-wing aircraft and helicopters, were audible;
- *Other Aircraft*: The percentage of observer log time that non-tour aircraft (e.g., general aviation, commercial jet, and military) were audible;
- *Human*: The percentage of observer log time that human noise sources (visitor- and mechanical-related) were audible; and
- *Natural*: The percentage of observer log time that natural noise sources were audible.

Table 2. Summary of measured ambient sound level data for the summer season.[*]

Acoustic Zone	Site Name	Site ID	Total # Days	Existing Ambient						Existing Ambient Without Air Tours (Daytime Data Only 7 am to 7 pm)	Existing Ambient Without All Aircraft (Daytime Data Only 7 am to 7 pm)	Natural Ambient (Daytime Data Only 7 am to 7 pm)
				Daytime Data Only 7 am to 7 pm			Nighttime Data Only 7 pm to 7 am					
				L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)
Developed	Scotty's Castle	DV1	20	44.3	38.3	32.7	39.6	35.9	28.9	38.3	38.2	32.7
Barren	Fall Canyon	DV2	30	39.4	18.5	10.2	31.3	13.1	8.5	18.5	16.9	16.2
Barren	Badwater Basin	DV3	29	44.0	23.1	14.2	39.4	17.9	10.9	23.1	19.8	19.2
Shrubland	Saratoga Spring	DV4	29	34.1	18.6	13.2	30.6	19.4	11.9	18.7	17.7	17.6
Shrubland	Panamint Dunes	DV5	28	55.4	19.9	10.7	31.5	11.2	9.3	19.9	16.2	15.6
Forested	Charcoal Kilns	DV6	28	41.1	28.0	17.4	38.8	17.8	10.9	28.0	27.0	23.9
Shrubland	Eureka Dunes	DV7	28	51.8	14.8	10.7	27.6	10.9	9.8	14.8	13.3	13.2

---

[*] As stated earlier, two ambient maps were agreed upon for use in ATMP analyses: the Existing Ambient Without Air Tours (L_{50}) and the Natural Ambient (L_{50}).

Table 3. Summary of acoustic observer log data (in situ and office listening combined) for all sites for the summer season.

Acoustic Zone	Site Name	Site ID	Level of Visitor-Use	% Time Audible			
				Fixed-Wing Aircraft and Helicopters	Other Aircraft	Other Human	Natural (noise free)
Developed	Scotty's Castle	DV1	High	0.0%	2.5%	78.1%	19.4%
Barren	Fall Canyon	DV2	Low	0.0%	13.6%	5.6%	80.8%
Barren	Badwater Basin	DV3	Low	0.0%	19.0%	5.2%	75.7%
Shrubland	Saratoga Spring	DV4	Low	0.0%	9.7%	2.0%	88.3%
Shrubland	Panamint Dunes	DV5	Low	0.0%	28.2%	2.8%	69.0%
Forested	Charcoal Kilns	DV6	Moderate	0.0%	10.1%	27.6%	62.4%
Shrubland	Eureka Dunes	DV7	Low	0.0%	17.0%	3.2%	79.9%

The measured ambient values presented in Table 2 are assigned to each acoustic zone. Then, because it is not feasible to carry out field data collection efforts in all areas of a park, the contributing effect of localized noise sources, such as waterfalls, river rapids, and vehicles on roads, are typically modeled and combined with the measured sound levels to develop a composite, baseline, ambient “map” of a park. An ambient “map” is essentially a comprehensive grid of ambient sound levels throughout a study area. The composite, baseline, ambient map (along with representative one-third octave-band spectral data) is used as input to the INM to compute various noise-related descriptors and generate the sound-level contours that will be used in the assessment of potential noise impacts due to air tour operations.

In the vicinity of and within Death Valley, there were a number of localized sound sources (e.g., roadways). Roadway sound sources were modeled using the Federal Highway Administration’s Traffic Noise Model® (TNM).[2] Details of modeled roadway sound sources can be found in Section 7.2.

The two ambient maps agreed upon for use in ATMP analyses are:

- Existing Ambient Without Source of Interest; and
- Natural Ambient.

Figure 4 through Figure 5 present the two ambient maps representing the summer season.

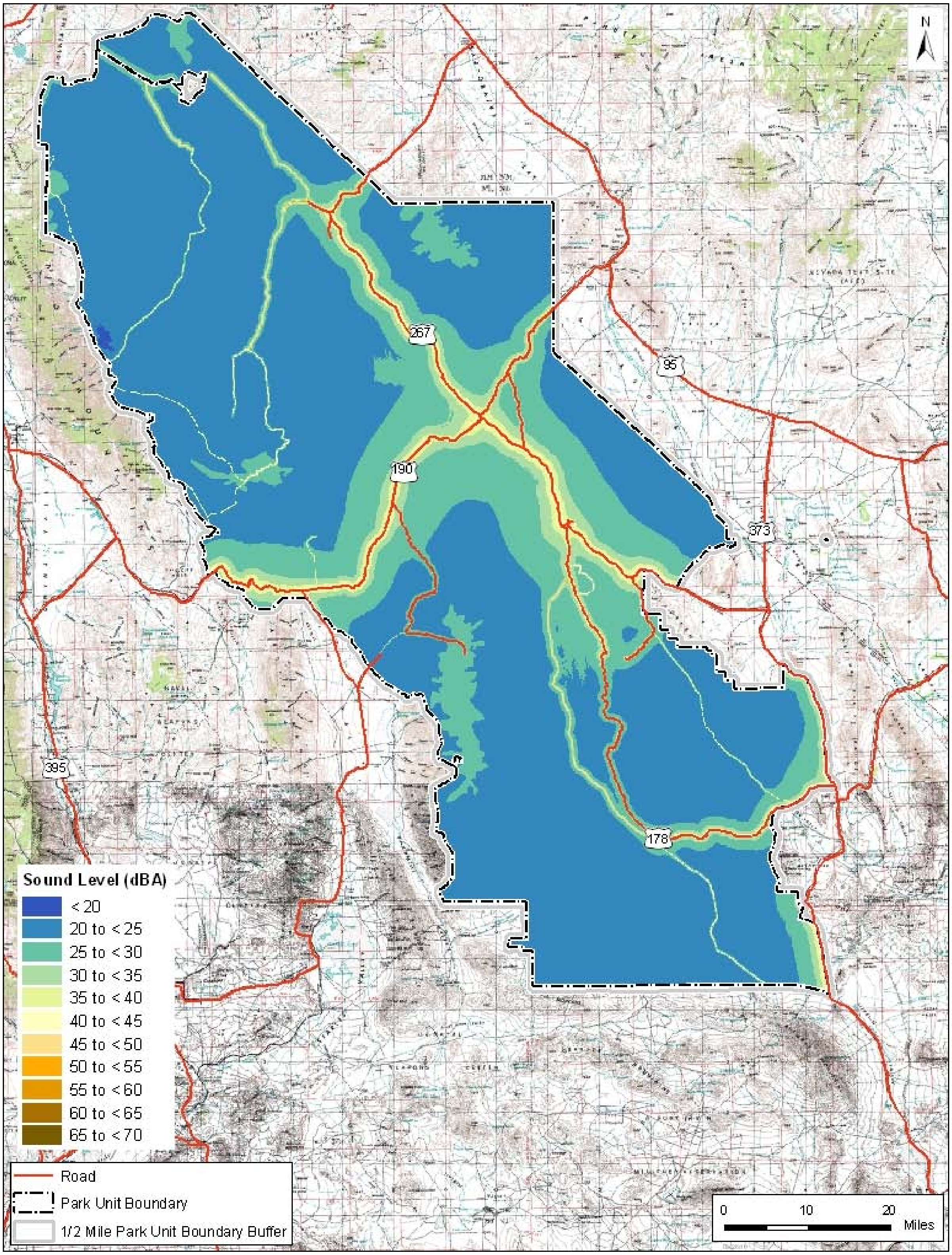


Figure 4. Baseline ambient map: Existing Ambient Without Air Tours (L_{50}) for the summer season.

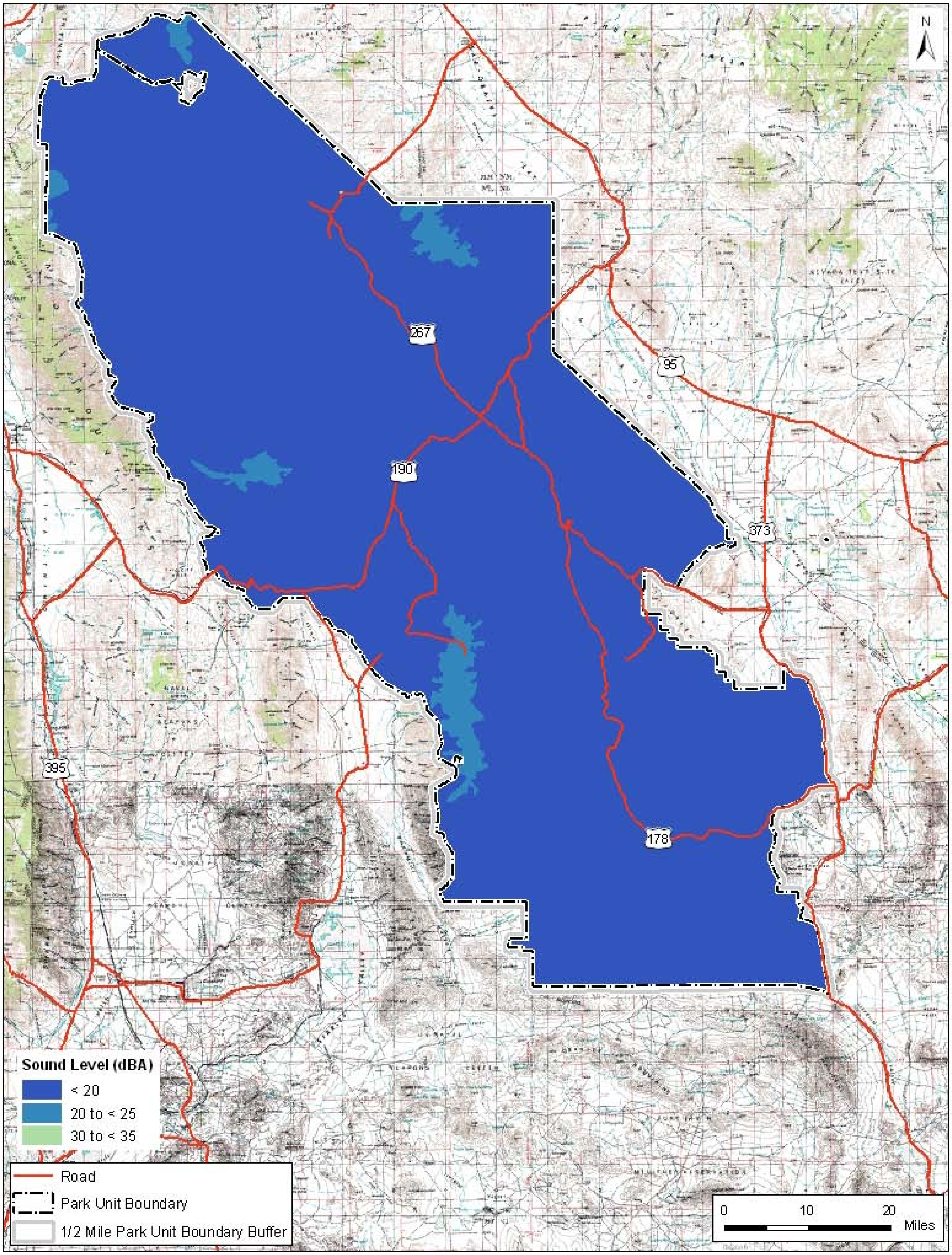


Figure 5. Baseline ambient map : Natural Ambient (L_{50}) for the summer season.

Page left blank intentionally.

1. INTRODUCTION

Congress passed the National Parks Air Tour Management Act of 2000 (NPATMA) to regulate commercial air tour operations over units of the National Park System.[3] NPATMA directed the Federal Aviation Administration (FAA), with the cooperation of the National Park Service (NPS), to develop Air Tour Management Plans (ATMP) for all national parks with commercial air tours with the exception of the Grand Canyon National Park (GCNP), tribal lands within or abutting the GCNP, air tour operations flying over or near the Lake Mead National Recreation Area solely as a transportation route to conduct an air tour over GCNP, Rocky Mountain National Park, and national park units located in Alaska. The objective of the ATMPs is to develop acceptable and effective measures to mitigate or prevent significant adverse impacts, if any, from the air tours on the natural and cultural resources, visitor experiences, and tribal lands within the parks.

The U.S. Department of Transportation, Research and Special Programs Administration, John A. Volpe National Transportation Systems Center (Volpe Center) is supporting the FAA, Western-Pacific Region (AWP), and working cooperatively with the NPS, Natural Sounds Office, in the development of ATMPs. Approximately 85 park units will need ATMPs developed. A major component of establishing noise impacts is the determination of representative baseline sound levels, or ambient levels for each park. The collection of ambient sound level data provides valuable information about a park's acoustic conditions for use in developing soundscape management plans.

The Volpe Center performed acoustical monitoring during April - May 2008 to measure baseline ambient data that will be used to represent the summer season for Death Valley National Park (Death Valley). Approximately one month of acoustical and meteorological data were measured at seven sites throughout the park.

1.1 Objectives

The primary objective of this study is to quantify the baseline ambient sound levels within Death Valley to establish a foundation from which potential noise impacts can be assessed. Approximately one month of acoustical and meteorological data were measured at multiple sites throughout the park. Ambient sound level data collected in this study will be used for the primary purposes of:

- Establishing baseline ambient sound levels (both overall and frequency based) in key areas within a park;
- Establishing the different sound sources contributing to the baseline levels in key areas within a park;
- Modeling sound levels in other similar areas within a park for which resource constraints (or other issues) do not allow for direct measurements;
- Building a library of baseline ambient sound levels (both overall and frequency based), which may potentially be used in future ATMPs to generalize baseline ambient sound levels within similar types of parks, or park areas; and
- Provide input into the FAA's Integrated Noise Model (INM), which will be used to assess the complete acoustical environment within the entire park and aid in the assessment of a range of air tour alternatives. INM is a computer program used by over 700 organizations in over 50 countries to assess changes in noise impact. Requirements for INM use are defined in

FAA Order 1050.1E, Environmental Impacts: Policies and Procedures, and Federal Aviation Regulations (FAR) Part 150, Airport Noise Compatibility Planning. In accordance with the results of the Federal Interagency Committee on Aviation Noise (FICAN) review ("Findings and Recommendations on Tools for Modeling Aircraft Noise in National Parks"), INM Version 6.2[*] is the best-practice modeling methodology currently available for evaluating aircraft noise in national parks and will be the model used for ATMP development.[4,5]

1.2 Report Organization

The presentation of this document, entitled "Baseline Ambient Sound Levels in Death Valley National Park," begins with an executive summary. Section 1 presents an introduction and the objectives of this document. Section 2 overviews the process of measurement site selection with a brief description of the preliminary sites chosen. Section 3 discusses instrumentation. Section 4 presents the measurement procedures employed in the field. Section 5 discusses data reduction. Section 6 discusses the results of the study. Section 7 discusses the development of ambient maps. Appendix A presents detailed measurement site information. Appendix B contains the User's Guides for the continuous monitoring systems. Appendix C presents the instrumentation frequency response adjustments. Appendix D describes the development of instrumentation noise floor adjustments. A glossary and all related references are presented at the end of this document.

---

[*] INM Version 6.2 was the latest version of the INM at the time of this determination. Since then, INM Version 7.0b has been released.

2. STUDY AREA AND SITE SELECTION

Death Valley is located northeast of Los Angeles, California along the border of the State of Nevada as shown in Figure 6. The park was established in February 1933 and encompasses 3.3 million acres. Located in the arid Mojave and Colorado desert Death Valley National Park is the largest National Park System in the contiguous 48 states and is noted as the lowest point in the Western Hemisphere. [6] Over 800,000 people visit the park annually.[7] Figure 7 provides a general overview of the areas within Death Valley.

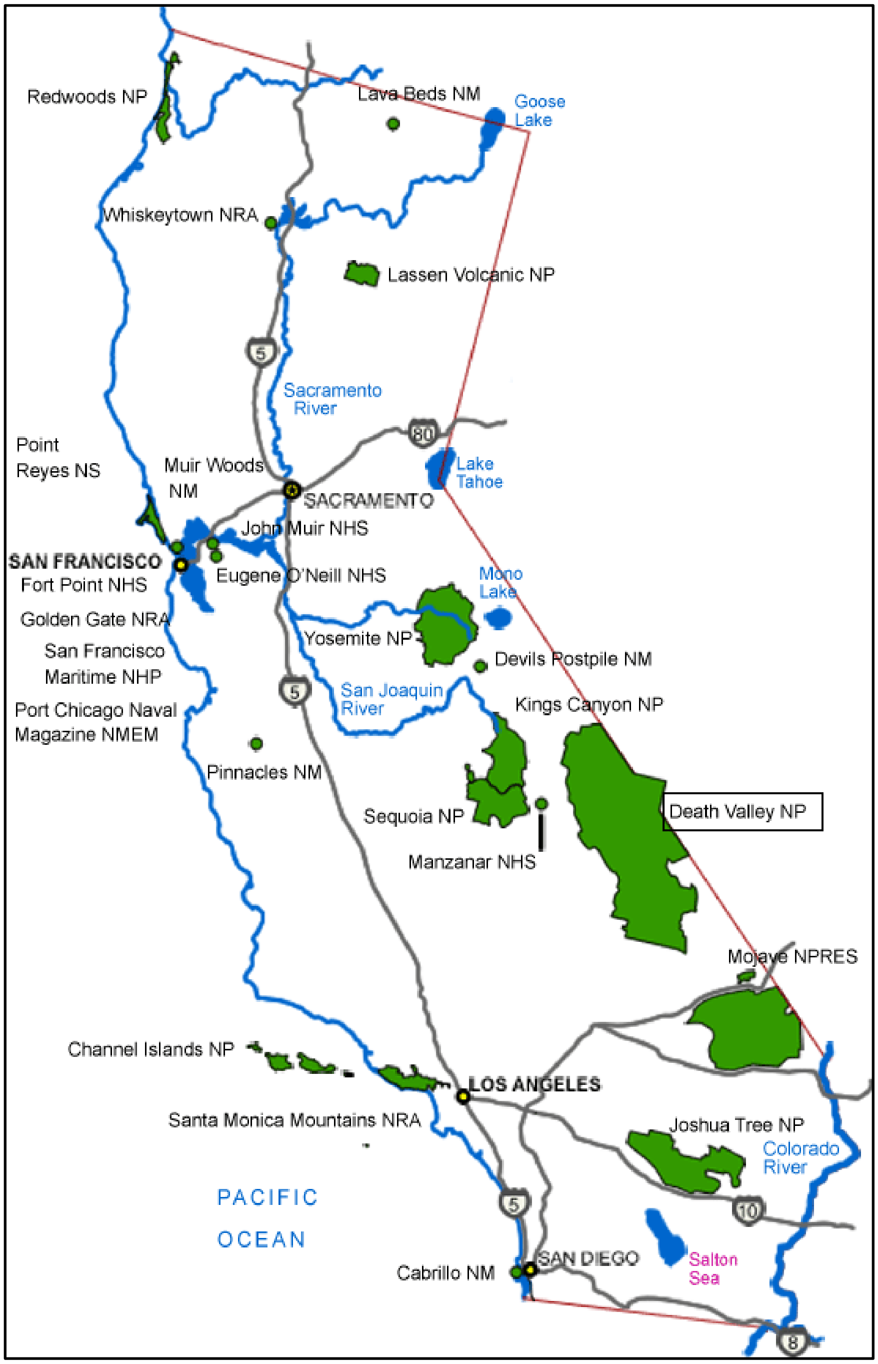


Figure 6. Location of Death Valley National Park. [1]

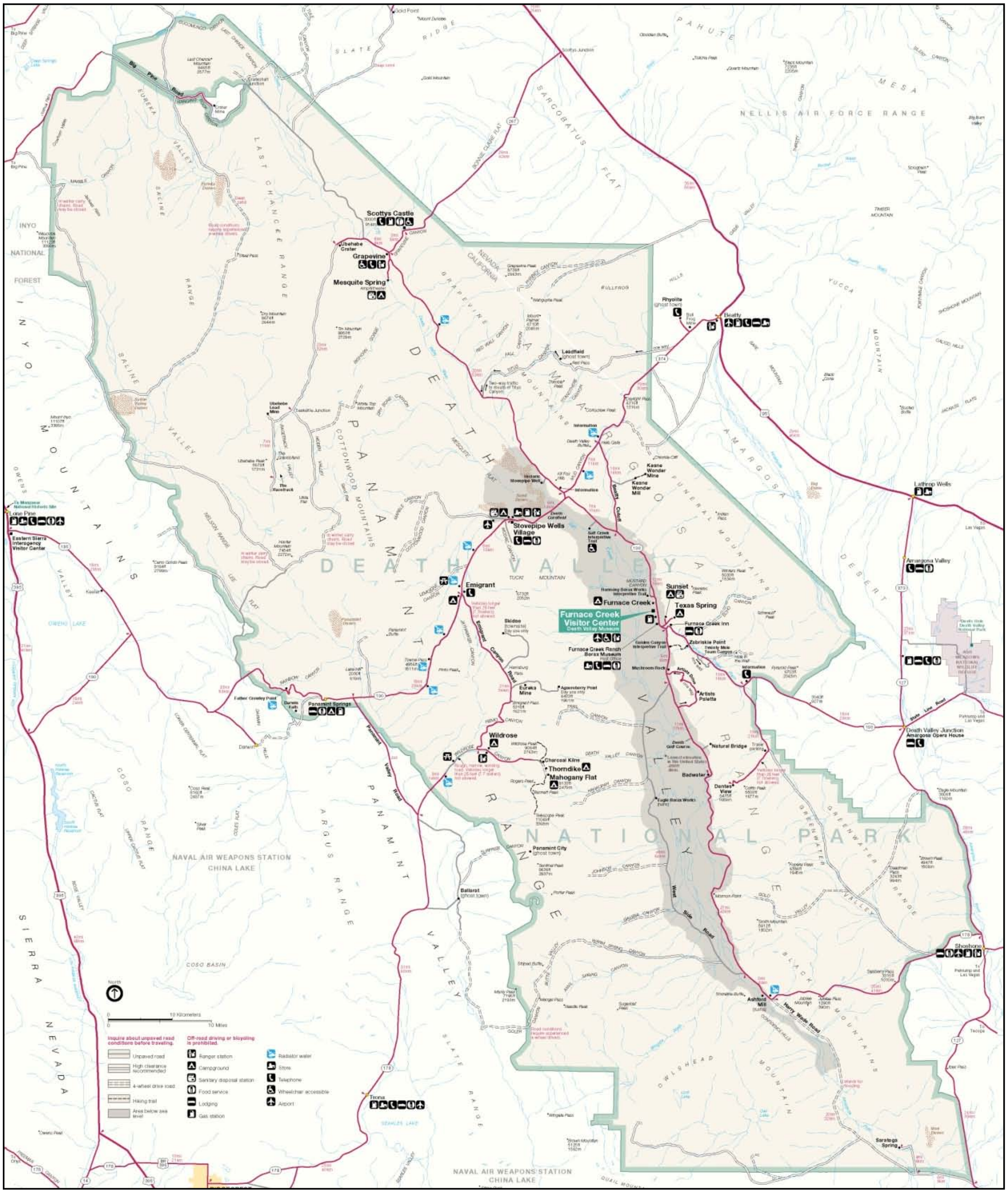


Figure 7. Overview map of Death Valley. [8]

2.1 Site Selection Criteria

The primary goal of the site selection process was to identify the minimum number of field-measurement sites, which would allow for characterization of the baseline ambient sound levels throughout the entire park. This was accomplished by identifying acoustically representative regions for which data could be collected and stratified, i.e., "acoustic zones." These data could then be applied to other regions possessing similar attributes, which will affect acoustics, such as land cover, wind conditions, and wildlife habitats. In the site selection process, the following primary criteria were used in the determination of acoustic zones:

- *Vegetation/Land Cover (see Section 2.2):* Sound propagates differently over different types of ground cover and through different types of vegetation. For example, sound propagates more freely over barren environments as compared with grasslands, and less freely through forest type environments. In addition, vegetation is typically dependent upon time-of-year, with foliage being sparser in the winter than other times in the year. Land cover can also affect wildlife activity. Previous studies in national parks have established a strong correlation between land cover, wind speed, and ambient sound level.[9,10,11,12]
- *Climate Conditions (see Section 2.3):* Climate conditions include: temperature, humidity, precipitation, wind speed, wind direction, etc.; all of which can affect ambient sound levels as shown in previously referenced studies. For example, higher elevation areas typically exhibit higher wind speeds resulting in higher ambient sound levels. Climate is also dependent upon daily and seasonal variations, which can affect ambient sound levels. For example, under conditions of a temperature inversion (temperature increasing with increasing height as in winter and at sundown), sound waves may be heard over larger distances; and winds tend to increase later in the day, and, as such, may be expected to contribute to higher ambient noise levels in the afternoon as compared with the morning. In addition, biological activity is also affected by climate and seasonality. Natural biological sounds fluctuate with season and might contribute to lower ambient sound levels in the winter. Finally, visitors contribute to a wide variety of sounds, including hikers talking and walking, tour buses and other vehicular noises, as well as air tours. The influence of weather on visitor-use patterns is also important. For example, moderate climate areas of a park are much more popular for backcountry hiking and camping. Areas with more extreme climates are visited less often, for shorter periods of time and more likely only during the day.

The above primary criteria were used to determine the acoustic zones in Death Valley, and then combined with the following secondary criteria to determine the final sites selected (see Section 2.6):

- *Park Resources/Management Zones (see Section 2.4):* As the objective of the ATMPs is to develop acceptable and effective measures to mitigate or prevent significant adverse impacts from the air tours on the natural and cultural resources, visitor experiences, and tribal lands within the parks, it is important to examine these resources and their locations/habitats during site selection. Park resources contribute, not only, to the multitude of sounds produced in certain areas of the park, but also to the serenity of other areas in the park. The way in which a park manages its resources can affect how potential impacts may be later assessed. It may also help identify where greater resource protection may be needed.

- *Commercial Air Tour Flight Routes (see Section 2.5):* Commercial air tours provide not only a unique experience for visitors of the National parks, but also a different way for visitors to enjoy certain areas of parks. However, these tours also have the potential to disrupt visitors' enjoyment of a park, its wilderness environment, and its native wildlife. As NPATMA directs the development of ATMPs to reduce or eliminate significant impacts, if any, caused by commercial air tours, the consideration of existing air tour routes during site selection is very important. Sites in the vicinity of air tour routes provide the unique opportunity to gather in-situ information during ambient data collection regarding the noise source of interest, i.e., air tour aircraft.

Overarching the above criteria, and in many cases the definitive criterion in the final-decision-making process, is site accessibility. As important as a given site is to satisfy any of the above criteria, if it is inaccessible, measurements cannot be conducted.

2.2 Vegetation/Land Cover

With the goal of potentially facilitating future data transferability between parks, all baseline acoustic data collected thus far have been organized/classified in accordance with the National Land Cover Database (NLCD). Developed by the U.S. Geological Survey (USGS), the NLCD is the only nationally consistent land cover data set in existence and is comprised of twenty-one NLCD subclass categories for the entire U.S.[13]

Figure 8 provides an overview of the general land cover in Death Valley. Death Valley’s shrubland cover 90 percent of the park. The remaining three land cover types are primarily bare rock/sand/clay (9 percent), evergreen forest (1 percent) and developed areas (less than 1 percent). This establishes four initial acoustic zones.

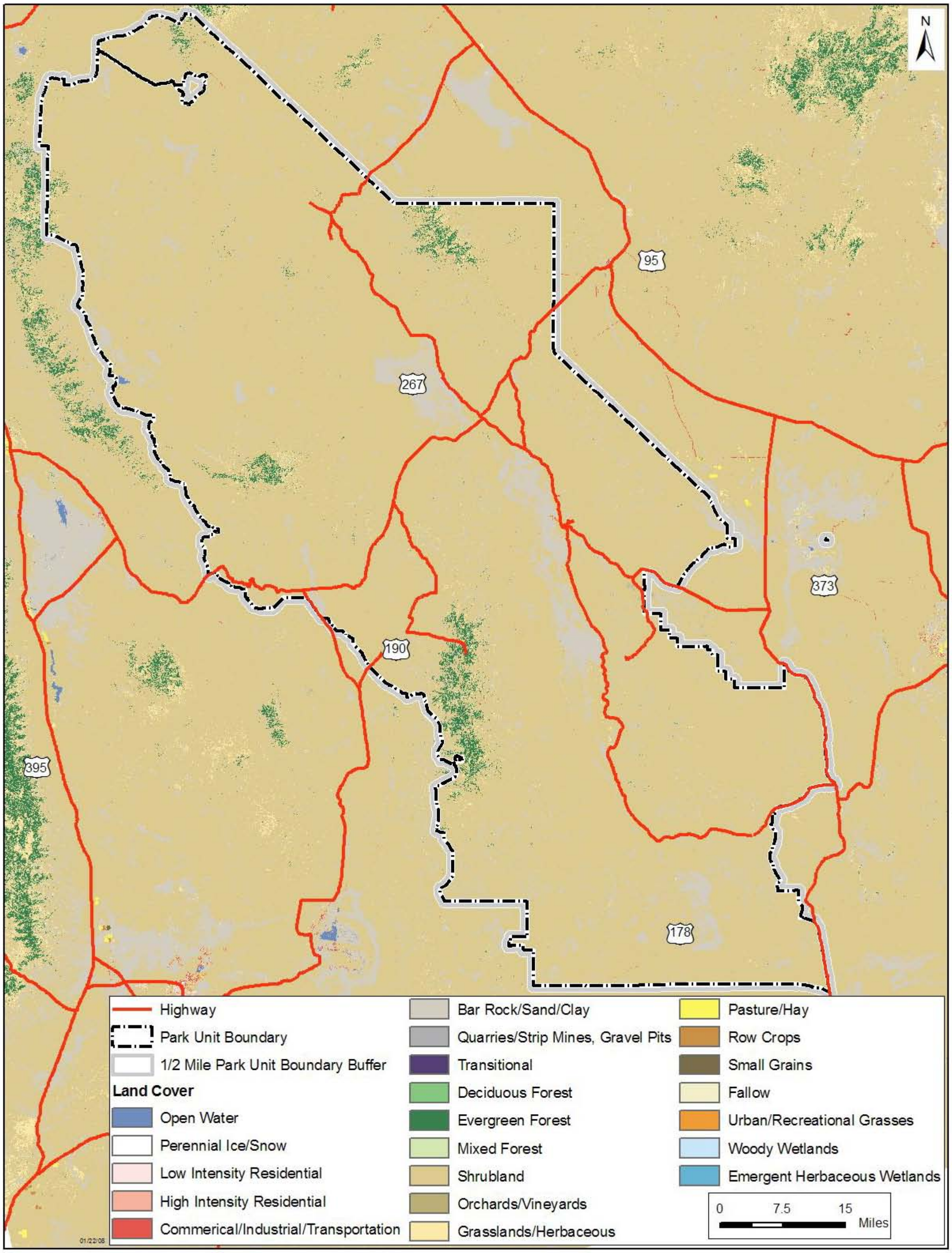


Figure 8. National Land Cover Database (NLCD) land cover types in Death Valley.

2.3 Climate Conditions

Climatology can also affect baseline ambient sound levels, as sound propagates differently in cold dry regions as opposed to warm humid regions; and substantial differences in wildlife activity can also be expected with varying climatology. With the goal of potentially facilitating future data transferability between parks, all baseline acoustic data collected thus far have been organized by ecological division.[14] This approach has been closely coordinated with NPS personnel.[*] Table 4 provides the monthly climate summary (averaged from 1961 to 2010) recorded by meteorological stations nearest the park.

Table 4. Monthly climate summary for Death Valley.[15]

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (mph)	4.3	5.1	5.8	7.4	8.8	9.1	7.9	7.2	6.1	4.6	3.9	4.1
Prevailing Direction	ESE	E	NW	NW	NW	NW	NW	NW	NW	NW	NW	E
Average Max Temp (F)	66.1	73.4	81.3	89.7	99.8	109.4	116.0	114.0	106.1	92.8	76.6	65.1
Average Min Temp (F)	39.2	46.0	53.8	61.6	71.9	80.8	87.6	85.4	75.3	61.7	48.0	38.3
Average Total Precipitation (in)	0.3	0.5	0.3	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.2	0.2
Average Total Snow Fall (in)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average Snow Depth (in.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2.4 Park Resources/Management Zones

The NPS' Death Valley General Management Plan (GMP) describes the management and protection of park resources.[16] Because of Death Valley's expansive wilderness areas (see Figure 9), it is important that sites be selected to appropriately characterize these areas.

---

[*] It should be noted that there is currently no standard vegetation classification system in the NPS. However, several classification systems, including NLCD and NatureServe described in this document, are being reviewed by the NPS for use in grouping NPS park units by common vegetation, topography, and habitat.

