National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Petroglyph National Monument

Acoustical Monitoring 2010 and 2012

Natural Resource Report NPS/NRSS/NRTR—2014/876

ON THE COVER
Petroglyph National Monument, taken in 2010
Photograph courtesy Volpe Center

Petroglyph National Monument

Acoustical Monitoring 2010 and 2012

Natural Resource Report NPS/NRSS/NRTR—2014/876

Amanda Rapoza
Cynthia Lee
John MacDonald

US Department of Transportation
Office of the Assistant Secretary for Research and Technology
John A. Volpe National Transportation Systems Center
Environmental Measurement and Modeling Division, RVT-41
Cambridge, MA 02142-1093

November 2014

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Rapoza, A., C. Lee, and J. MacDonald. 2014. Petroglyph National Monument: Acoustical monitoring 2010 and 2012. Natural Resource Report NPS/NRSS/NRTR—2014/876. National Park Service, Fort Collins, Colorado.

NPS 354/127129, November 2014

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE March 2014	3. REPORT TYPE AND DATES COVERED Final Report

4. TITLE AND SUBTITLE Petroglyph National Monument: Acoustical Monitoring 2010 and 2012	5. FUNDING NUMBERS VX-K6 / MLE72
6. AUTHOR(S) Amanda Rapoza, Cynthia Lee and John MacDonald	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology John A. Volpe National Transportation Systems Center Environmental Measurement and Modeling Division, RVT-41 Cambridge, MA 02142-1093	8. PERFORMING ORGANIZATION REPORT NUMBER DOT-VNTSC-NPS-XX-XX
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of the Interior National Park Service Natural Resource Program Center Natural Sounds and Night Skies Division 1201 Oakridge Drive Fort Collins, CO 80525	10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
NPS Program Managers: Vicki Ward

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

13. ABSTRACT (Maximum 200 words)
During the summer of 2010 (August – September) and winter of 2012 (February – April), baseline acoustical data were collected at Petroglyph National Monument (PETR) at two sites deployed for approximately 30 days each. The baseline data collected during this period will help park managers and planners estimate the effects of future noise impacts and will help to inform future park planning objectives such as creating acoustic resource management plans, as well as the development of an Air Tour Management Plan (ATMP), which provides for the regulation of commercial air tours. The sound sources of concern at PETR include developments near park boundaries, air tours, commercial and private aircraft activities, and requests for special use permits for noisy activities. 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, soundscape	15. NUMBER OF PAGES 68
	16. PRICE CODE

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

NSN 7540-01-280-5500

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

Table of Contents

Figures

Page

Figures (continued)

Page

Tables

Executive Summary

The National Park Service (NPS) Natural Sounds and Night Skies Division (NSNSD) and the U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) performed acoustical monitoring during August to September of 2010 and February to April of 2012 to characterize existing sound levels and estimate natural ambient sound levels representing summer and winter seasons, respectively, for Petroglyph National Monument (PETR). This monitoring effort also serves to identify audible sound sources in support of the potential development of an air tour management plan (ATMP). This report provides a summary of results of these measurements.

In determining the current conditions of an acoustical environment, the NPS examines how often sound pressure levels exceed certain decibel values that relate to human health and speech. The NPS uses these values for making comparisons; they should not be construed as thresholds of impact. Table 1 and Table 2 report the percent of time that measured levels were above four sound level values at each of the Montezuma Castle measurement locations for each season in dBA and dBT. The first value, 35 dBA, addresses the health effects of sleep interruption (Haralabidis, et. al., 2008). The second value is based on the World Health Organization's recommendation that noise levels inside bedrooms remain below 45 dBA (Berglund, et. al., 1999). The third value, 52 dBA, is based on the Environmental Protection Agency's speech interference threshold for speaking in a raised voice to an audience at 10 meters (Environmental Protection Agency, 1974). This value addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m (3 ft.). Hikers and visitors in the park would likely be conducting such conversations.

Table 1. Percent Time Above Metrics (dBA).

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Summer season (2010)									
PETR001	Rinconada	47.7	6.8	1.2	0.2	56.1	2.3	0.5	0.1
PETR002	Volcano Vista	30.8	5.9	2.1	0.3	11.4	1.4	0.5	0.1
Winter season (2012)									
PETR001	Rinconada	27.2	2.2	0.5	0.1	10.6	0.5	0.1	0.0
PETR002	Volcano Vista	20.5	3.2	0.8	0.1	3.2	0.7	0.2	0.0

Table 2. Percent Time Above Metrics (truncated spectra – dBT).

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Summer season (2010)									
PETR001	Rinconada	46.7	5.9	1.2	0.2	40.5	2.0	0.4	0.1
PETR002	Volcano Vista	30.4	5.8	1.9	0.3	10.4	1.3	0.5	0.1
Winter season (2012)									
PETR001	Rinconada	26.9	2.1	0.5	0.1	10.4	0.4	0.1	0.0
PETR002	Volcano Vista	19.9	3.0	0.8	0.1	2.9	0.5	0.2	0.0

Table 3 and Table 4 summarize the daytime and nighttime* acoustical observer log data (off-site listening and *in situ* logging combined) which provides an indication of the amount of time that certain sources are audible at each site. The *in situ* logging is performed during visits to the site itself; off-site listening is performed in an office environment using the audio files collected at each site.

Table 3. Summary of daytime acoustical observer log data (*in situ* and off-site listening combined).

Site ID	Site Name	% Time Audible: Daytime (7 am to 7 pm)			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
Summer season (2010)					
PETR001	Rinconada	15.2	38.6	1.6	44.6
PETR002	Volcano Vista	30.5	17.9	4.1	47.4
Winter season (2012)					
PETR001	Rinconada	27.1	19.6	6.5	46.8
PETR002	Volcano Vista	28.5	11.8	1.6	58.1

* Nighttime acoustical observer logs are not available for the 2010 summer season.

Table 4. Summary of nighttime acoustical observer log data (off-site listening).

Site ID	Site Name	% Time Audible: Nighttime (7 pm to 7 am)			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
Winter season (2012)					
PETR001	Rinconada	3.7	8.6	40.1	47.6
PETR002	Volcano Vista	3.6	4.8	13.6	78.0

Acknowledgments

The authors of this report wish to express their sincere gratitude to all who helped make this a successful study. Invaluable coordination and support were provided by the staff of the National Park Service (NPS), Natural Sounds and Night Skies Division. We would also like to thank the Petroglyph National Monument team, especially Mike Medrano, for their expertise and assistance during site selection and deployment.

List of Terms

Acoustical Environment
The actual physical sound resources, regardless of audibility, at a particular location.

Amplitude
The instantaneous magnitude of an oscillating quantity such as sound pressure. The peak amplitude is the maximum value.

Audibility
The ability of animals with normal hearing, including humans, to hear a given sound. Audibility is affected by the hearing ability of the animal, the masking effects of other sound sources, and by the frequency content and amplitude of the sound.

dBA
A-weighted decibel. A-Weighted sum of sound energy across the range of human hearing. Humans do not hear well at very low or very high frequencies. Weighting adjusts for this.

dBT
Truncated decibel. A measure of sound energy in the range of frequencies where transportation noise is most often focused (20 - 1250 Hz). Transportation is often a major contributor of low frequency sound, but this range does not correspond to a specific vehicle or type of transportation.

Decibel
A logarithmic measure of acoustic or electrical signals. The formula for computing decibels is: $20*(\text{Log}_{10}(\text{sound level/reference sound level}))$. 0 dB represents the lowest sound level that can be perceived by a human with healthy hearing. Conversational speech is about 65 dB.

Frequency
The number of times per second that the sine wave of sound repeats itself. It can be expressed in cycles per second, or Hertz (Hz). Frequency equals Speed of Sound/ Wavelength.

Hearing Range (frequency)
By convention, an average, healthy, young person is said to hear frequencies from approximately 20 Hz to 20,000 Hz.

Hertz
A measure of frequency, or the number of pressure variations per second. A person with normal hearing can hear between 20 Hz and 20,000 Hz.

Human-Caused Sound
Any sound that is attributable to a human source.

L_{eq}
Energy Equivalent Sound Level. The level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period.

L_x
A metric used to describe acoustical data. It represents the level of sound exceeded x percent of the time during the given measurement period.

Masking
The process by which the threshold of audibility for a sound is raised by the presence of another sound.

Noise-Free Interval
The period of time between noise events (not silence).

Noise
Sound which is unwanted, either because of its effects on humans, its effect on fatigue or malfunction of physical equipment, or its interference with the perception or detection of other sounds (Source: McGraw Hill Dictionary of Scientific and Technical Terms).

Off-site Listening
The systematic identification of sound sources using digital recordings previously collected in the field.

1. Introduction

An important part of the National Park Service (NPS) mission is to preserve and/or restore the resources of the parks, including the natural and cultural soundscapes associated with units of the national park system. The collection of ambient sound level data provides valuable information about a park's acoustical conditions for use in developing acoustic resource management plans.

Ambient data are also required to establish a baseline from which noise impacts can be assessed. The National Parks Air Tour Management Act of 2000 provides for the regulation of commercial air tour operations over units of the national park system through air tour management plans (ATMPs). The objective of the ATMPs is to develop acceptable and effective measures to mitigate or prevent significant adverse impacts, if any, of commercial air tour operations upon the natural and cultural resources of and visitor experiences in national park units as well as tribal lands (those included in or abutting a national park).

The U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) is supporting the Federal Aviation Administration (FAA), Western-Pacific Region (AWP) and NPS, Natural Sounds and Night Skies Division (NSNSD) in the development of ATMPs.

Ambient data were collected in Petroglyph National Monument (PETR) by Volpe personnel during August to September of 2010 to represent the summer season and by NPS, NSNSD personnel during February to April of 2012 to represent the winter season. A map of the areas managed by PETR is shown in Figure 1. The purpose of this report is to provide a summary of the results of these measurements that will be used to represent PETR's summer and winter seasons, respectively. Measurements representing PETR's summer season were summarized previously in a separate document (National Park Service 2013a).