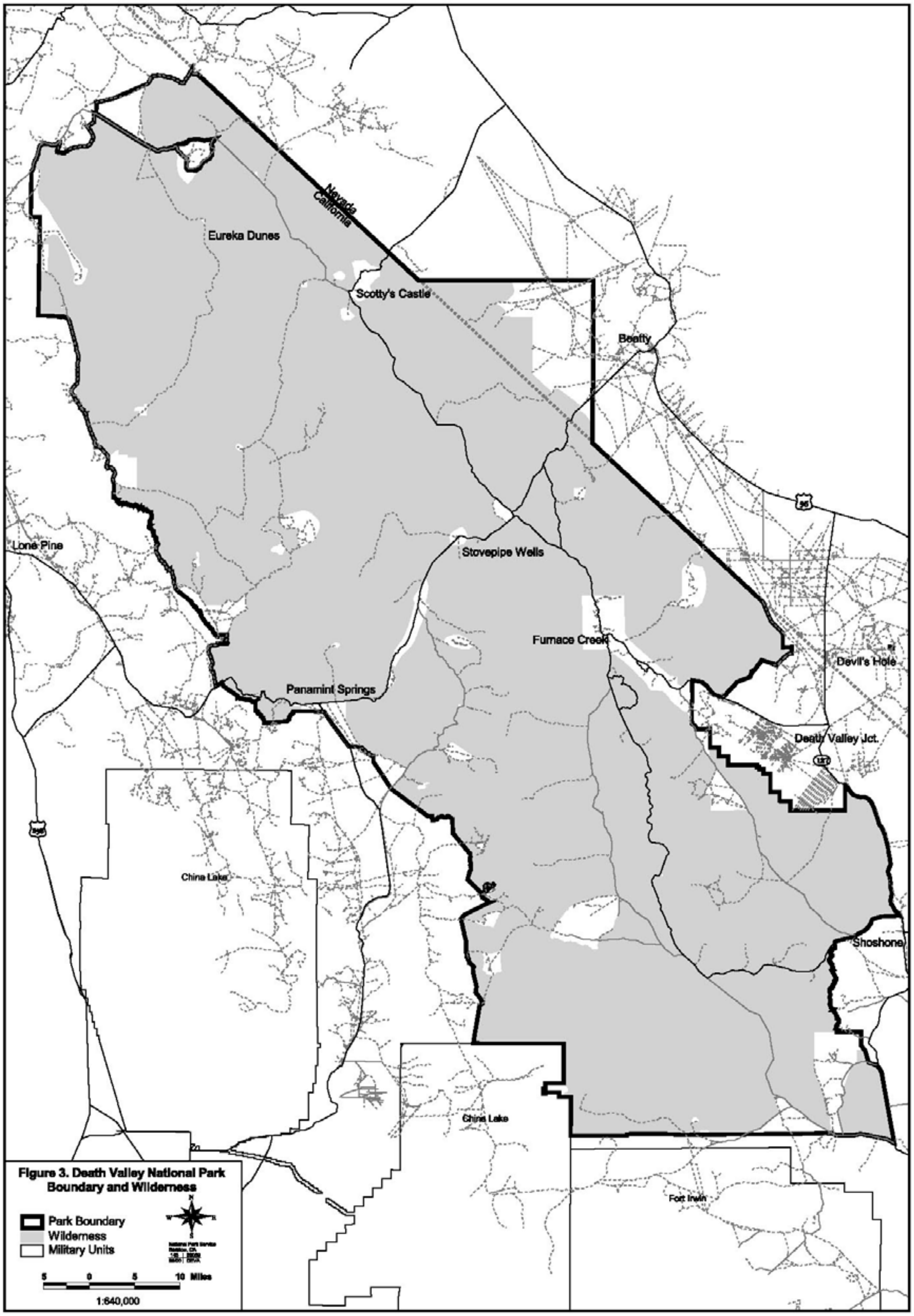


Figure 9. Death Valley GMP: Map of park boundary and preliminary wilderness.[16]

2.5 Commercial Air Tour Flight Routes

According to the Interim Operating Authority applications received by the FAA, there are currently seven existing commercial air tour operators approved to provide a combined total of 67 tours over Death Valley annually. During the time that the acoustical monitoring was performed, information regarding typical routes used by air tour operators was not available. Since then, that information has been included on the NPS' Planning, Environment & Public Comment (PEPC) website in the Public Scoping Packet for the Death Valley ATMP.[17]

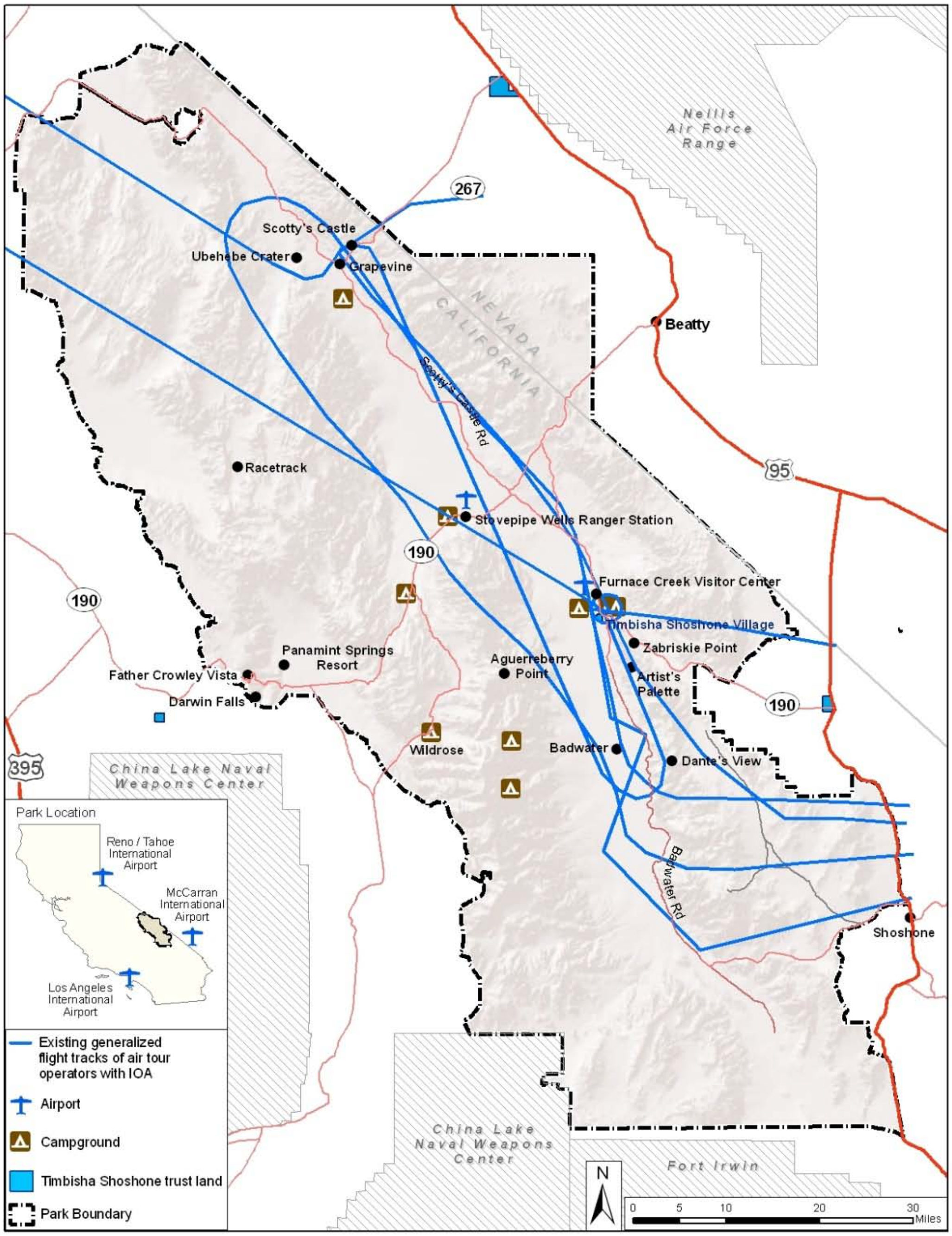


Figure 10. Existing air tour flight tracks as of January 2010.[17]

2.6 Death Valley Acoustic Zones

A meeting was held prior to deployment at NPS Headquarters between Death Valley NPS, FAA personnel, and the Volpe Center (with FAA Western-Pacific Region personnel and NPS Natural Sounds Program Office personnel participating via phone) to discuss the above site selection considerations. As stated earlier, it is anticipated that the use of acoustic zones as representative units, within which data can be collected and grouped (by vegetation, management zone, etc), may be extrapolated to similar areas in Death Valley. Based on the land cover data and the meeting discussion, four final acoustic zones were developed:

- Shrubland (90% of area)
- Barren (9% of area)
- Forested (1% of area)
- Developed (less than 1% of area)

With the goal of site selection to ensure at least one measurement location within each of the acoustic zones, Table 5 and Figure 11 display the locations of the final acoustic zones and measurement sites. Appendix A contains individual descriptions and photographs of each measurement site location.

Table 5. Summary of measurement sites selected for Death Valley.

Site ID	Site Name	National Land Cover Database Classification	Acoustic Zone	Latitude (decimal degrees)	Longitude (decimal degrees)	# Days of Data
DV1	Scotty's Castle	Developed	Developed	37.03271°	117.34097°	20 days
DV2	Fall Canyon	Bare Rock/Sand/Clay	Barren	36.82576°	117.17743°	30 days
DV3	Badwater Basin	Bare Rock/Sand/Clay	Barren	36.24768°	116.88197°	29 days
DV4	Saratoga Spring	Shrubland	Shrubland	35.68490°	116.42400°	29 days
DV5	Panamint Dunes	Shrubland	Shrubland	36.39832°	117.41119°	28 days
DV06	Charcoal Kilns	Evergreen Forest/ Mixed Forest	Forested	36.24635°	117.07715°	28 days
DV7	Eureka Dunes	Shrubland	Shrubland	37.10390°	117.68548°	28 days

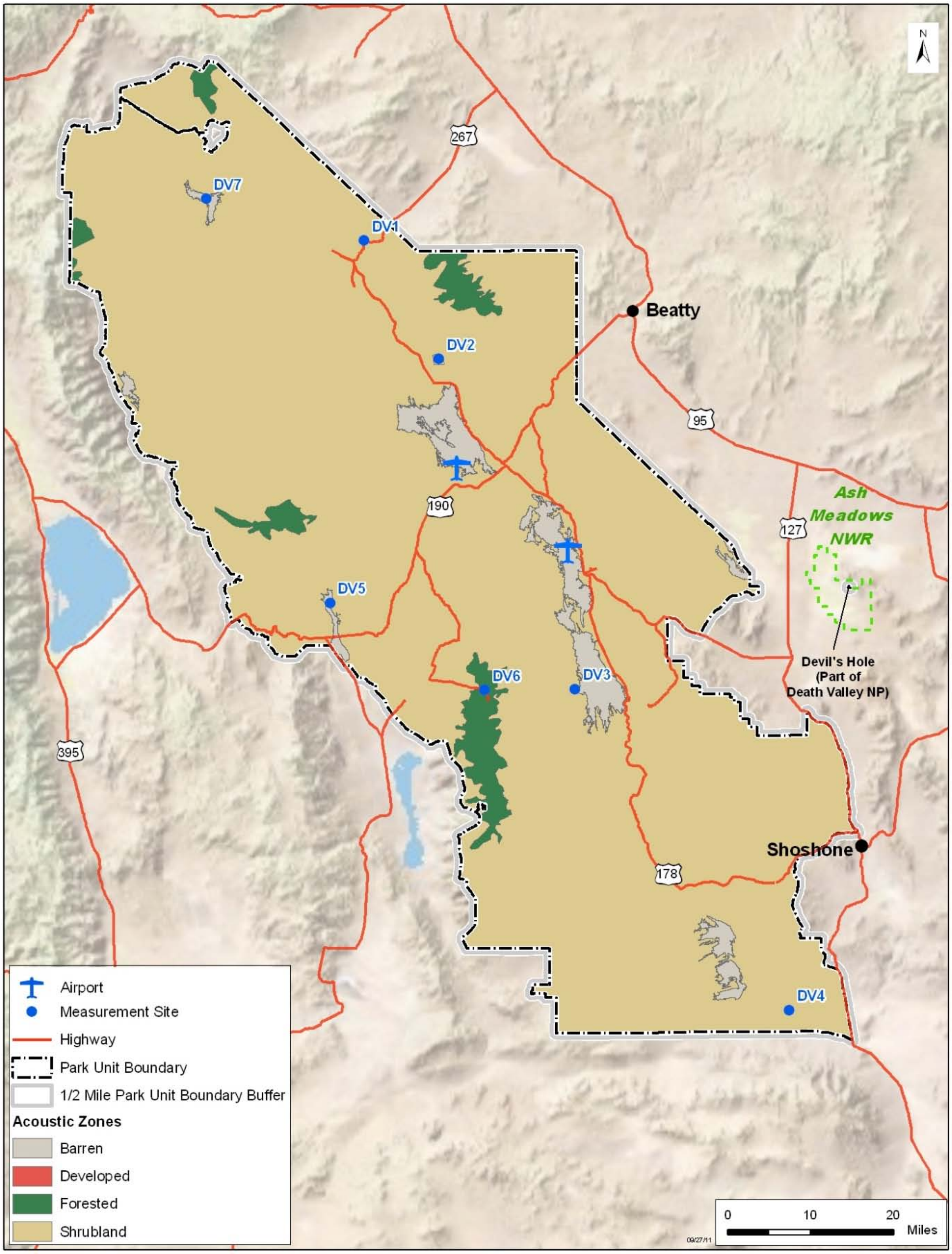


Figure 11. Final acoustic zones and measurement sites for Death Valley.

2.7 Temporal Considerations (Seasonal, Daily, and Duration)

Measurement duration is a very difficult technical issue on which to reach consensus. It is likely that there will be substantial day-to-day, and for that matter, week-to-week, and possibly season-to-season variability, for many parks. For example, insect activity, which generally increases at night, may cause higher ambient sound levels than during the daytime. As another example, some wildlife activities (e.g., breeding) increase during certain months of the year, and, as such, may be expected to contribute to different ambient noise levels. However, it is typically not practical to measure at sites continuously for periods of many months, or several years. The choice of how long to measure must balance technical considerations and available resources. Measurements at a particular site should not only be of sufficient duration to ensure statistical confidence in the data, but also be reasonable in light of practical and other resource considerations.

2.7.1 Seasonal Considerations

Because the ultimate purpose of this data is to support impact assessment due to commercial air tours on park resources, acoustic data should be collected during the season (summer and/or winter) when air tours occur (not necessarily during the peak month of the activity, but during a month representative of the season when the activity occurs). Because visitation for Death Valley peaks in the spring and summer, ambient measurements during this season were agreed upon by FAA and NPS.

2.7.2 Time of Day Considerations

FAA and NPS have agreed that impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur – typically daytime hours. Daytime (as used in this report) will refer to the time period 7 am to 7 pm; nighttime will refer to the time period 7 pm to 7 am. For Death Valley ATMP analysis, only daytime data (measured during the time period of 7 am to 7 pm) will be used.

2.7.3 Measurement Duration

Based on long-term ambient data collected in Hawai`i Volcanoes National Park[18], as well as a joint review of acoustic literature and other relatively recent long-term NPS ambient studies in Bryce Canyon National Park and Arches National Park,[19] a 3-dB variability was achieved between 10, 25, and 40 days, depending on individual site variables/ characteristics. Since 2005, the FAA and NPS have jointly agreed that a minimum 25-day measurement period would be conducted for all future ATMP acoustic monitoring to limit measurement uncertainty to 3 decibels. An exception to the 25-day requirement would be for measurements in close proximity to localized sound sources, which generally don’t vary substantially in level, such as waterfalls, river rapids, and busy visitor centers. The measurement period for such situations will be situation dependent, but generally, for visitor centers and travel corridors, a 10-day measurement period will be adequate. Even shorter periods may be adequate for waterfalls or rivers with very little variability and for which only attenuation data is needed.

3. INSTRUMENTATION

Ambient sound levels measured in remote areas of the country under low wind conditions often approach the threshold of human hearing. As a result, specialized low-level instrumentation is required to accurately measure these sounds. This section discusses the specialized ambient measurement system used for this study.

3.1 NoiseLogger™ Continuous Monitoring System

The NoiseLogger™ Continuous Monitoring System can conduct unattended, long-term (30+ days), continuous ⅓-octave band noise measurements in outdoor environments. It is compact, light, rugged, and can run with external battery power, or solar panels, thus, enabling the system to store uninterrupted acoustic and wind data. Appendix B contains a more detailed description of system deployment, calibration, and dismantling.[20]

The system uses a large diameter windscreen and a ½-inch electret condenser microphone, interfaced with a sound level meter and a handheld personal computer for storing measured data using the NoiseLogger™ software. The system includes an ultrasonic anemometer to measure wind speed and direction. The output of the anemometer is also stored by the PDA via the NoiseLogger™ software.

3.1.1 Microphone System

The G.R.A.S. Model 40AQ and Model 40AE ½-inch, prepolarized microphones used in this study are electret condenser microphones. The random-incidence, frequency response of each microphone utilized in this study is shown in Appendix C. Being pre-polarized, the microphone functions as a closed system with regard to humidity, thus eliminating the potential for condensation in high humidity situations. Additionally, LD Model PRM902 preamplifiers were employed at each site. The cable to preamplifier connection is protected by plastic housing, which can contain desiccant cartridges to minimize humidity.

The microphone is protected from precipitation and birds with a Larson Davis Model EPS2108 special acoustic foam windscreen outfitted with birdspikes. The use of a windscreen also reduces the effects of wind-generated noise at the microphone diaphragm. Such reduction can effectively improve the signal-to-noise ratio of sound measurements. The attenuation of this windscreen is shown in Appendix C.

3.1.2 Sound Level Meter (SLM)

The microphone system was connected to a Larson Davis™ (LD) Model 824 sound level meter (SLM). The Model 824 SLM was set up with slow exponential time-weighting to continuously measure the overall A-weighted equivalent sound level for each 1-second sample, as well as the Z-weighted equivalent sound level in each ⅓-octave-band from 12.5 Hz to 20 kHz.

3.1.3 Handheld Personal Computer

The AC output of the LD Model 824 SLM was connected directly to the input of a Handheld Systems Husky™ Model Fex-21 handheld personal computer (H/PC) for data storage. With a 128-MB CompactFlash™ card, the Husky™ H/PC can provide approximately 2-weeks of continuous data storage.

3.1.4 MP3 Audio Recorder

The AC output of the LD 824 SLM was also connected directly to the input of an Edirol by Roland Model R-09 digital audio recorder. The audio recorder was set up to operate at a sample rate of 44.1 kHz recording MP3 files at 96 kbps. The use of a audio recorder allowed for later repeated playback and analysis, including the option for narrow-band analysis if deemed necessary.

3.1.5 Ultrasonic Anemometer

Wind speed and direction data were measured using an FT Technologies™ Model 702 ultrasonic anemometer. The FT 702 samples wind speed and direction at a rate of 5 samples per second and also provides a 1-second averaged output that was stored in the Husky™ H/PC. Due to the low ambient sound levels anticipated at many of the measurement sites, the use of these ultrasonic anemometers over a conventional wind cup/vane anemometer provides the advantages of: (1) the elimination of moving parts, which could potentially contaminate the acoustic data collected; and (2) a rugged, stainless steel construction, which means they are well suited for outdoor environments.

3.1.6 Solar Panel Array

Power to the instrumentation was provided by one of two means: (1) in areas with sun exposure during the day, a portable solar panel array was used; and (2) in areas with little or no sun exposure, marine batteries were used. Two marine batteries provided enough power to support collection of data for approximately two weeks; whereas systems using a solar panel array allowed for continuous data collection, as long as a modest amount of direct sunlight was available during daylight hours.

3.2 Volpe Low-Amplitude Recording Equipment (VoLARE) System

This is a specialized “turn-key” system, developed by the Volpe Center for low-level ambient noise measurements. It facilitates direct recording or on-site ⅓-octave-band analysis of measured low-level ambient sound level data. More detailed discussion on this system can be found in Reference 10. VoLARE has been extensively tested and successfully used in previous FAA and NPS studies.[9,10,11]

3.2.1 Microphone System

The microphones used in most conventional acoustic systems, including the NoiseLogger™ system, are capable of measuring sound levels down to about 15 to 20 dBA. For measuring sound level data near the threshold of human hearing (approximately 0 dBA), which is common in some of the remote areas within national parks, the microphone is the limiting component in a conventional measurement system. The Brűel & Kjær™ (B&K) Model 4179 microphone is a highly sensitive, 1-inch condenser microphone specially designed for very low-level sound measurements and capable of measuring down to the threshold of human hearing.*

---

* Because the B&K 4179 microphone is a condenser microphone, it is extremely sensitive to humidity, which can result in electrical arcing in high humidity environments. Arcing will contaminate the measured signal, and can, in extreme situations, cause damage to the microphone. It is for this reason that the B&K 4179 microphone is only used in the VoLARE system with an acoustic observer present and not used in the unmanned, long-term NoiseLogger™ and NoiseLogger Plus™ systems.

Additionally, the B&K Model 2660 preamplifier and Model 2804 power supply were employed in this system. As per manufacturer's specifications, the Model 2804 power supply was modified for use with the Model 4179 and 2660.

The VoLARE system utilizes a tripod-mounted, two-stage windscreen, which is documented extensively in Reference 10, consists of a 20-in (51 cm) diameter, fabric-covered, outer stage, and a conventional, B&K Model UA0207 3.5-in (9 cm) diameter, foam windscreen making up the inner stage.

3.2.2 Sound Level Meter (SLM)

The microphone system was connected to a Larson Davis™ (LD) Model 824 sound level meter (SLM). The Model 824 SLM was set up with slow exponential time-weighting to continuously measure the overall A-weighted equivalent sound level for each 1-second sample, as well, as the Z-weighted equivalent sound level in each ⅓-octave-band from 12.5 Hz to 20 kHz.

To successfully utilize the 824 SLM for measurements down to the threshold of human hearing, it was necessary to bypass the unit's built-in firmware parameters, which limit the minimum levels that can be quantified and stored (about 20 dBA). To circumvent this limitation, an offset calibration technique was employed. Specifically, the SLM requires that the output level of the sound calibrator be specified. In this case, the B&K Model 4231's 94-dB nominal output level was used. By means of setting the SLM so that the 94-dB level indicated a level of 119 dB, an effective 25-dB-offset calibration was applied. The result was that all of the sound level data measured and stored by the SLM was artificially high by an offset of 25 dB. This 25-dB factor was accounted for, as if it were system gain, in the data reduction process (see Section 5). This technique allowed the SLM to accurately measure sound levels down to below 0 dBA.

3.2.3 Digital Audio Tape (DAT) Recorder

The AC output of the LD 824 SLM was connected directly to the input of a Sony™ Model TCD-D100 digital audio tape (DAT) recorder. The DAT recorder was set up to operate at single speed in a two-channel recording mode. At single speed, the 295-ft. (90-meter) tapes used were capable of providing slightly more than 3 hours of recording time. The use of a DAT recorder allowed for later repeated playback and analysis, including the option for narrow-band analysis if deemed necessary.

3.3 Source Identification/Acoustic Observer Log

In characterizing natural and non-natural acoustic conditions in a park, knowledge of the intensity, duration, and distribution of the sound sources is essential. Thus, during sound-level data collection, FAA and NPS have agreed that periods of observer logging "*in situ*" (i.e., on site and in real-time) and/or post measurements using high-quality digital recordings will be conducted in order to discern the type, timing, and duration of different sound sources.

In situ observer logging takes full advantage of human binaural hearing capabilities, allows identification of sound source origin, simultaneous sound sources, and directionality, and closely matches the experience of park visitors. In performing this activity, the acoustic environment was documented as a timed record of audible sounds using an automated spreadsheet programmed onto a Hewlett-Packard™ Model 200LX palmtop computer. Using preprogrammed macros, the spreadsheet allows the observer to place an immediate time stamp for an event and categorize that event into one of three primary acoustic states, based on the following hierarchal order: (1) Aircraft intrusions; (2) Human intrusions; and (3) Natural sounds. Aircraft intrusions include air tour, commercial, general aviation, military, and other aircraft sounds. Non-aircraft (human) intrusions may include hikers, campers, talking, motor vehicles, etc. The natural category is documented when no aircraft or other human-made sounds can be heard. If more than one event within the same state category could be heard, the louder one (based on the observer's judgment) is logged with a notation of the other sounds that were present. An acoustic state would prevail until the current intrusion is no longer audible, or a new intrusion higher in the hierarchal order becomes audible to the observer.

Off-site audio playback observer logging allows for sampling periodically throughout the entire measurement period (e.g., 10 seconds every 2 minutes) and repeated playback of the recordings (e.g. when the sound is difficult to identify). Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustic environment.

3.4 Other Instrumentation

Three additional pieces of acoustic-support instrumentation are worthy of mentioning:

- *Sound level calibrator* - A B&K Model 4231 sound level calibrator was used in the field for establishing and checking the sensitivity of the entire acoustic instrumentation system (i.e., microphone, preamplifier, cables, and SLM). The Model 4231 produces a user-selectable 94-dB sound pressure level at a frequency of 1 kHz.
- *Microphone simulator* - A microphone simulator was used to establish the electronic noise floor of the entire electrical system absent of the microphone.
- *GPS unit* - A Garmin™ GPS Plus III unit was used to perform time synchronization of all pertinent instrumentation and documentation of the exact site location.

Page left blank intentionally.

4. FIELD MEASUREMENT PROCEDURES

This section presents the field measurement procedures utilized in the study. Sections 4.1 through 4.5 present a step-by-step description of the field measurement procedure, including deployment and dismantling.

4.1 NoiseLogger™ System Deployment

Figure 12 shows the NoiseLogger™ system as deployed in the field at Site DV2.

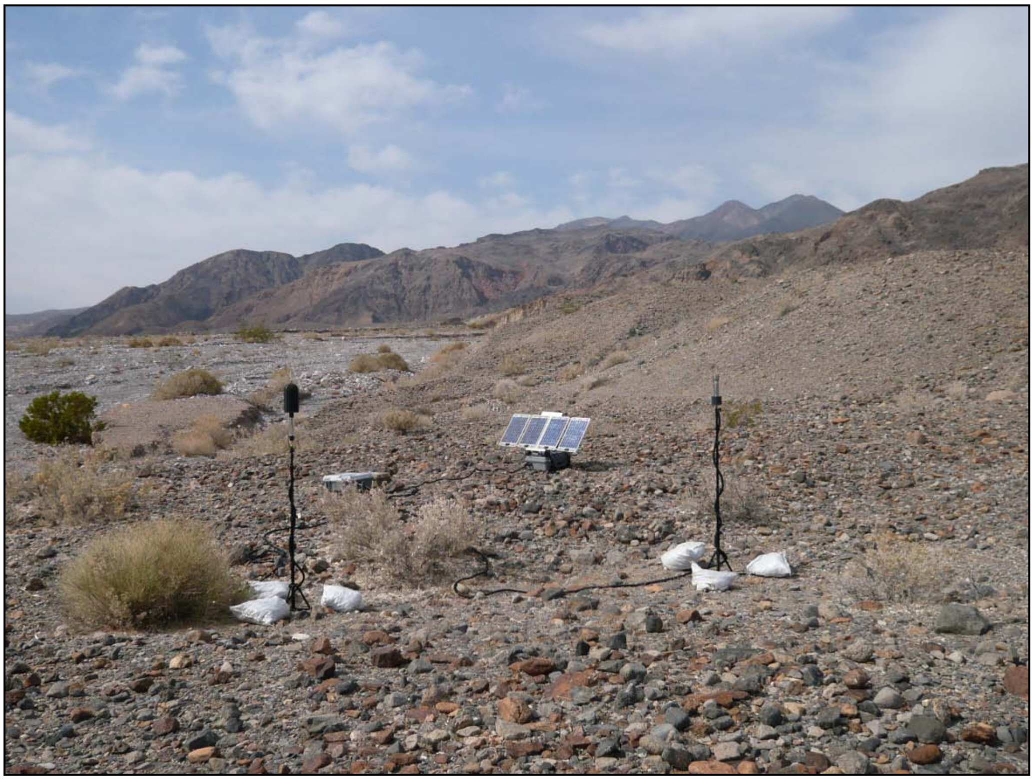


Figure 12. NoiseLogger™ system deployment: Site DV2.

Following is a general step-by-step description of the system setup, which took place at all measurement sites:

1. The microphone, preamplifier, and windscreen were attached to a tripod, which was positioned in a location considered typical of the surrounding ambient environment. Care was taken to ensure that this location was not near any known localized noise sources and/or reflective surfaces. The tripod was adjusted to locate the microphone diaphragm at a height of 5 ft (1.5 m) above the local ground surface and oriented vertically (microphone grid facing the sky). To ensure physical stability, the tripod legs were secured using nylon rope with tension adjusters and/or sandbags.
2. The ultrasonic anemometer was attached to a second tripod, which was positioned at least 1 ft (0.3 m), but within 5 ft (1.5 m) of the microphone location. The tripod was adjusted to locate the anemometer sensor at a height of 5 ft (1.5 m) above the local ground surface and

oriented north using a compass. To ensure physical stability, the tripod legs were secured using nylon rope with tension adjusters and/or sandbags.

3. The solar panel array was deployed facing due south to ensure maximum exposure to daytime sunlight. Note: For the NoiseLogger Plus™ system, two solar panel arrays were deployed. If adequate sun exposure was not available for sites located within forested areas, marine batteries were used in place of the solar panel arrays.
4. All connections in the SLM system case were checked and a new CompactFlash™ card, which was used to store measured data, was inserted into the Husky™ H/PC prior to turning on the H/PC. Note: For the NoiseLogger Plus™ system, CompactFlash™ cards were not necessary as this system utilized the Fujitsu laptop computer and measured data were stored in its internal hard drive (see also Section 3.2).
5. The NoiseLogger™ program was retrieved from the CompactFlash™ card, and then invoked. Note: Because CompactFlash™ cards were not necessary for the NoiseLogger Plus™ system, the NoiseLogger Plus™ program, stored in its internal hard drive, was invoked from the computer desktop.
6. Per the program instructions, the following information/action was entered/performed:
7. *Site information:* The unique three-character ID representing the site "number" (e.g., DV2 for site 2), and the site's name (e.g., Fall Canyon) were entered;
8. *Synchronization with the GPS unit:* Two minutes of one-second latitude and longitude data from the GPS unit were collected by the Husky™ H/PC;
9. *Equipment information:* System component model and serial numbers;
10. *System calibration:* Approximately 30 seconds of calibration signal are collected by the Husky™ H/PC;
11. *Sound Level Range:* The maximum sound level anticipated to be measured at the site. Given this user-selected "maximum," the NoiseLogger™ program automatically sets both a designated amount of gain and an absolute sound level limit ("ceiling") to LD Model 824 SLM. For example, for sites where a wide range of natural and mechanical sound sources were expected, this range was set to 90 dB. At this setting, the NoiseLogger™ program would apply 20 dB of gain to the LD Model 824 SLM, and the loudest sound level that could be measured would be 108 dB. For quieter sites, the "Sound Level Range" was set to lower levels, as appropriate.

Following calibration, the large windscreen was replaced onto the microphone and all external system cables were "dressed" to allow for easy visual inspection, and to prevent disturbance by site activity.

4.2 VoLARE System Deployment

Figure 13 and Figure 14 show the VoLARE system as deployed in the field at Site DV7.

Figure 13. VoLARE microphone system deployment: Site DV7.

Figure 14. VoLARE recording system deployment: Site DV7.

Following is a step-by-step description of the VoLARE system setup:

1. The microphone, preamplifier, and windscreen were attached to a tripod. The tripod was adjusted to locate the microphone diaphragm at a height of 5 ft (1.5 m) directly above the local ground surface, oriented vertically (microphone grid facing the sky).
2. The SLM, DAT, and acoustic data recording instrumentation were positioned in full view of the microphone location, but at a distance approximately 50 to 100 ft (15-30 m) away from it, to avoid noise intrusions by the acoustic observers.
3. Internal clocks of all pertinent instrumentation (namely the SLM, DAT, meteorological system and palmtop) were set to the time of the nearby NoiseLogger™ or NoiseLogger Plus™ system.
4. With all electrical components of the acoustic measurement system connected and given adequate time to warm up (typically 10 to 15 minutes), a preliminary sound level calibration of the system was performed. The purpose of the preliminary calibration was to ensure that all equipment was operating properly. A frequency-response calibration of the entire electrical system, absent of the microphone was then performed with the pink noise generator.
5. The electronic noise floor of the entire electrical system absent of the microphone was established, using a non-transducive (i.e., mechanically passive) capacitive load.
6. After re-installation of the microphone and given adequate time to stabilize, a pre-measurement sound level calibration of the system was performed.
7. The two-stage windscreen was then deployed and the preamplifier cable secured to a leg of the tripod, to prevent possible vibration. All other cables were "dressed" to allow for easy visual inspection, and to prevent disturbance by site activity.
8. Section 4.3 next presents the step-by-step description of the field data collection procedure.

4.3 Measurements

The following types of data were collected:

- *Acoustical*:
    - Continuous, one-second, A-weighted sound levels and their associated one-third octave-band un-weighted spectrum from 20 to 20,000 Hz;
    - Continuous digital audio recordings
- *Meteorological*: Continuous, one-second wind speed and direction data; and
- *Observer Logs*: During site visits, a field observer would perform short-term documentation of the acoustic environment at the site. Events audible within the acoustic environment were categorized into one of three primary acoustic states, based on the following hierarchal order: (1) Aircraft intrusions; (2) Human intrusions; and (3) Natural sounds. Aircraft intrusions include air tour, commercial, general aviation, military, and other aircraft sounds. Examples of non-aircraft (human) intrusions include hikers, campers, talking, motor vehicles, etc. The natural category was documented when no aircraft or other human-made sounds could be heard. If more than one sound within the same acoustic state category could be heard, the

louder one (based on the observer's judgment) was logged with a notation of the other sounds that were present. An acoustic state would prevail until the current intrusion was no longer audible, or a new intrusion higher in the hierarchal order became audible to the observer. In addition to the three primary acoustic states, there were several sub-states as shown in Table 6.

The following is the step-by-step description of the field data collection procedure:

1. One field observer continuously documented the acoustic environment at the site, i.e., acoustic observer logging.
2. The other field observer periodically checked the equipment and took photographs of any visible aircraft for later determination of slant range. Detailed logs, including site, data, time, aircraft type, aircraft model, operator, tail number, and direction (when identifiable), were kept for later correlation with the recorded images. Note: Slant range data collection occurred only during the initial systems deployment, and not during remaining measurement period, when NPS personnel performed all site visits, acoustic observer logging, and system maintenance/relocation.
3. At the end of the site visit, all data were downloaded and transferred onto a central computer. For NoiseLogger™ systems, data were downloaded by removing the CompactFlash™ card from the Husky™ H/PC. For the VoLARE system, data were downloaded by removing the DAT tape from the recorder and using Larson Davis software to transfer data from the LD824 sound level meter to a laptop.
4. A post-measurement sound level calibration of the VoLARE's acoustical system was performed and any drift from the initial calibration was documented. The internal clocks of the SLM and DAT were compared with the master clock and any time drift was documented.
5. All VoLARE instrumentation was powered down, disconnected, and stored.
6. The NoiseLogger™ systems were then recalibrated and ambient sound level data collection re-initiated. If it were the end of the measurement trip, then the systems was dismantled and packed into backpacks for transport from the site.

Table 6. Acoustic state identifiers.

Primary Acoustic States					
Aircraft Intrusions		**Human Intrusions**		**Natural Sounds**	
Sub-State	**Description**	**Sub-State**	**Description**	**Sub-State**	**Description**
Helicopter Aircraft	Designates noise produced by rotor-type aircraft	Human	Designates noise produced by park visitors, e.g., voices	Wildlife Animal	Designates noise produced by wildlife, e.g., birds
Propeller Aircraft	Designates noise produced by propeller-type aircraft	Vehicle	Designates noise produced by vehicles, e.g., automobiles	“Wind in the Foliage”	Designates noise produced the wind in foliage, e.g., trees
Jet Aircraft	Designates noise produced by jet-type aircraft	Domesticated Animal	Designates noise produced by pets, e.g., dog barking	“Wind in the Ear”	Designates noise produced the wind in the observer’s ear, including silence
Unknown	Designates noise produced by unknown-type aircraft (invoked primarily for aircraft, which are heard, but not seen)	Other	Designates noise produced by other human-induced sources	Water	Designates noise produced the water sources, e.g., waterfall
Tour Operator	Designates tour operator	Measurement Team	Designates noise produced by the field measurement team (Note: All sound level data measured during acoustic states identified with “Human Intrusion - Measurement Team” designations are not included in the data analysis.)	Other	Designates noise produced by other natural sources
Commercial Operator	Designates commercial operator				
General Aviation Operator	Designates general aviation operator				
Military Operator	Designates military operator				
Unknown Operator	Designates unknown operator (invoked primarily for aircraft, which are heard, but not seen)				
High Altitude	Designates high altitude aircraft (typically greater than 2000 ft above ground level, or AGL)				
Medium Altitude	Designates medium altitude aircraft (typically between 1000-2000 ft AGL)				
Low Altitude	Designates low altitude aircraft (typically below 1000 ft AGL)				

5. DATA REDUCTION AND PROCESSING

This section summarizes the steps involved in the reduction and processing of the acoustic and meteorological data. These data were used by the Volpe Center as input to its data processing program, entitled NLcrunch (see Section 5.3). NLcrunch is a program developed by the Volpe Center to reduce, analyze and archive the large volume of data collected at the national parks in support of the ATMP Program.

5.1 Acoustic and Meteorological Data Reduction

5.1.1 NoiseLogger™ Data

Raw NoiseLogger™ and NoiseLogger Plus™ files contain both acoustic and meteorological data. The filename format of the files was as follows:

“TH13OB_Sxxx_YYYYMMDD.000,”

where “TH13OB_” is the default NoiseLogger™ header label, “Sxxx” is a unique four-character ID representing the site number (e.g., “SDV1” represents Site DV1), “YYYY” is the four-digit representation for the year, “MM” is the two-digit representation for the month, and “DD” is the two-digit representation for the day of the month. The “.000” extension identifies these files as binary formatted.

NoiseLogger™ files were then translated into ASCII text files by the NLcrunch program. Each line of the text file represented a 1-second data sample containing the date, time, equipment ID, battery voltage, internal temperature, and 1-second averaged wind speed, wind direction, Z-weighted (flat or no weighting) L_{eq}, C-weighted L_{eq}, A-weighted L_{eq}, and Z-weighted spectral data (12.5-20,000 Hz).