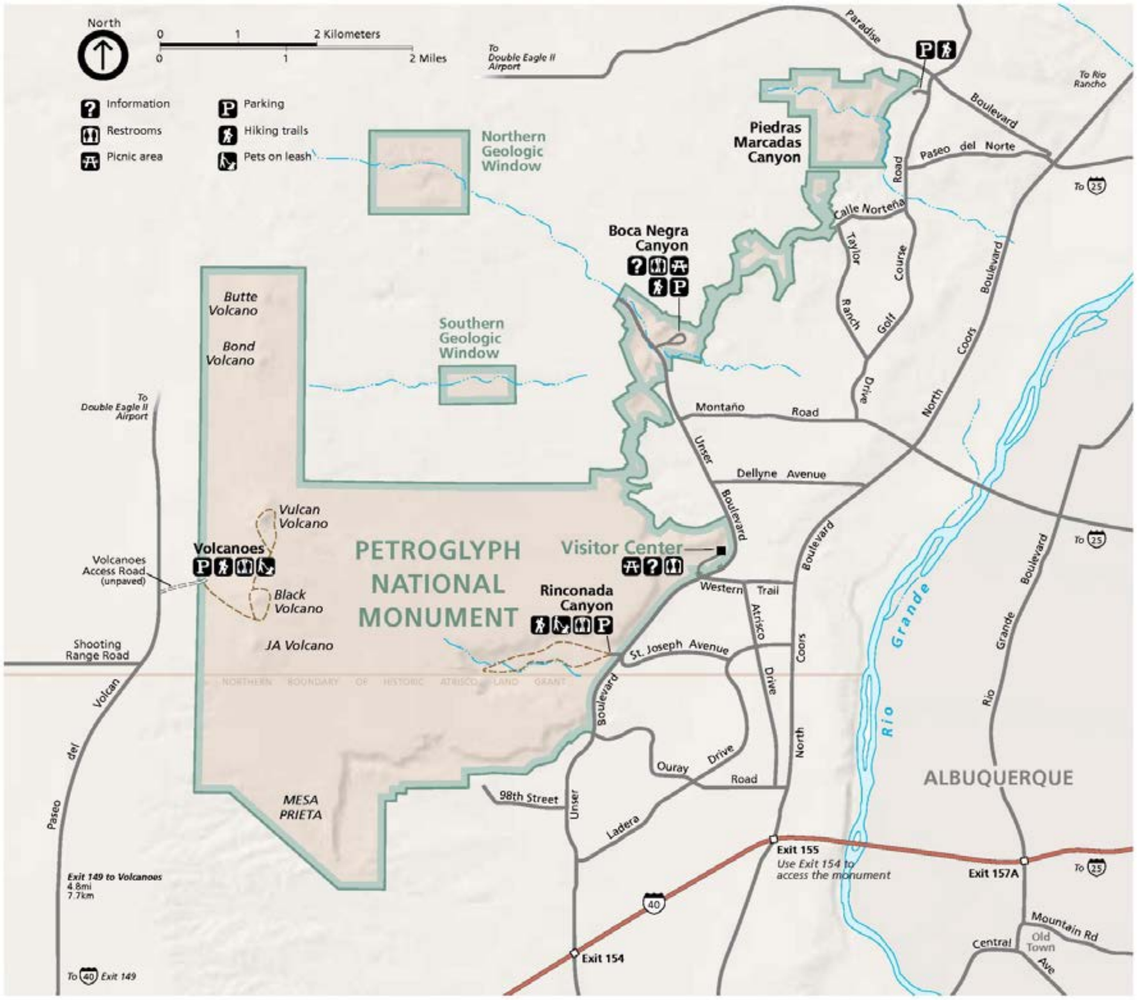

Figure 1. Map of area managed by Petroglyph National Monument (National Park Service 2014).

2. Study Area

Two acoustical monitoring systems were deployed during each season. These sites were selected based on discussion between Volpe, NSNSD, and PETR personnel and are shown in Table 4.

Table 5. Summary of measurement sites selected for Petroglyph.

Site ID	Site Name	# Days of Data	NLCD[2] Classification	Coordinates (latitude/longitude in decimal degrees)	Elevation (m)
Summer season (2010)					
PETR001	Rinconada	29 days	Scrub/Shrub	35.12819° 106.74941°	1,689 m (5,541 ft)
PETR002	Volcano Vista	30 days	Scrub/Shrub	35.15976° 106.76436°	1,742 m (5,716 ft)
Winter season (2012)					
PETR001	Rinconada	34 days	Scrub/Shrub	35.12814° 106.74934°	1,690 m (5,545 ft)
PETR002	Volcano Vista	34 days	Scrub/Shrub	35.15991° 106.76385°	1,738 m (5,702 ft)

[2] With the goal of potentially facilitating future data transferability between parks, all baseline acoustical data collected for the ATMP program 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. (Homer, et. al. 2004).

3. Methods

3.1 Automatic Monitoring

Larson Davis 831 sound level meters (SLM) were employed for continuous acoustical monitoring over both monitoring periods at PETR. The Larson Davis SLM is a hardware-based, real-time analyzer which constantly records one second sound pressure level (SPL) and one-third octave-band data, and exports these data to a portable storage device (thumb drive). These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards (American National Standards Institute 1990).

In addition to the Larson Davis SLM, each acoustical sampling station consisted of:

- Microphone with environmental shroud
- Preamplifier
- Multiple 12V NiMH rechargeable battery packs
- Anemometer
- MP3 recorder
- Meteorological data logger
- Photo voltaic panels

Each acoustical sampling station collected:

- Sound level data in the form of A-weighted decibel readings (dBA) every second
- Continuous digital audio recordings
- One-third octave-band data every second ranging from 12.5 Hz to 20,000 Hz
- Meteorological data

3.2 Source Identification/Observer Logging

In characterizing natural and non-natural acoustical 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 off-site 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. 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 are used for off-site audio playback to minimize limitations imposed by the office acoustical environment.

3.3 Calculation of Sound Level Descriptors

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

- L_{Aeq}: 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 along with its associated one-third 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 one-third 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 one-third octave band spectrum associated with a particular measurement sample, but a composite spectrum using the computed descriptor for each one-third octave-band.

3.4 Definitions of ambient

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 (Fleming, et. al., 1999), (Fleming, et. al., 1998), (Plotkin, 2002).

- *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 (fixed-wing aircraft and helicopters);
- *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);[3] and

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

- *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 and the four types of ambient characterizations above, twelve ambient descriptors could potentially be computed as shown in Table 5.

Table 6. 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. 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:

- L_{50}, Existing Ambient Without Source of Interest – Descriptor 5 from the table above; and
- L_{50}, Natural Ambient (L_{Nat}) – Descriptor 11 from the table above.

3.5 Calculation of Ambients

Using the data in the acoustical observer logs, different characterizations of ambient can be estimated from the sound level data. This method was developed through detailed data analyses conducted by the Volpe Center, working closely with the NPS, comparing several approaches of estimating of the Natural Ambient and is comprised of the following steps: (Rapoza, et. al., 2008)

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 acoustical state), and remove the loudest percentage (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, L_0 to L_{40} 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 mentioned earlier, 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 L_x approaches L_{50}; as it approaches 100 percent, the L_x approaches L_{100}. A concern with this approach is that sporadic, 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 Air Tours, and Existing Ambient Without All Aircraft) is a similar process.

4. Results

This section summarizes the results of the study. Included are an overall summary of the final ambient sound levels for each measurement site, time analysis, temporal trends, and the acoustical observer data logged at each measurement site.

4.1 Summary Results

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

- Figure 2 presents a plot of the overall daytime[4] L_{50} sound level computed for each site and both summer and winter seasons (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;[5]
- Table 6 presents a tabular summary of the daytime and nighttime and computed ambient;
- Table 7 and 8 contain a summary of overall ambient spectral data at each site;
- Figures 3 through 6 present the associated spectral data for the ambient maps.

---

[4] For most parks, the majority of air tour operations occur during the day, the NPS and FAA 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 are based on daytime ambient data. In general, daytime refers to the time period of 7:00 am to 7:00 pm unless otherwise specified by the NPS and FAA.

[5] 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.

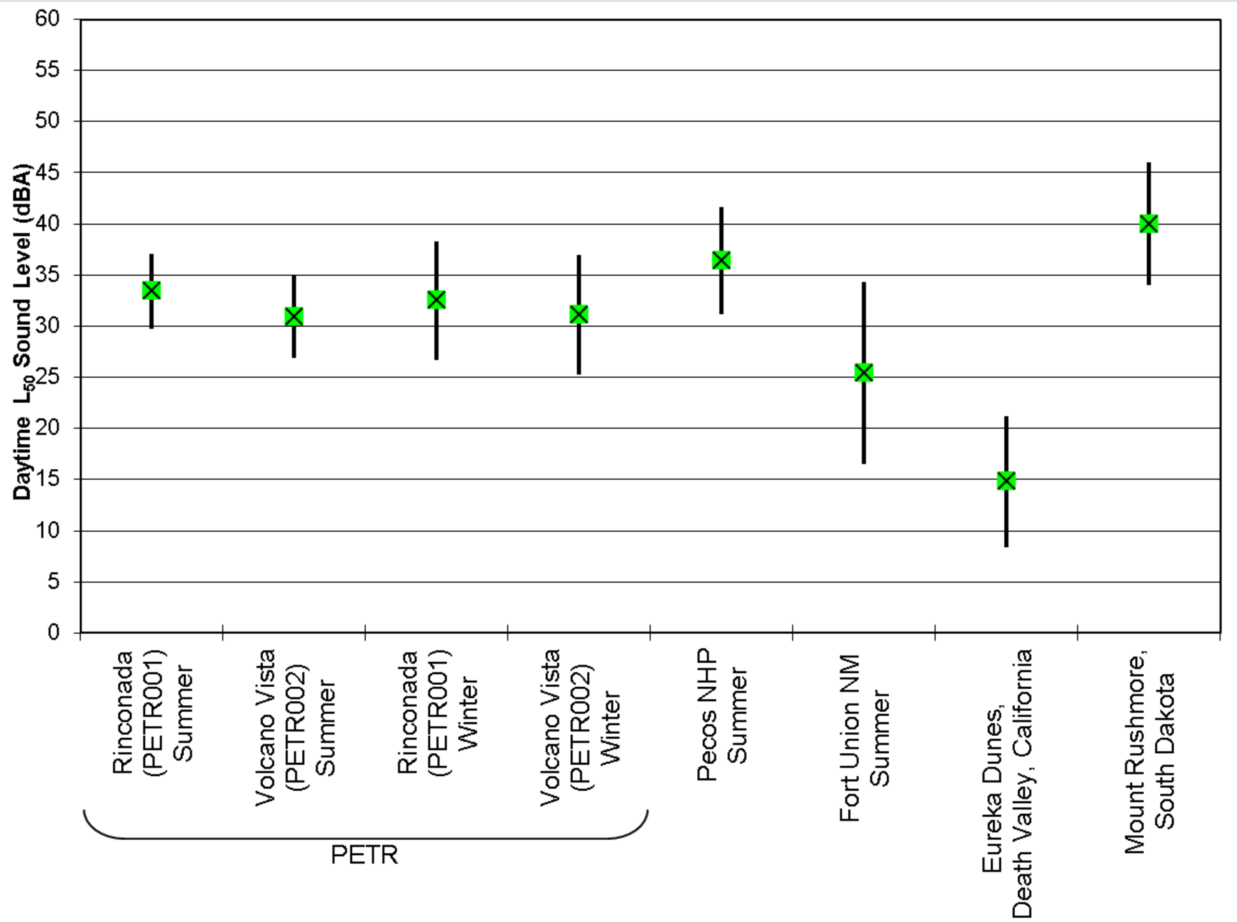

Figure 2. Comparison of overall <u>daytime</u> L_{50} sound levels.

Table 7. Summary of measured ambient sound level data. [6]

Site ID	Site Name	Total # Days	Existing Ambient: Daytime Data Only: 7 am to 7 pm			Existing Ambient: Nighttime Data Only: 7 pm to 7 am			Existing Ambient Without Air Tours (Daytime Data 7 am to 7 pm)	Existing Ambient Without All Aircraft (Daytime Data 7 am to 7 pm)	Natural Ambient (Daytime Data 7 am to 7 pm)
			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)
Summer season (2010)											
PETR001	Rinconada	29	42.3	33.4	27.0	49.8	35.6	30.1	34.0	31.0	30.8
PETR002	Volcano Vista	30	45.5	30.9	22.8	44.5	28.0	21.6	28.0	26.2	25.9
Winter season (2012)											
PETR001	Rinconada	34	41.2	31.1	26.2	36.2	29.2	21.6	29.4	28.3	27.8
PETR002	Volcano Vista	34	42.7	30.6	23.4	34.4	24.9	18.1	28.2	27.2	27.0

[6] 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 8. Summary of measured, daytime (7 am to 7 pm), ambient sound level spectral data.[7]

Frequency (Hz)	Existing Ambient Without Air Tours L_{50} (dB)				Natural Ambient L_{50} (dB)			
	Summer season (2010)		Winter season (2012)		Summer season (2010)		Winter season (2012)	
	PETR001	PETR002	PETR001	PETR002	PETR001	PETR002	PETR001	PETR002
12.5	45.6	49.3	49.8	52.2	41.0	45.3	46.4	49.1
16	43.0	46.9	47.1	48.3	39.2	43.4	44.9	46.5
20	42.1	43.7	46.3	47.2	38.5	41.4	43.5	44.8
25	40.0	41.2	44.8	43.8	37.0	38.6	42.2	42.0
31	39.0	40.3	43.9	42.3	36.9	38.3	40.6	41.1
40	39.2	38.6	41.8	40.7	37.3	36.9	39.2	39.5
50	38.8	37.7	39.9	39.2	37.5	35.9	38.0	37.9
63	39.2	36.9	39.4	38.1	38.1	35.8	37.7	36.8
80	39.7	36.5	39.1	37.2	38.2	35.3	37.0	35.8
100	36.8	34.0	36.4	34.2	35.7	32.8	34.5	33.1
125	35.9	31.5	35.4	33.2	34.4	30.4	33.7	31.9
160	33.3	29.1	32.0	31.3	31.7	27.6	30.2	30.2
200	31.5	26.3	29.2	28.9	29.2	24.6	27.8	27.8
250	29.4	24.1	27.0	26.6	27.1	22.6	25.4	25.2
315	25.4	21.5	23.6	22.4	23.1	19.8	22.0	20.8
400	21.7	18.8	20.8	18.4	19.2	16.9	19.1	16.8
500	19.5	16.2	18.3	15.3	17.4	14.2	17.4	14.2
630	17.3	14.4	14.9	12.0	15.7	13.0	13.7	11.1
800	15.3	13.0	11.0	8.3	14.2	11.6	9.6	7.6
1000	12.6	10.0	5.9	4.6	11.6	9.0	5.0	3.9
1250	8.6	5.9	1.3	1.9	7.4	5.0	0.7	1.6
1600	4.7	1.9	0.8	1.3	3.6	1.0	0.4	1.1
2000	2.7	-0.5	1.2	1.6	1.7	-1.6	1.0	1.5
2500	2.3	-2.7	2.0	2.2	1.3	-3.9	1.8	2.2
3150	1.3	-4.7	2.8	3.0	-0.5	-6.1	2.7	3.0
4000	2.9	-7.0	3.7	3.8	1.4	-8.4	3.6	3.7
5000	5.7	-8.3	4.5	4.4	4.1	-9.5	4.3	4.4
6300	7.7	-9.8	5.1	5.0	6.0	-11.2	5.0	4.9
8000	8.7	-10.3	5.8	5.4	7.1	-12.1	5.6	5.3
10000	10.4	-11.7	6.3	5.6	8.6	-13.3	6.1	5.6
12500	10.8	-13.4	5.7	5.5	9.3	-14.5	5.5	5.4
16000	10.0	-15.7	3.2	3.7	8.7	-17.0	2.9	3.7
20000	12.5	-14.7	0.8	0.7	11.3	-16.0	0.5	0.5

[7] As discussed in Section 3.5, 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.

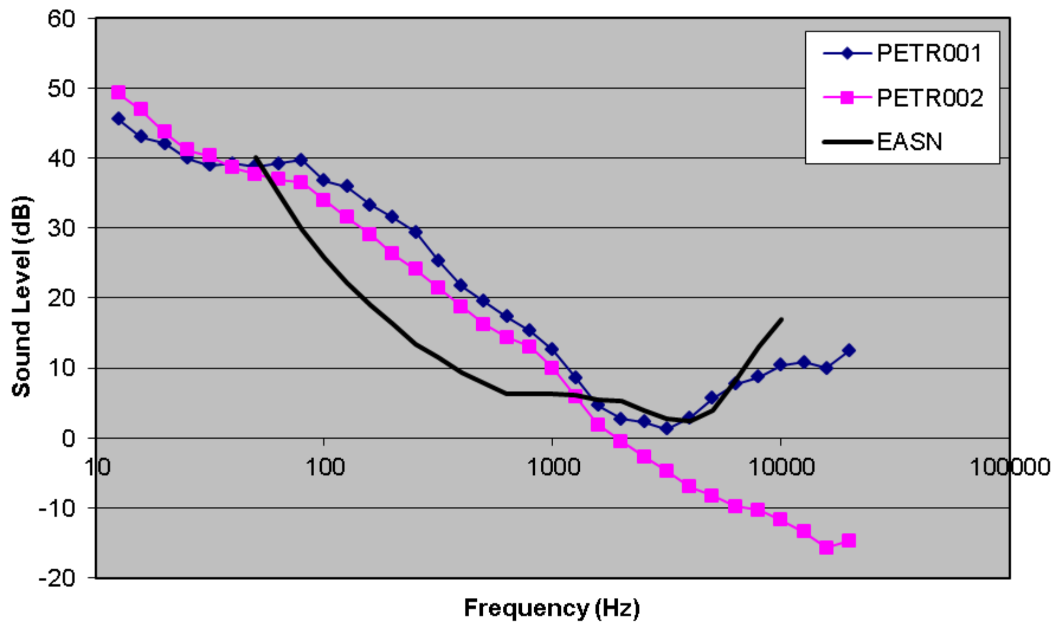

Figure 3. Spectral data for the Existing Ambient Without Air Tours (L_{50}), summer season (2010). [8]

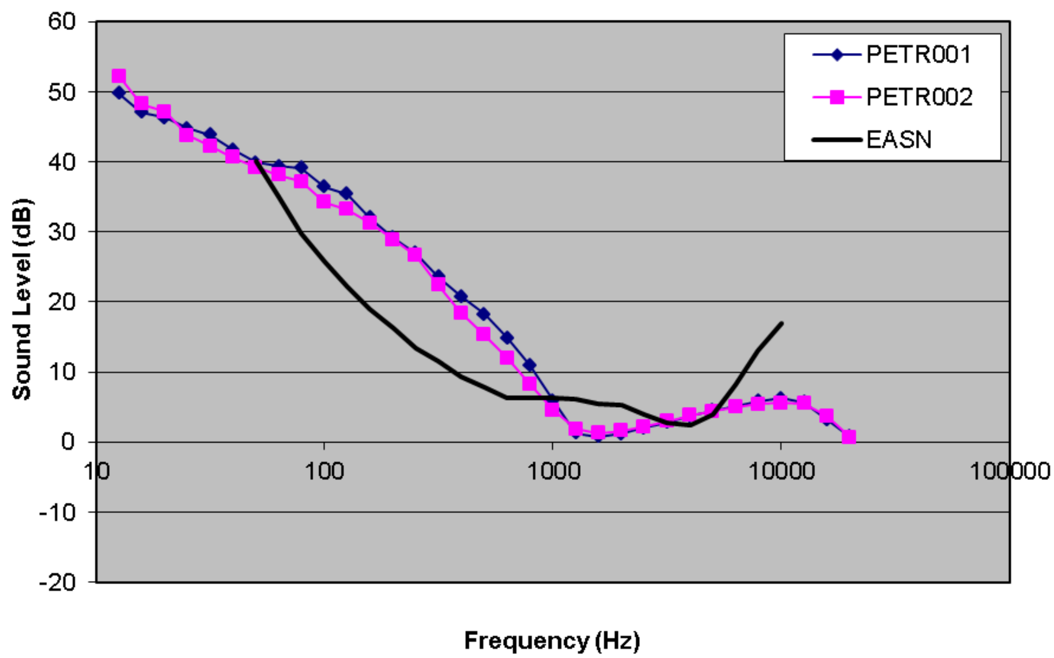

Figure 4. Spectral data for the Existing Ambient Without Air Tours (L_{50}), winter season (2012). [8]

---

[8] 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.

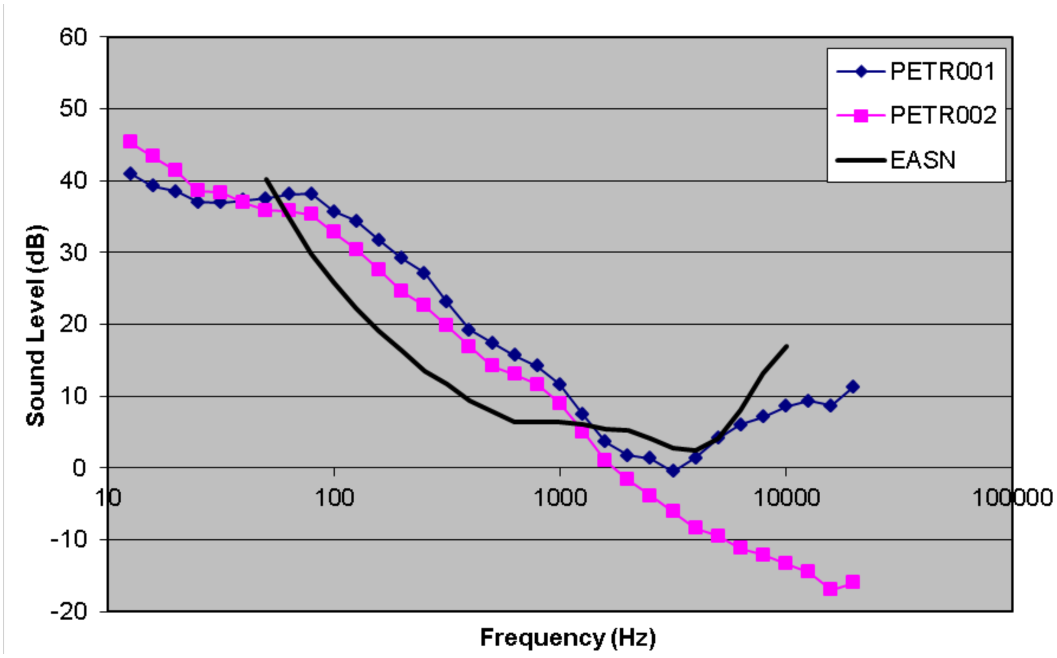

Figure 5. Spectral data for the Natural Ambient (L_{50}), summer season (2010). [9]

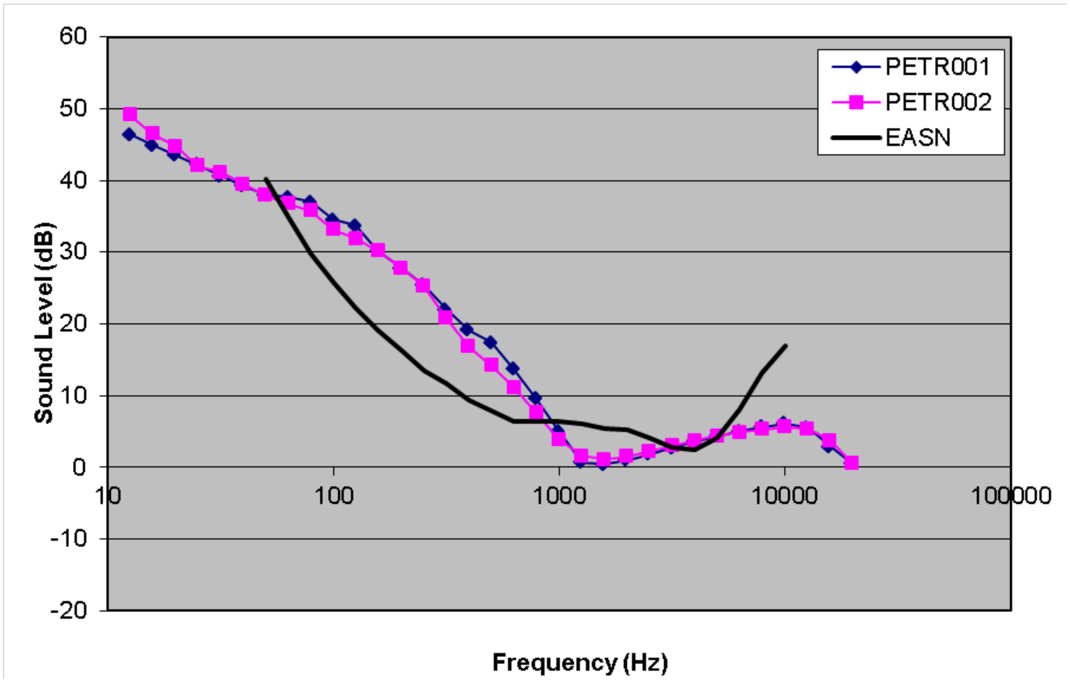

Figure 6. Spectral data for the Natural Ambient (L_{50}), winter season (2012). [9]

---

[9] 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.