In addition to the binary files, the NoiseLogger™ system also recorded live audio samples. These files were used for later repeated playback during detailed analysis of distinct acoustic events.

5.1.2 VoLARE Acoustic Data Reduction

The filename format of the raw, binary files was as follows:

“MMDDYYxx.slmdl”

where “MM” is the two-digit representation for the month, “DD” is the two-digit representation for the day of the month, “YY” is the two-digit representation for the year, and “xxx” is a unique three-character character ID representing the site (e.g., “DV1” represents Site DV1). The “.slmdl” extension identifies these files as binary formatted Larson Davis (LD) Model 824 sound level meter (SLM) files.

The raw, binary VoLARE files were translated into comma-delimited ASCII text files using the LD 824 Utility Software (or LD 820 Utility Software, as appropriate). The text file contained the SLM settings and the 1-second data samples, which included the date, time, battery voltage, internal temperature, 1-second A-weighted L_{eq}, and Z-weighted spectral data (12.5-20,000 Hz).

5.2 Acoustic Observer Log Data Reduction

The acoustic observer log data files were checked by the actual field observer for accuracy, and edited as necessary to complete incomplete entries, clarify ambiguous comments, fix typographical errors, and remove blank rows. The files were then translated to Microsoft™ Excel format for input into NLcrunch.

5.3 Data Processing

As stated earlier, the acoustical, meteorological data, and observer log data were used as input to the data processing program, entitled NLcrunch, Version 4. The NLcrunch program applies several quality assurance filters and checks (Section 5.4.1), and then several adjustments (Section 5.4.4) to the acoustic data prior to detailed data analysis.

5.3.1 Data Filters

Several quality assurance filters and checks were applied to the acoustic data to ensure that any questionable data is identified and that only “good” data is used in the preparation of acoustic results and conclusions. The list of filters used to identify “bad” or questionable data indicating system errors/problems:

- Data whose associated battery readings were less than 11.0 volts, the minimum voltage required to properly run the NoiseLogger™ system;
- Data whose associated internal temperature readings were greater than 122 degrees Fahrenheit, the LD Model 824 SLM’s maximum operating temperature limit;
- Data whose associated 1-second average wind speeds were less than zero m/s, indicating an anemometer error;
- Data whose associated 1-second, unweighted sound levels exceeded the manufacturer’s instrumentation noise “ceiling level” for the gain setting of the instrument, which indicate a system overload; and
- Data, which indicates a problem with the sound-level sample (e.g., data whose associated one-third octave-band data look flat-lined).

The following list of filters should be used to identify “bad” or questionable data that may bias the ambient sound level data:

- Data whose associated 1-second average wind speeds were greater than 11 mph (5 m/s). Note: Available data suggests that there is a high probability of microphone-induced distortion above this wind speed threshold; however, unless such wind conditions occur more than 50 percent of the hour, exceedence metrics (e.g., L_{50}, L_{90}) will not likely be influenced. If necessary, a portion of this data may be included in the final data set. This process is referred to as “backfilling” (see Section 5.4.3).
- Data that were contaminated by field personnel (e.g., data potentially contaminated by field personnel handling instrumentation during the calibration process) and/or other activities atypical for that area; and
- Data in any given hour, for which greater than 25 percent of the samples are lost due to the above and previously listed system error factors. This ensures hours with only a few samples

cannot bias the analysis. See also Section 5.4.2 for guidance on pooled versus un-pooled data, and Section 5.4.3 for guidance to potentially recover hourly datasets with data loss due to high wind conditions (i.e., backfilling).

5.3.2 Data Pooling

There are two approaches to grouping data for analysis: pooled and unpooled. The pooled approach is to combine individual 1-second data from the entire sample period into a single dataset. Sound level descriptors, averages, variances, confidence levels, etc., are then computed for the set of statistical metrics for the pooled dataset. The unpooled approach is to analyze the data in discrete time periods, such as hourly. That is, sound level descriptors are computed for each individual hour; then the descriptors from individual hours across all days of the measurement period are determined.

The FAA and NPS have agreed that ambient analysis for ATMP parks will be performed using unpooled, hourly summary data. Although prior studies[21] have shown that results for pooled analyses are generally more conservative (i.e., lower) than results for an hourly analysis, analyzing ambient data by hour helps to ensure hour-to-hour and day-to-day variation is addressed. For hourly data analyses, hourly datasets are discarded for those hours that contain less that 75 percent of “good” data. This ensures hours with only a few samples do not bias the analysis.

5.3.3 Data Recovery for High Wind

In previous ATMP data analyses, high-wind data [i.e., acoustic data measured whose associated 1-second average wind speeds were greater than 11 mph (5 m/s), the predetermined, acceptable, wind speed threshold] were removed from the dataset prior to data analyses. Removing this data has the clear potential to underestimate the median (L_{50}) ambient sound level estimates, because high winds may elevate the natural ambient sound levels. Discarding all the high-wind data would also limit the amount of useful data from high-wind sites, such as along a coastline or in alpine areas. Since the cost of field data collection is expensive and time consuming, it is desirable not only to recover hourly samples and use as much data as possible, but also to ensure that the ambient calculated at naturally-windy sites is accurately represented.

Based on recent Volpe analyses[22] of ambient data previously collected within ATMP parks, it was determined that up to 10% of any hourly measurement dataset can consist of high-wind data before a significant change to the statistical median (L_{50}) is observed. For the majority of measurement hours, this allowed for almost all of the measured data to be used in the hourly estimates (i.e., at the majority of sites measured for the ATMP project, high-wind data represented less than 10 percent of the dataset).

However, even with the addition of 10-percent high-wind data, there are still some occurrences where 45 minutes of data in each hour (i.e., 75 percent as discussed in Section 5.4.2) are not available for analyses, such as along a coastline or in alpine areas. In order to recover a portion of the hours that do not meet this criteria, a process was developed to recover as much data as possible from these sites by replacing, or “backfilling,” data measured under high-wind conditions with data measured under high, but acceptable, wind conditions - specifically, data measured whose associated 1-second average wind speeds were between and 9 and 11 mph (4 and 5 m/s). Backfilling allows for the recovery of not only more hourly samples, but also ensures that the ambient calculated at naturally-windy sites is proportionally representative of windy conditions. Analysis showed that the effect to statistical descriptors, such as L_{50} and L_{90}, is typically less than 1 dBA.

The methods and criteria recommended for backfilling sound level data measured during high-wind conditions are as follows:

- The hour must contain at least 30 minutes (50 percent) of good data;
- The goal for each hour is to have 75 percent of its samples (i.e., 45 minutes) used for analysis. Therefore, allow 10 percent, or 4.5 minutes, to be high-wind data (i.e., data measured when wind speeds were greater than 11 mph);
- Perform backfilling using data measured when wind speeds were high, but acceptable (between 9 and 11 mph) until the “75 percent good” criteria is met (i.e. 45 minutes of data for each candidate hour) - replacing data up to 100% of the hour would be adding unnecessary simulated data.

5.3.4 Data Adjustments

The following is the list of adjustments applied to the acoustic data by the NLcrunch program:

- Gain adjustments were applied, if necessary (Note: No gain adjustments were required for NoiseLogger™ data).
- Calibration adjustments were applied. These adjustments accounted for calibration drift as determined by measuring a calibration signal at the start and end of each data collection period.
- Microphone frequency response adjustments were applied. These adjustments accounted for frequency response biases of the microphone and were provided by a microphone calibration facility. Appendix C presents these adjustments in detail.
- Windscreen frequency response adjustments were applied. These adjustments accounted for frequency response effects of the windscreen. Appendix C presents these adjustments in detail.
- Noise floor adjustments were applied to NoiseLogger™ data, as appropriate. Note: Because ambient noise levels measured in remote areas of the country under low wind conditions (such as in national parks) often approach the threshold of human hearing, a process was developed to adjust the NoiseLogger™ data for contamination effects of the system noise floor. Application of these adjustments provide for more accurate estimation of the true ambient sound levels without being limited by the equipment’s electrical noise floor. Appendix D discusses the method used to determine the noise floor of each NoiseLogger™ systems, as well as the final noise-floor adjustments used during data reduction.

5.4 Sound Level Descriptors

All sound-level data were analyzed in terms of the following metrics (also refer to the Terminology section for definitions):

- L_{eq}: The equivalent sound level determined by the logarithmic average of sound levels of a specific time period;
- L_{50}: A statistical descriptor describing the sound level exceeded 50 percent of a specific time period (i.e., the median); and

- L_{90}: A statistical descriptor describing the sound level exceeded 90 percent of a specific time period.

For each descriptor, both the broadband A-weighted sound level is determined and its associated ⅓-octave band un-weighted spectrum from 12.5 to 20,000 Hz. The process of computing the un-weighted one-third octave-band spectrum is virtually identical to the process for computing the broadband A-weighted sound level descriptors. The only difference is that the sound-level value is computed for un-weighted frequency-based sound levels rather than for broadband A-weighted sound levels. Specifically, the un-weighted sound level is computed individually for each ⅓-octave-band. The 33 un-weighted one-third octave-band sound levels (12.5 to 20,000 Hz) define the un-weighted sound level spectrum. This method of constructing the sound level spectrum means it is not an actual measured ⅓-octave band spectrum associated with a particular measurement sample, but a composite spectrum using the computed descriptor for each ⅓-octave-band.

5.5 Observer Log Descriptors

Periods of observer logging performed either in situ during sound-level data collection or later in the office or laboratory using high-quality digital recordings provides for an invaluable chronicle of the type, timing, and duration of the different sound sources that were audible during the observer log period (see also Section 4.2). These data not only provide a more complete characterization of the ambient environment, but also can be used to provide reasonableness checks with predicted audibility results from computer modeling efforts. Below are several commonly utilized metrics that can be determined from observer log data (the latter two are becoming more and more commonly found in NPS management plans):

- Time Audible is defined as the amount or percentage of time during a specified time period that the sound source of interest (e.g., aircraft) can be heard by the human ear.
- Number of Events per Hour (NEH) – The number of events of the sound source of interest (e.g., aircraft) that are audible within a specified time period.
- Noise-Free Interval (NFI) – The length of time that the sound source of interest (e.g., aircraft) is inaudible within a specified time period – essentially, the inverse of the Time Audible descriptor. For example, if aircraft sounds are audible 10 percent of the day, then the NFI is 90 percent.

5.6 Ambient Descriptors

The following four types of "ambient" characterizations are generally used and considered sufficient by the FAA and NPS in environmental analyses related to transportation noise: [21,23,24]

- *Existing Ambient:* The composite, all-inclusive sound associated with a given environment, excluding only the analysis system's electrical noise (i.e., aircraft-related sounds are included);
- *Existing Ambient Without Source of Interest:* The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sound source of interest, in this case, commercial air tour aircraft;

- *Existing Ambient Without All Aircraft* (for use in assessing cumulative impacts): The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sounds produced by the sound source of interest, in this case, all types of aircraft (i.e. commercial air tours, commercial jets, general aviation aircraft, military aircraft, and agricultural operations);* and
- *Natural Ambient:* The natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excluding all human and mechanical sounds.

If one considers the three sound level descriptors presented in Section 5.4 and the four types of ambient characterizations above, twelve ambient descriptors could potentially be computed as shown in Table 7.

Table 7. Matrix of twelve potential ambient descriptors

Metric	Ambient Type			
	Existing	Existing Without Air Tours	Existing Without All Aircraft	Natural
L_{Aeq}	1	4	7	10
L_{50}	2	5	8	11
L_{90}	3	6	9	12

From the above twelve potential ambient descriptors, only the first three can be readily computed (see Section 5.7). The computation of ambient types other than Existing Ambient is more challenging because different sound sources often overlap in both frequency and amplitude; there is currently no practical method to separate out acoustic energy of different sound sources (i.e., human-caused sounds imbedded with natural sounds). The two ambient descriptors agreed upon for use in ATMP analyses are:

- Existing Ambient Without Source of Interest ($L_{Existw/oTours}$) – Descriptor 5 from the table above; and
- Natural Ambient (L_{Nat})– Descriptor 11 from the table above.

5.7 Calculation of Ambients

Using the data in the acoustic observer logs, different characterizations of ambient can be *estimated* from the sound level data. This method was developed by performing a detailed data analyses conducted by the Volpe Center, working closely with the NPS, in comparing several approaches of estimating of the Natural Ambient and is comprised of the following steps:[25]

1. From the short-term in situ and off-site logging, determine the percent time human-caused sounds are audible.
2. Sort, high-to-low, the A-weighted level data, derived from the short-term, one-second, one-third octave-band data (regardless of acoustic state), and remove the loudest percentage

---

[*] The definition of Existing Ambient Without All Aircraft used in this report is consistent with FAA's historical approach for cumulative impact analysis.

(determined from the percent time audible of human-caused sounds in the short-term observer logs) of sound-level data. For example, if from Step 1 above, it is determined that at a particular site, the percent time audible of all human-caused sounds is 40 percent, then the loudest 40 percent of the A-weighted level data is removed. The L_{50} computed from the remaining data is the estimated A-weighted natural ambient. This L_{50}, computed from the remaining data, can be mathematically expressed as an L_x of the entire dataset as follows (%TA is the percent of time human-caused sounds are audible in the short-term observer logs):

$$L_x, \text{ where } x = 50 + \frac{\%TA}{2}$$

For example, if non-natural sounds are audible for 40% of the time, L0 to L40 corresponds to the loudest (generally non-natural) sounds, and L_{40} to L_{100} corresponds to the quietest (generally natural) sounds. The median of L_{40} to L_{100} data is L_{70}. Therefore, the A-weighted decibel value at L_{70}, the sound level exceeded 70 percent of the time, would be used for the entire dataset to characterize the natural ambient sound level.

3. The associated one-third octave-band un-weighted spectrum from 12.5 to 20,000 Hz is constructed similarly, except the L_{50} is computed from the remaining data for each one-third octave-band. As with the Volpe method, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample, but rather a composite spectrum derived from the L_x for each one-third octave-band.

This method for estimating the natural ambient is conceptually straightforward – as percent time audible approaches 0 percent, the Lx approaches L_{50}; as it approaches 100 percent, the L_x approaches L_{100}. A concern with this approach is that loud natural sounds, such as thunder, could be removed from the data before calculating natural ambient sound levels, and the resulting calculated natural ambient sound levels could be an under-estimate of natural ambient sound levels. Although this is a valid concern, such events are rare relative to the entire measurement period (>25 days). Therefore, removing these data should not likely have a significant impact on calculations of natural ambient sound levels. This method also eliminates the possibility of having an estimated natural ambient level that exceeds the existing ambient level.

Based on the concept of the above method, the computation of the other ambient types (Existing Without Sound Source of Interest using the percentage of time sounds from the source of interest, e.g., air tour aircraft, are audible from short-term in situ and off-site observer logging, and Existing Ambient Without All Aircraft using the percentage of time all aircraft are audible from the observer logging) is a similar process.

Page left blank intentionally.

6. RESULTS

This section summarizes the results of the study. Included are an overall summary of the final, ambient sound levels for each measurement site (Section 6.1), temporal trends (Section 6.2), and the acoustic observer data logged at each measurement site (Section 6.3).

6.1 Summary Results

The following figures and tables are presented to show overall site-to-site comparisons:

- Figure 15: A plot of the overall daytime[*] L_{50} sound level computed for each site with all days included for the summer season (a few points of interest outside the parks are also shown for comparison purposes only). The figure also shows a dark line above and below each plotting symbol, which indicate the 95% confidence interval on the results[†];
- Table 8 contains a table of the ambient, sound level data measured at each measurement site; and
- Table 9, Figure 16, and Figure 17 present the associated spectral data for the two ambient maps agreed upon for use in ATMP analyses: Existing Ambient Without Air Tours (L_{50}) and Natural Ambient (L_{50}).

---

[*] FAA and NPS have agreed that impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur – typically daytime hours. Daytime (as used in this report) will refer to the time period 7 am to 7 pm; nighttime will refer to the time period 7 pm to 7 am. For Death Valley ATMP analysis, only daytime data (measured during the time period of 7 am to 7 pm) will be used.

[†] The confidence interval is a measure of how certain one is of the value shown. The length of each of the dark lines indicate the day-to-day variability of the measurement for a particular site - the longer the line, the larger the day-to-day variability.

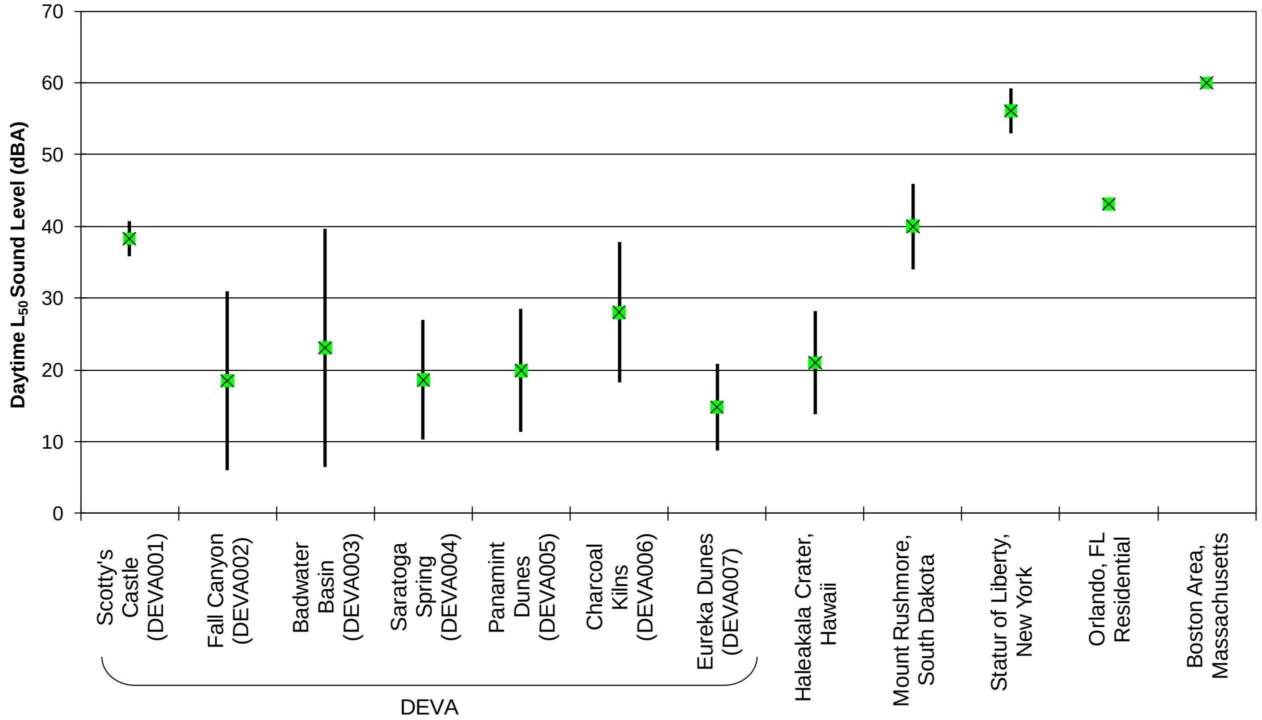


Figure 15. Comparison of overall daytime L_{50} sound levels for all sites for the summer season.[*]

---

[*] Confidence intervals for Orlando and Boston are not shown due to the limited amount of data represented (2 days and 1 week, respectively). Ambient data at ATMP parks, such as DEVA, are typically measured for at least 25 days.

Table 8. Summary of measured ambient sound level data for the summer season. [*]

Acoustic Zone	Site Name	Site ID	Total # Days	Existing Ambient						Existing Ambient Without Air Tours (Daytime Data Only 7 am to 7 pm)	Existing Ambient Without All Aircraft (Daytime Data Only 7 am to 7 pm)	Natural Ambient (Daytime Data Only 7 am to 7 pm)
				Daytime Data Only 7 am to 7 pm			Nighttime Data Only 7 pm to 7 am					
				L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)
Developed	Scotty's Castle	DV1	20	44.3	38.3	32.7	39.6	35.9	28.9	38.3	38.2	32.7
Barren	Fall Canyon	DV2	30	39.4	18.5	10.2	31.3	13.1	8.5	18.5	16.9	16.2
Barren	Badwater Basin	DV3	29	44.0	23.1	14.2	39.4	17.9	10.9	23.1	19.8	19.2
Shrubland	Saratoga Spring	DV4	29	34.1	18.6	13.2	30.6	19.4	11.9	18.7	17.7	17.6
Shrubland	Panamint Dunes	DV5	28	55.4	19.9	10.7	31.5	11.2	9.3	19.9	16.2	15.6
Forested	Charcoal Kilns	DV6	28	41.1	28.0	17.4	38.8	17.8	10.9	28.0	27.0	23.9
Shrubland	Eureka Dunes	DV7	28	51.8	14.8	10.7	27.6	10.9	9.8	14.8	13.3	13.2

---

[*] As stated earlier, two ambient maps were agreed upon for use in ATMP analyses: the Existing Ambient Without Air Tours (L_{50}) and the Natural Ambient (L_{50}).

Table 9. Summary of measured, daytime (7 am to 7 pm), ambient (without air tours) sound level spectral data for the summer season.[*]

Frequency (Hz)	Existing Ambient Without Air Tours L_{50} (dB)						
	DV1	**DV2**	**DV3**	**DV4**	**DV5**	**DV6**	**DV7**
12.5	53.9	48.9	54.9	49.0	50.9	37.1	47.2
16	50.6	45.7	51.8	45.0	47.8	35.4	43.6
20	47.6	42.0	48.3	40.8	44.3	33.8	40.0
25	45.6	39.2	45.7	36.5	41.1	32.9	37.2
31	46.3	36.2	42.5	32.2	38.2	31.2	33.9
40	45.7	33.4	39.5	29.0	36.3	29.4	30.4
50	44.0	30.7	36.7	25.4	33.8	27.4	27.6
63	44.2	28.9	33.8	23.0	31.0	25.7	26.2
80	42.8	26.8	31.7	21.7	28.0	23.5	23.1
100	37.5	24.0	27.6	19.0	25.6	21.6	20.6
125	35.5	21.4	24.8	17.0	23.2	20.4	17.6
160	34.7	19.2	22.0	16.9	20.5	20.7	16.0
200	31.7	17.7	20.6	14.7	19.3	22.1	16.1
250	31.1	17.5	19.4	13.2	18.2	23.2	16.1
315	33.3	13.7	16.8	11.1	16.5	24.3	11.2
400	33.3	10.0	14.3	10.3	12.5	25.1	8.9
500	32.0	8.1	12.7	10.0	9.3	24.1	6.6
630	29.5	6.4	12.3	8.5	7.3	21.9	3.7
800	29.0	3.3	11.2	6.8	4.9	19.1	3.1
1000	27.9	2.3	9.5	6.0	3.6	16.0	2.3
1250	26.2	1.8	7.7	5.8	2.0	12.3	1.5
1600	25.0	1.3	5.8	2.8	1.5	8.3	1.2
2000	23.7	-0.7	4.3	2.4	1.3	3.8	1.0
2500	22.0	-0.5	2.8	1.2	1.5	0.7	0.3
3150	19.8	-2.6	2.9	-0.3	-1.0	-0.5	0.4
4000	17.9	-5.1	2.1	1.6	-3.5	0.5	0.7
5000	16.9	-7.6	2.9	3.4	1.9	2.3	-0.7
6300	16.0	-10.1	1.6	3.7	3.1	3.3	-3.2
8000	15.2	-12.6	-1.7	5.1	-10.9	5.3	-5.7
10000	15.2	-15.1	-4.3	6.4	-13.6	6.5	-8.2
12500	14.7	-17.6	-6.8	3.5	-16.0	4.4	-10.7
16000	12.8	-20.1	-9.4	3.8	-18.6	1.6	-13.2
20000	13.9	-22.6	-11.8	5.2	-21.1	-1.2	-15.7

---

[*] As discussed in Section 5.7, the spectral data associated with the L_{50} exceedence level is constructed by determining the L_{50} from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

Table 10. Summary of measured, daytime (7 am to 7 pm), natural ambient sound level spectral data for the summer season.[*]

Frequency (Hz)	Natural Ambient L_{50} (dB)						
	DV1	**DV2**	**DV3**	**DV4**	**DV5**	**DV6**	**DV7**
12.5	40.2	46.2	51.1	46.9	45.2	33.2	44.2
16	39.6	42.8	47.6	42.8	41.6	32.1	40.4
20	40.3	39.8	44.6	38.9	38.6	30.4	37.5
25	37.3	37.1	41.7	34.5	36.4	29.1	34.5
31	43.1	34.1	39.2	30.9	33.8	27.3	30.6
40	36.5	31.5	36.4	28.0	32.1	25.8	27.6
50	38.1	29.0	33.1	24.4	29.5	24.1	25.0
63	41.1	27.4	29.7	22.0	26.9	22.4	23.7
80	39.1	24.9	28.0	20.4	23.7	20.9	20.7
100	33.3	22.2	23.7	17.7	21.1	19.4	18.5
125	31.9	19.5	21.1	15.8	18.9	18.3	15.4
160	31.4	17.4	19.0	15.2	16.4	18.5	14.2
200	26.6	16.4	17.8	13.7	15.6	19.8	14.8
250	27.8	15.9	17.0	12.2	15.4	20.8	13.4
315	29.3	11.0	13.4	10.4	11.1	21.5	7.9
400	29.3	7.7	11.6	9.5	8.5	22.4	7.3
500	28.8	5.6	10.8	8.7	5.2	21.4	4.6
630	27.2	4.9	10.2	6.8	3.1	19.3	2.6
800	25.6	2.7	8.8	5.7	1.4	16.5	1.5
1000	24.3	1.6	7.6	5.3	1.5	13.2	1.4
1250	22.4	0.1	6.4	4.5	0.7	9.3	1.0
1600	21.3	0.8	5.0	2.4	0.2	5.0	0.9
2000	19.6	-1.0	3.8	1.8	1.0	1.0	0.7
2500	17.5	-0.7	2.5	0.5	1.2	-1.2	0.1
3150	15.5	-3.2	2.6	-0.9	-1.4	-2.1	0.2
4000	13.0	-5.6	2.0	2.0	-3.9	-1.0	0.5
5000	11.7	-8.1	2.5	3.2	-1.7	1.2	-1.7
6300	9.9	-10.6	0.0	3.7	-2.8	2.5	-4.2
8000	8.7	-13.1	-2.6	5.1	-11.3	4.8	-6.7
10000	8.6	-15.6	-5.1	6.3	-13.9	6.0	-9.2
12500	6.7	-18.1	-7.6	3.0	-16.4	3.8	-11.7
16000	4.2	-20.6	-10.1	1.2	-18.9	-7.9	-14.2
20000	1.7	-23.1	-12.6	4.5	-21.4	-11.0	-16.7

---

[*] As discussed in Section 5.7, the spectral data associated with the L_{50} exceedence level is constructed by determining the L_{50} from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

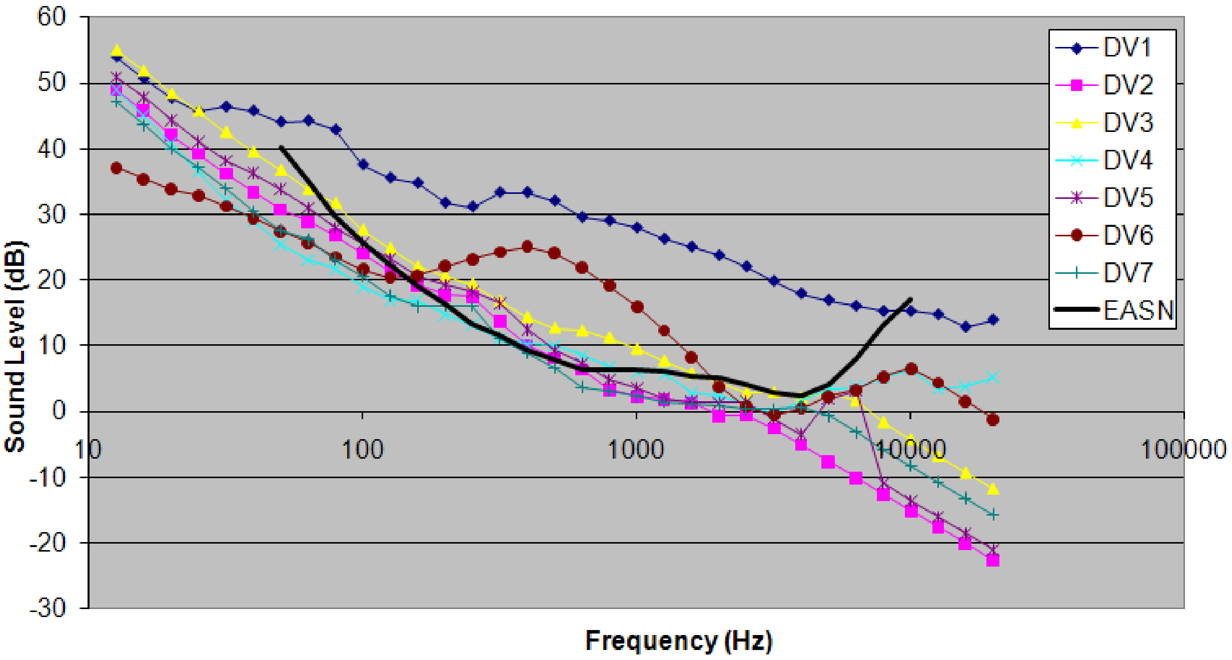


Figure 16. Spectral data for the Existing Ambient Without Air Tours (L_{50}) for each site for the summer season.[*]

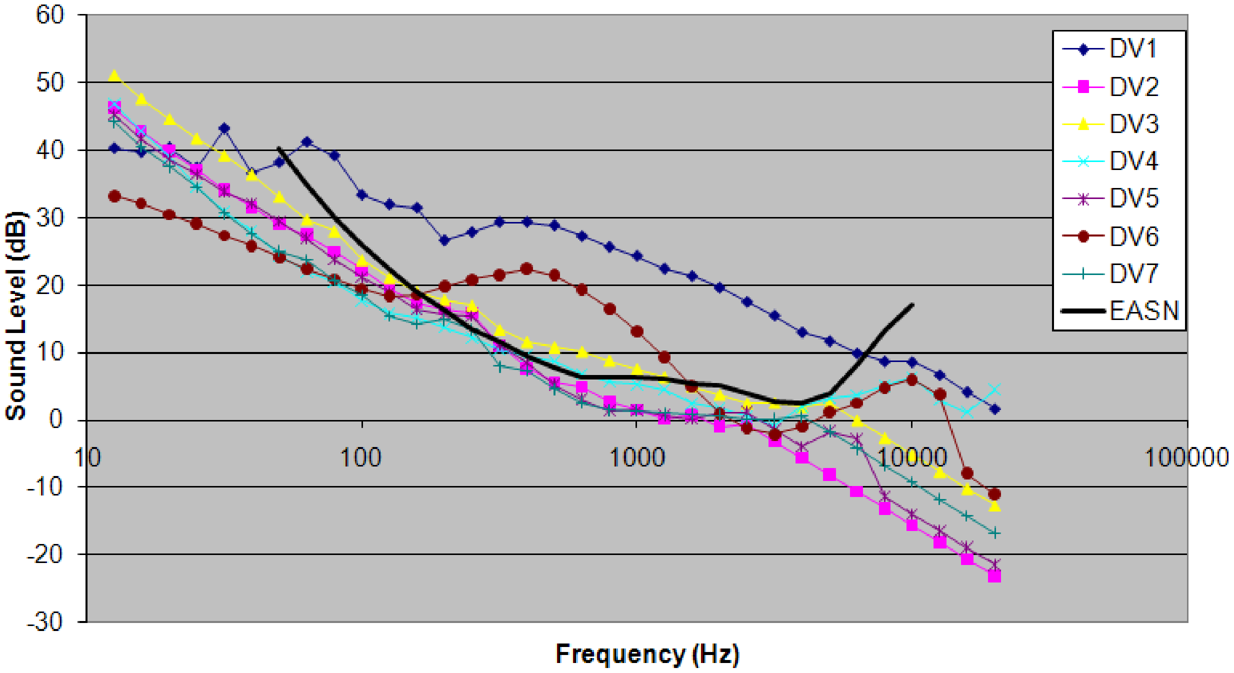


Figure 17. Spectral data for the Natural Ambient (L_{50}) for each site for the summer season.[*]

---

[*] Also shown in each figure is the Equivalent Auditory System Noise (EASN), which represents the threshold of human hearing for use in modeling audibility using one-third octave-band data.

6.2 Temporal Trends

This section discusses the daily and diurnal trends of the data. Daily trends are shown on a 24-hour basis. Figure 18 presents the daily median Existing Ambient (i.e., the L_{50} with all sounds included) for the summer and winter seasons, respectively. For the purpose of assessing daily trends in the data, sound level descriptors are computed for each individual hour; then the median from the 24 hours each day is determined. Dips and increases in daily sound levels are usually an indication of passing inclement weather and localized events. This data is useful in visually identifying potential anomalies in the data. Data anomalies would then be further examined from data recorded by the sound level meter and/or recorded audio samples.

Diurnal trends are shown on an hourly basis. Figure 19 presents the hourly median Existing Ambient (i.e., the L_{50} with all sounds included) for the summer and winter seasons, respectively. Sites with a strong daytime diurnal pattern typically indicate the presence of human activity largely influencing the sound levels at those sites. Sites with a nighttime pattern typically indicate the presence of insect activity. Sites with little discernable pattern, e.g., somewhat constant across all hours, typically indicates a constant sound source. Examples of constant sound sources include nearby generators or shoreline surf. This data is also useful in visually identifying potential anomalies in the data.

Note: As stated earlier in Section 2.7.2, the FAA and NPS have agreed that impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur – that is, daytime hours. Daytime (as used in this report) will refer to the time period 7 am to 7 pm; nighttime will refer to the time period 7 pm to 7 am.

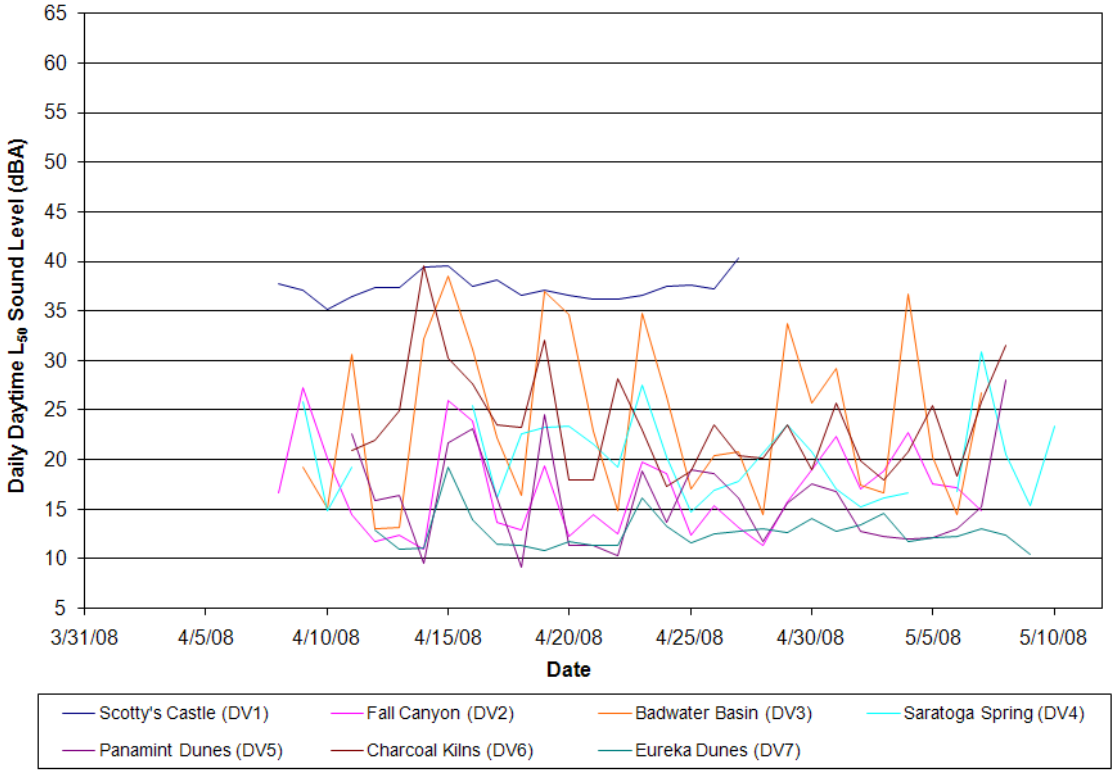


Figure 18. Comparison of daily L_{50} sound levels for all sites for the summer season.