4.2 Time Above Results

The Time Above metric indicates the amount of time that the sound level exceeds specified decibel values. In determining the current conditions of an acoustical environment, the NPS examines how often sound pressure levels exceed certain decibel values that relate to human health and speech. The NPS uses these values for making comparisons, but they should not be construed as thresholds of impact. Table 8 and Table 9 report the percent of time that measured levels were above four sound level values at each of the PETR measurement locations for each season in dBA and dBT. The first value, 35 dBA, addresses the health effects of sleep interruption (Haralabidis, et. al., 2008). The second value is based on the World Health Organization's recommendation that noise levels inside bedrooms remain below 45 dBA (Berglund, et. al., 1999). The third value, 52 dBA, is based on the Environmental Protection Agency's speech interference threshold for speaking in a raised voice to an audience at 10 meters (Environmental Protection Agency, 1974). This value addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m (3 ft.). Hikers and visitors in the park would likely be conducting such conversations.

Table 9. Percent Time Above Metrics (dBA).

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Summer season (2010)									
PETR001	Rinconada	47.7	6.8	1.2	0.2	56.1	2.3	0.5	0.1
PETR002	Volcano Vista	30.8	5.9	2.1	0.3	11.4	1.4	0.5	0.1
Winter season (2012)									
PETR001	Rinconada	27.2	2.2	0.5	0.1	10.6	0.5	0.1	0.0
PETR002	Volcano Vista	20.5	3.2	0.8	0.1	3.2	0.7	0.2	0.0

Table 10. Percent Time Above Metrics (truncated spectra – dBT).

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Summer season (2010)									
PETR001	Rinconada	46.7	5.9	1.2	0.2	40.5	2.0	0.4	0.1
PETR002	Volcano Vista	30.4	5.8	1.9	0.3	10.4	1.3	0.5	0.1
Winter season (2012)									
PETR001	Rinconada	26.9	2.1	0.5	0.1	10.4	0.4	0.1	0.0
PETR002	Volcano Vista	19.9	3.0	0.8	0.1	2.9	0.5	0.2	0.0

4.3 Temporal Trends

This section discusses the diurnal and daily trends of the data. Diurnal trends are shown on an hourly basis in Figure 7. 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 discernible pattern, e.g., somewhat constant across all hours, typically indicates a constant sound source. Examples of constant sound sources include nearby brook or river. This data is also useful in visually identifying potential anomalies in the data.

Daily trends are shown on a 24-hour basis. Figure 8 and Figure 9 present the daily median Existing Ambient (i.e., the L_{50} with all sounds included). 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.

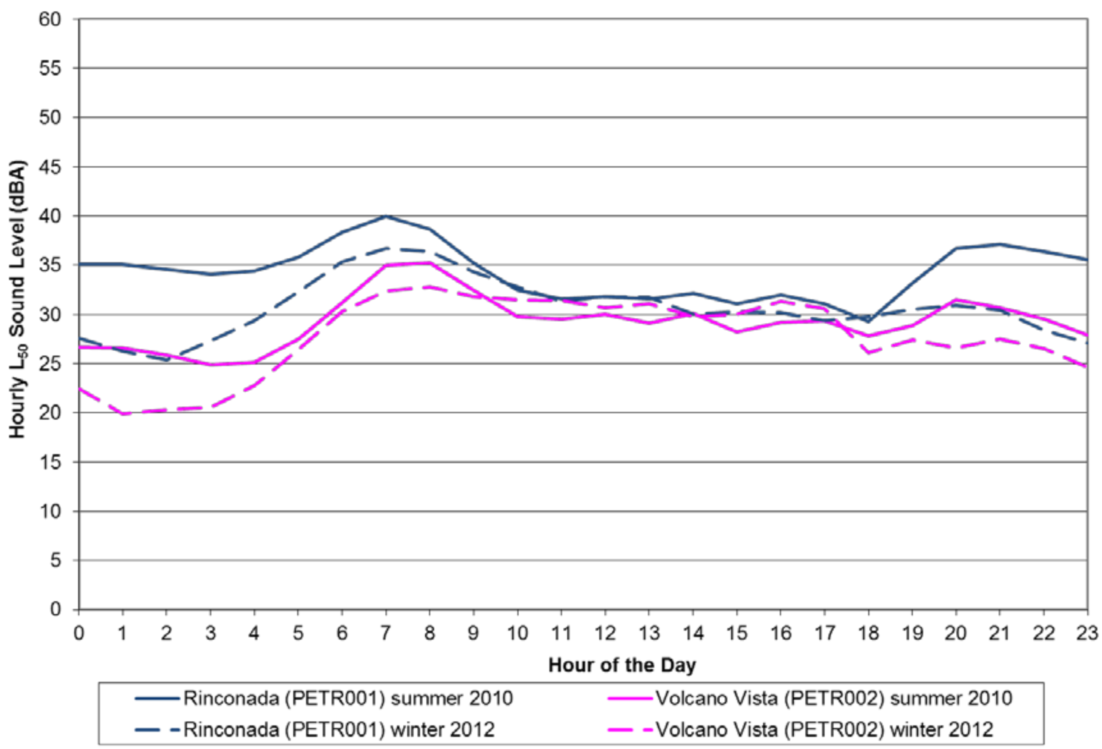

Figure 7. Comparison of hourly L_{50} sound levels for sites at PETR.

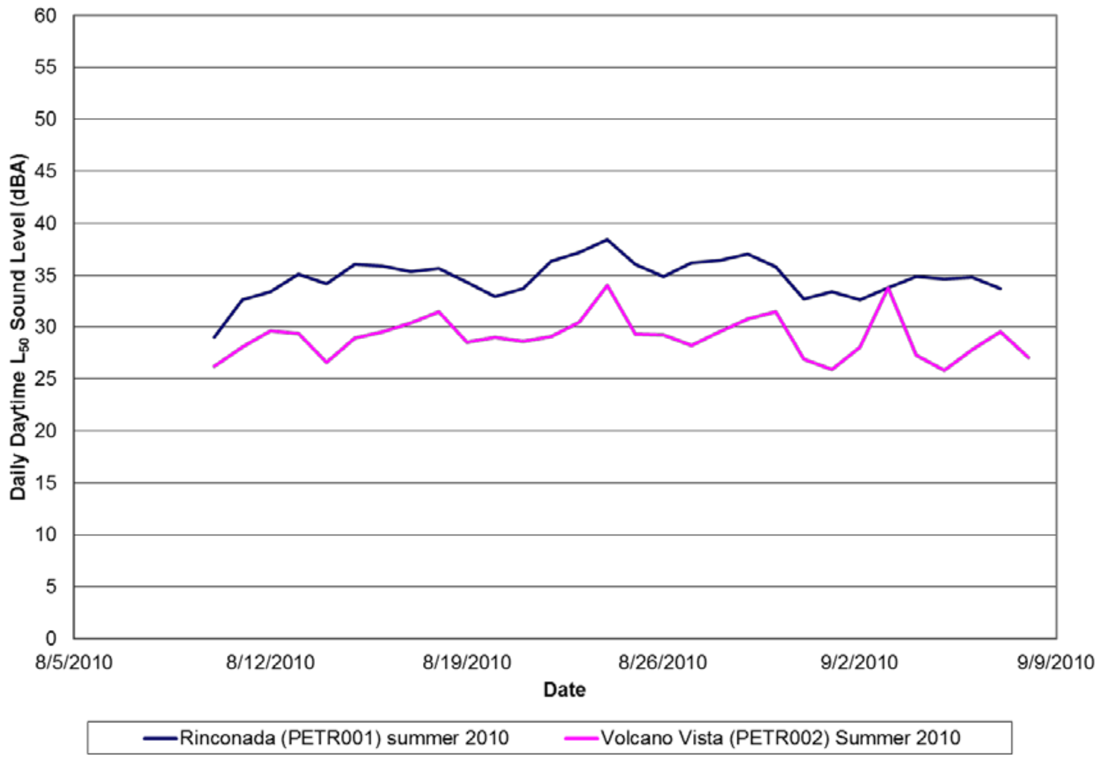

Figure 8. Comparison of daily L_{50} sound levels for sites at PETR, summer season (2010).

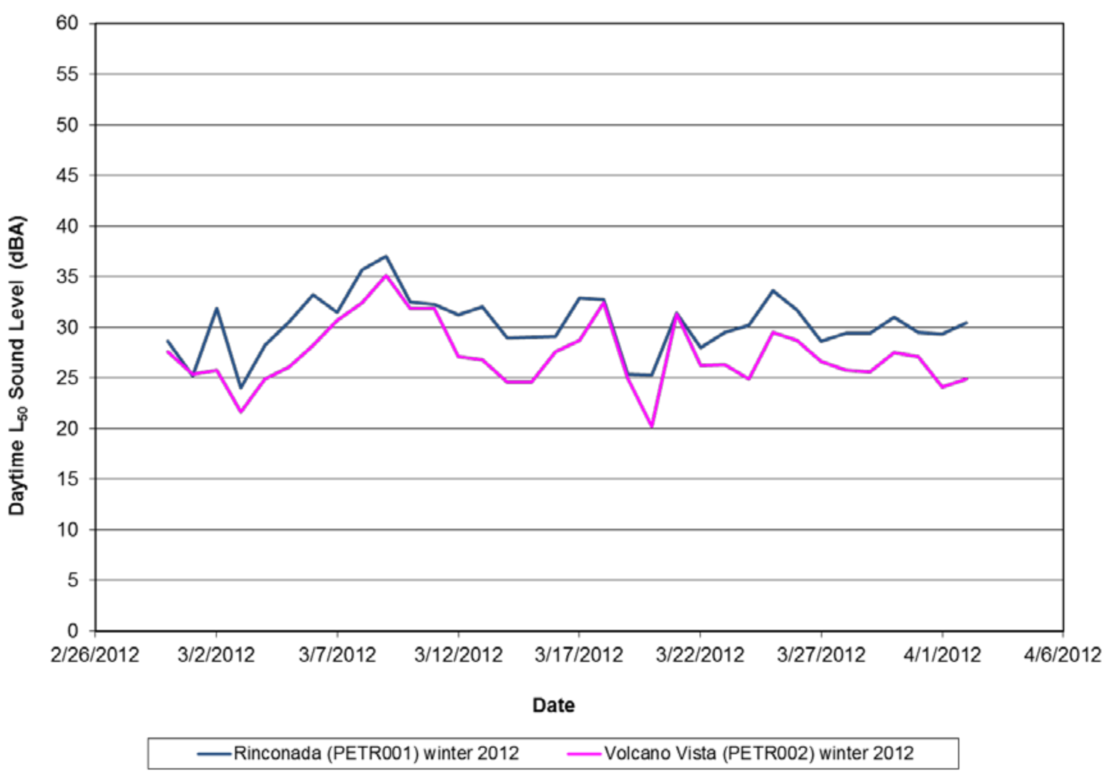

Figure 9. Comparison of daily L_{50} sound levels for sites at PETR, winter season (2012).