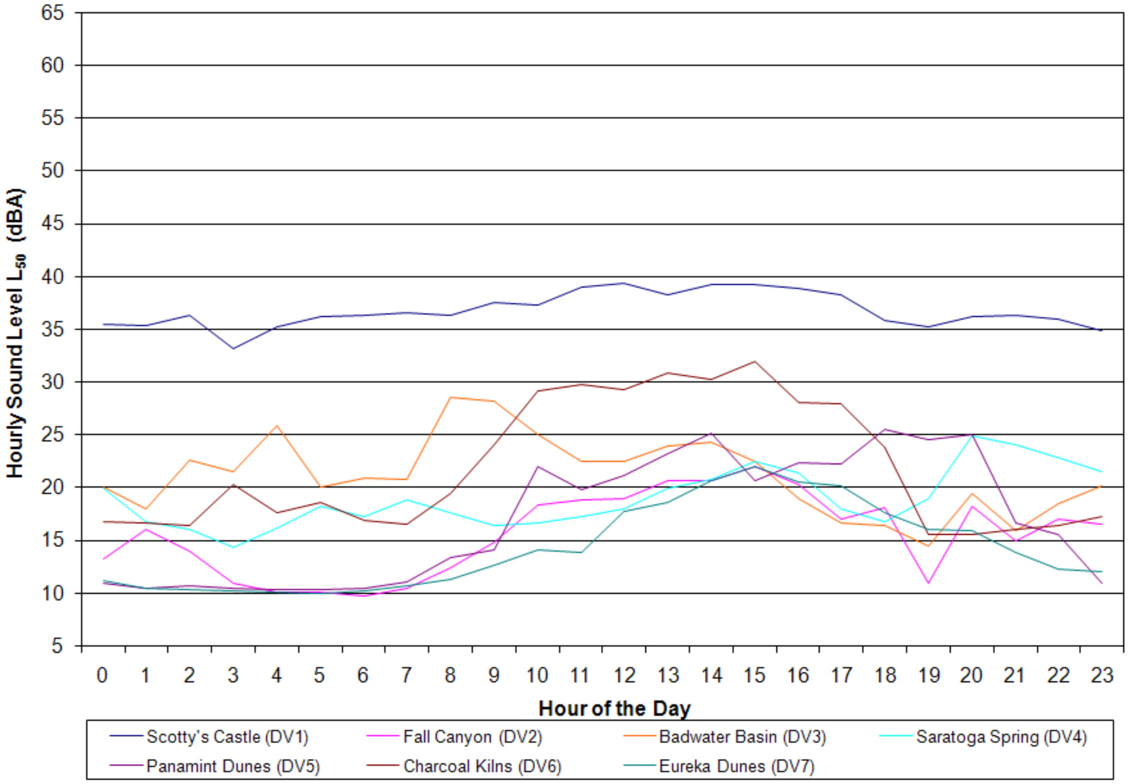


Figure 19. Comparison of hourly L_{50} sound levels for all sites for the summer season.

6.3 Acoustic Observer Log Results

Table 11 and Figure 20 provide a summary of the acoustic observer data logged at each measurement site. This information gives an indication of the amount of time that certain sources are present at each site. Using the data in the acoustic observer logs, different characterizations of ambient can be *estimated* from the sound level data (as discussed in Section 5.7). The first four columns in the table are arranged as follows:

- *Acoustic Zone*: The acoustic and management zone in which the measurement site was located;
- *Site Name:* The name of the site;
- *Site ID*: The unique three-character ID representing the site "number";
- *Level of Visitor-Use*: A designator indicating expected visitor use (with "high" indicating sites such as overlooks, "moderate" indicating short hikes, and "low" indicating minimal or no visitor use such as in the wilderness/backcountry) in the measurement site area;

The next four columns define the percentage of time that different noise sources were audible to the acoustic observer. Events audible within the acoustic environment were categorized into one of three primary acoustic states, based on the following hierarchal order: (1) Aircraft intrusions; (2) Human intrusions; and (3) Natural sounds. For aircraft intrusions, the acoustic observer would attempt to discern whether the aircraft was an air tour operation, or other operation (i.e., commercial, general aviation, or military) based on visual and auditory cues (e.g., type of aircraft and proximity to known air tour routes). Examples of non-aircraft (human) intrusions include hikers, campers, talking, motor vehicles, etc. The natural category was documented when no aircraft or other human-made sounds could be heard.

- *Fixed-Wing Aircraft and Helicopters*: The percentage of observer log time that typical air tour aircraft, fixed-wing aircraft and helicopters, were audible;
- *Other Aircraft*: The percentage of observer log time that air tour aircraft (e.g., commercial, military, general aviation, and agricultural) were audible;
- *Human*: The percentage of observer log time that human noise sources (visitor- and mechanical-related) were audible; and
- *Natural*: The percentage of observer log time that natural noise sources were audible.

Table 11. Summary of acoustic observer log data (in situ and office listening combined) for all sites for the summer season.

Acoustic Zone	Site Name	Site ID	Level of Visitor-Use	% Time Audible			
				Fixed-Wing Aircraft and Helicopters	Other Aircraft	Other Human	Natural
Developed	Scotty's Castle	DV1	High	0.0%	2.5%	78.1%	19.4%
Barren	Fall Canyon	DV2	Low	0.0%	13.6%	5.6%	80.8%
Barren	Badwater Basin	DV3	Low	0.0%	19.0%	5.2%	75.7%
Shrubland	Saratoga Spring	DV4	Low	0.0%	9.7%	2.0%	88.3%
Shrubland	Panamint Dunes	DV5	Low	0.0%	28.2%	2.8%	69.0%
Forested	Charcoal Kilns	DV6	Moderate	0.0%	10.1%	27.6%	62.4%
Shrubland	Eureka Dunes	DV7	Low	0.0%	17.0%	3.2%	79.9%

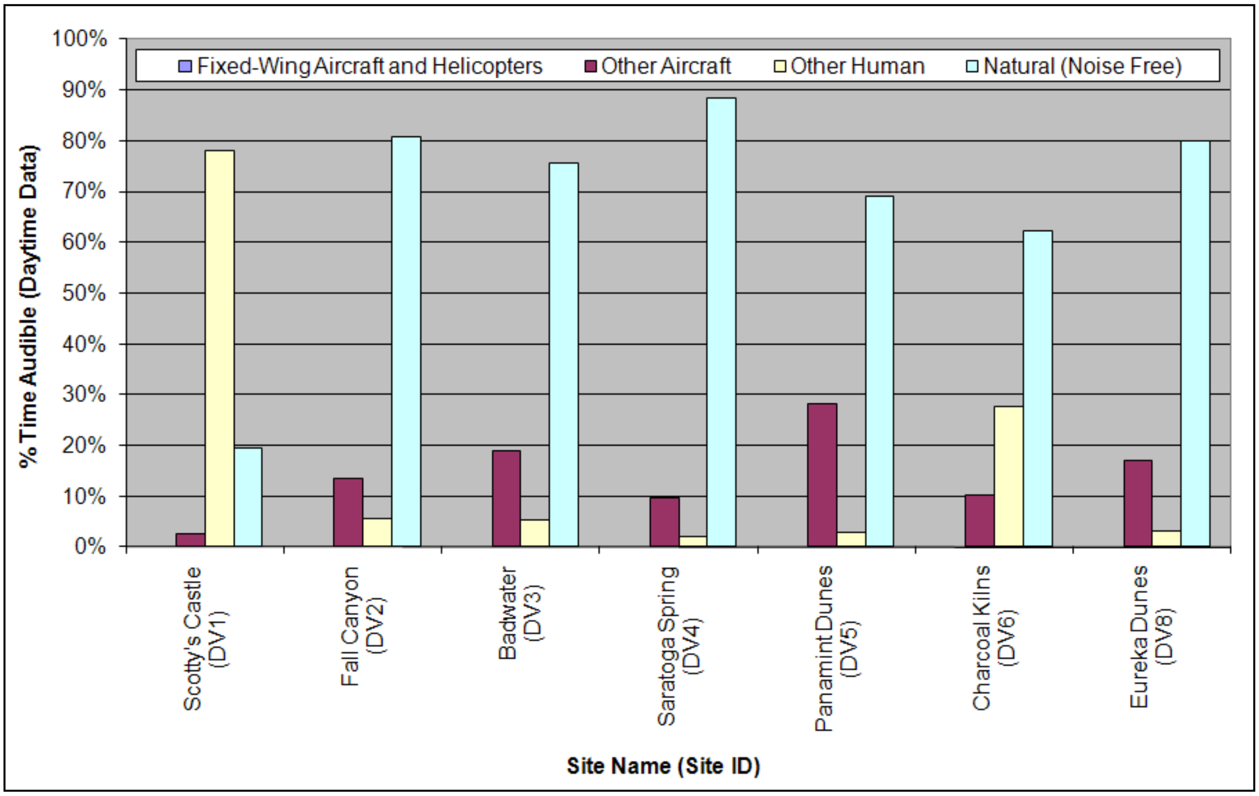


Figure 20. Summary of acoustic observer log data (in situ and office listening combined) for all sites for the summer season.

7. AMBIENT MAPPING

As stated earlier, the primary objective of this study was to quantify the baseline ambient sound levels within the park to establish a foundation from which potential noise impacts due to air tour operations can be assessed. This was accomplished by developing a comprehensive grid of ambient sound levels (i.e., ambient maps) throughout the park.

The measured data provide the base layer for the map and are then combined with the contributing effect of roads and localized noise sources (see Section 7.2), such as waterfalls, and river rapids, to develop a final, composite, ambient map of the park. Ambient maps are useful to: (1) graphically characterize the ambient environment throughout an entire study area; and (2) to establish baseline, or background values in computer modeling from which various noise-related descriptors may be computed (e.g., percentage of time aircraft sounds are above the ambient). The descriptors could then be used in the assessment of potential noise impacts due to aircraft operations.

The development of ambient maps is accomplished using Geographic Information System (GIS). In GIS, the following actions are performed:

- Define the input "objects":
  - Define the park boundary in Universal Transverse Mercator (UTM)[*] coordinates to set the initial grid area boundary.[†]
  - Divide the park into a regular grid of points at a desired spacing using a Digital Elevation Model (DEM), which is a digital representation of a topographic surface typically used in GIS applications. Each point is assigned an elevation value and UTM coordinates from the DEM. Note: For Death Valley, a grid spacing of 500 ft (152.4 m) was used.
  - Define the acoustic zone boundaries in UTM coordinates.
  - Define the location of each measurement site.
- Assign a "measured" ambient sound level (and its associated one-third octave-band, unweighted spectrum) to each grid point within an acoustic zone based on the measurement site nearest to it (see Section 7.1).

For development of all ambient maps, except for Natural Ambient, three additional steps are performed:

- Define the location of localized noise sources, primarily vehicles on roads, but may also include waterfalls, and river rapids. The closest distance to each source is calculated and assigned to each grid point.
- Assign an ambient sound level (and its associated one-third octave-band, unweighted spectrum) for each roadway to each grid point using the drop-off rates determined by computer modeling discussed in Section 7.2.
- Compute a combined measured and roadway ambient (and spectra). This is performed by using energy-addition, i.e., sound levels in decibels were converted to energy prior to addition.

The resultant ambient maps are presented in Section 7.3.

---

[*] The UTM system provides coordinates on a worldwide flat grid for easy manipulation in GIS applications.

[†] Because the ATMP Act applies to all commercial air tour operations within the ½-mile outside the boundary of a national park, the park boundary included a ½-mile buffer.

7.1 Assignment of Measured Ambient Data to Acoustic Zones

As discussed in Section 2.6, areas of like vegetation, topography, elevation, and climate were grouped into "acoustic zones," with the assumption that similar wildlife, physical processes, and other sources of natural sounds occur in similar areas with similar attributes. With the goal of site selection to ensure at least one measurement location within each of the acoustic zones, "measured" ambient sound level (and its associated one-third octave-band, unweighted spectrum) for each measurement site is assigned to an acoustic zone. Figure 21 presents the acoustic zones that were developed and the location of the measurement sites for Death Valley. Table 12 presents which measurement site data were applied to each acoustic zone. If multiple measurement sites were available for any one acoustic zone, site data were applied to acoustic zone polygons based on geographical proximity.

Table 12. Assignment of ambient data to acoustic zones

Acoustic Zone	Site ID	Site Name
Developed	DV1	Scotty's Castle
Barren	DV2 DV3	Fall Canyon Badwater Basin
Shrubland	DV4 DV5 DV7	Saratoga Spring Panamint Dunes Eureka Dunes
Forested	DV6	Charcoal Kilns

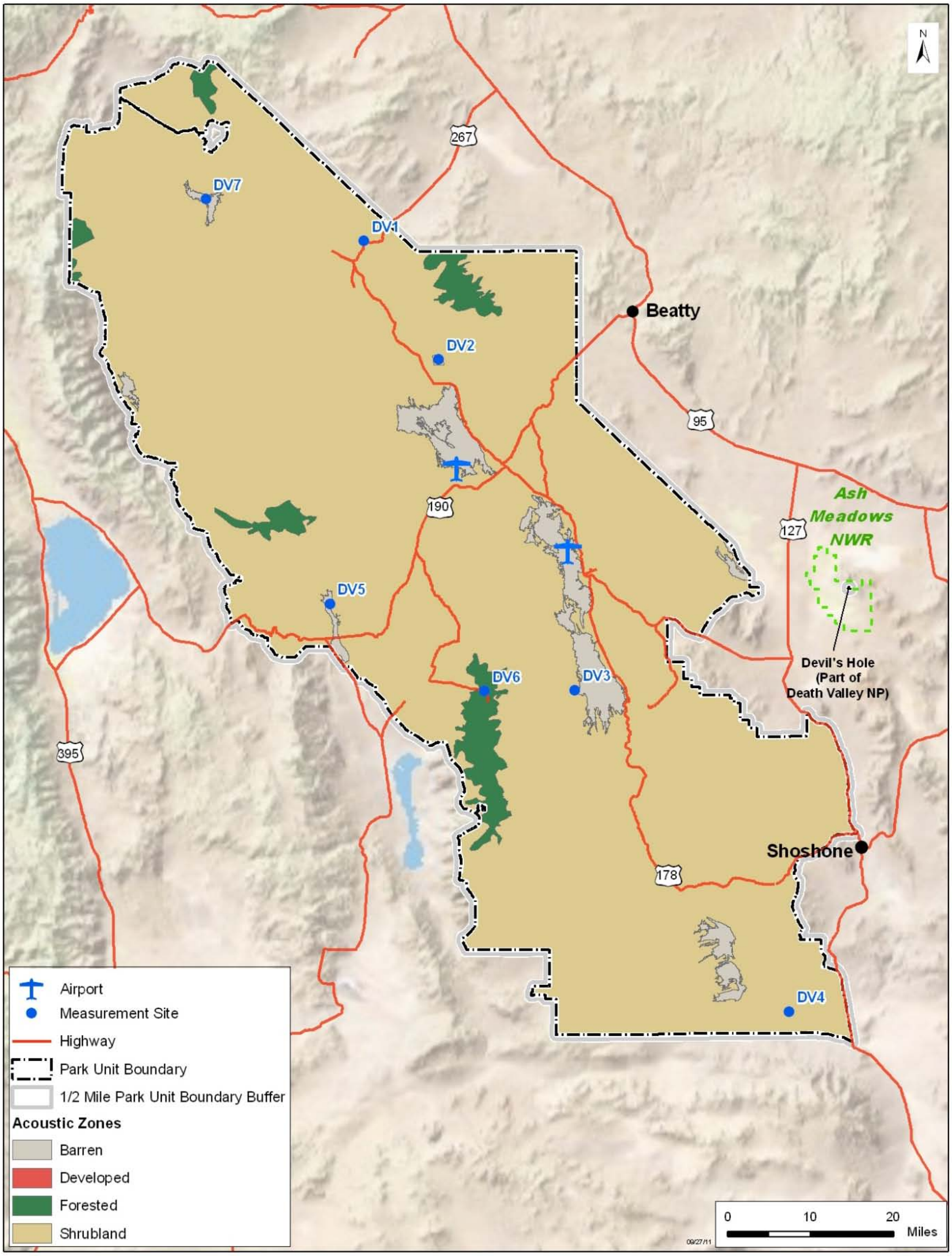


Figure 21. Final acoustic zones and measurement sites for Death Valley.

7.2 Ambient Mapping of Localized Sound Sources

The contributing effect of localized noise sources, primarily vehicles on roads, but may also include waterfalls, and river rapids, are typically modeled and combined with the measured sound levels to develop a composite, baseline, ambient "map" of a park for all ambient maps, except natural ambient (see Table 13). The combined (measured plus roadway, for example) ambient are computed by using energy-addition, i.e., sound levels in decibels were converted to energy prior to addition. Roadway sound sources were modeled using the Federal Highway Administration's Traffic Noise Model® (TNM),[2] where the estimated drop-off rate, reflecting a continuous decrease in sound level as a function of increasing distance from each sound source, was computed. For a non-time-varying source, such as roadway noise, the TNM-computed L_{Aeq} sound level parameters may be conservatively assumed to be equivalent to the L_{50} and L_{90} and, thus, used interchangeably as the "roadway" ambient.

Table 13. Composite ambient maps.

Metric	**Ambient Type**			
	Existing	**Existing Without Sound Source of Interest**	**Existing Without All Aircraft**	**Natural**
L_{50}	Measured + Localized Noise Source(s)	Measured + Localized Noise Source(s)	Measured + Localized Noise Source(s)	Measured

In the vicinity of and within Death Valley, there were a number of roadways. The following general assumptions were made in the modeling:

- Roadway Traffic Volumes – Annual traffic volume on each roadway was determined using data collected by the California Department of Transportation (Caltrans). The Caltrans (http://traffic-counts.dot.ca.gov/2008all.htm). Where data are available for multiple years, the most current year was chosen. The traffic volume for an average day during the actual summer month (August) was obtained by using monthly visitation data obtained from the NPS Public Use Statistics Office website (http://www2.nature.nps.gov/stats/) to apportion the Caltrans annual traffic. Hourly volume is estimated by dividing the month's volume by the number of days in the month (31) and by 12 hours per day, which assumes the majority of traffic for Death Valley occurs between 7:00 a.m. and 7:00 p.m. – typical commute hours.
- Roadway Traffic Mix and Speeds –The traffic mix and speeds on a given roadway were based on two sources: (1) The NPS Monthly Usage information (http://nature.nps.gov/stats/viewReport.cfm?selectedReport=ParkMonthlyReport.cfm; and (2) observations by field personnel during site visits. In some cases, a specific speed limit was determined using Google Maps using the "street view" to view an actual speed limit sign. When multiple speed limit signs showed varying speeds over a single road segment, an average. In some specific cases, notations from the Volpe field notes en route to measurement site locations were used to determine speed limits over various segments. An average speed of 35 mph was assumed as the default within the park when another more specific speed limit could not be determined.
- Ground Impedance – An effective flow resistivity of 1000 cgs/rayls was used for Death Valley.

Table 14. Estimated hourly roadway traffic volume and speed for the summer season.

Roadway			Estimated Hourly Volume				
#	Name	Average Speed (mph)	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles
1	Big Pine Road NW of park	40	23	1	1	2	1
2	Big Pine Road from Pavement to Crankshaft Junction	20	9	0	0	0	0
3	Road to Eureka Dunes	35	18	0	0	1	1
4	Eureka Dunes to Saline Valley Dunes	30	7	0	0	0	0
5	Road N od Marble Canyon	30	6	0	0	0	0
6	Marble Canyon S to South Pass via Saline Valley Dunes	30	3	0	0	0	0
7	Dirt/Gravel roads near South Pass/Cerro Gordo Peak	25	4	0	0	0	0
8	Hidden Valley Road	40	7	0	0	0	0
9	Racetrack Road S of Teakettle Junction	30	11	0	0	0	0
10	Racetrack Road N of Teakettle Junction	40	13	0	0	0	1
11	Grapevine Entrance/Ubehebe Crater	25	105	2	0	3	5
12	Big Pine Road S of Crankshaft Junction	40	18	0	0	1	1
13	Scotty's Castle Road NE of Grapevine	40	98	2	0	4	4
14	Mesquite Spring Campsite	25	9	0	0	0	0
15	Scotty's Castle Road Grapevine to Daylight Pass Road	60	127	3	0	6	6
16	Daylight Pass RoadHell's Gate to Beatty	40	115	3	0	5	5
17	Daylight Pass Road S of Beatty Cutoff	40	85	2	0	4	4
18	Beatty Cutoff	30	30	1	0	1	1
19	Scotty's Castle Road to SR190 Connector	40	212	5	0	9	9
20	SR190 Devil's Cornfield to (North of) Furnace Creek	70	153	8	6	15	8
21	Road to Rhyolite	20	70	2	0	2	3
22	SR190 through Stovepipe Wells	20	117	6	4	12	6
23	SR190 Emigrant to Stovepipe Wells	60	117	6	4	12	6
24	SR190 through Emigrant	20	117	6	4	12	6
25	SR190 Panamint Srpings to Emigrant	60	105	5	4	10	5
26	Emigrant Canyon Road	30	13	0	0	0	1
27	Road to Panamint Dunes	30	4	0	0	0	0
28	SR190 through Panamint Springs	20	138	7	5	14	7
29	SR190 W of Panamint Springs	70	99	5	4	10	5
30	Panamint Valley Road	40	46	2	2	5	2
31	Narrow road from Panamint Valley Road to Wildrose	20	3	0	0	0	0
32	SR178 S of Panamint Valley Road	70	168	8	6	17	8
33	Roads to Ballarat	30	35	1	0	1	2
34	Road to Darwin	30	44	1	0	1	2
35	SR190 through Furnace Creek	20	176	9	7	17	9
36	SR190 Furnace Creek to Greenwater Valley Road	50	138	7	5	14	7

Roadway			Estimated Hourly Volume				
#	**Name**	**Average Speed (mph)**	**Autos**	**Medium Trucks**	**Heavy Trucks**	**Buses**	**Motor-cycles**
37	SR 190 Greenwater Valley Road to DV Junction	70	111	6	4	11	6
38	Badwater Road from Furnace Creek to Badwater	50	70	2	0	2	3
39	Artist's Drive	15	54	0	0	0	2
40	Badwater Road from Badwater S to H. Wade Road	40	18	0	0	1	1
41	Road to Dante's View	20	88	2	0	3	4
42	Greenwater Valley Road	30	5	0	0	0	0
43	SR178 Ashford Mill to Shoshone	70	35	1	0	1	2
44	SR127 from Jct 178 S to Shoshone	40	138	7	5	14	7
45	SR178 to Pahrump	70	147	7	5	15	7
46	SR127 Shoshone to Tecopa cutoff/Old Spanish Trail	40	138	7	5	14	7
47	Old Spanish Trail	70	113	6	4	11	6
48	SR127 S of Tecopa cutoff/Old Spanish Trail	70	138	7	5	14	7
49	SR127 DV Junction to 178 Junction	70	42	2	2	4	2
50	CA SR127/NV SR373 North of DV Junction	70	50	2	2	5	2
51	State Line Road East of DV Junction	70	111	6	4	11	6
52	Road through Ash Medows National Refuge (Devil's Hole)	30	26	1	0	1	1
53	West Side Road	40	18	0	0	1	1
54	Harry Wade Road from Ashford Mill to 127 Junction	40	9	0	0	0	0

7.3 Final Ambient Maps

The two ambient maps agreed upon for use in ATMP analyses are:

- Existing Ambient Without Air Tours (i.e., the Source of Interest); and
- Natural Ambient.

Figure 22 through Figure 23 present the two ambient maps for the summer season.

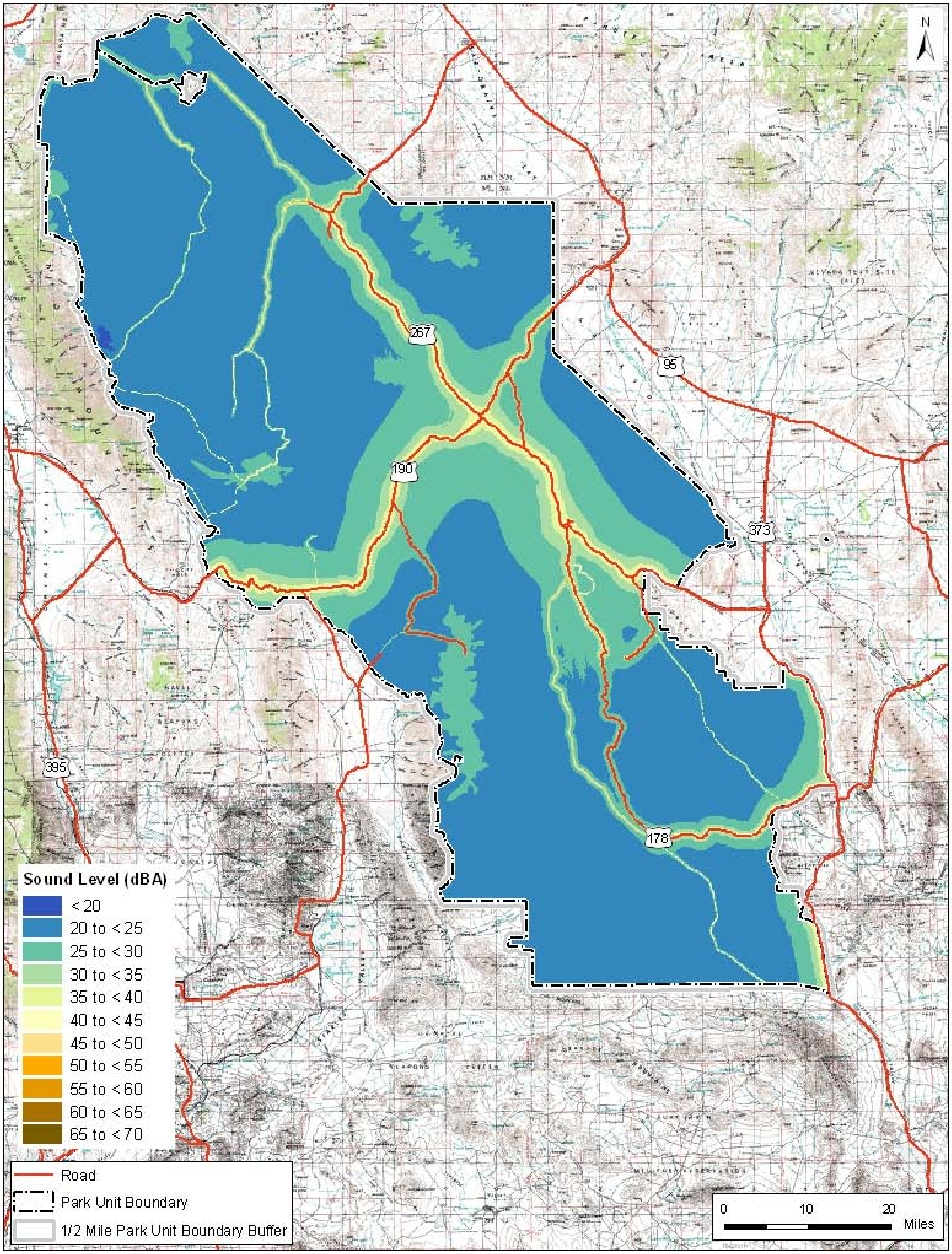


Figure 22. Baseline ambient map: Existing Ambient Without Air Tours (L_{50}) for the summer season.

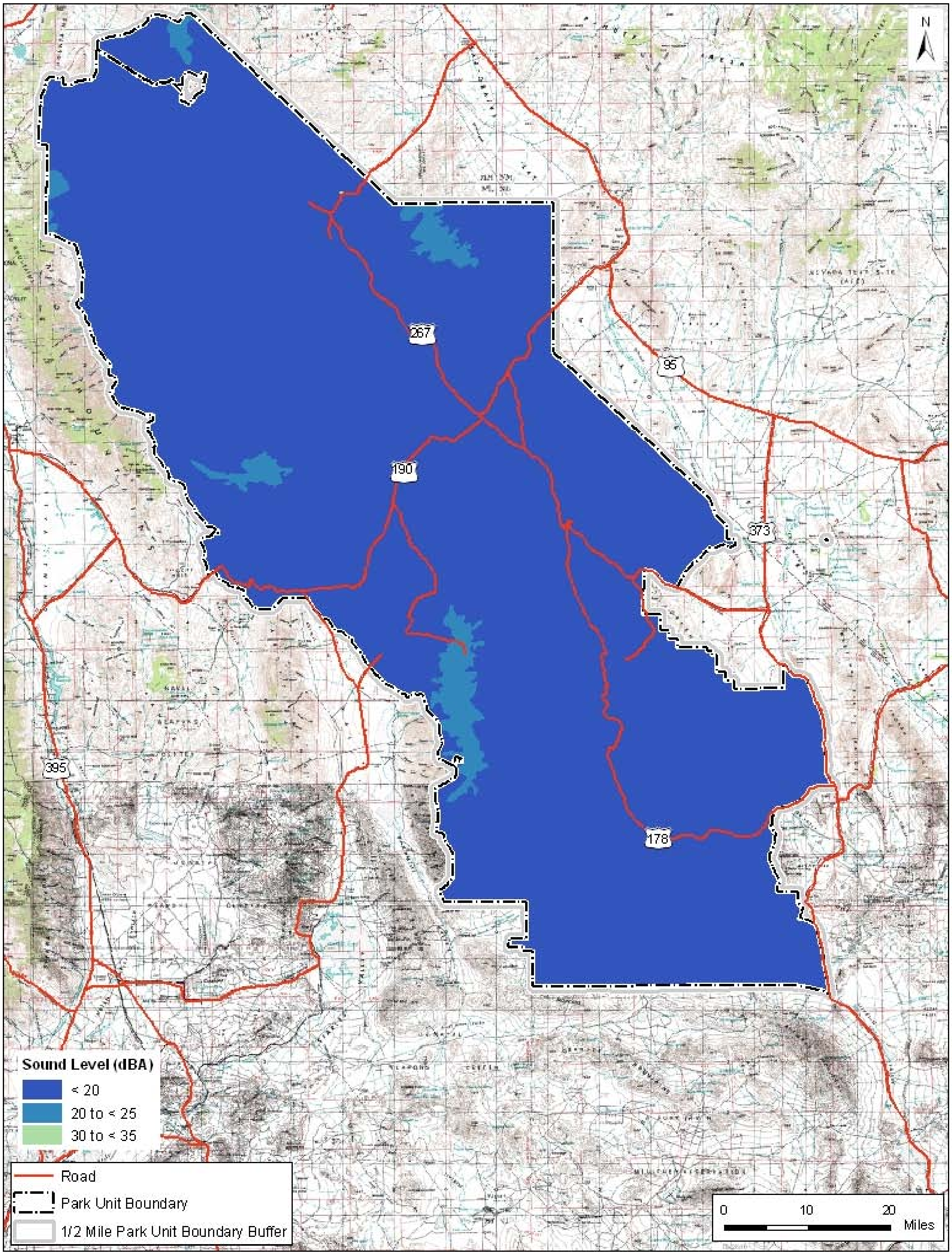


Figure 23. Baseline ambient map : Natural Ambient (L_{50}) for the summer season.

APPENDIX A. MEASUREMENT SITE DETAILS

This section provides more detailed information for each individual site. For each site, the following are included:

- A photograph of the measurement site and a brief discussion of preliminary observations;
- A pie chart presenting a comparison of types of sound sources that were audible during observer logging;
- A graphic presenting distribution plots of the number of 1-second samples of each sound pressure level measured during daytime and nighttime hours, and daytime/nighttime combined;
- A graphic presenting the daily sound levels using three hourly A-weighted metrics (L_{Aeq}, L_{50}, and L_{90} - refer to Terminology for definitions), as well as average daily wind speeds over the entire measurement period;
- A graphic presenting the hourly sound levels using three hourly A-weighted metrics (L_{Aeq}, L_{50}, and L_{90} - refer to Terminology for definitions), as well as average hourly wind speeds over the entire measurement period

A.1 Site DV1 – Scotty's Castle

Figure 24. Site DV1: Description and photograph.

Observations

Site DV1 was located within the popular Scotty's Castle area. Visitors related sounds were prevalent in the parking lot, and the area's various attractions (the Castle, a gift shop/eatery, and an unpaved trail to a grave site). Occasional bus traffic occurred in the parking lot that including idling. A rooftop HVAC system was audible at this site whenever it was operating. Natural sounds were primarily wind flowing through the castle structure, through the Grapevine Canyon, and sometimes gusting through the Cottonwoods present in the area. The ground was bare - a mixture of rock and sand. The daily sound levels are relatively consistent from day to day, most likely due to the new constant visitor activity at this site. Trends of visitor-use are also evident in the diurnal patter of the hourly L_{Aeq} sound levels with louder sound levels during the daytime and quieter levels in the evening and early morning hours.

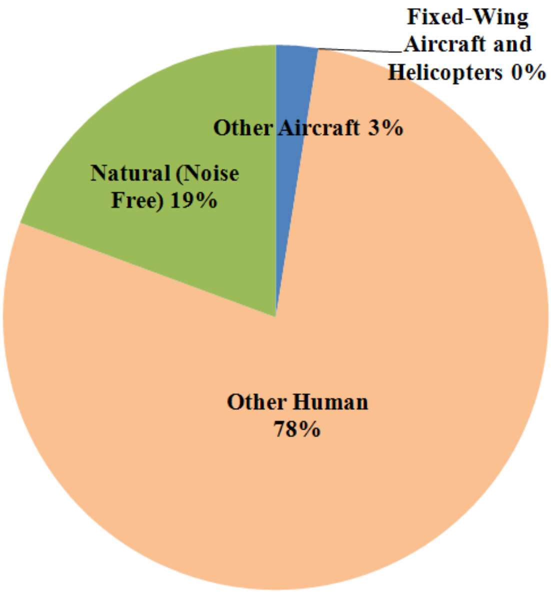
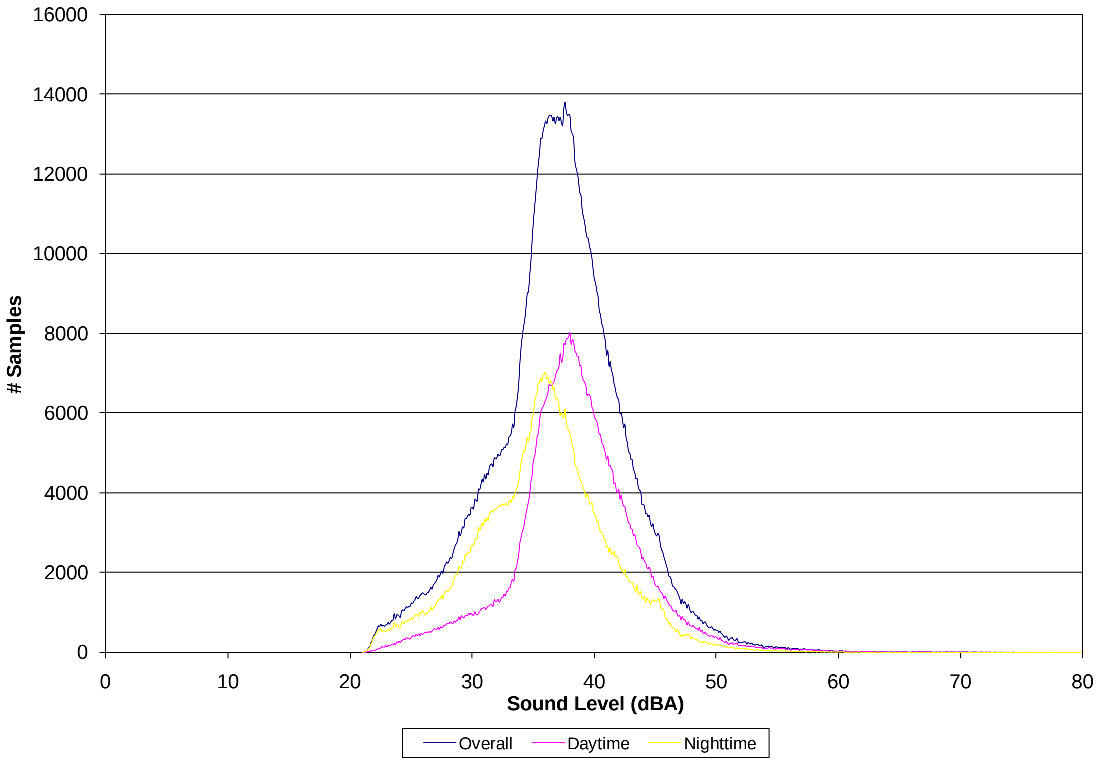


Figure 25. Distribution of audible sound sources (in situ and office listening combined) at Site DV1 for the summer season.



/

Figure 26. Distribution of data for Site DV1 for the summer season.

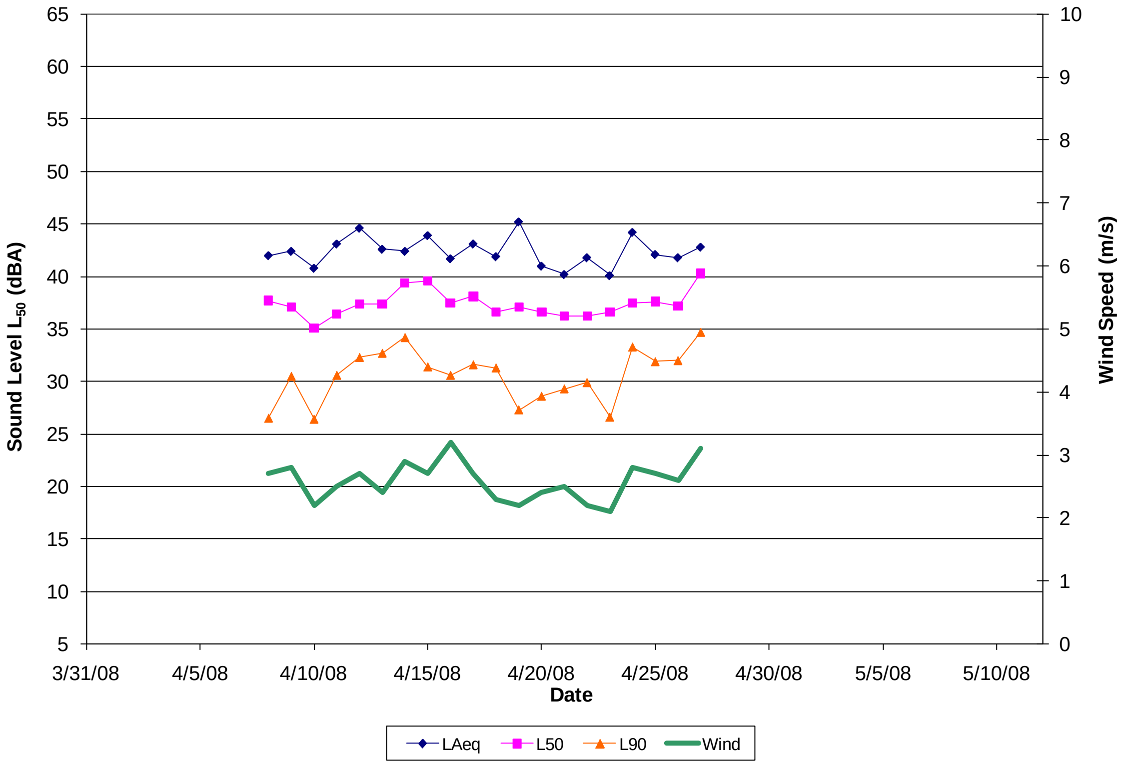


Figure 27. Daily sound levels and wind speeds for Site DV1 for the summer season.

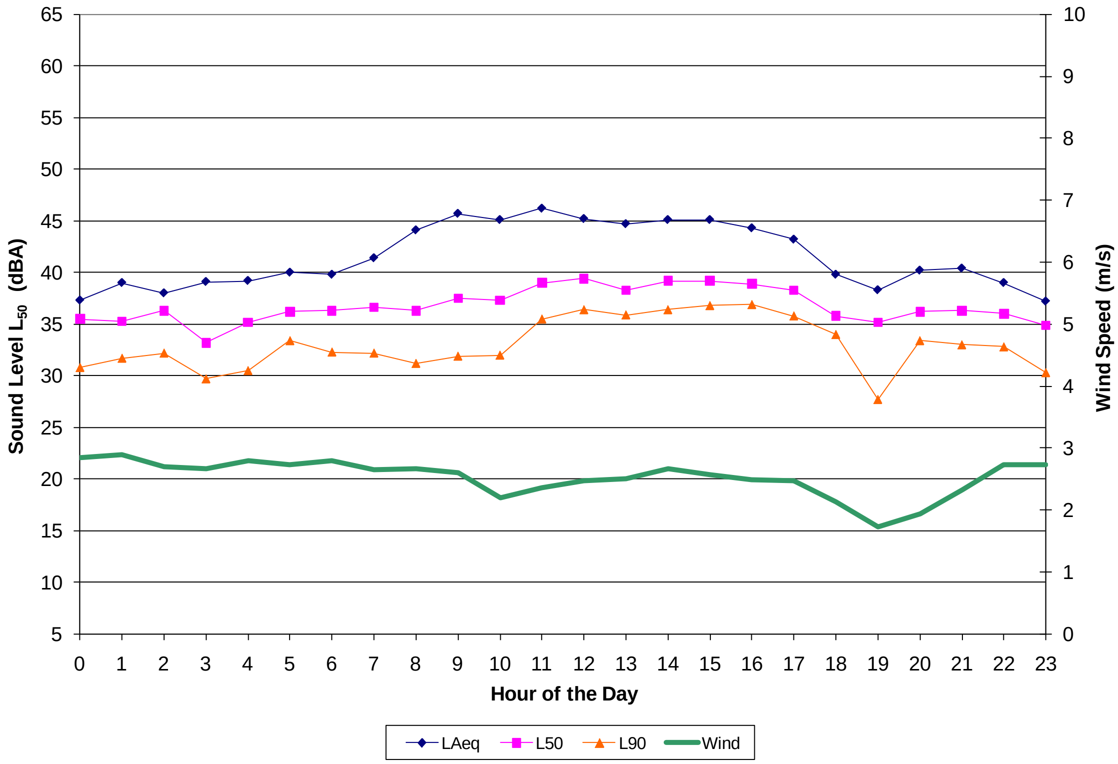


Figure 28. Hourly sound levels and wind speeds for Site DV1 for summer season.

A.2 Site DV2 – Fall Canyon

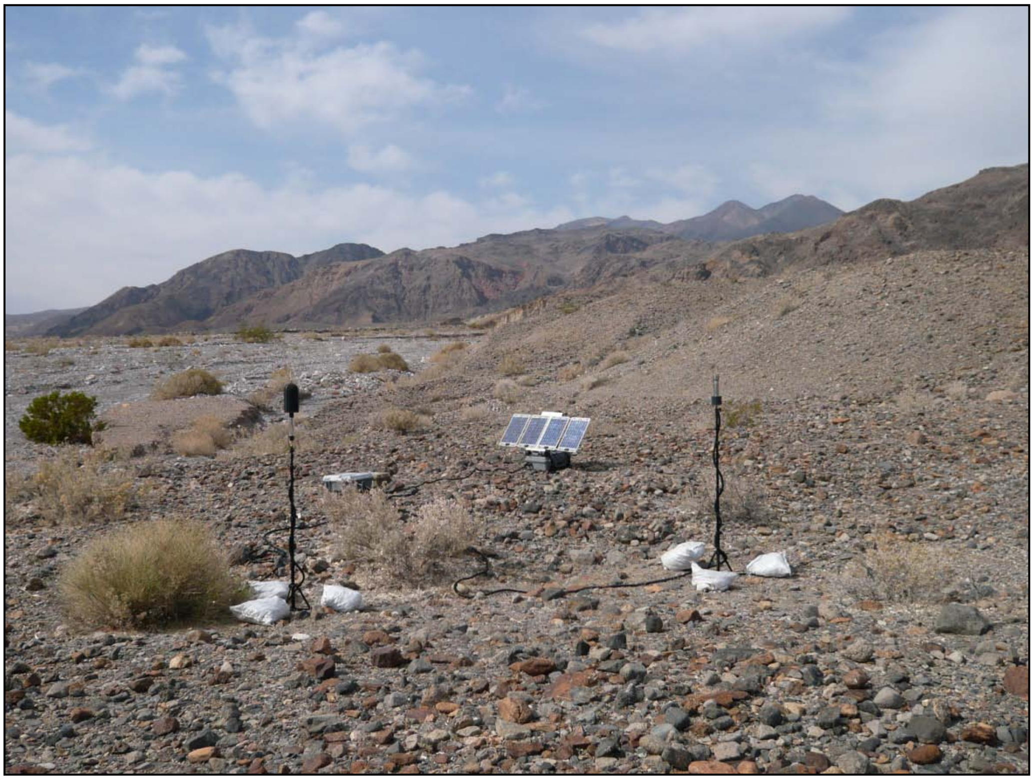


Figure 29. Site DV2: Description and photograph.

Observations

Site DV2 was located within Fall Canyon at the boundary of a large wash with exposed bare rock of a variety of aggregate sizes from small smooth stones to large craggy boulders. The site is at the foot of the Grapevine Mountains and overlooks the Death Valley Wash. The site was desolate and subject to gusty winds. The site was quite desolate, but did experience occasional hikers through the area and some audible traffic noise on Titus Canyon Road (approximately 0.3 miles from the measurement location) and 2.0 miles from Scotty's Castle Road. Distant military aircraft were audible - most likely flying in the Panamint Valley area. Crickets and other insects were audible during low wind conditions. Commercial and general aviation air traffic was also observed, but very low levels.

As can be seen in all the sound level charts, this location was very quiet with a daytime median sound level of 18.5 dBA and a nighttime median of 13.1 dBA. The fluctuating daytime sound levels correlated with wind speeds. A review of a "loud" day occurring on May 7, 2008 indicated that military activity likely occurred on this day during the 0900 and 1000 morning hours.

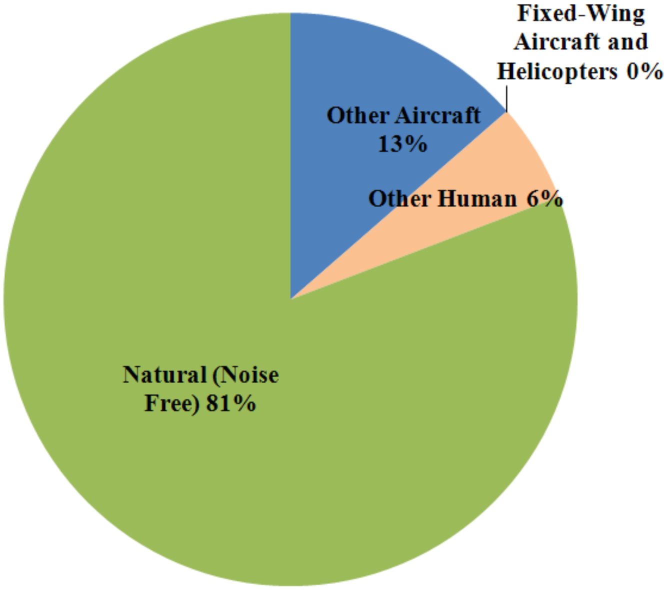


Figure 30. Distribution of audible sound sources (in situ and office listening combined) at Site DV2 for the summer season.

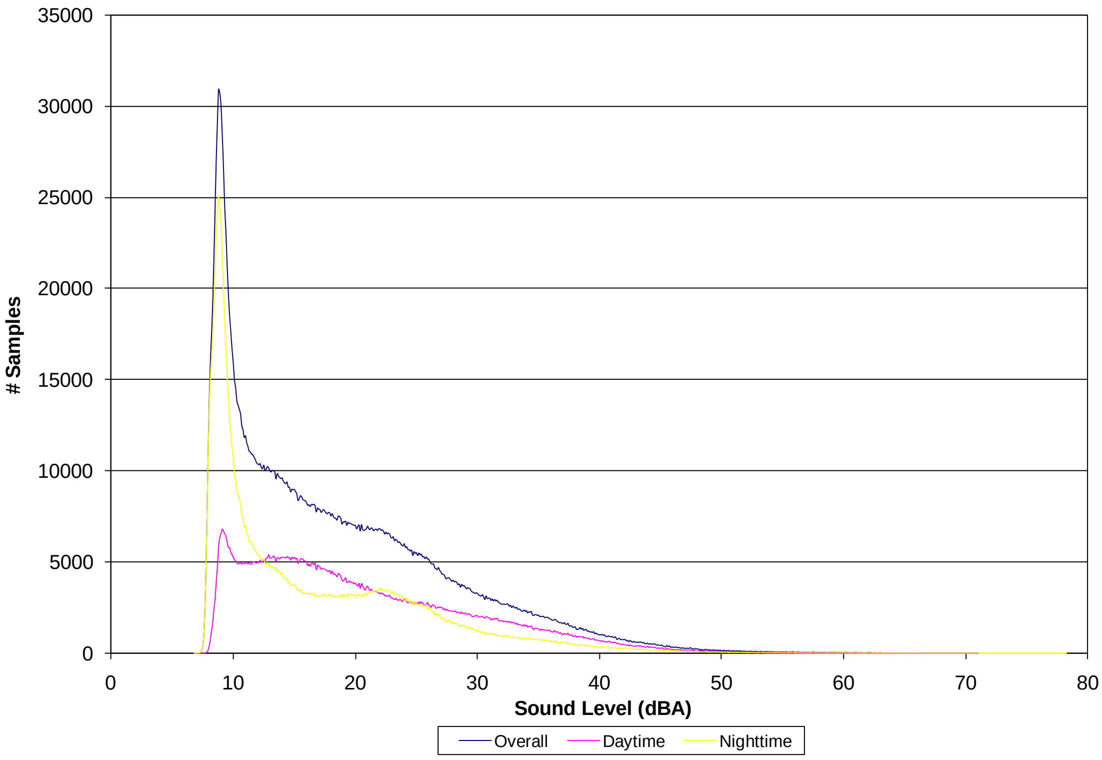


Figure 31. Distribution of data for Site DV2 for the summer season.

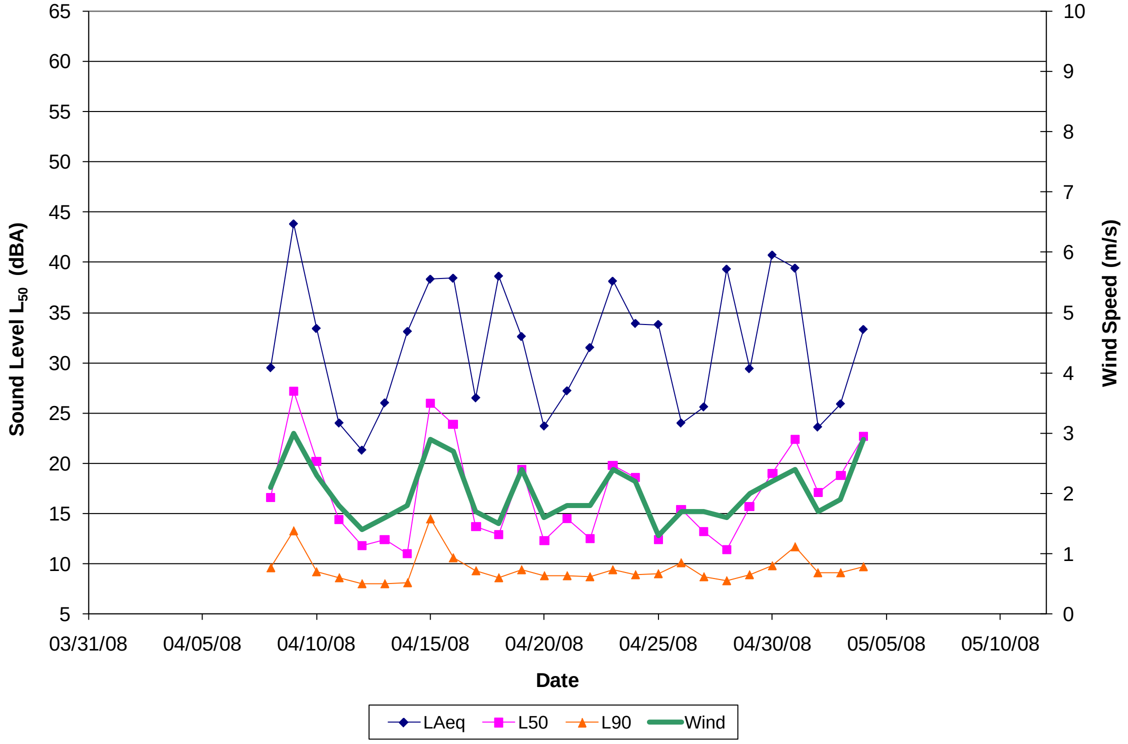


Figure 32. Daily sound levels and wind speeds for Site DV2 for the summer season.

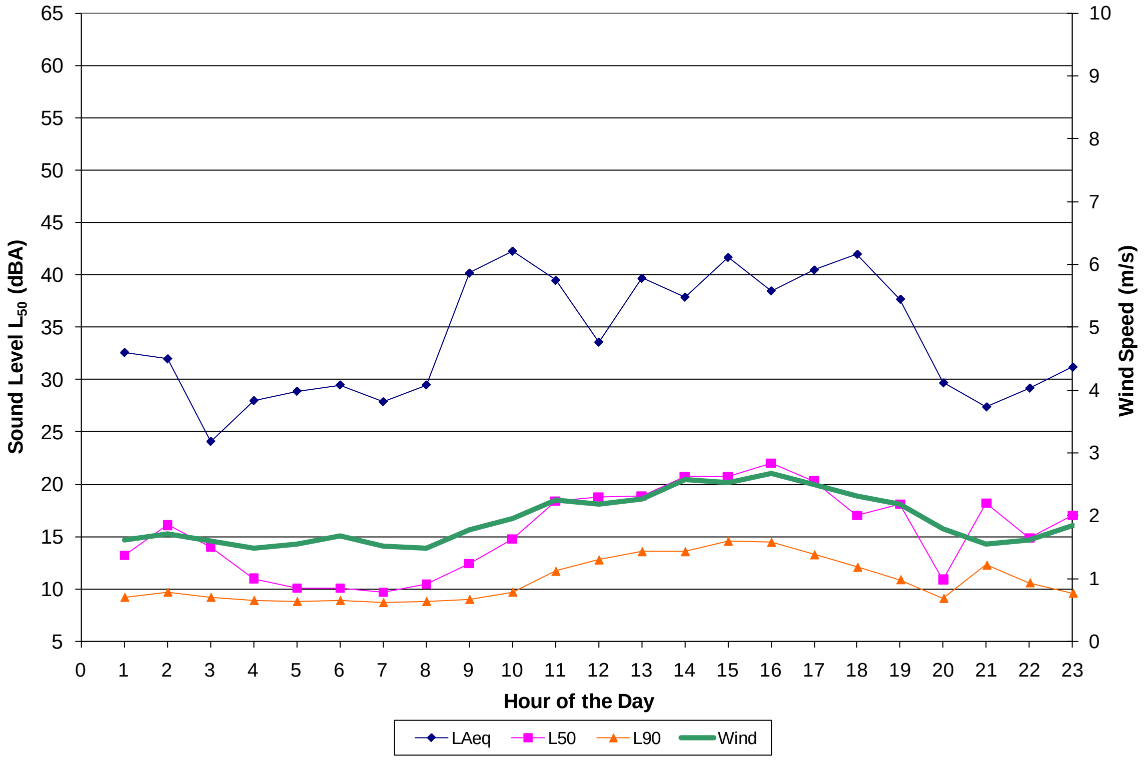


Figure 33. Hourly sound levels and wind speeds for Site DV2 for the summer season.

A.3 Site DV3 – Badwater Basin

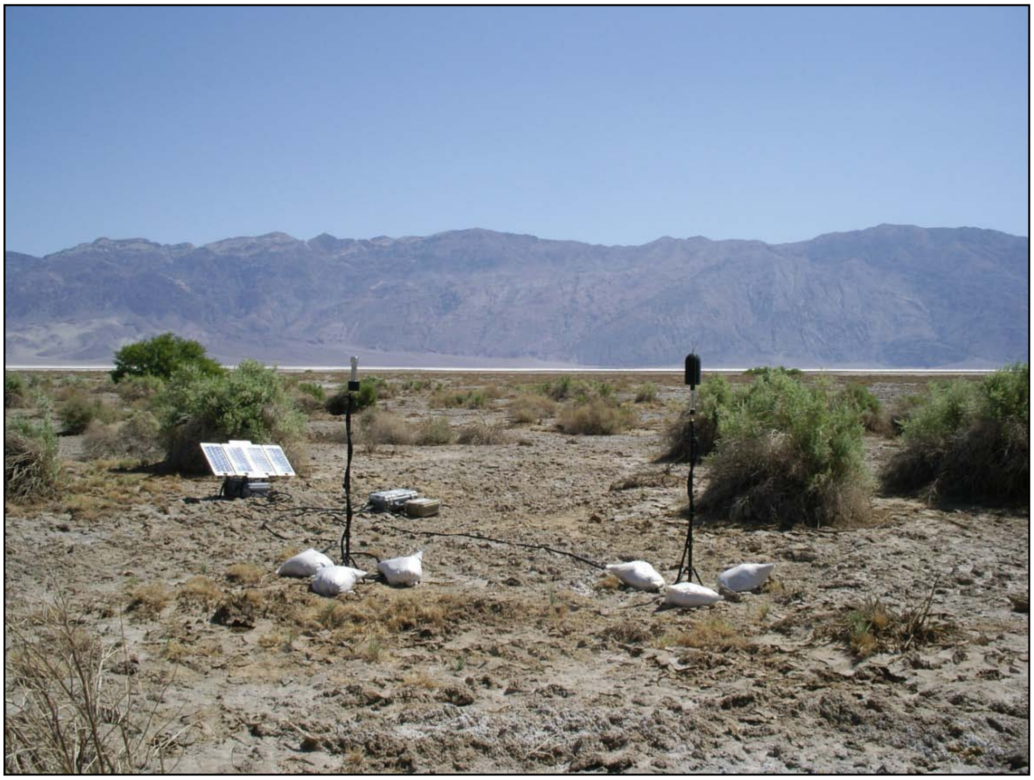


Figure 34. Site DV3: Description and photograph.

Observations

Site DV3 was located on the west side of Badwater Basin near the Hanaupah Canyon (about 0.3 miles north of the Tule Spring and 0.2 miles east of the West Side Highway). The ground cover was dried mud and had a distinctive crust (approximately ¼ in. thick with visible salt residue) and an underlying air gap of about an inch. The soil underneath the crust was very fine and similar to talcum. There was clumpy, sparse foliage in this area that acted as a source of sound during gusty wind conditions. Other sound sources in this area include small birds, insects near the foliage, some vehicles (automobiles, motorcycles and ATV's) on the West Side Road, visitor noise (hikers to Tule Spring), commercial jet aircraft, fixed-wing aircraft, and one helicopter.

Winds generally increase throughout the day as solar heating occurs; however winds in this area were unpredictable - at times extremely windy and gusty in the hours before noon, other days calm during this time period. Sound levels at this site were louder than Fall Canyon (Site DV2), but still relatively quiet with a daytime median sound level of 23.1 dBA and a nighttime median sound level of 17.9 dBA. A review of the increased sound levels of the 1300 hour on April 30, 2008 indicated that military aircraft activity was present. Military aircraft was also observed in this area during site visits by the measurement team.

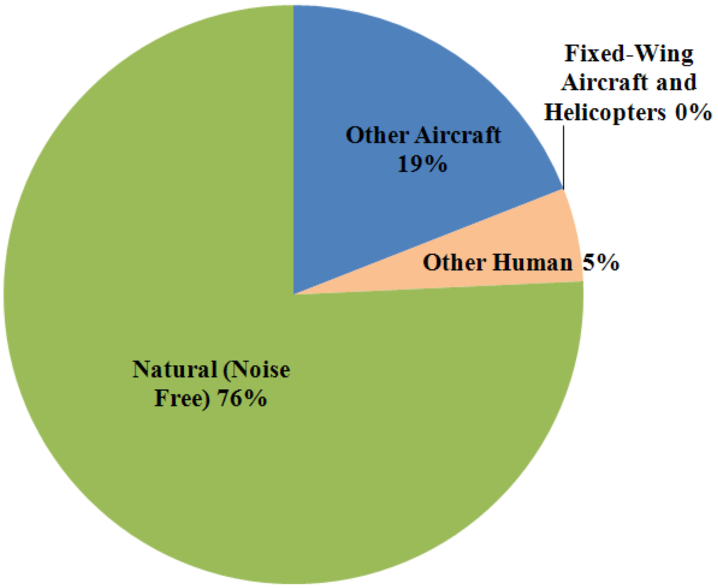


Figure 35. Distribution of audible sound sources (in situ and office listening combined) at Site DV3 for the summer season.

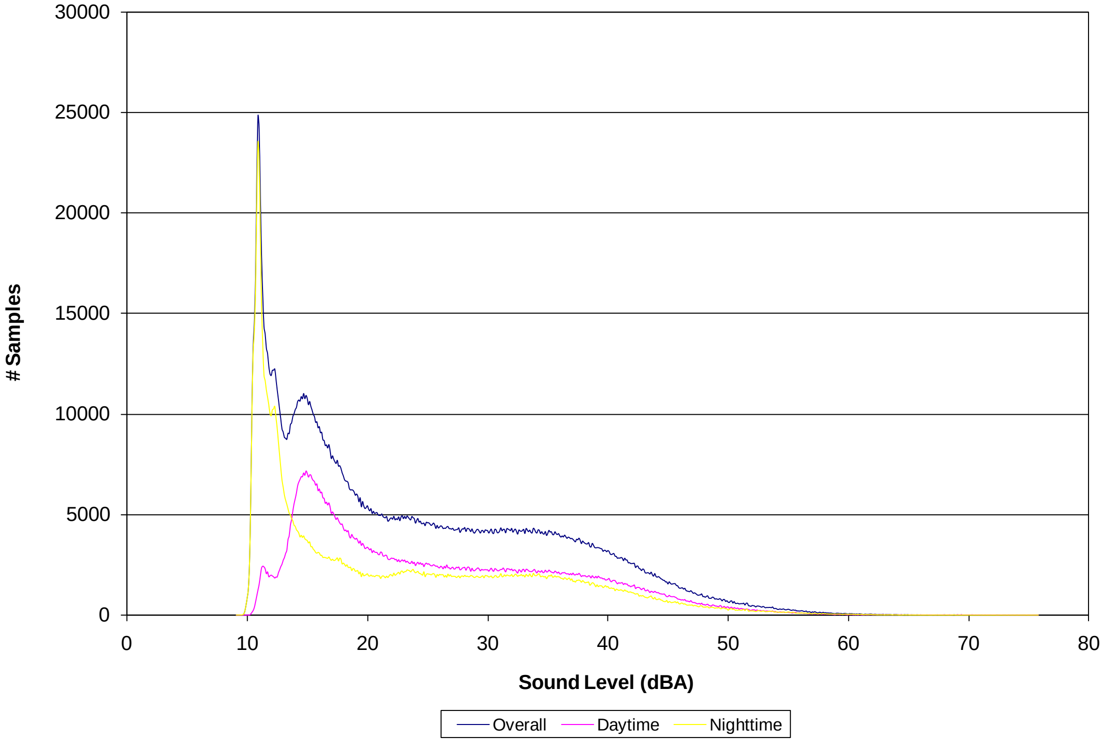


Figure 36. Distribution of data for Site DV3 for the summer season.

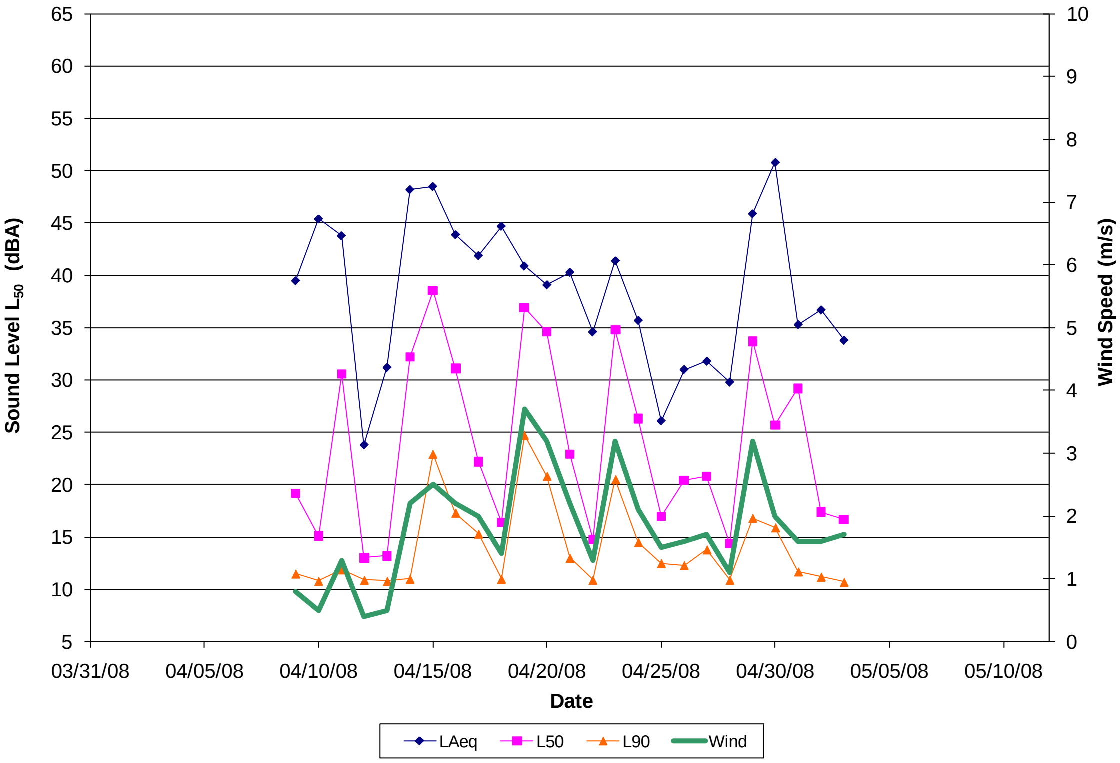


Figure 37. Daily sound levels and wind speeds for Site DV3 for the summer season.

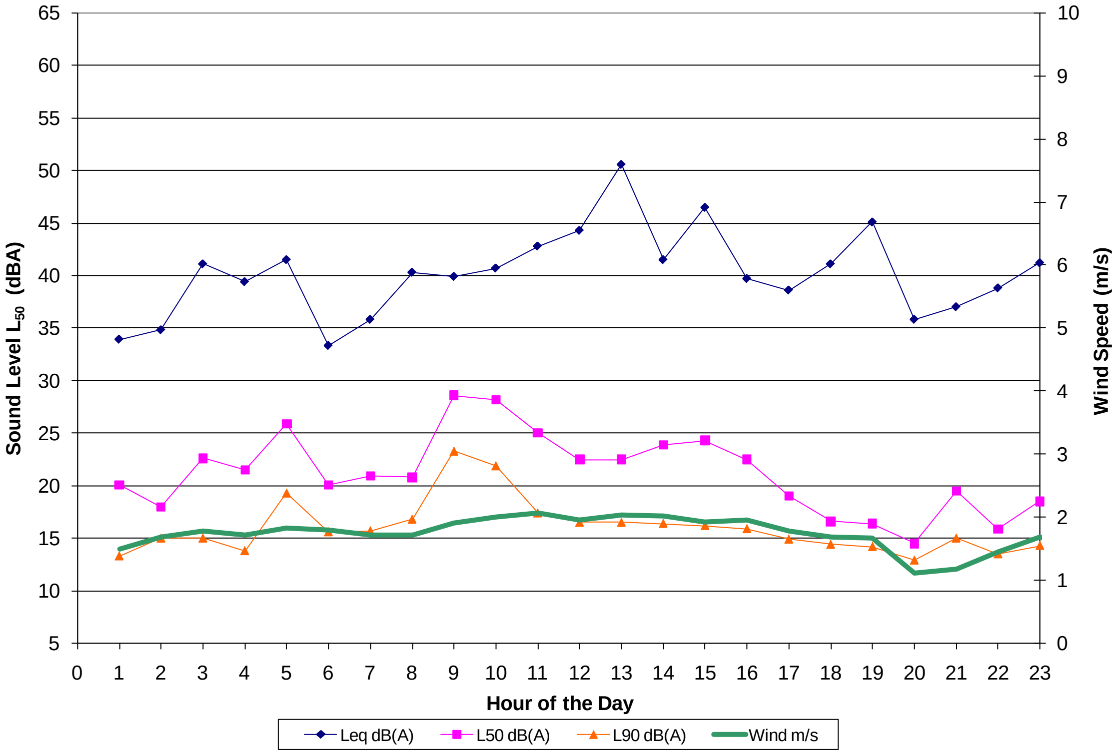


Figure 38. Hourly sound levels and wind speeds for Site DV3 for the summer season.

A.4 Site DV4 – Saratoga Spring

Figure 39. Site DV4: Description and photograph.

Observations

Site DV4 was located at the Saratoga Spring in the south-eastern corner of the park, just a few miles west of Ibex Dunes. This site has a lush environment surrounding the spring and is frequented by waterfowl and other birds attracted to the water. The Spring is surrounded by tall grasses (reeds and bulrush) and sand dunes that have accumulated on the perimeter. The measurement site was located on the valley side of the dune that borders the spring. The measurement site is approximately 70 feet from the water edge and in a location not obvious to a visitor to the spring. Sound level sources at this site include wind through reeds and grasses, birds, insects (especially flies), hiker activity, ducks, and commercial and military jet aircraft.

Sound levels were quiet at this site with a median daytime level of 18.6 dBA and a median nighttime level of 19.4 dBA (nighttime was a bit louder than daytime, probably due to insect activity at the spring and the surrounding wet/marshy areas). A review of the daily and hourly average sound levels noted that the 0700 hour was loud relative to other hours of the day and this was primarily due to dramatic changes in wind speeds at this time of day, going from nearly calm conditions up to gusty, sustained winds in a matter of minutes.