4.4 Acoustical Observer Log Results

Table 10 summarizes the daytime off-site listening results and provides an indication of the amount of time that certain sources are present at each site. The *in situ* logging occurs on-site; an observer logs the source, time and duration of sounds heard at the site. Typically a limited amount of *in-situ* logging is available due to logistics of the measurement and the days that the acoustical team is in the area; however, no *in-situ* logging was performed at this park. Off-site listening results are from a review of the audio files that were collected at each site. Continuous audio files were collected for the entire measurement and this allows a greater ability to listen and log sound sources for several days and any time period. Table 11 summarizes the nighttime off-site listening results for the winter measurements (nighttime off-site listening was not performed for the summer season data).

Table 11. Summary of daytime acoustical observer log data (off-site listening).

Site ID	Site Name	% Time Audible			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
Summer season (2010)					
PETR001	Rinconada	15.2	38.6	1.6	44.6
PETR002	Volcano Vista	30.5	17.9	4.1	47.4
Winter season (2012)					
PETR001	Rinconada	27.1	19.6	6.5	46.8
PETR002	Volcano Vista	28.5	11.8	1.6	58.1

Table 12. Summary of nighttime acoustical observer log data (off-site listening).

Site ID	Site Name	% Time Audible			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
Winter season (2012)					
PETR001	Rinconada	3.7	8.6	40.1	47.6
PETR002	Volcano Vista	3.6	4.8	13.6	78.0

5. Ambient Mapping

Using the ambient data measured at each site, a comprehensive grid of ambient sound levels throughout the park (i.e., an ambient "map") is developed. 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. For ATMPs, the FAA's Integrated Noise Model (INM)[10] will be used to model air tour aircraft activities and compute various noise-related descriptors (e.g., percentage of time aircraft sounds are above the ambient) and generate the sound-level contours that will be used in the assessment of potential noise impacts due to air tour 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)[11] coordinates to set the initial grid area boundary.[12]
    - 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 Petroglyph, a grid spacing of 200 ft. (61 m) was used.
    - Define the acoustical 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), computed in Section 3.5, to each to each grid point within an acoustical zone.

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

---

[10] For ATMPs, the FAA and NPS have agreed to use the INM. The 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.

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

[12] 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.

- Define the location of localized noise sources, primarily vehicles on roads, but may also include brooks, 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, un-weighted spectrum) for each roadway to each grid point using the drop-off rates determined by computer modeling discussed in Section 5.2.
- 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 5.3.

5.1 Assignment of Measured Ambient Data to Acoustical Zones

Because it is neither economically nor expeditiously feasible to manually collect noise data under all possible conditions throughout an entire park, areas of like vegetation, topography, elevation, and climate were grouped into "acoustical zones," with the assumption that similar wildlife, physical processes, and other sources of natural sounds occur in similar areas with similar attributes. 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 by assigning measured data stratified to these acoustical zones. The following considerations are used in the determination of acoustical zones:

- Vegetation/Land Cover: 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.
- Climate Conditions: Climate conditions (temperature, humidity, precipitation, wind speed, wind direction, etc.) can also affect ambient sound levels. 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.
- Park Resources/Management Zones: 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.

Based on the above considerations, Figure 10 presents the acoustical zones that were developed and the location of the measurement sites for PETR. The ATMP Act applies to all commercial air tour operations within the ½-mile outside the boundary of a national park. Table 12 presents which measurement site data were applied to each acoustical zone based on best available data and geographical proximity.

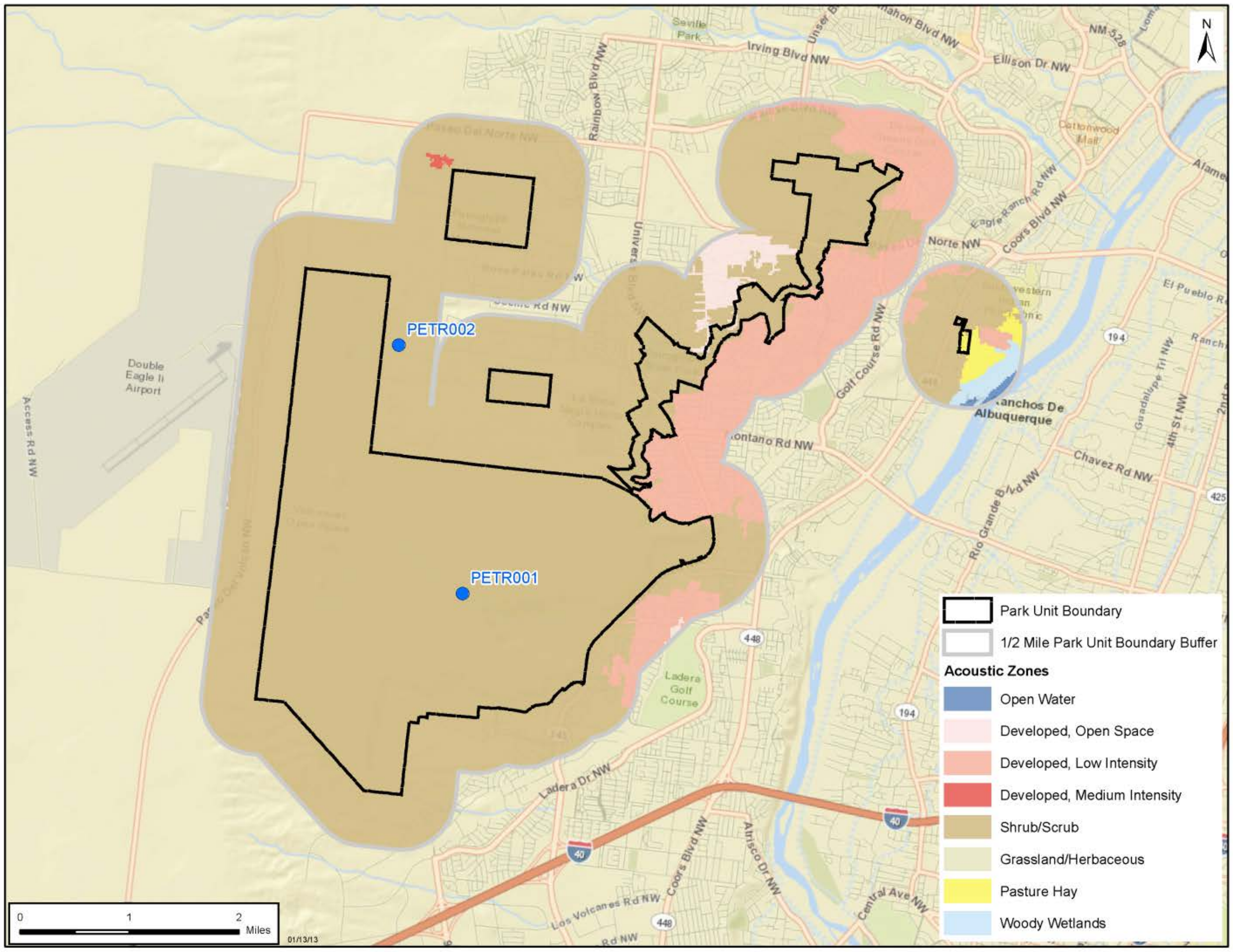

Figure 10. Acoustical zones and measurement sites for PETR.

Table 13. Assignment of ambient data to acoustical zones.

Acoustic Zone	Site ID	Site Name
Open Water	PETR001	Rinconada
Developed, Open Space	PETR002	Volcano Vista
Developed, Low Intensity	PETR001	Rinconada
Developed, Medium Intensity	PETR002	Volcano Vista
Shrub/Scrub	PETR001, PETR002	Rinconada, Volcano Vista
Grassland/Herbaceous	PETR001	Rinconada
Pasture/Hay	PETR001	Rinconada
Woody Wetlands	PETR001	Rinconada

5.2 Ambient Mapping of Localized Sound Sources

The contributing effect of localized noise sources, primarily vehicles on roads, but may also include brooks, 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) 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 (Lee, 2004). 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 14. 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 Petroglyph, 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 New Mexico Department of Transportation (NMDOT) (New Mexico Department of Transportation 2013). Where data are available for multiple years, the year corresponding to the study year was chosen. The traffic volume for an average day during the actual summer month (July) and peak winter month (November) was obtained by using monthly visitation data obtained from the NPS Public Use Statistics Office website (National Park Service 2013b) to apportion the NMDOT annual traffic. Hourly volume is estimated by dividing the month's volume by the number of days in the month (31 and 30 respectively) and by 12 hours per day, which assumes the majority of traffic for PETR occurs between 7:00 am and 7:00 pm – 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 (National Park Service 2013); and (2) observations by field personnel during pervious 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. In some specific cases, notations from the 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 Petroglyph.

Table 15. Estimated hourly roadway traffic volume and speed.

Roadway			Estimated hourly volume									
#	Name	Average Speed (mph)	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles
			Summer season (2010)					Winter season (2012)				
1	I40 (West of Paseo Del Volcan NW)	75	2,378	112	65	8	47	1,640	77	45	5	32
2	I40 (East of Paseo Del Volcan & West of Unser Blvd)	75	3,509	165	96	12	69	2,800	132	77	9	55
3	I40 (East of Unser Blvd & West of North Coors Blvd)	75	5,208	246	143	17	103	4,950	234	136	16	98
4	I40 (East of North Coors Blvd & West of Rio Grande Blvd)	75	12,407	585	340	41	245	8,406	397	231	28	166
5	I40 (East of Rio Grande Blvd)	75	17,996	849	493	59	355	9,298	439	255	31	184
6	Paseo del Volcan (North of I40) only a portion of it	55	712	33	19	2	23	126	6	3	0	4
7	Unser Blvd (South of I40)	45	880	41	24	2	28	927	43	25	2	30
8	Unser Blvd (North of I40 to Western Trail)	45	1,213	56	32	3	39	1,156	53	31	3	37
9	Unser Blvd (North of Western Trail)	45	1,513	70	40	4	49	969	45	26	2	31
10	Mountain Rd NW	55	797	37	21	2	26	325	15	9	1	11
11	Central Ave NW (West of 345)	55	680	32	18	2	22	903	42	24	2	29
12	Central Ave NW	55	2,156	100	58	5	70	1,577	73	42	4	51
13	Ladera Drive (Unser Blvd to Ouray Dr)	55	506	23	14	1	16	391	18	11	1	13
14	Ladera Drive (Ouray Dr to N. Coors Blvd)	55	1,089	50	29	3	35	469	22	13	1	15
15	Ouray Drive	55	986	46	26	2	32	337	16	9	1	11
16	Western Trail	55	705	33	19	2	23	373	17	10	1	12
17	North Coors Blvd (South of I40)	55	3,896	180	104	9	126	2,480	115	66	6	80
18	North Coors Blvd (North of I40 and South of Montano Rd)	55	4,727	219	126	11	153	3,376	156	90	8	109
19	North Coors Blvd (North of Montano Rd and South of Paradise Blvd)	55	3,844	178	103	9	124	2,540	117	68	6	82
20	North Coors Blvd (north of Paradise Blvd)	55	5,133	237	137	12	166	3,521	163	94	8	114
21	Atrisco Dr NW	55	668	31	18	2	22	584	27	16	1	19