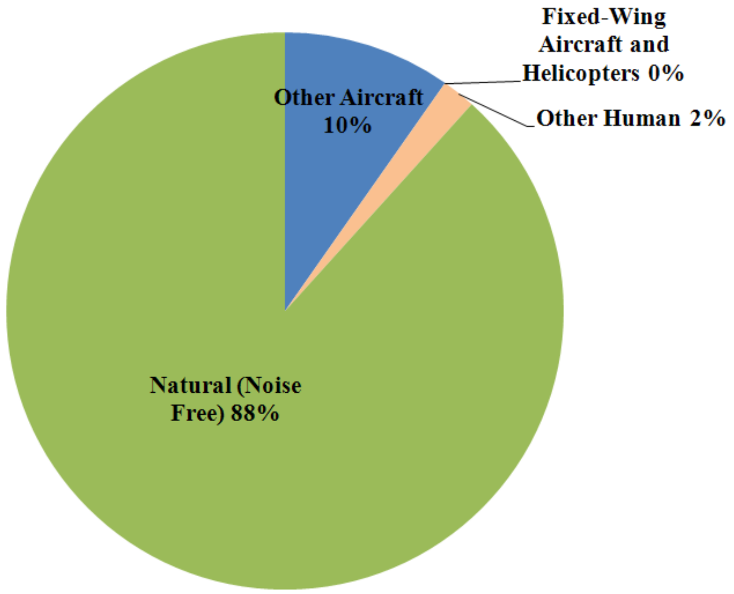


Figure 40. Distribution of audible sound sources (in situ and office listening combined) at Site DV4 for the summer season.

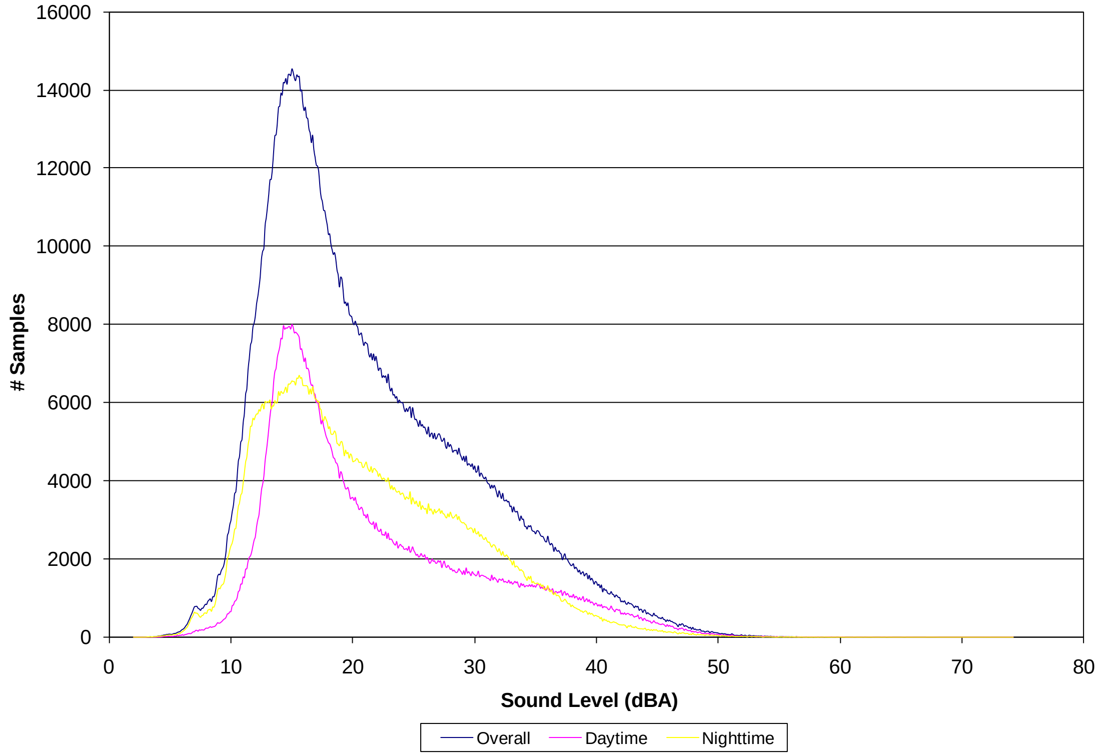


Figure 41. Distribution of data for Site DV4 for the summer season.

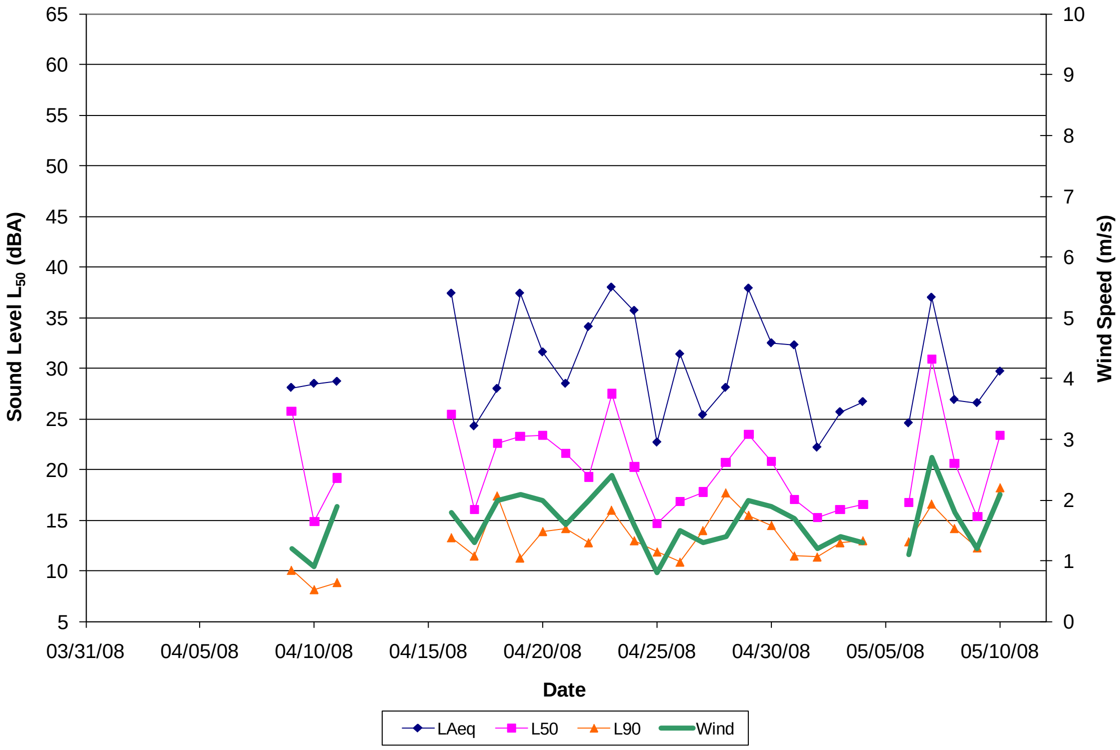


Figure 42. Daily sound levels and wind speeds for Site DV4 for the summer season.

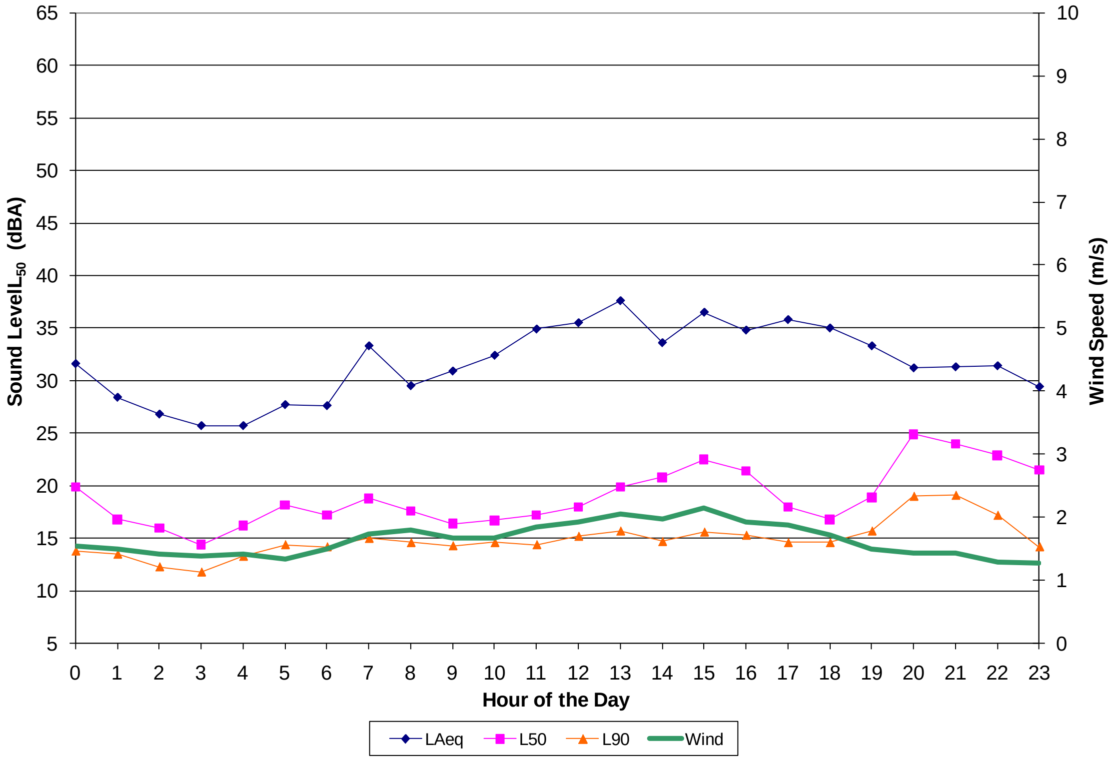


Figure 43. Hourly sound levels and wind speeds for Site DV4 for the summer season.

A.5 Site DV5 – Panamint Dunes

Figure 44. Site DV5: Description and photograph.

Observations

Site DV5 is located in the Panamint Valley approximately four miles north of Highway 190 and within sight of Panamint Dunes. The area is a vast, flat, barren region with occasional tufts of vegetation near dried mud holes. Numerous animal tracks were observed going to and from partially dehydrated water sources. The site was very quiet despite very loud military events which are evident in the daily and hourly L_{Aeq} sound levels – especially, April 14, 21, 30 and May 7, 2008. The measurement team observed military fighter jets flying at low altitudes in this area. During low wind conditions, this area was very quiet with a median daytime level of 19.9 dBA and a median nighttime level of 11.1 dBA. Generally, sound levels correlated with win speeds. Sources of sound in this area included general aviation aircraft, military aircraft, distant roadway traffic, distant visitors, insects (flies), and wind.

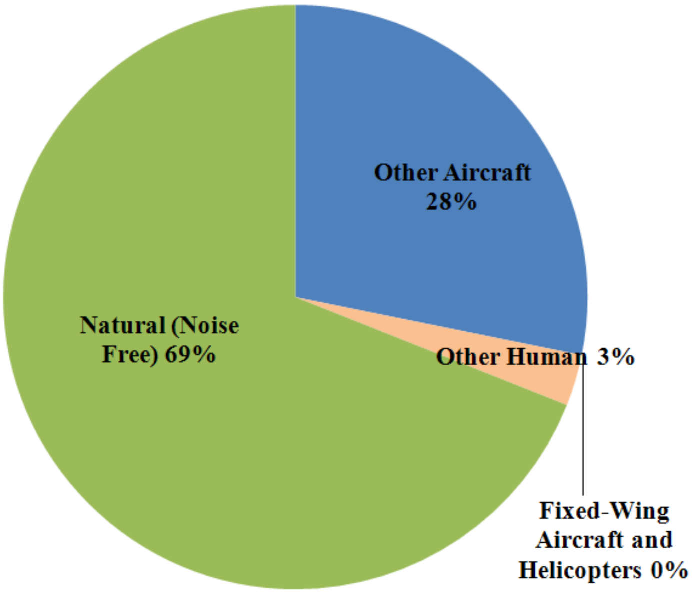


Figure 45. Distribution of audible sound sources (in situ and office listening combined) at Site DV5 for the summer season.

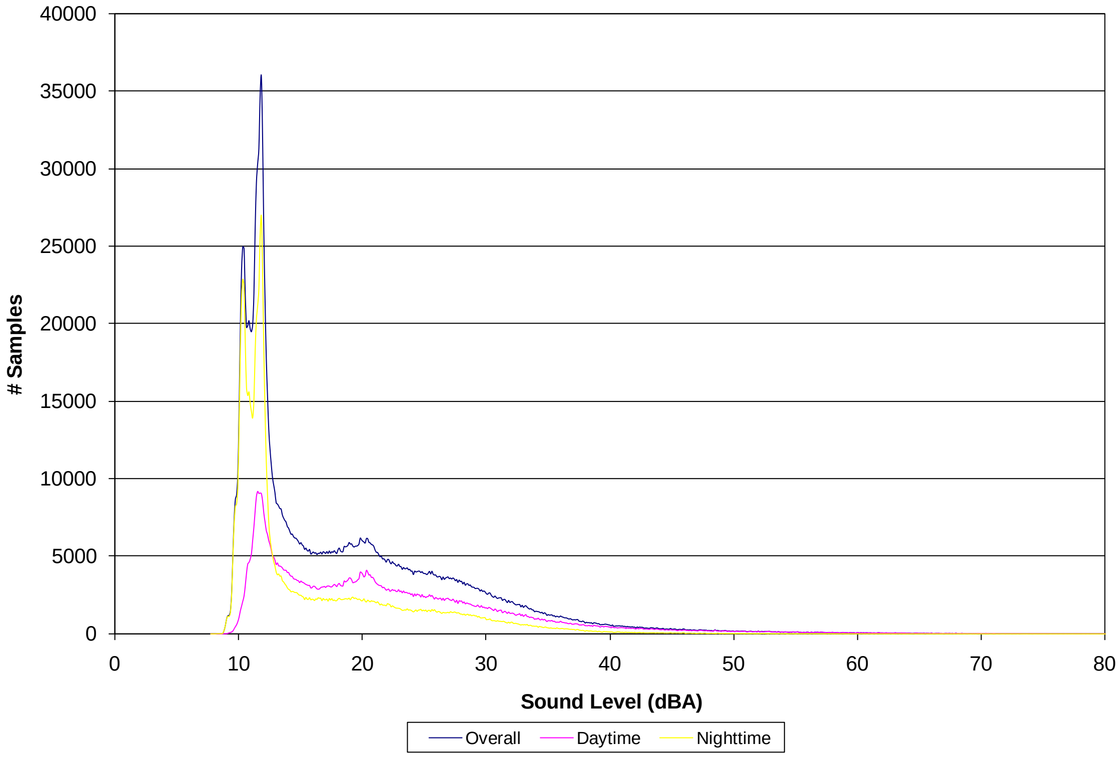


Figure 46. Distribution of data for Site DV5 for the summer season.

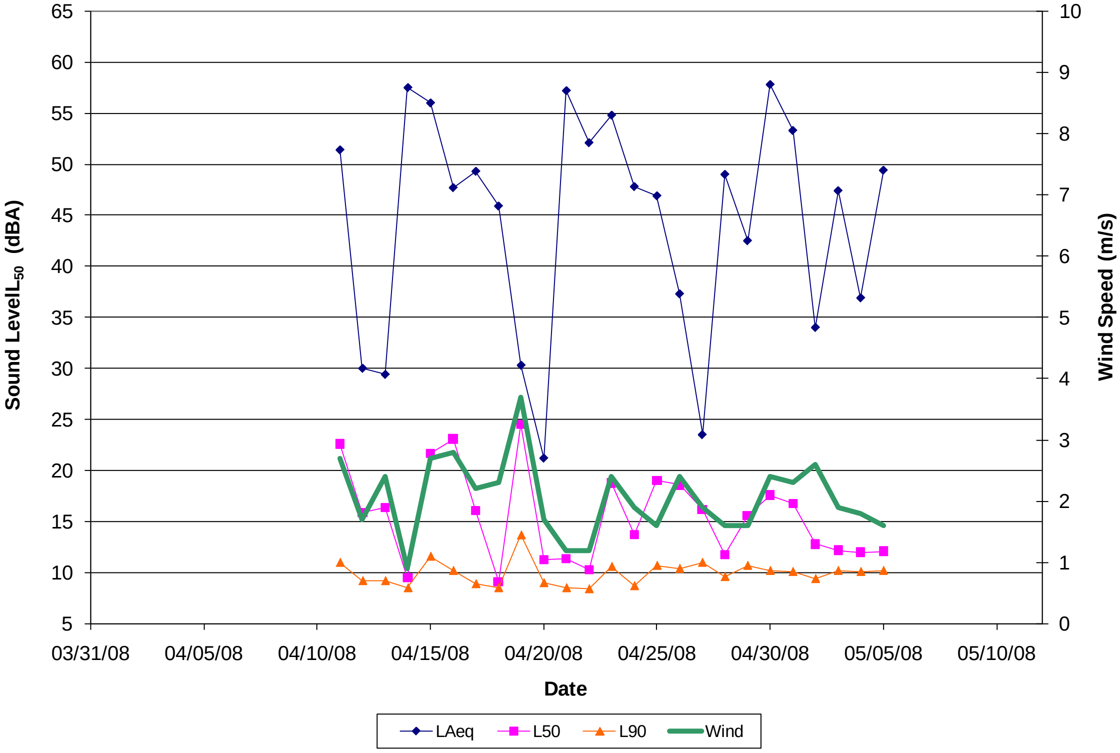


Figure 47. Daily sound levels and wind speeds for Site DV5 for the summer season.

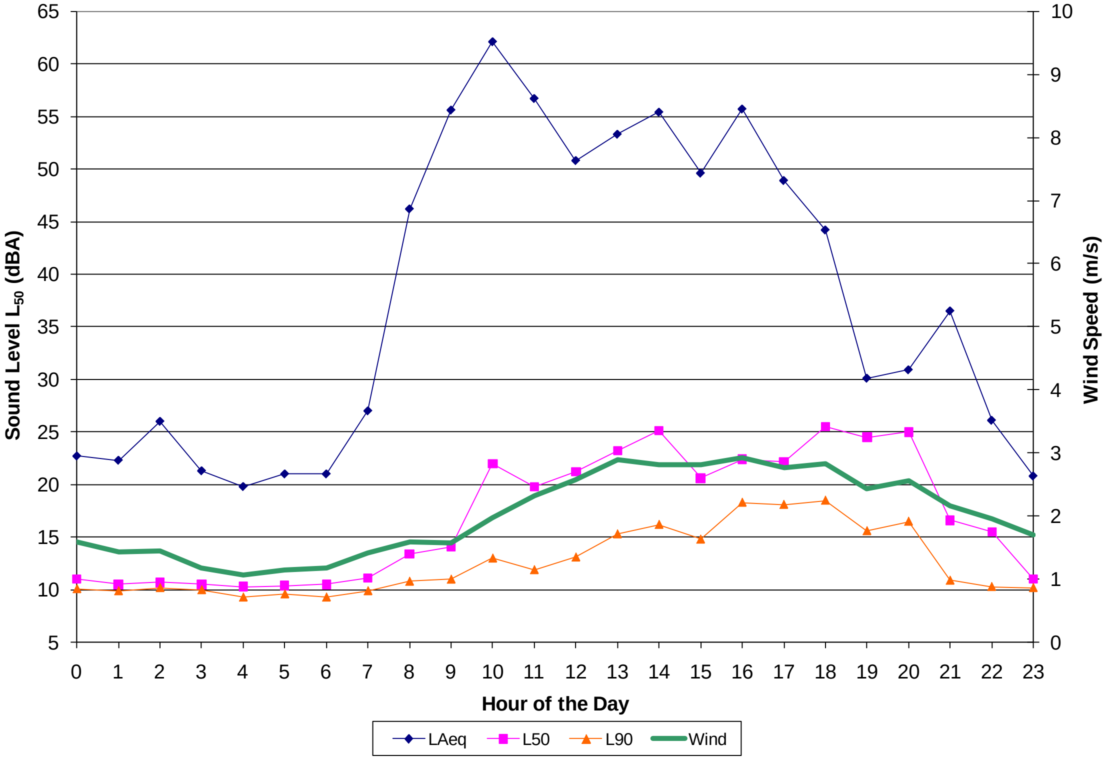


Figure 48. Hourly sound levels and wind speeds for Site DV5 for the summer season.

A.6 Site DV6 – Charcoal Kilns

Figure 49. Site DV6: Description and photograph.

Observations

Site DV6 was located within sight of the Wildrose Canyon charcoal kilns at an elevation of 6920 feet. The ground surface was gravel and fine/dusty soil with occasional swaths of land covered in pine needles surrounded by new growth Pinyon forest. There were a variety of sources of sound in this location including traffic on Emigrant Canyon Road approaching the kilns and within the parking lot, voices inside and outside the kilns, and clanging of trash can lids. The canyon effect in this area also echoed and amplified visitor sounds and created a distinctive "whoosh" sound as wind moved through the canyon and trees.

The median daytime sound level was 28.0 dBA and a median nighttime level of 17.8 dBA. Sound levels generally followed wind trends. A review of several "loud" time periods revealed: (1) the morning of April 18th experienced several loud vehicles and visitors to the kiln during the 0800 to 0900 hours; (2) a 400-Hz source was present during the morning 0800-0900 hours of April 23 (turned out to be a screeching bird near the measurement system); (3) April 14 and May 8 had loud events caused by wind rushing through the forest; and (4) May 8 during the hours of 1000 and 1200 experienced several aircraft events in this area (a mix of military and turboprop).

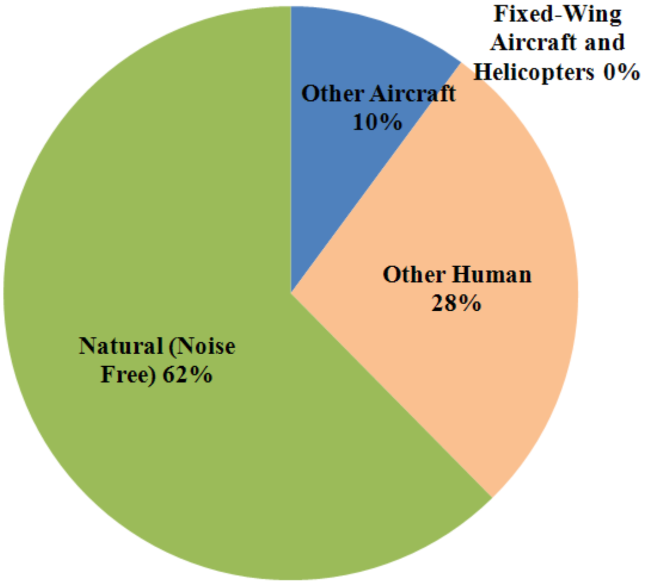


Figure 50. Distribution of audible sound sources (in situ and office listening combined) at Site DV6 for the summer season.

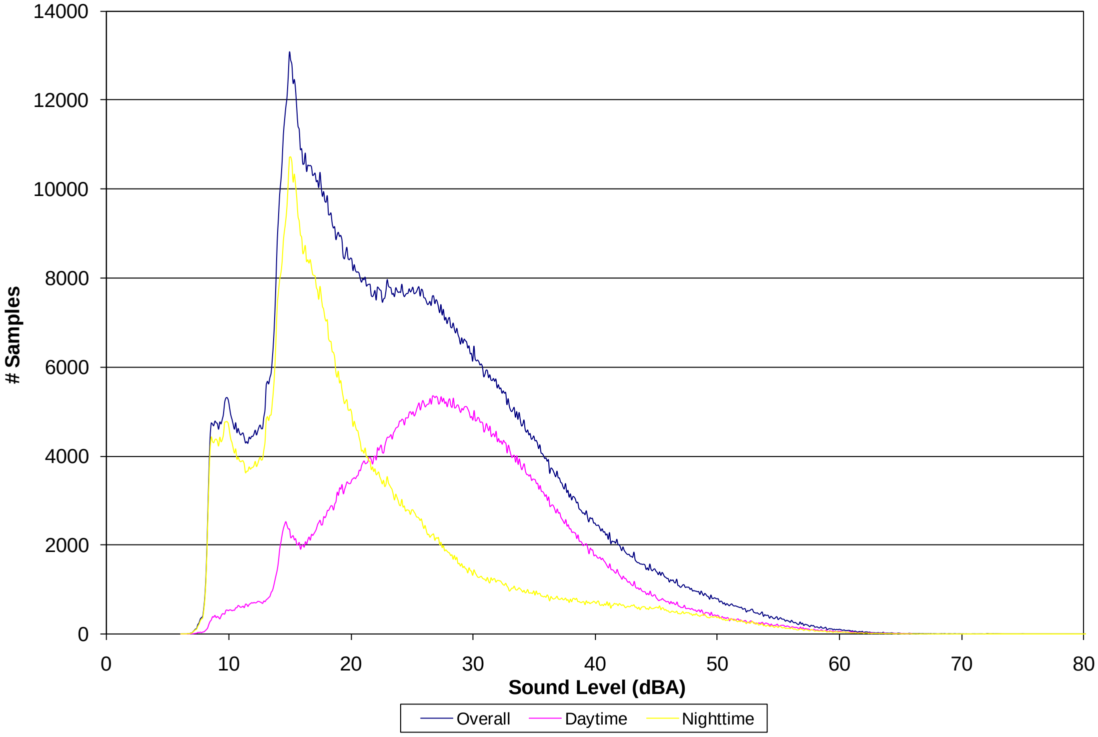


Figure 51. Distribution of data for Site DV6 for the summer season.

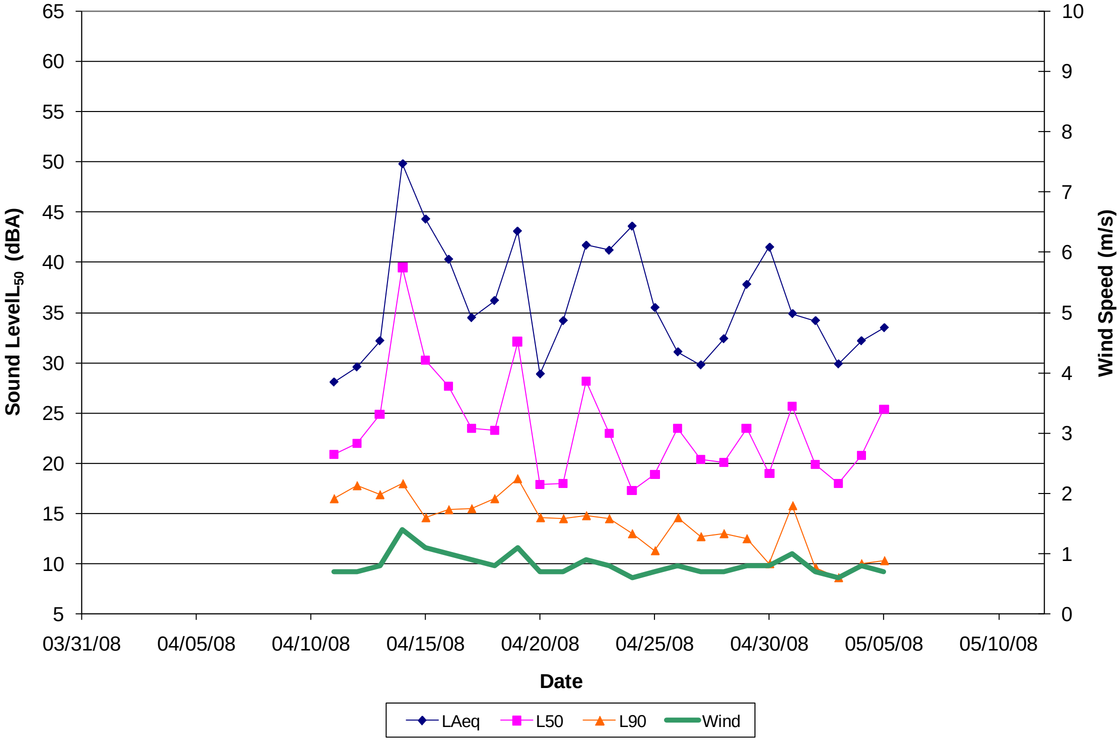


Figure 52. Daily sound levels and wind speeds for Site DV6 for the summer season.

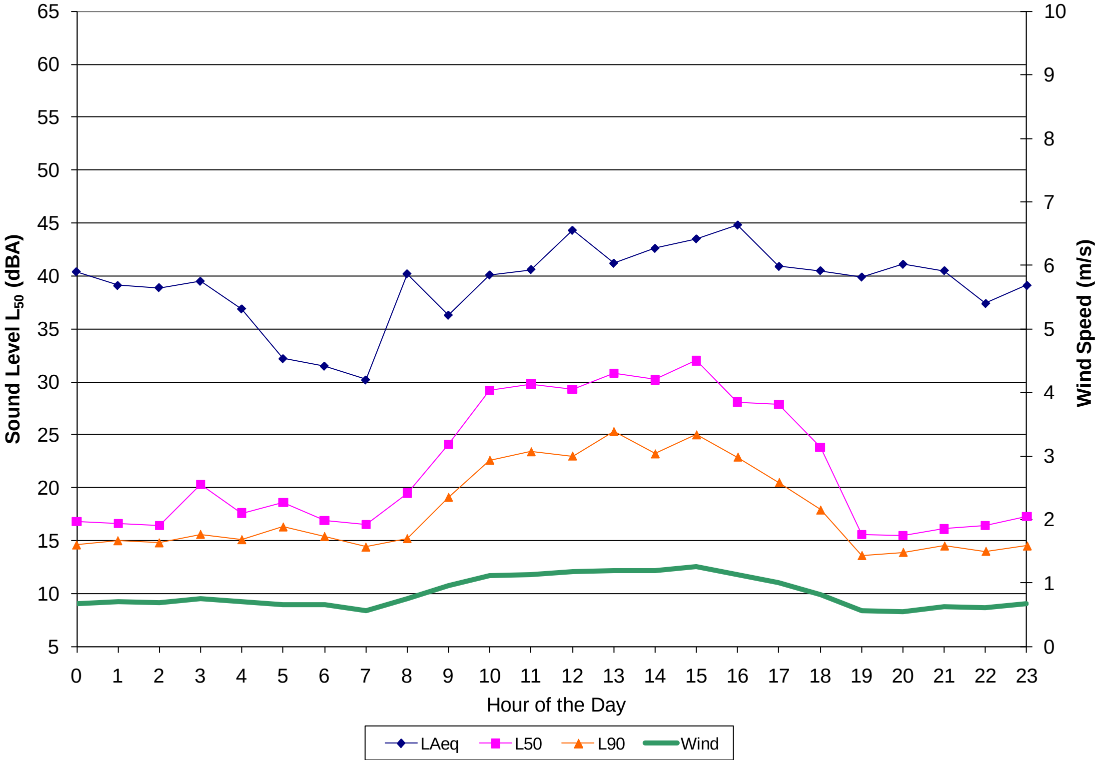


Figure 53. Hourly sound levels and wind speeds for Site DV6 for the summer season.

A.7 Site DV7 – Eureka Dunes

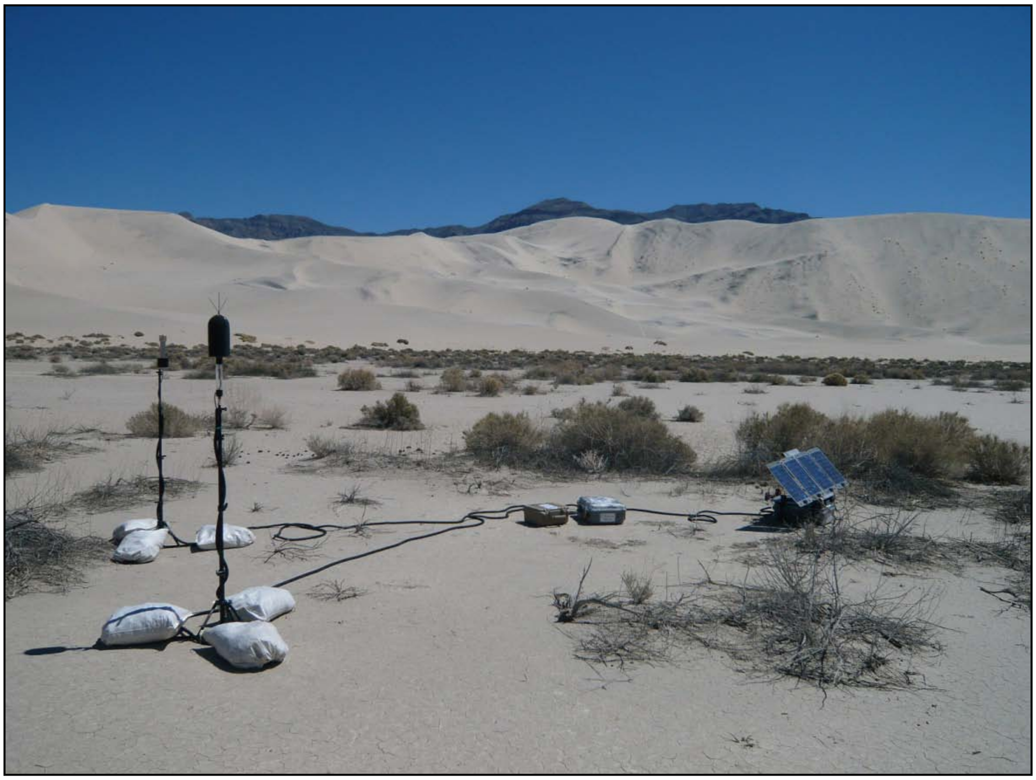


Figure 54. Site DV7: Description and photograph.

Observations

The DV7 measurement location was in the Eureka Valley on the west side of the Eureka Dunes, approximately 0.6 miles from the South Eureka Road. These dunes are the location of the famous “singing sand” phenomenon, which was unfortunately not observed during manned observations. The ground surface was hard packed sand at the measurement location with the occasional creosote bush and tumble weed. Sources of sound other than aircraft (military jets, commercial jets, turboprops and a helicopter) were insects, the occasional raven, and wind. Sounds from visitors in the parking lot, the camping area, and on the dunes themselves were audible only during quietest conditions. This site was very quiet with a daytime median sound level of 14.8 dBA and a nighttime median of 10.9 dBA.

Specific days with loud events occurred on April 16 and 23, and again on May 3 and 8, 2008. Most of these loud events were military aircraft, which were spotted in the Panamint Valley as well.

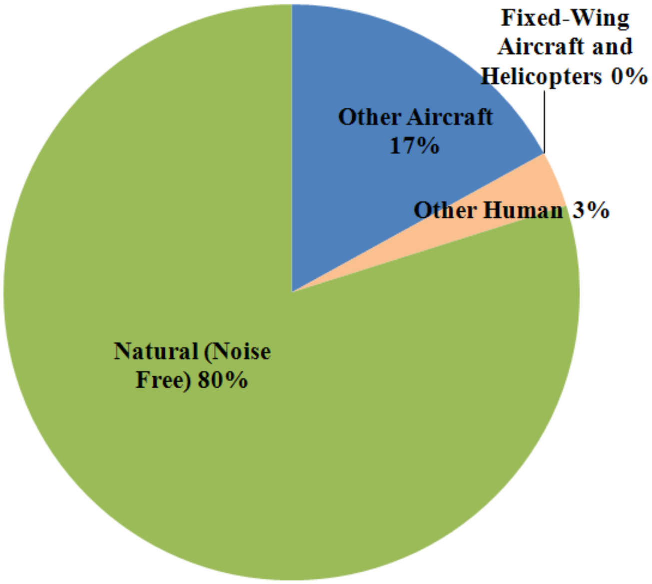


Figure 55. Distribution of audible sound sources (in situ and office listening combined) at Site DV7 for the summer season.