Roadway			Estimated hourly volume									
#	Name	Average Speed (mph)	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles
			Summer season (2010)					Winter season (2012)				
22	Rio Grande Blvd (North of I40 and South of Montano Rd)	55	1,142	53	31	3	37	813	38	22	2	26
23	Rio Grande Blvd (North of Montano Rd)	55	517	24	14	1	17	385	18	10	1	12
24	Montano Rd (West of Rio Grande Blvd)	55	2,469	114	66	6	80	1,432	66	38	3	46
25	Montano Rd (East of Rio Grande Blvd)	55	2,314	107	62	6	75	1,661	77	44	4	54
26	Taylor Ranch Dr. (North of Golf Course Rd)	55	333	15	9	1	11	355	16	10	1	12
27	Calle Nortena NW	55	710	33	19	2	23	469	22	13	1	15
28	Paseo Del Norte Blvd (West of North Coors Blvd)	55	2,367	109	63	6	77	1,607	74	43	4	52
29	Paseo Del Norte Blvd (East of North Coors Blvd)	55	6,945	321	186	17	224	4,761	220	127	11	154
30	Golf Course Road	55	1,461	68	39	4	47	1,083	50	29	3	35
31	Paradise Blvd (West of Golf Course Rd)	55	2,492	115	67	6	81	981	45	26	2	32
32	Paseo del Volcan (South of I40)	45	201	9	5	1	7	247	11	7	1	8
33	9th St NW/Nolasco Rd NW (South of I40)	45	3,159	146	85	8	102	1,866	86	50	4	60
34	9th St NW/Nolasco Rd NW (North of I40)	45	1,028	48	28	2	33	415	19	11	1	13
35	Rainbow Blvd NW	40	276	13	7	1	9	367	17	10	1	12
36	Universe Blvd NW (North of Paseo Del Norte NW)	35	292	14	8	1	9	788	36	21	2	26
37	Irving Blvd NW (West of Unser Blvd)	35	1,383	64	37	3	45	457	21	12	1	15
38	Irving Blvd NW (East of Unser Blvd & West of Golf Course Rd)	35	952	44	25	2	31	578	27	15	1	19
39	Irving Blvd NW (East of Golf Course Rd)	35	784	36	21	2	25	915	42	25	2	30
40	Unser Blvd (North of Paradise Rd)	40	462	21	12	1	15	1,077	50	29	3	35
41	McMahon Blvd NW	45	2,492	115	67	6	81	1,577	73	42	4	51

Roadway			Estimated hourly volume									
#	Name	Average Speed (mph)	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles
			Summer season (2010)					Winter season (2012)				
42	Paradise Blvd (East of Golf Course Rd)	55	1,634	76	44	4	53	1,113	52	30	3	36
43	Golf Course Road (North of Paradise Blvd)	40	1,797	83	48	4	58	1,258	58	34	3	41
44	Ellison Dr NW	40	610	28	16	1	20	1,475	68	39	4	48
45	Corrales Rd	45	1,259	58	34	3	41	710	33	19	2	23
46	Alameda Blvd (West of 2nd St)	55	3,783	175	101	9	122	2,955	137	79	7	96
47	Alameda Blvd (East of 2nd St)	45	2,584	120	69	6	84	1,854	86	50	4	60
48	4th St (North of Alameda Blvd)	35	451	21	12	1	15	397	18	11	1	13
49	4th St (North of Paseo Del Norte & South of Alameda)	35	837	39	22	2	27	469	22	13	1	15
50	4th St (North of Osuna Rd & South of Paeo Del Norte)	35	1,678	78	45	4	54	1,005	47	27	2	33
51	4th St (North of Montano Rd & South of Osuna Rd)	35	1,888	87	51	5	61	1,156	53	31	3	37
52	4th St (North of I40 and South of Montano Rd)	35	730	34	20	2	24	1,360	63	36	3	44
53	2nd St NW (North of I40 and South of Montano Rd)	35	1,034	48	28	3	33	1,144	53	31	3	37
54	2nd St NW (North of Montano Rd and South of Osuna Rd)	45	1,499	69	40	4	48	1,324	61	35	3	43
55	2nd St NW (North of Osuna and South of Paseo Del Norte)	45	2,489	115	67	6	80	1,607	74	43	4	52
56	2nd St NW (North of Paseo Del Norte and South of Alameda Blvd)	45	1,423	66	38	3	46	734	34	20	2	24
57	2nd St NW (North of Alameda Blvd and South of 4th St)	45	426	20	11	1	14	433	20	12	1	14
58	Paseo Del Norte (East of 2nd St NW)	45	5,877	272	157	14	190	4,111	190	110	10	133
59	Jefferson St	40	1,288	60	34	3	42	1,318	61	35	3	43
60	Osuna Rd	45	276	13	7	1	9	650	30	17	2	21
61	Griegos Rd NW	35	967	45	26	2	31	788	36	21	2	26
62	12th St NW	35	504	23	14	1	16	698	32	19	2	23

Roadway			Estimated hourly volume									
#	Name	Average Speed (mph)	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles
			Summer season (2010)					Winter season (2012)				
63	Artrisco Dr (South of I40)	35	770	36	21	2	25	650	30	17	2	21
64	Bridge Blvd	40	392	18	11	1	13	421	20	11	1	14
65	Sage Rd	35	733	34	20	2	24	463	21	12	1	15
66	Coors Blvd (South of Central Ave)	45	2,487	115	67	6	80	1,517	70	41	4	49
67	Old Coors Dr SW	35	1,402	65	38	3	45	861	40	23	2	28
68	Paseo Del Volcan NW (Past Airport to Rainbow Blvd)	50	76	4	2	0	3	108	5	3	0	4
69	Paseo Del Norte Blvd (from Universe Blvd to Golf Course Rd)	50	125	6	3	0	4	626	29	17	2	20
70	Southern Blvd SE (West of Unser)	45	3,005	139	80	7	97	1,198	55	32	3	39
71	Southern Blvd SE (East of Unser & West of Rio Rancho Blvd)	45	376	17	10	1	12	1,101	51	29	3	36
72	Southern Blvd SE (East of Rio Rancho Blvd SE)	45	36	2	1	0	1	355	16	10	1	12
73	High Resort Blvd	40	657	30	18	2	21	662	31	18	2	21
74	Golf Course Blvd (South of Southern Blvd & North of McMahon Blvd)	40	1,253	58	34	3	41	1,150	53	31	3	37
75	Indian School Rd	35	591	27	16	1	19	626	29	17	2	20
76	Menaul Blvd NW	35	1,416	65	38	3	46	1,288	60	34	3	42
77	Odelia Rd NE	35	340	16	9	1	11	439	20	12	1	14
78	4th St (South of I40)	35	518	24	14	1	17	614	28	16	2	20
79	Tingley Dr. SW (North of Lead Ave)	25	585	27	16	1	19	494	23	13	1	16
80	Tingley Dr. SW (South of Lead Ave)	25	161	7	4	0	5	181	8	5	0	6
81	Atrisco Dr SW	30	459	21	12	1	15	644	30	17	2	21
82	Golf Blvd SW	25	217	10	6	1	7	445	21	12	1	14
83	I25 (South of I40)	55	17,470	824	479	58	345	9,766	461	268	32	193
84	I25 (North of I40)	55	15,024	708	412	49	297	10,027	473	275	33	198

5.3 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 11 through Figure 14 present the ambient maps for the summer and winter seasons.

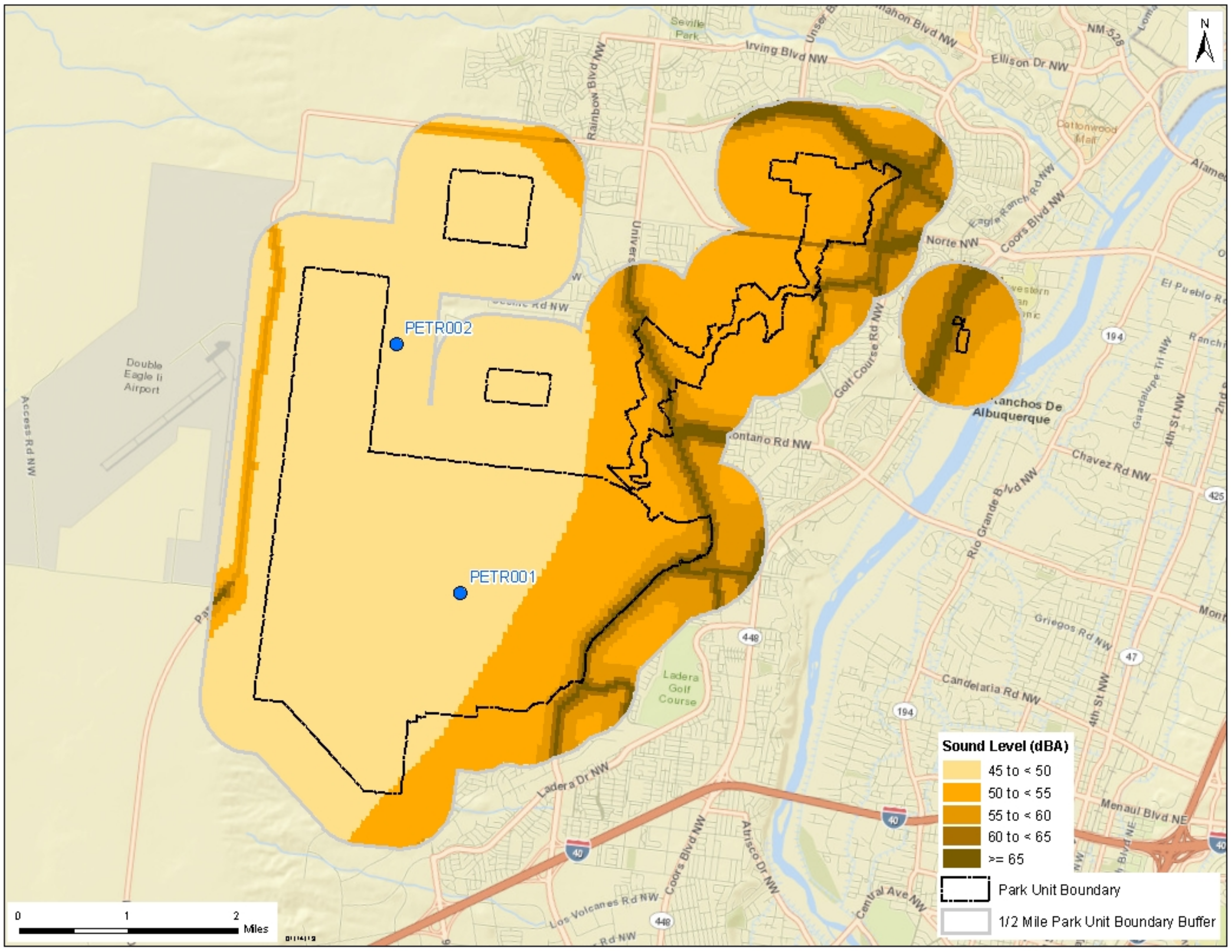

Figure 11. Baseline ambient map; Existing Ambient Without Air Tours (L_{50}), summer season (2010).