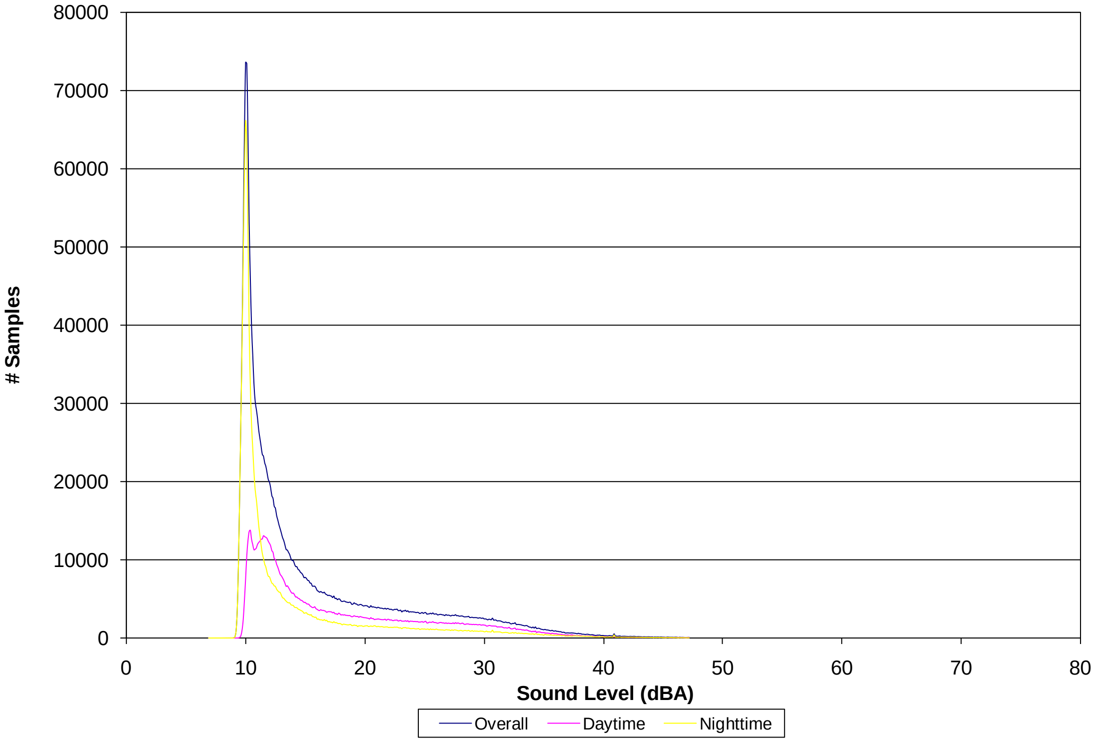


Figure 56. Distribution of data for Site DV7 for the summer season.

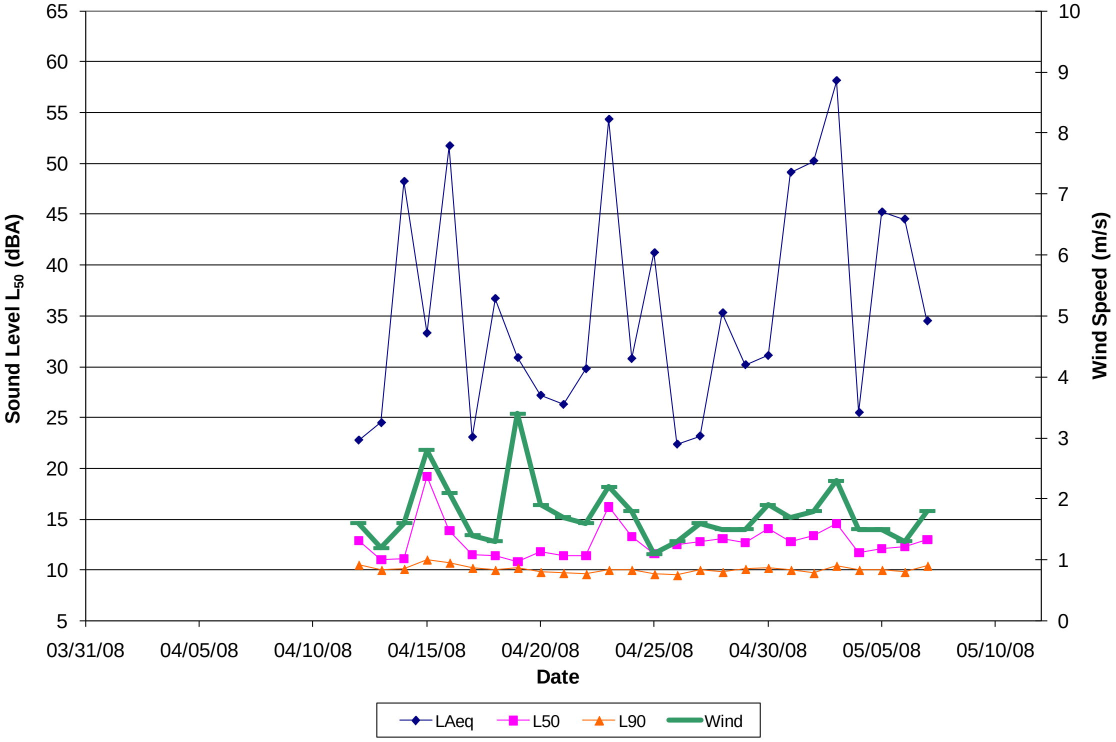


Figure 57. Daily sound levels and wind speeds for Site DV7 for the summer season.

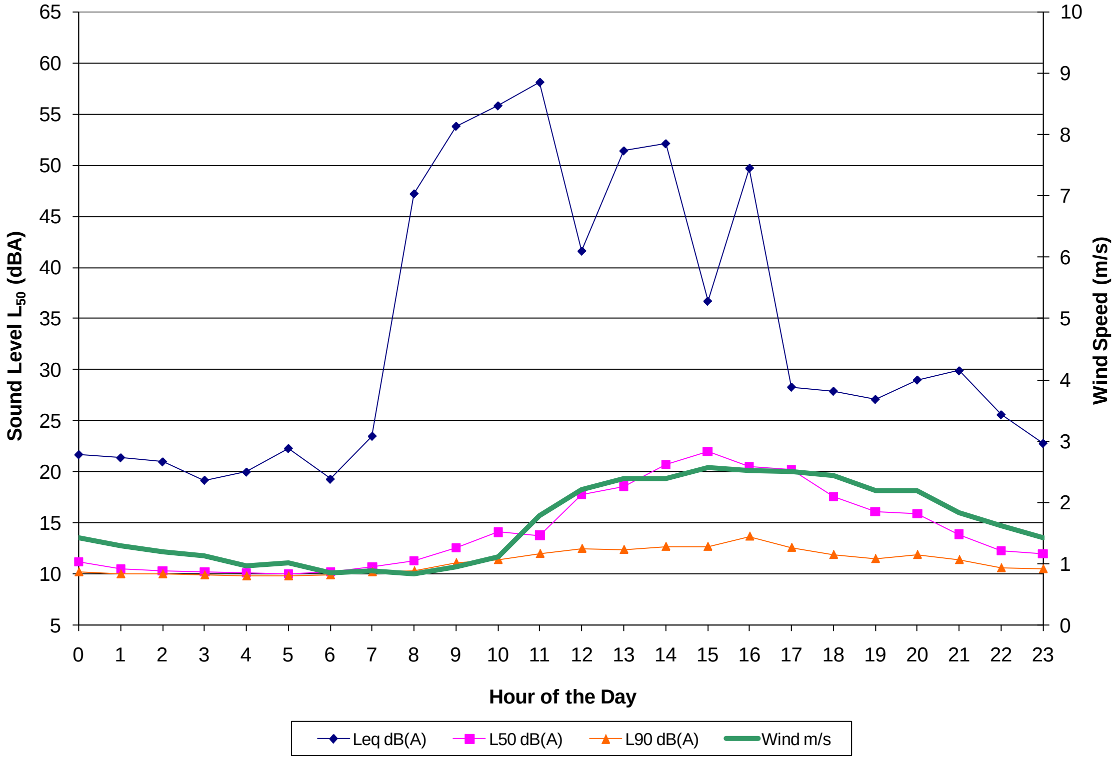


Figure 58. Hourly sound levels and wind speeds for Site DV7 for the summer season.

APPENDIX B. NOISELOGGER™ CONTINUOUS SYSTEM REFERENCE

This appendix presents the step-by-step procedures for the deployment, setup, and dismantling of the NoiseLogger™ system. Section 3 discusses the systems' component instrumentation in more detail.

B.1 Deployment

Locate an approximate 5x5 ft area that is both relatively flat and at least 50 ft (15 m) from reflective objects.

Carefully unpack the system backpacks.

B.1.1 Wind Sensor System

1. Extend tripod so that the legs are flat on the ground.
2. The FT702 anemometer is stored in the SLM acoustics case. Remove mount from anemometer. Screw the mount onto the tripod. Connect one end of anemometer cable to the base of the anemometer THRU the mount. Secure anemometer to mount using hex key and screws. Attach anemometer (see Figure 59) to tripod.
3. Adjust tripod height such that top of the anemometer sensor is 5 ft (1.5 m) above the ground.
4. Orient the anemometer properly toward North direction (look for the "N" marked on the anemometer). A compass can be found in the calibration kit.
5. Carefully wrap the anemometer cable around the tripod or tie with zip-ties, so that it will not hit the tripod in the wind. Connect other end of cable to the SLM case external connector.
6. Anchor the tripod to the ground or a nearby stationary object using the rope, stakes, and sandbags, as necessary, so that it will not sway in the wind.

Figure 59. FT702 anemometer.

B.1.2 Microphone System

1. Extend tripod so that the legs are flat on the ground. Attach the microphone aluminum collar to top of tripod.
2. Attach the microphone to the preamp. Connect the mic/preamp to the microphone cable (red cable, black connector, 7-pin connector with twist locking collar) and carefully slide mic/preamp/cable into the aluminum collar from the top (see Figure 60).
3. Adjust tripod height such that top of the microphone is 5 ft (1.5 m) above the ground and oriented vertically.
4. Carefully slide the large foam windscreen over the top of the mic/preamp until the windscreen mount reaches the black line on the microphone collar. Finger-tighten the plastic set screw to the collar (not the preamp).

5. Carefully wrap the microphone cable around the tripod or tie with zip-ties, so that it will not hit the tripod in the wind. Connect one end of microphone cable to the SLM case external connector.
6. Anchor the tripod to the ground or a nearby stationary object using the rope, stakes, and sandbags, as necessary, so that it will not sway in the wind.

Figure 60. Microphone/preamp assembly.

B.1.3 Power System

1. Unfold the metal panel and carefully remove solar panels. Align panels one though four from left to right (see Figure 61). Remove the two smooth rods and 4 panel rods from the array accessories bag.
2. Insert the two smooth rods into the metal "panel plate" and black corner blocks on the base plate to prop up "panel plate" at about 60-degree angle.

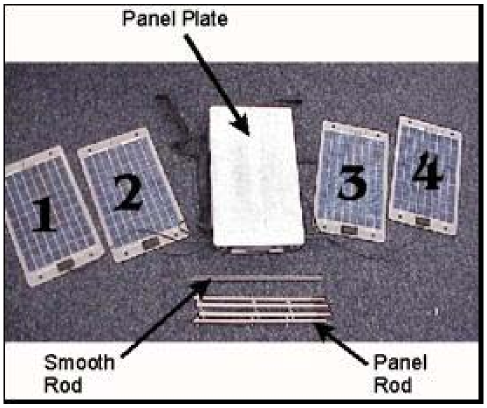


Figure 61. Unpack solar array.

3. Place left inner orange loop on the right upper panel plate tube; place right inner orange loop on the left upper panel plate tube (see Figure 62).
4. Place a panel rod into each side of the upper panel plate tube. Rotate panel rod so that the connection points are facing away from the panel plate.
5. Place the outer left loop of the orange line to the outer end of the left panel rod. Place the outer right loop of the orange line to the outer end of the right panel rod. The inner orange lines should now form an "X" pattern behind the "panel plate."

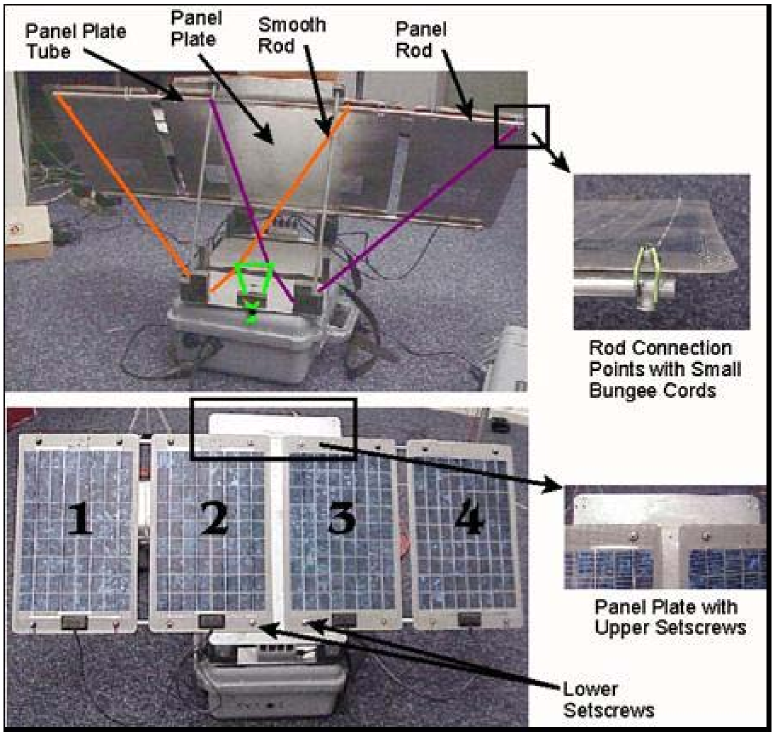


Figure 62. Solar panel array setup.

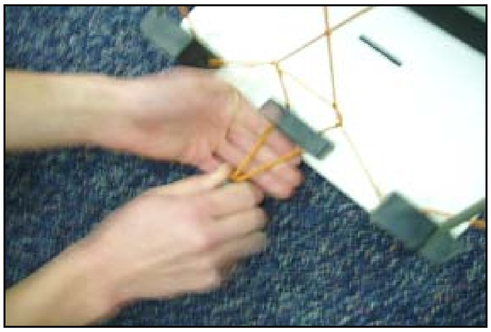


Figure 63. Close-in view of string tensioner.

6. Tighten the "X" pattern by pulling the small string loop at the base of the "X" and raising the tension knob (see Figure 63).
7. Insert the two lower panel rods into the tubes at the bottom of the "panel plate."
8. First attach panel #2 to the left inner position and panel #3 to the right inner position and secure with the four thumbscrews, which can be found in a small plastic bag within the array accessories bag. Make sure that the black cables are at the bottom of the plate and not between the lower panel rods and the panel.
9. Attach the outer panel #1 to the left outer position, and panel #4 to the right outer position.
10. Attach the small bungee cords (found in small plastic) bag to the rod connection points on the faces of the solar panels and to the back of the rod.
11. Connect the solar panel power cable to the power case (3-pin connector with twist locking collar).
12. Verify that the green "charging" LED is lit on the Sun Saver 6 input block.
13. Verify that the vent knob on the front of the power case is removed and placed inside the case.
14. Close the power case.
15. Place solar panel array on top of the power case. Secure the array to the power case with the black straps.
16. Orient the entire solar panel array in the desired position for the specific site location

(typically in a southerly direction).

17. Connect the system power cable (2-pin connector with twist locking collar) to the SLM case external connector and to the power case external connector.
18. For the NoiseLogger Plus™ system, a second solar panel array should be setup similarly.

B.2 Operation:

B.2.1 NoiseLogger™ Startup

1. See Section B.3.2 for NoiseLogger Plus startup.
2. Open SLM acoustics case. Remove top foam piece.
3. Verify connections as shown in Figure 64, specifically verify that the silver connector/red cable is connected to right Husky™ com port and the black Husky™ adapter/beige serial cable is connected to the left com port, also that the small black cable is connected to the side of the black Husky™ adapter. Verify also that the cable from the “Mic In” connector to the top of the LD824 is connected.
4. Open the plastic back plate to the Husky™ by squeezing the two clips on the back of the Husky™ and check to ensure a 128-MB CompactFlash™ card (Storage Card) is in one of the two card slots. Restore the back plate.
5. Power up the Husky™ by pressing the red center button below the screen. Note: If the Husky™ hasn’t been turned on for a long time, the unit may display several screens to calibrate the touch screen and perform time zone setup on the unit.

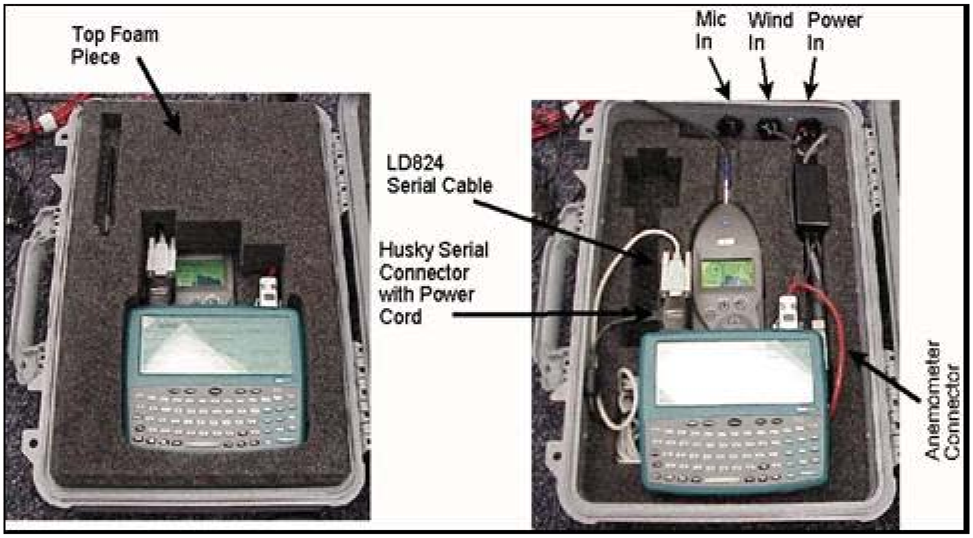


Figure 64. SLM acoustics case.

6. Power up the LD824 by pressing the lighted green (left-most) button on the front panel Note: The LD824 may power up automatically when the Husky™ is started.
7. Reset/reboot the Husky™ by pressing both the contrast and brightness buttons on either side of the power button.
8. Using the red tip of the stylus, select “My Handheld PC” icon on the desktop.
9. A Windows browser is displayed. Select the “Storage Card” directory to access the 128-MB CompactFlash™ card. Select the “NoiseLogger™ ver 2.1.0.0” folder and then run the

NoiseLogger.exe program by double clicking the filename with the stylus.

10. An “About NoiseLogger” dialog is displayed. Select OK.
11. Per the program instructions, enter a unique three-character ID representing the site “number” (e.g., DV1 for Site DV1), and the site’s name (e.g., Scotty’s Castle).*
12. Select “Equipment Info” and proceed to the GPS Synchronization (Section B.2.3).

B.2.3 GPS Synchronization

1. A GPS unit and cable can be found in the calibration kit. Connect the serial end of the GPS cable to the Husky™ right-side com port. If the anemometer cable is already connected to this com port, disconnect the silver connector with red cable, and then connect the black GPS cable.
2. Connect the other end of the GPS cable to the back of the GPS unit.
3. Turn on the GPS unit by pressing the red light-bulb button. When the unit has adequate satellite communication, the unit will display “3-D Navigation,” which may take several minutes. Use the “PGDN” button to display latitude, longitude, and elevation information. Write this information onto the site log sheet.
4. Select the [Sync with GPS] button on the computer screen. Date, time, and satellite information will begin to scroll for approximately 2 minutes. Note: If you are unable to sync with GPS, manually update the date and time and select the “Update” button.
5. Disconnect the GPS unit and cable from the computer when data stops scrolling and a message is displayed on the computer screen that says “Please disconnect GPS…”
6. Turn off the GPS unit by pressing the light-bulb button on its front panel.
7. Reconnect the anemometer cable.
8. Select the [Close] button on the screen and proceed to Section B.2.4.

B.2.4 Equipment Information

1. Verify that the wind sensor (anemometer) cable is connected properly to the computer.
2. Select the type of anemometer being used in the pull-down menu in the “Equipment Info” dialog. Note: This must be performed even if the anemometer is the default type. Select [Continue].
3. If an anemometer error occurs or a com port error message is displayed, check the connection, then press [Continue] and select [Equipment Info] again. If the problem persists continue on to the [Calibrate SLM] procedure (Section B.3.4).
4. Enter the sound level meter type and serial number. Refer to the equipment info sheet taped to the inside cover of the case). Note: The info sheet should be checked as some equipment may have been switched out in the field.
5. Enter the anemometer type and serial number.
6. Select the desired calibration level. If a level other than 94 or 114 dB is selected, enter the level in the field to the right. Verify that the “Frequency” field shows 1000.
7. Enter the calibrator type and serial number. A calibrator can be found in the calibration kit.
8. Select the [Continue] button.
9. Enter the microphone type and serial number.
10. Enter the preamp type and serial number.

---

* Although the NoiseLogger™ system only allows for a three-character ID, an NPS site-ID naming convention is used – specifically the four-letter park acronym followed by a three-digit number.

11. Enter the GPS unit type and serial number.
12. Enter the computer type and serial number.
13. Enter operator name and comments.
14. Select the [Finish] button. If prompted to "Sync with GPS" again, select the [Cancel] button. Proceed to Section B.2.5

B.2.5 Calibration

1. The NoiseLogger™/ NoiseLogger Plus™ program sends commands to the LD824 to control it during calibration and data logging. There is no need to handle the LD824 other than ensuring the preamp cable connection, serial data connection and power connection.
2. Carefully remove the large foam windscreen and apply the calibrator to microphone (see Figure 65). A calibrator can be found in one of the calibration kits. Note: To ensure the calibrator is seated properly, gently rotate it clockwise ¼ turn.
3. Carefully apply power to calibrator by pressing the left button on the calibrator (94-dB setting).
4. Select the [Calibrate SLM] button on the computer screen.
5. Verify information in the resultant calibrator info dialog. Select [Calibrate] button.

Figure 65. System calibration.

6. Verify that the LD824 is responding to the calibration process (a sound level of approximately 94 dBA at 1000 Hz should be displayed. When calibration is complete, a message is displayed on the computer screen with the calibration offset (typically between –45 and –50 dB). Write this offset level on the site log sheet. Note: During strong wind conditions, it may be difficult to observe a steady calibration signal. In such instances, cover the calibrator and mic/preamp assembly with a bag (such as the solar array accessories bag) and select the [Calibrate] button to redo calibration, taking care not to disturb the microphone and calibrator during this process.
7. After system calibration is completed, record approximately 30 seconds of the calibrator tone by selecting the [Collect Data] button. Verify that the anemometer cable is securely connected to the computer and select [Yes].
8. Verify that the sound level being reporting on the computer screen is approximately 94 dB for A, C, and flat weighting.
9. After about 30 seconds, stop data collection by selecting the [Stop Collection] button. Select [Yes] to verify.
10. Carefully de-activate the calibrator and remove it from the microphone.
11. After recording the calibration signal, carefully de-activate the calibrator and remove it from the microphone. Carefully replace the large foam windscreen.

B.2.6 System Integrity Check

1. System integrity is checked prior to the start of data collection to ensure that there is no outside signal influence on the system. This is performed by recording the sound level with a dummy microphone.
2. Carefully remove the large foam windscreen. Carefully replace the microphone on the preamp with a microphone simulator. Place the microphone back in its holder during this

exercise for safekeeping.

3. In the "Sound Level Range" (located in the upper right corner of the computer screen) pull-down menu, change the sound level range to 60.
4. Select the [Collect Data] button. Verify that the anemometer cable is securely connected to the computer and select [Yes].
5. Verify that the sound level being reporting is low, approximately 10-15 decibels for A, C, and flat weighting.
6. After about 20 seconds, stop data collection by selecting the [Stop Collection] button. Select [Yes] to verify.
7. Replace the microphone simulator on the preamp with the microphone.
8. Carefully replace the large foam windscreen over the top of the mic/preamp until the windscreen mount reaches the black line on the microphone collar. Finger-tighten the plastic set screw to the collar (not the preamp).

B.3 Data Collection

1. Carefully slide the large foam windscreen over the top of the mic/preamp until the windscreen mount reaches the black line on the microphone collar. Finger-tighten the plastic set screw to the collar (not the preamp).
2. In the "Sound Level Range" (located in the upper right corner of the computer screen) pull-down menu, select the desired sound level range (90 dB is the default). Note: This level is the anticipated maximum sound level to be measured at the site. Given this user-selected "maximum," the NoiseLogger™ program automatically sets both a designated amount of gain and an absolute sound level limit ("ceiling") to LD824 (see Table 15 below). For example, for sites where a wide range of natural and mechanical sound sources was expected, this range should be set to 90 dB. At this setting, 20 dB of gain is automatically applied to the LD824, and the loudest sound level that could be measured is 108 dB. For quieter sites, the "Sound Level Range" should be set to lower levels, as appropriate.

Table 15. LD Model 824 SLM sound level range and associated gain setting and ceiling level.

Sound Level Range (dB)	LD824 Gain Setting (dB)	Ceiling Level (dB)
110	0	128
100	+10	118
90	+20	108
80	+30	98
70	+40	88
60	+50	78

3. Select the [Collect Data] button. Verify that the anemometer cable is securely connected to the computer and select [Yes].
4. Verify that data is being collected: "Samples saved" is incrementing, and wind and sound level data are being read.

5. Replace top foam piece carefully over the computer. Verify that data appears reasonable and that "Samples saved" is incrementing. Also verify a battery reading above 11.0. Note: The system will not run properly if the battery reading is below 11.0. A fully charged system would display approximately 12.5.
6. Close the SLM case and secure the site.

B.4 Data Download

1. Stop data collection by selecting the [Stop Collection] button. Select [Yes] to verify.
2. Perform an end-calibration by recording the sound level with a calibrator applied.
3. Carefully remove the large foam windscreen. Apply the calibrator to microphone. A calibrator can be found in one of the calibration kits. Note: To ensure the calibrator is seated properly, gently rotate it clockwise ¼ turn.
4. Carefully apply power to calibrator by pressing the left button on the calibrator (94-dB setting).
5. Select the [Collect Data] button. Verify that the anemometer cable is connected to the Husky™ and select [Yes].
6. Verify that the sound level being reporting on the computer screen is approximately 94 dB for A, C, and flat weighting. Note: During strong wind conditions, it may be difficult to observe a steady calibration signal. In such instances, cover the calibrator and mic/preamp assembly with a bag (such as the solar array accessories bag), taking care not to disturb the microphone and calibrator during this process.
7. After about 30 seconds, stop data collection by selecting the [Stop Collection] button. Select [Yes] to verify.
8. To download the data from the computer, press the power button below the computer screen to power down the computer. Carefully remove the plastic back plate by squeezing the two clips on the back of the Husky™. Remove the plastic back plate and push the lever with green handle (do not pull it) like a plunger to pop out the 128-MB CompactFlash™ card. Make sure the flashcard is properly labeled with site info, date and other pertinent information. A wax pen can be found in one of the calibration kits. Also write this information, including the card number, on the site log sheet. If this is the end of the measurement period for this site, proceed to Section B.6 for instructions on dismantling the system. If measurements are to continue, install new flashcard, reinstall the plastic back plate, reconnect black Husky™ adapter ensuring that the Husky™ power cord is attached to the adapter, and power up the computer. Note the new card number on the site log sheet.
9. Perform calibration (see Section B.2.5).
10. Start data collection (see Section B.3).

B.5 System Dismantling

B.5.1 SLM Acoustics Case

1. Verify that the computer is powered down by disconnecting the power cable from the side of the Husky™ adapter on the left com port. Press the red center button above the keyboard of the Husky™ keypad to power down the computer.
2. Power down the LD824 if it has not already shut down by pressing and holding down the lighted green (left-most) button on the LD824.

3. Disconnect main power cable from SLM case and Power case.
4. Disconnect mic/preamp cable and anemometer cable from SLM case.
5. Store the stylus, hex key, and small screwdriver, replace top foam piece on the Husky, and close SLM acoustics case.

B.5.2 Wind Sensor System

1. Remove the anemometer from its mount by using the hex key to remove the screws. Disconnect the anemometer cable from the base of the anemometer THRU the mount. Unscrew the mount from the tripod. Replace the anemometer onto the mount with the screws. Place the anemometer/mount assembly in the SLM acoustics case.
2. Collapse the anemometer tripod.
3. Roll up the anemometer cable.

B.5.3 Microphone System

1. Remove large foam windscreen.
2. Remove mic/preamp/cable assembly from aluminum collar.
3. Carefully remove the microphone from the preamp and place it in its protective case.
4. Disconnect preamp from cable, replace the protective red cap on preamp (microphone end) and insert preamp into plastic tube (connector end first, not red cap).
5. Remove aluminum collar from tripod. Place collar and preamp tube in the SLM acoustics case.
6. Roll up the microphone cable
7. Collapse the microphone tripod.

B.5.4 Power System

1. Disconnect power cable from solar array to the power case.
2. Remove small bungee cords from the solar panels, place in plastic bag, and then place in solar-array accessories bag.
3. Remove the outer two panels and carefully place on the ground, panel facing up.
4. Remove the four setscrews holding the two inner panels, place set screws in bag with bungee cords.
5. Remove the two inner panels and place on ground facing up.
6. Disconnect orange loop from ends of upper panel rods.
7. Remove all four panel rods and place in solar-array accessories bag.
8. Remove smooth rods and place in solar-array accessories bag.
9. With the panel plate upright, place panel #4 on base plate with panel facing up.
10. Place panel #3 facing down on top of panel #4, making sure that panel #4 and #3 power cable connection blocks are on opposite sides of each other.
11. Loop power cables in between panel faces.
12. Place panel #2, metal to metal on top of panel #3, so that the panel is facing up.
13. Place panel #1 facing down on top of panel #2, making sure that panel #1 and #2 power cable connection blocks are on opposite sides of each other.
14. Loop power cables in between panel faces.
15. Route main power cable over the top of panel #1 so the connector is actually beyond the panel slightly and won’t crush either the connector or the top panel when the panel plate is closed (see Figure 66).

16. Close panel plate over the top of the stack of panels and secure with black straps.

Figure 66. Packing the solar panel array.

Note: Once the system is fully dismantled, place the components into their appropriate backpack. Perform a visual inspection of the site to ensure nothing was left behind.

APPENDIX C. INSTRUMENTATION FREQUENCY RESPONSE ADJUSTMENTS

All NoiseLogger™ acoustic data were adjusted prior to data analysis to account for microphone and windscreen frequency response biases – that is, the diffraction and interference effects that occur at the microphone diaphragm when it is placed in a diffuse sound field (Section C.1) and the acoustic effects, i.e., insertion losses, that occur when using a microphone windscreen (Section C.2). These adjustments were either measured or determined from the instrument's calibration certificate.* This appendix presents a description of these adjustments.

Table 16 provides a summary each system's equipment information used for the summer and winter seasons, respectively.

Table 16. Summary of NoiseLogger™ system equipment information.

Site ID	Site Name	LD824 Serial #	Microphone Type and Serial #	Preamplifier Serial #	Anemometer Type and Serial #	Windscreen #
DV1	Scotty's Castle	A1148	40AE #24020	1643	FT702 #2080-68	5
DV2	Fall Canyon	A0842	40AQ #25836	1243	FT702 #2080-77	1
DV3	Badwater Basin	A1150	40AE #24039	1678	FT702 #2110-42	7
DV4	Saratoga Spring	A1155	40AE #24040	1630	FT702 #2080-56	2
DV5	Panamint Dunes	A0844	40AQ #38110	1268	FT702 #2080-88	11
DV6	Charcoal Kilns	A0845	40AQ #38116	1282	FT702 #2360-33	6
DV7	Eureka Dunes	A1151	40AQ #83642	1650	FT702 #2080-58	10

C.1 Microphone Frequency Response Adjustments

The frequency response of a microphone varies with the angle of incidence between the sound waves and the microphone diaphragm. In measuring ambient noise, the locations of the sound sources are somewhat arbitrary, i.e., randomly occurring. As a result, the random-incidence, frequency response of each microphone was determined from its annual calibration certificate and used to adjust the acoustic data prior to data analysis (see Table 17 and Figure 67).

Table 17. Microphone frequency responses.

Frequency (Hz)	Frequency Band	Death Valley Site ID						
		DV1	DV2	DV3	DV4	DV5	DV6	DV7
12.5	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	13	-0.04	-0.06	0.01	-0.04	-0.05	0.00	-0.09

---

[*] Note: All acoustic instrumentation, including microphones, preamplifiers, sound level meters, and sound-level calibrators are calibrated annually by their manufacturer or other certified laboratory to verify accuracy. All calibrations are traceable to the National Institute of Standards and Technology (NIST).

Frequency (Hz)	Frequency Band	Death Valley Site ID						
		DV1	**DV2**	**DV3**	**DV4**	**DV5**	**DV6**	**DV7**
25	14	-0.04	-0.08	0.04	-0.04	-0.06	-0.03	-0.04
31	15	-0.01	-0.03	0.03	-0.05	-0.05	0.00	-0.04
40	16	-0.02	-0.04	0.02	-0.04	-0.04	-0.04	-0.02
50	17	-0.03	0.00	0.03	-0.04	-0.03	-0.01	0.00
63	18	0.01	-0.06	0.02	-0.05	-0.03	-0.01	-0.04
80	19	0.05	-0.02	0.01	-0.03	-0.03	-0.02	-0.01
100	20	0.02	0.00	0.02	-0.02	-0.01	-0.01	-0.01
125	21	0.02	0.02	0.01	-0.02	-0.01	-0.02	-0.01
160	22	0.06	0.02	-0.01	-0.02	0.01	-0.01	-0.04
200	23	0.04	0.01	-0.01	-0.01	0.02	-0.02	0.00
250	24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
315	25	0.01	0.04	-0.01	-0.01	0.02	0.01	0.00
400	26	0.01	0.00	0.04	-0.03	0.01	-0.01	-0.02
500	27	0.00	-0.01	-0.01	-0.03	0.03	0.01	-0.04
630	28	0.00	0.01	-0.04	-0.03	0.01	-0.01	-0.01
800	29	-0.01	-0.03	-0.08	-0.06	0.02	-0.01	-0.03
1000	30	-0.02	0.00	-0.06	-0.05	0.05	0.01	0.02
1250	31	0.02	-0.01	-0.11	-0.05	0.08	0.03	0.03
1600	32	-0.04	-0.03	-0.20	-0.07	0.11	0.04	0.04
2000	33	-0.13	-0.09	-0.34	-0.13	0.14	0.05	0.05
2500	34	-0.28	-0.16	-0.53	-0.21	0.19	0.01	0.01
3150	35	-0.40	-0.14	-0.82	-0.37	0.26	0.05	0.05
4000	36	-0.69	-0.44	-1.37	-0.64	0.26	-0.05	0.01
5000	37	-1.20	-0.42	-1.89	-1.01	0.29	-0.15	-0.06
6300	38	-1.68	-0.43	-2.39	-1.45	0.39	-0.16	-0.03
8000	39	-2.11	0.31	-2.75	-1.83	0.58	-0.02	0.14
10000	40	-2.73	0.26	-3.00	-2.46	0.37	0.09	0.29
12500	41	-4.10	-1.27	-3.82	-3.75	-1.08	-0.81	-1.09
16000	42	-4.95	-3.67	-4.45	-4.55	-2.44	-1.28	-1.84
20000	43	-7.74	-8.32	-7.50	-7.05	-5.59	-3.54	-5.35

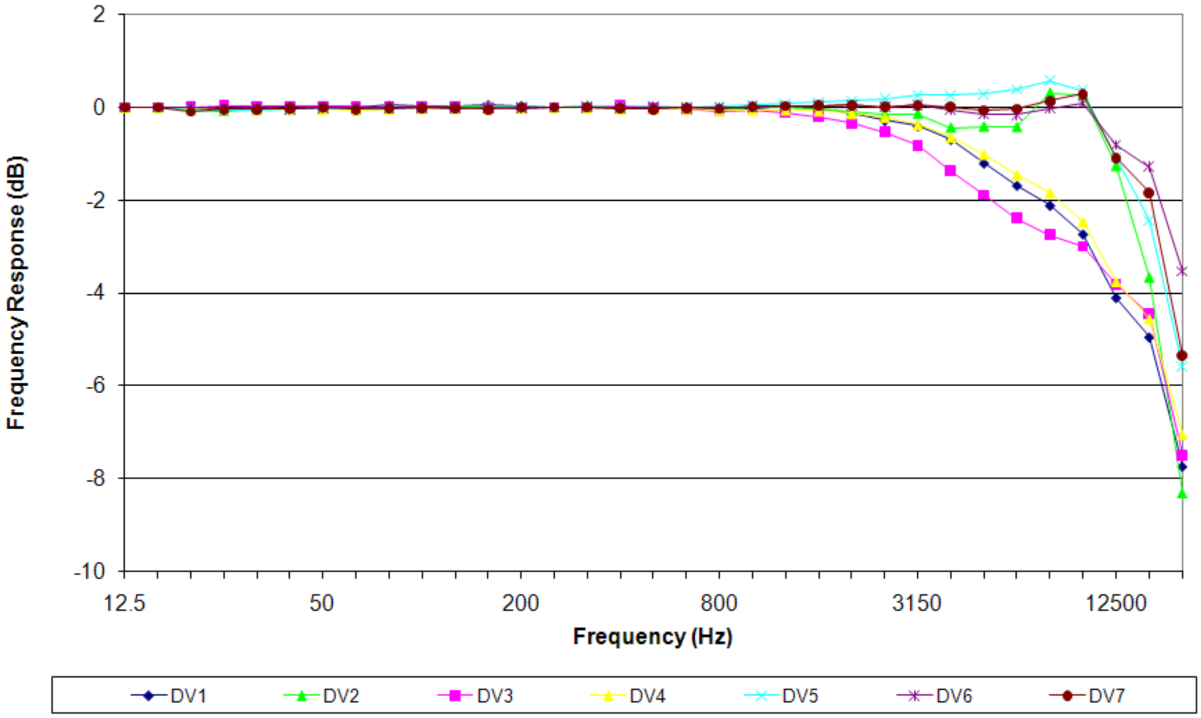


Figure 67. Microphone frequency responses.