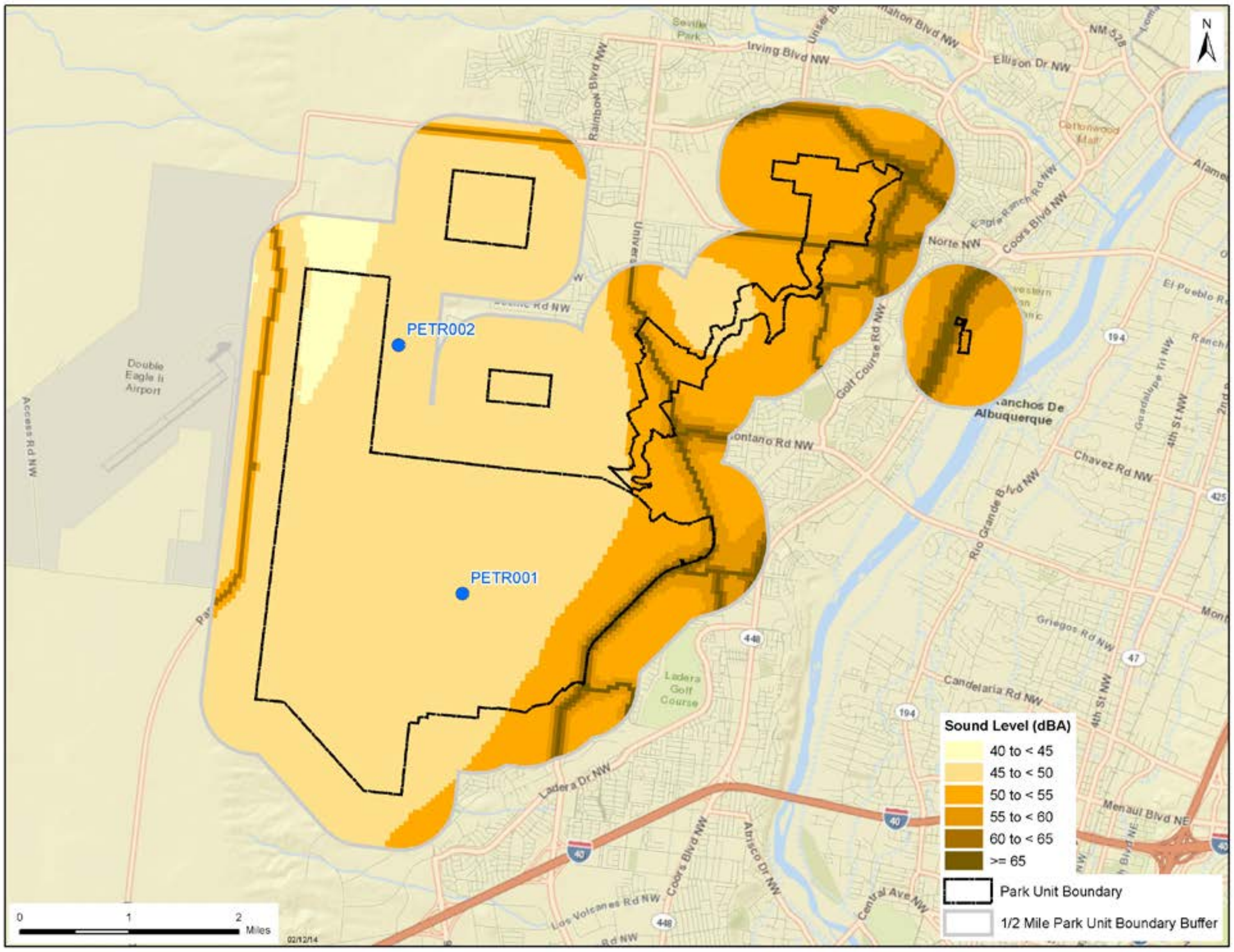

Figure 12. Baseline ambient map; Existing Ambient Without Air Tours (L_{50}), winter season (2012).

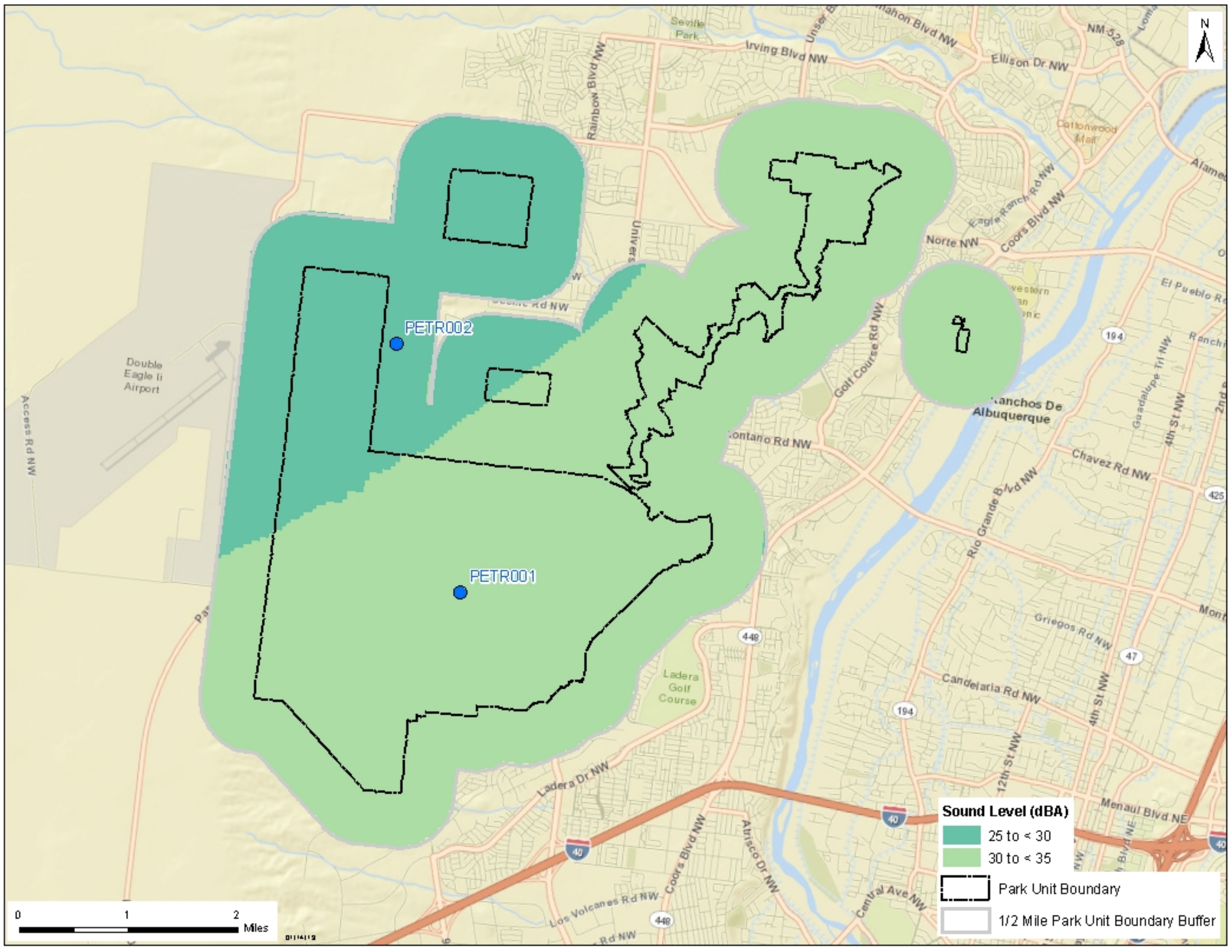

Figure 13. Baseline ambient map; Natural Ambient (L_{50}), summer season (2010).

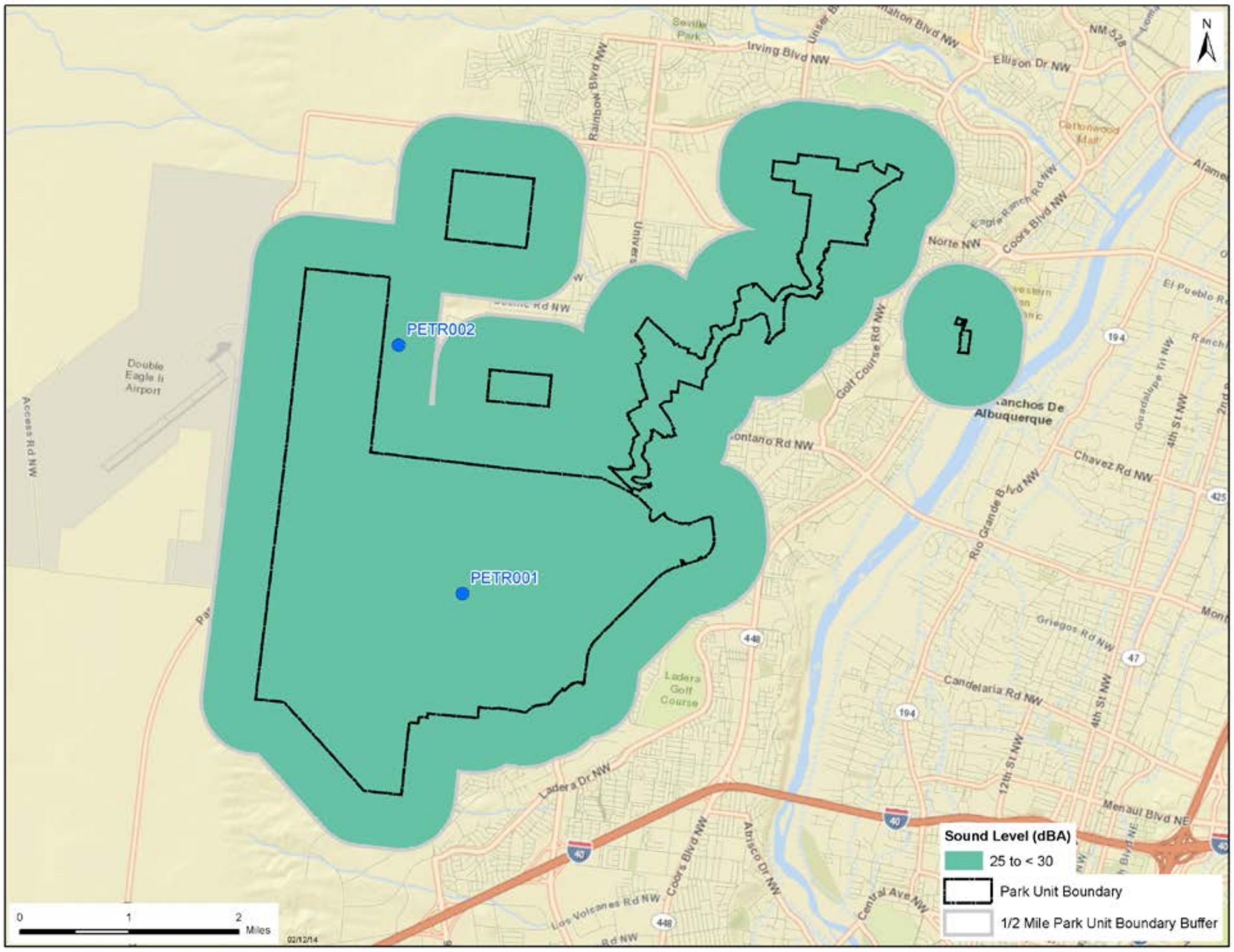

Figure 14. Baseline ambient map; Natural Ambient (L_{50}), winter season (2012).