C.2 Windscreen Frequency Response Adjustments

As discussed in Section 3.1, the use of a windscreen reduces the effects of wind-generated noise at the microphone diaphragm. The attenuation shown as a function of frequency is provided in Table 18 and Figure 68.[26]

Table 18. Windscreen frequency responses.

Frequency (Hz)	Frequency Band	All Sites
12.5	11	0.00
16	12	0.00
20	13	0.00
25	14	0.00
31	15	0.00
40	16	0.00
50	17	0.00
63	18	0.00
80	19	0.00
100	20	0.00
125	21	0.00
160	22	0.00

Frequency (Hz)	Frequency Band	All Sites
200	23	0.00
250	24	0.00
315	25	-0.07
400	26	0.00
500	27	-0.10
630	28	-0.13
800	29	-0.13
1000	30	-0.20
1250	31	-0.20
1600	32	-0.20
2000	33	-0.20
2500	34	-0.23
3150	35	0.00
4000	36	0.00
5000	37	0.60
6300	38	1.07
8000	39	1.73
10000	40	2.40
12500	41	2.60
16000	42	2.03
20000	43	3.40

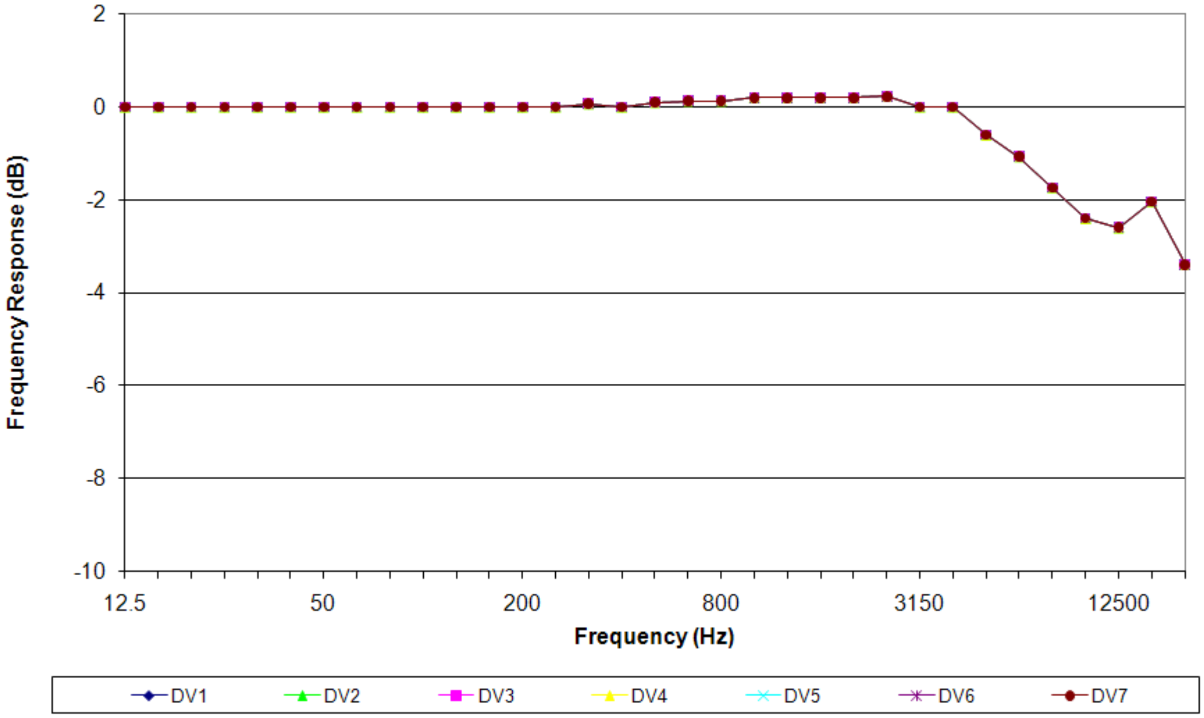


Figure 68. Windscreen frequency responses.

APPENDIX D. INSTRUMENTATION NOISE FLOOR ADJUSTMENTS

Documented ambient noise levels measured in remote areas of the country under low wind conditions (such as in national parks) often approach the threshold of human hearing. The NoiseLogger™ system has the capability of measuring sound levels down to approximately 15 to 20 dBA. A process was developed, to estimate and adjust the NoiseLogger™ data for contamination effects of the system noise floor. The process used for noise floor adjustments combines several elements of the method presented by HMMH in Reference 27, as well as other additional criteria developed by the Volpe Center.[18]

Application of these adjustments provide for more accurate estimation of the true ambient sound levels without limitations of the equipment's electrical noise floor. This appendix presents the method used to determine the noise floor of each of eleven NoiseLogger™ systems, as well as the final noise-floor adjustments used during data reduction.

D.1 Resultant Noise Floors

Table 19 and Figure 69 show the resultant noise floor levels used for each site.

Table 19. Derived noise floors.

Frequency (Hz)	Frequency Band	Death Valley Site ID						
		DEVA 001	DEVA 002	DEVA 003	DEVA 004	DEVA 005	DEVA 006	DEVA 007
12.5	11	16.57	10.10	15.20	16.57	12.20	15.00	16.57
16	12	15.35	10.40	15.10	15.35	17.80	14.50	15.35
20	13	13.96	14.90	12.40	13.96	9.70	17.10	13.96
25	14	12.47	12.00	16.40	12.47	11.60	16.20	12.47
31	15	10.75	10.80	6.10	10.75	13.70	17.60	10.75
40	16	9.03	9.80	4.00	9.03	6.90	7.40	9.03
50	17	7.27	1.30	3.70	7.27	1.20	6.20	7.27
63	18	5.63	1.20	-2.40	5.63	-2.80	3.00	5.63
80	19	4.19	-1.80	-3.90	4.19	-2.70	0.60	4.19
100	20	2.69	-3.50	-4.00	2.69	-4.90	0.00	2.69
125	21	1.46	-4.20	-4.60	1.46	-3.40	-0.90	1.46
160	22	0.97	-3.20	-4.60	0.97	-4.10	-1.80	0.97
200	23	0.31	-3.10	-5.00	0.31	-4.10	-2.20	0.31
250	24	-0.30	-1.20	-4.60	-0.30	-3.70	-2.60	-0.30
315	25	-0.43	-1.20	-5.00	-0.43	-4.10	-2.70	-0.43
400	26	-0.45	-1.10	-5.00	-0.45	-4.10	-2.50	-0.45
500	27	-0.35	-0.40	-5.00	-0.35	-3.40	-2.00	-0.35
630	28	-0.08	-4.20	-5.00	-0.08	-3.70	-1.70	-0.08
800	29	0.28	-4.20	-5.40	0.28	-3.10	-1.00	0.28
1000	30	0.91	-1.50	-3.20	0.91	-4.80	-3.80	0.91
1250	31	1.54	-0.60	-1.80	1.54	-3.40	-3.00	1.54
1600	32	2.33	-1.70	-0.60	2.33	-3.00	-2.00	2.33
2000	33	2.95	1.00	0.80	2.95	-1.50	-1.00	2.95
2500	34	3.65	1.80	2.30	3.65	0.70	0.00	3.65
3150	35	4.33	3.40	2.80	4.33	1.70	4.60	4.33
4000	36	4.82	5.30	4.20	4.82	2.80	5.90	4.82
5000	37	5.25	6.40	5.00	5.25	4.60	5.50	5.25
6300	38	5.45	6.60	5.40	5.45	5.70	6.60	5.45
8000	39	5.64	7.00	5.70	5.64	6.90	8.00	5.64
10000	40	5.56	7.30	6.00	5.56	7.60	8.90	5.56
12500	41	5.48	6.80	6.00	5.48	7.70	8.50	5.48
16000	42	5.26	8.20	6.50	5.26	8.10	8.90	5.26
20000	43	5.01	11.40	8.70	5.01	9.80	11.30	5.01

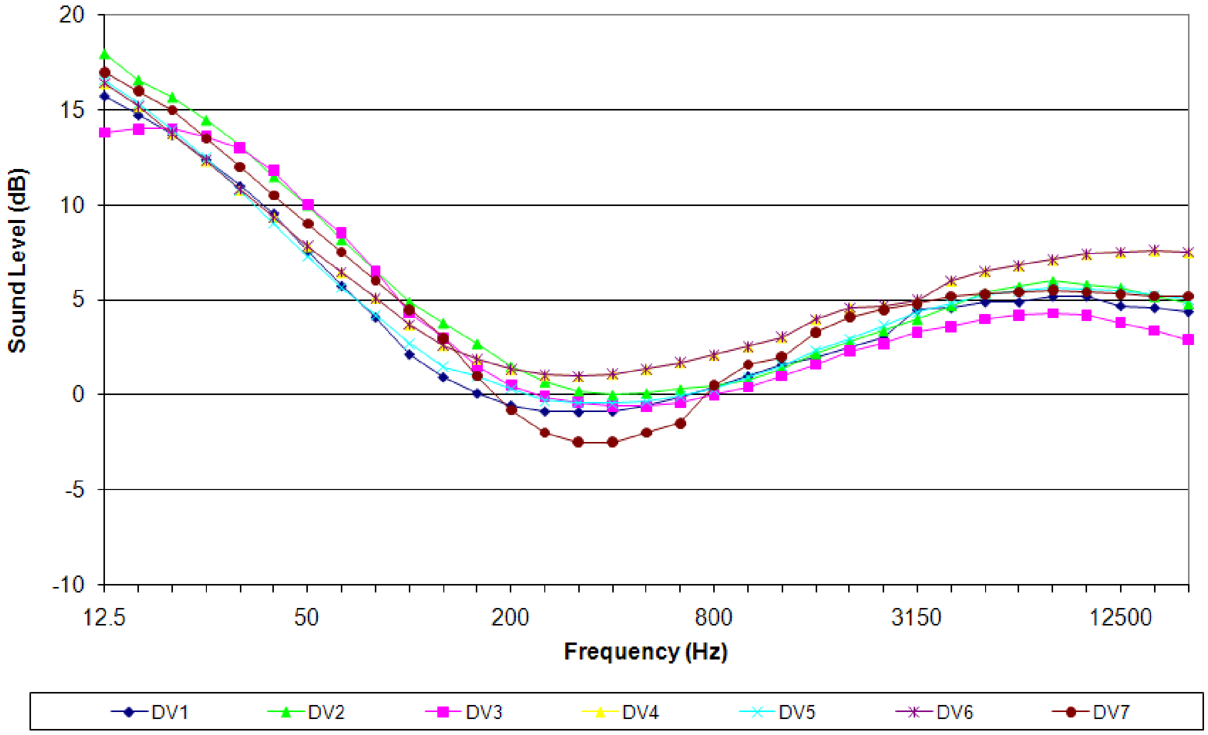


Figure 69. Derived noise floors for each site.

D.2 Applying Noise Floor Adjustments

The algorithm used in applying noise floor adjustments is based on HMMH's work as presented at the Inter-Noise Conference in August 2002.[26] The method applies the noise floor adjustments as an energy subtraction from the sound levels in each frequency band, whenever the measured-band sound level is within 1 dB of the noise floor of the system. At the ⅓-octave frequency band where the subtraction criterion is no longer met, the remainder of the spectrum (out to ⅓-octave frequency band 43, or 20 kHz) is extrapolated downward using a constant slope. The overall A-weighted sound level is then computed using the reconstructed spectrum.

D.4 Comparison with VoLARE Data

As stated earlier, because of the VoLARE system's ability to measure sound levels below that of the NoiseLogger™ system, data measured simultaneously using the VoLARE system were used to validate the noise floor adjustments applied to NoiseLogger™ data, which approached or were below the "noise floor" of the NoiseLogger™ systems. In comparing raw NoiseLogger™ and VoLARE data, it was observed that the NoiseLogger™ low-level data tended to fluctuate around VoLARE levels. As a result, small variations of raw NoiseLogger™ sound levels in the vicinity of the floor level caused large and usually short variations in the adjusted NoiseLogger™ sound levels. To resolve these fluctuations, raw 1-second L_{eq} samples were time-averaged to 30- and 120-second samples for this part of the analysis. Figure 70 presents a comparison for data collected at Death Valley site DV7 using a time-history plot of 120-second L_{eq}'s. As shown, the adjusted NoiseLogger™ data follows the trend of the raw NoiseLogger™ data. Definite improved overall agreement is seen between the adjusted NoiseLogger™ data and the higher quality VoLARE data.

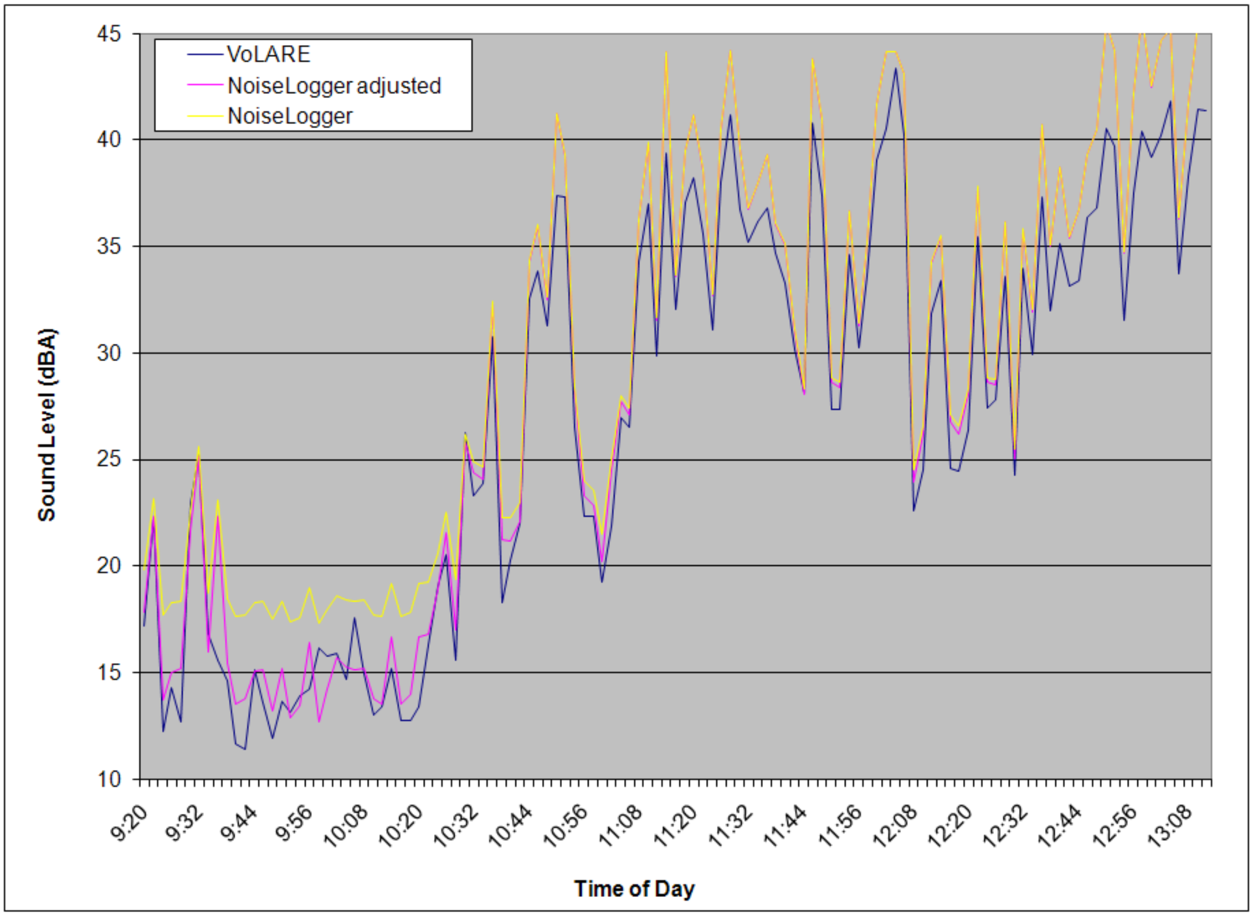


Figure 70. Comparison of adjusted NoiseLogger™ with raw and VoLARE data for Death Valley National Park site DV7.

It should be noted that comparisons between adjusted NoiseLogger™ and VoLARE data are based on two underlying assumptions: (1) the VoLARE data represents a more accurate measurement; and (2) the method used to develop noise floor adjustments is accurate. The first assumption is confirmed with the VoLARE's ultra-sensitive microphone affording it the ability to measure well below the noise floor of the NoiseLogger™ system. The second assumption has shown good results with comparisons performed thus far with Death Valley and other ATMP parks, including Hawai`i Volcanoes, Haleakala, and Badlands data.

TERMINOLOGY

This section presents pertinent terminology used throughout the document. Note: Definitions are generally consistent with those of the American National Standards Institute (ANSI) and References 28 through 32.

A-WEIGHTING - A frequency-based methodology used to account for changes in human hearing sensitivity as a function of frequency. The A-weighting network de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 kHz and 6.3 kHz, in an effort to simulate the relative response of human hearing.

ACOUSTIC ENERGY - Commonly referred to as the mean-square sound-pressure ratio, sound energy, or just plain energy, acoustic energy is the squared sound pressure (often frequency weighted), divided by the squared reference sound pressure of 20 μPa, the threshold of human hearing. It is arithmetically equivalent to $10^{LEV/10}$, where LEV is the sound level, expressed in decibels.

AMBIENT - The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sound source of interest. Several definitions of ambient noise have been adopted by different organizations depending on their application. *Existing Ambient*: The composite, all-inclusive sound associated with a given environment, excluding only the analysis system's electrical noise (i.e., aircraft-related sounds are included);

- *Existing Ambient Without Air Tours*: The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sound source of interest, in this case, commercial air tour aircraft;
- *Existing Ambient Without All Aircraft* (for use in assessing cumulative impacts): The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sounds produced by the sound source of interest, in this case, all types of aircraft (i.e. commercial air tours, commercial jets, general aviation aircraft, military aircraft, and agricultural operations); and
- *Natural Ambient*: The natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excluding all human and mechanical sounds.

ANNOYANCE - Any bothersome or irritating occurrence.

BACKCOUNTRY - Any location in a study area subject to minimal human activity, such as designated wilderness areas or restricted, hiking and camping areas (destinations generally located 1 hour or more from frontcountry locations).

C-WEIGHTING - A frequency-based methodology that is linear over the mid frequency range from 200 Hz to 1.6 kHz, and de-emphasizes the low (below 200 Hz) and high (above 1.6 kHz) frequencies.

DAY-NIGHT AVERAGE SOUND LEVEL (DNL, denoted by the symbol L_{dn}) - A 24-hour time-averaged sound exposure level (see definition below), adjusted for average-day sound source operations. In the case of aircraft noise, a single operation is equivalent to a single aircraft operation. The adjustment includes a 10-dB penalty for operations occurring between 2200 and 0700 hours, local time.

DECIBEL - (symbol dB) A unit of measure for defining a noise level or a noise exposure level. The number of decibels is calculated as ten times the base-10 logarithm of the squared sound pressure (often frequency weighted), divided by the squared reference sound pressure of 20 μPa, the threshold of human hearing.

EQUIVALENT SOUND LEVEL (TEQ, denoted by the symbol L_{AeqT}) - Ten times the base-10 logarithm of the time-mean-square, instantaneous A-weighted sound pressure, during a stated time interval, T (where $T=t_2-t_1$, in seconds), divided by the squared reference sound pressure of 20 μPa, the threshold of human hearing. L_{AeqT} is related to L_{AE} by the following equation:

$$L_{AeqT} = L_{AE} - 10Lg(t_2-t_1) \qquad \text{(dB)}$$

Where L_{AE} = Sound exposure level (see definition below).

The L_{Aeq} for a specific time interval, T1 (expressed in seconds), can be normalized to a longer time interval, T2, via the following equation:

$$L_{AeqT2} = L_{AeqT1} - 10Lg(T2/T1) \qquad \text{(dB)}$$

FRONTCOUNTRY - Any location in a study area subject to substantial human activity, such as scenic overlooks, visitor centers, recreation areas, or destinations reached by short hikes (1 hour or less).

FREQUENCY – For a function periodic in time, the reciprocal of the period (the smallest increment of an independent variable for which a function repeats itself).

HARD GROUND - Any highly reflective surface in which the phase of the sound energy is essentially preserved upon reflection; examples include water, asphalt and concrete.

HERTZ - (abbreviation Hz) Unit of frequency, the number of times a phenomenon repeats itself in a unit of time.

L_{50} - A statistical descriptor describing the sound level exceeded 50 percent of a specific time period. For example, from a fifty-sample measurement period with the samples sorted from highest sound level to lowest sound level, the twenty-fifth sound level is the 50-percentile exceeded sound level.

L_{90} - A statistical descriptor describing the sound level exceeded 90 percent of a specific time period. For example, from a fifty-sample measurement period with the samples sorted from highest sound level to lowest sound level, the forty-fifth sound level is the 90-percentile exceeded sound level.

L_{AE} (see Sound Exposure Level)

L_{Aeq} (see Equivalent Sound Level)

L_{ASmx} (see Maximum Sound Level)

L_{dn} (see Day-Night Average Sound Level)

L_x - A statistical descriptor describing the sound level exceeded “x” percent of a specific time period, e.g., L_{50} and L_{90}.

LINE SOURCE - Multiple point sources moving in one direction, radiating sound cylindrically. Note: Sound levels measured from a line source decrease at a rate of 3 dB per doubling of distance.

LOW-LEVEL NOISE ENVIRONMENT - An outdoor sound environment typical of a remote suburban setting, or a rural or public lands setting. Characteristic day-night average sound levels (DNL, represented by the symbol, L_{dn}) would generally be less than 45 dB, and the everyday sounds of nature, e.g., wind blowing in trees and birds chirping would be a prominent contributor to the DNL.

MAXIMUM SOUND LEVEL - The maximum, A-weighted sound level associated with a given event (see figure with definition of sound exposure level). Fast exponential response (L_{AFmx}) and Slow exponential response (L_{ASmx}) characteristics effectively damp a signal as if it were to pass through a low-pass filter with a time constant (τ) of 125 and 1000 milliseconds, respectively.

NATURAL AMBIENT (see Ambient)

NATURAL QUIET - The natural sound conditions found in a study area. Natural quiet is a subset of ambient noise. Traditionally, it is characterized by the total absence of human or mechanical sounds, but includes all sounds of nature, such as wind, streams, and wildlife. In a park environment, the National Park Service (NPS) on Page 74 of its Report to Congress[32] defines natural quiet as the absence of mechanical noise, but containing the sounds of nature, such as wind, streams, and wildlife, as well as human-generated “self-noise” (e.g., talking, the tread of hiking boots on the trail, a creaking packframe, the rattle of pots or pans).

NATURAL SOUNDSCAPE - In accordance with National Park Service’s Director's Order #47, the natural soundscape is the Natural Ambient sound level of a park. It is comprised of the natural sound conditions in a park, which exist in the absence of any human-produced noises. [33]

NOISE - Any unwanted sound. “Noise” and “sound” are used interchangeably in this document.

NOISE DOSE - A measure of the noise exposure to which a person is subjected.

NOISE-POWER DISTANCE (NPD) DATA – A set of noise levels representing a particular aircraft/engine combination in the FAA’s INM, expressed as a function of: (1) engine power, usually the corrected net thrust per engine; and (2) source-to-receptor distance.

OVERLOOK - Any frontcountry location in a study area subject to substantial human activity, or destinations reached by automobile or bus, and generally traversable within thirty minutes.

PERCENT TIME-ABOVE – The percentage of time that a time-varying sound level is above a given sound level threshold.

POINT SOURCE - Source that radiates sound spherically. Note: Sound levels measured from a point source decrease at a rate of 6 dB per doubling of distance.

SHORT HIKE - Any frontcountry location in a study area subject to moderate to substantial human activity, or destinations generally reached within one hour of hiking.

SOFT GROUND - Any highly absorptive surface in which the phase of the sound energy is changed upon reflection; examples include terrain covered with dense vegetation or freshly fallen snow. (Note: At grazing angles greater than 20 degrees, which can commonly occur at short ranges, or in the case of elevated sources, soft ground becomes a good reflector and can be considered hard ground).

SOUND – Auditory sensation evoked by the oscillation in pressure, stress, particle displacement, particle velocity, etc., in a medium with internal forces (e.g., elastic or viscous), or the superposition of such propagated oscillations.

SOUND EXPOSURE LEVEL (SEL, denoted by the symbol L_{AE}) – Over a stated time interval, T (where $T=t_2-t_1$, in seconds), ten times the base-10 logarithm of a given time integral of squared instantaneous A-weighted sound pressure, divided by the product of the squared reference sound pressure of 20 μPa, the threshold of human hearing, and the reference duration of 1 sec. The time interval, T, must be long enough to include a majority of the sound source's acoustic energy. As a minimum, this interval should encompass the 10-dB down points (see Figure 71).

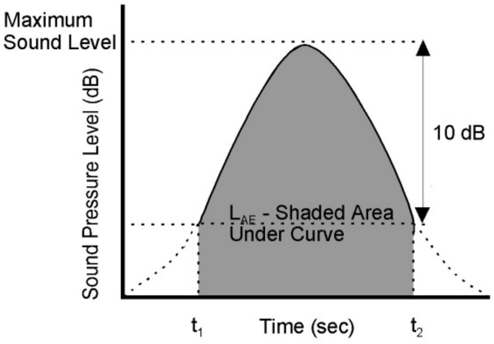


Figure 71. Graphical representation of L_{AE}.

The L_{AE} can be developed from 1-second, A-weighted sound levels (L_{Ak}) by the following equation:

$$L_{AE} = 10Lg\left[\sum_{k=t_1}^{t_s} 10^{L_{AK}/10}\right] \qquad \text{(dB)}$$

In addition, L_{AE} is related to L_{AeqT} by the following equation:

$$L_{AE} = L_{AeqT} + 10Lg(t_2-t_1) \qquad \text{(dB)}$$

Where L_{AeqT} = Equivalent sound level in dB (see definition above).

SOUND PRESSURE LEVEL (SPL) - Ten times the base-10 logarithm of the time-mean-square sound pressure, in a stated frequency band (often frequency-weighted), divided by the squared reference sound pressure of 20 μPa, the threshold of human hearing.

$$SPL = 10Lg[p^2/ p_{ref}^2]$$

Where p^2 = time-mean-square sound pressure; and p_{ref}^2 = squared reference sound pressure of 20 μPa.

SOUNDSCAPE - In accordance with National Park Service's Director's Order #47 (http://www.nps.gov/policy/DOrders/DOrder47.html), soundscape is defined as "the total ambient acoustic environment associated with a given environment in an area such as a national park. In a national park setting, this soundscape is usually composed of both Natural Ambient sounds and a variety of human-made sounds."

SPECTRUM – A set of sound pressure levels in component frequency bands, usually one-third octave-bands.

TIME-ABOVE – The duration that a time-varying sound level is above a given sound level threshold in a given area during a given time period.

TIME-AUDIBLE – The percentage of time that a time-varying sound level can be heard by a receiver in a given area during a given time period.

Z-WEIGHTING – Indicates no frequency-based methodology was used (also referred to as flat or no weighting).

Page left blank intentionally.

REFERENCES

1 National Park Service. http://www.nps.gov/state/ca/.

2 Lee, et. al., FHWA Traffic Noise Model® (FHWA TNM®) User's Guide Version 2.5 Addendum to the User's Guide Version 1.0, Report No. FHWA-PD-96-009, Washington, D.C.: Federal Highway Administration, April 2004.

3 National Parks Air Tour Management Act of 2000. Public Law 106-181, 114 Stat. 61, Title VIII, Section 801, April 2000.

4 FICAN Findings and Recommendations on Tools for Modeling Aircraft Noise in National Parks, Washington, DC: Federal Interagency Committee on Aviation Noise, February 2005.

5 Fleming, Gregg G., Plotkin, Kenneth J., Roof, Christopher J., Ikelheimer, Bruce J., Senzig, David A., FICAN Assessment of Tools for Modeling Aircraft Noise in the National Parks, Cambridge, MA: John A. Volpe National Transportation Systems Center, Arlington, VA: Wyle Laboratories, Winchester, MA: Senzig Engineering, March 2005.

6 Unrau, Harlan D., A History of the Lands Added to Death Valley National Monument by the California Desert Protection Act of 1994 – Special History Study, United States Department of the Interior, National Park Service, September 1997. http://www.nps.gov/history/history/online_books/deva1/unrau.pdf.

7 National Park Service Public Use Statistics Office. http://www.nature.nps.gov/stats/.

8

http://www.nps.gov/pwr/customcf/apps/maps/showmap.cfm?alphacode=deva&parkname=Death%20Valley%20National%20Park.

9 Fleming, G., et. al., Ambient Sound Levels at Four Department of Interior Conservation Units in Support of Homestead Air Base Reuse Supplemental Environmental Impact Statement, Report Nos. DOT-VNTSC-FAA-99-3, FAA-AEE-99-02, Cambridge, MA: John A. Volpe National Transportation Systems Center, June 1999.

10 Fleming, G., et. al., Development of Noise Dose/Visitor Response Relationships for the National Parks Overflight Rule: Bryce Canyon National Park Study, Report Nos. DOT-VNTSC-FAA-98-6, FAA-AEE-98-01, Cambridge, MA: John A. Volpe National Transportation Systems Center, July 1998.

11 Fleming, G., et. al., Development of Noise Dose/Visitor Response Relationships for the National Parks' Overflight Rule: Bryce Canyon National Park & Grand Canyon National Park Overlook Study, Cambridge, MA: John A. Volpe National Transportation Systems Center, (to be published).

12 Sneddon, Matthew, Silvati, Laura, Pearsons, Karl, and Fidell, Sanford, Measurements and Analyses of the Indigenous Sound Environment of Coniferous Forests Canoga Park, CA: BBN Systems and Technologies, January 1994.

13 Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, N. Van Driel, Completion of the 1990s National Land Cover Data Set for the Conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources, Photogrammetric Engineering and Remote Sensing, 67:650-652, 2001.

14 Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K., Snow, and J. Teague, Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems, NatureServe, Arlington, Virginia, 2003.

15 Western Regional Climate Center: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca2319, http://www.wrcc.dri.edu/htmlfiles/westwinddir.html#CALIFORNIA, http://www.wrcc.dri.edu/htmlfiles/westwind.final.html#CALIFORNIA.

16 General Management Plan: Death Valley National Park, Maine. U.S. Department of the Interior, National Park Service, April 2002.

17 NPS Planning, Environment & Public Comment (PEPC): Scoping Packet for DEVA Air Tour Management Plan, January 2010. http://parkplanning.nps.gov/documentsList.cfm?parkID=297&projectID=27781.

18 Lee, et. al., Baseline Ambient Sound Levels in Hawai`i Volcanoes National Park, Report No. DOT-VNTSC-FAA-06-07, Cambridge, MA: John A. Volpe National Transportation Systems Center, April 2006.

19 NPS report on ambient sound levels in Arches National Park and Bryce Canyon National Park (to be published).

20 Macdonald, J., Lee, C., and Scarpone, C., NoiseLogger™ System Reference, Cambridge, MA: John A. Volpe National Transportation Systems Center, April 2003.

21 Plotkin, Kenneth J., Review of Technical Acoustical Issues Regarding Noise Measurements in National Parks, Draft Report WR 01-20, Arlington, VA: Wyle Laboratories, January 2002.

22 Rapoza, et. al., Development of Improved Ambient Computation Methods in Support of the National Parks Air Tour Management Act, Cambridge, MA: John A. Volpe National Transportation Systems Center, October 2008 (draft).

23 Fleming, G., et. al., Ambient Sound Levels at Four Department of Interior Conservation Units in Support of Homestead Air Base Reuse Supplemental Environmental Impact

Statement, Report Nos. DOT-VNTSC-FAA-99-3, FAA-AEE-99-02, Cambridge, MA: John A. Volpe National Transportation Systems Center, June 1999.

[24] Fleming, G., et. al., Development of Noise Dose/Visitor Response Relationships for the National Parks Overflight Rule: Bryce Canyon National Park Study, Report Nos. DOT-VNTSC-FAA-98-6, FAA-AEE-98-01, Cambridge, MA: John A. Volpe National Transportation Systems Center, July 1998.

[25] Rapoza, et. al., Development of Improved Ambient Computation Methods in Support of the National Parks Air Tour Management Act, Cambridge, MA: John A. Volpe National Transportation Systems Center, October 2008.

[26] Miller, Nicholas P., Ross, Jason C., Horonjeff, Richard D., Anderson, Grant S., Acoustic Data Collected at Hawai`i Volcanoes National Park, HMMH Report No. 295860.341, Burlington, MA: Harris Miller Miller & Hanson Inc., July 2003.

[27] Horonjeff, Richard C., Ross, Jason, C., Overcoming Instrument Noise Floors When Measuring In Quiet Environments, Inter-Noise 2002, Paper No. N599F, Dearborn, Michigan: Institute of Noise Control Engineering, August 19-21, 2002.

[28] "Acoustical Terminology," American National Standard, ANSI S1.1-1994, New York: American National Standards Institute, 1994.

[29] "Procedures for Outdoor Measurement of Sound Pressure Level," American National Standard, ANSI Standard S12.18-1994, New York: American National Standards Institute, 1994.

[30] Johnson, D.L., Marsh, A.H., and Harris, C.M. "Acoustical Measurement Instruments," Handbook of Acoustical Measurements and Noise Control, New York: Columbia University, 1991.

[31] "Specification for Sound Level Meters," American National Standard, ANSI Standard S1.4-1983 (R 1990), New York: American National Standards Institute, 1990.

[32] Report on Effects of Aircraft Overflights on the National Park System, Washington, DC: National Park Service, July 1995.

[33] "Soundscape Preservation and Noise Management," Director's Order #47, Washington, DC: National Park Service, December 2000.