6. Data for Individual Sites

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

- Figure 15, Figure 16, Figure 27, Figure 28: A photograph of the measurement site and a brief discussion of preliminary observations;
- Figure 17, Figure 18, Figure 29, Figure 30: A pie chart presenting a comparison of types of sound sources that were audible during observer logging;
- Figure 19, Figure 20, Figure 31, Figure 32: 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;
- Figure 21, Figure 22, Figure 33, Figure 34: 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;
- Figure 23, Figure 24, Figure 35, Figure 36: 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; and
- Figure 25, Figure 26, Figure 37, Figure 38: A graphic presenting the dB levels for each of 33 one-third octave-band frequencies over the day and night periods using three hourly A-weighted metrics (L_{10}, L_{50}, and L_{90}). The L_{10} exceedance level represents the value exceeded 10 percent of the time; 90 percent of the measurement values are less than the L_{10}. Refer to Terminology for definitions of L_{50} and L_{90}. The grayed area represents sound levels outside of the typical range of human hearing.

6.1 Site PETR001 – Rinconada

Figure 15. Photograph of Site PETR001, summer season (2010).

Figure 16. Photograph of Site PETR001, winter season (2012).

The PETR001 Rinconada site was located in the backcountry of Petroglyph National Monument. The measurement system collected data from February 29, 2012 to April 2, 2012 to represent the winter season and from August 10, 2010 to September 7, 2010 for the summer season. PETR001 was located on a flat, exposed grassy hillside in the proximity of a large wash out area (natural formation). This site is within two miles of subdivisions that lie on the outskirts of Albuquerque, New Mexico and is subject to commercial and general aviation aircraft activity from nearby airports. The vegetation near the measurement system consisted of desert with sparse vegetation at an altitude of 1,690 meters above sea level. Daytime sources of sound included vehicle sounds, birds, insects, aircraft, and wind-related sounds.

Natural sounds (wind, water, birds, and insects) were audible for 45% of daytime hours during the summer season and 47% of daytime hours during the winter season. Aircraft sounds were audible 54% of the daytime hours in the summer and 47% during the winter. Propeller aircraft audibility in winter was approximately doubled compared with the summer season (24% versus 11%). The consistency of sound levels and audibility from season to season may be due to the proximity to the urban area of Albuquerque. The majority of audible human sounds during the nighttime period of the winter season were due to automobile traffic.

The daily and hourly L_{50} sound levels were generally between 30 dBA and 40 dBA for both seasons. The overall daytime L_{50} was slightly higher in summer than in winter (33.4 dBA versus 32.5 dBA) but the night time L_{50} levels were much louder (35.6 dBA versus 29.2 dBA) in the summer season due to insect activity. A particularly loud day in the summer season occurred on August 23, 2010 and was due to a heavy storm that included winds, rain and thunder.

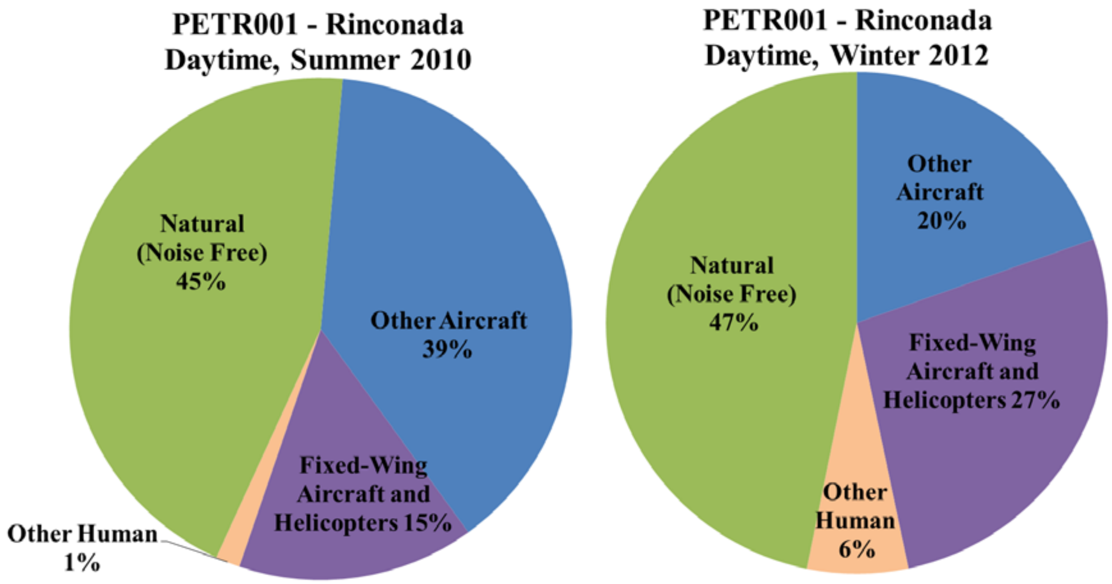

Figure 17. Distribution of daytime sound sources audible (off-site listening) for Site PETR001, summer season (2010) (left) and winter season (2012) (right).

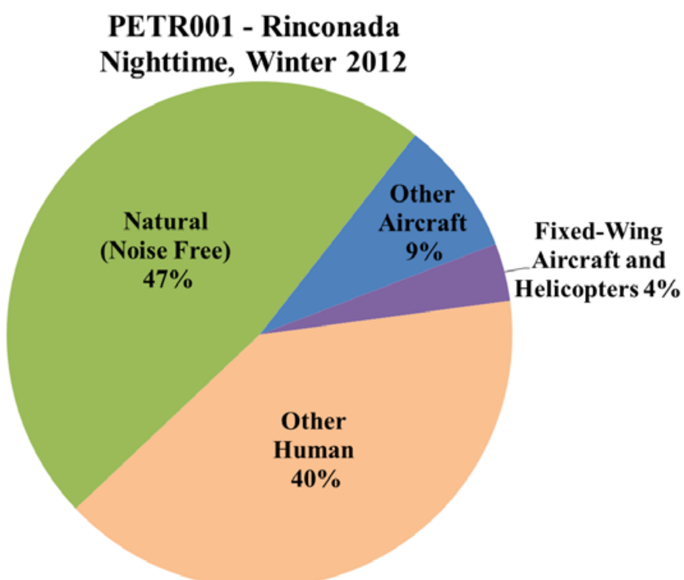

Figure 18. Distribution of nighttime sound sources audible (off-site listening) for Site PETR001, winter season (2012) (summer season results unavailable).

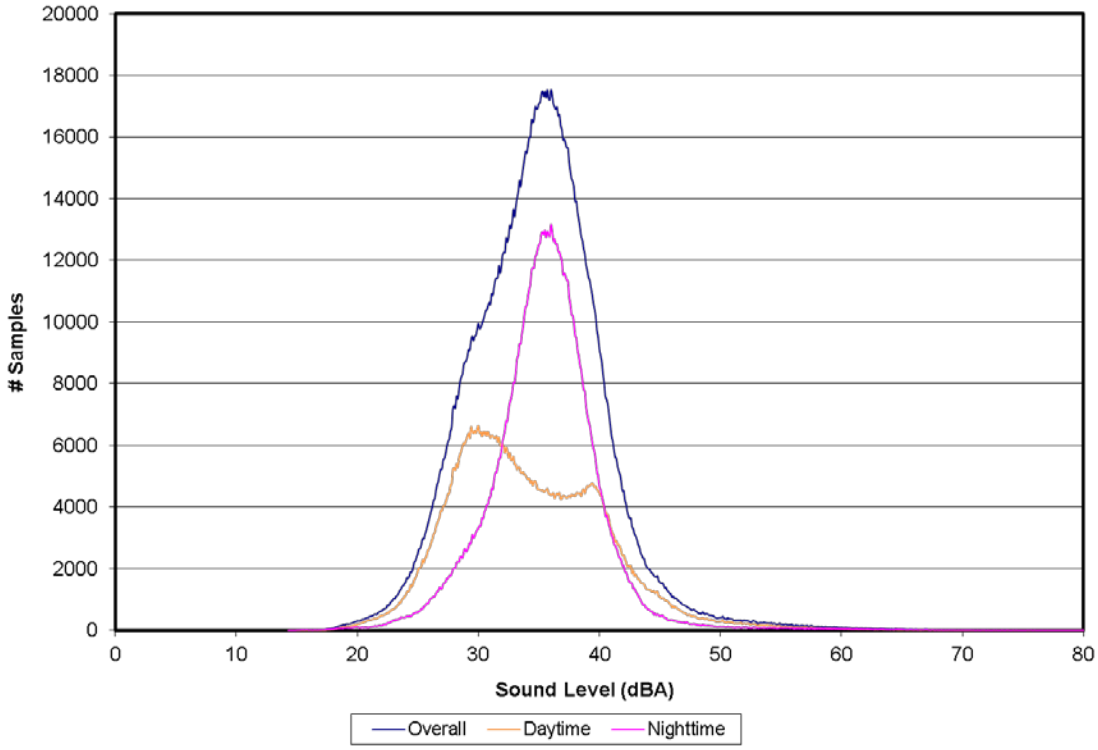

Figure 19. Distribution of sound level data for Site PETR001, summer season (2010).

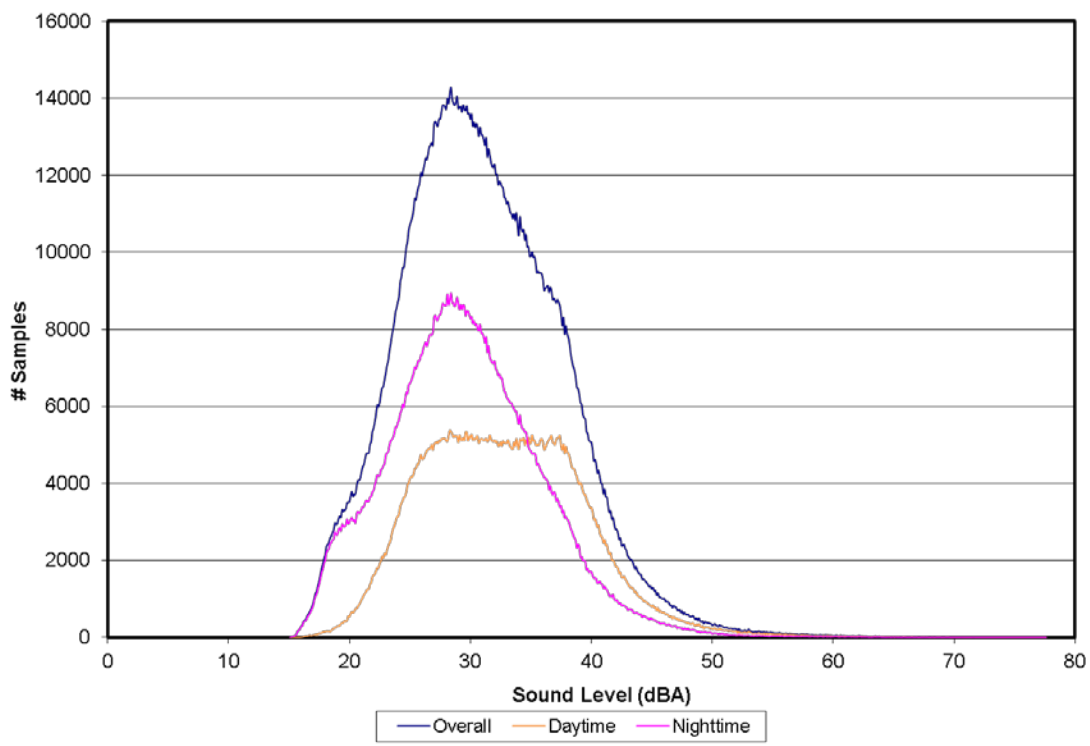

Figure 20. Distribution of sound level data for Site PETR001, winter season (2012).

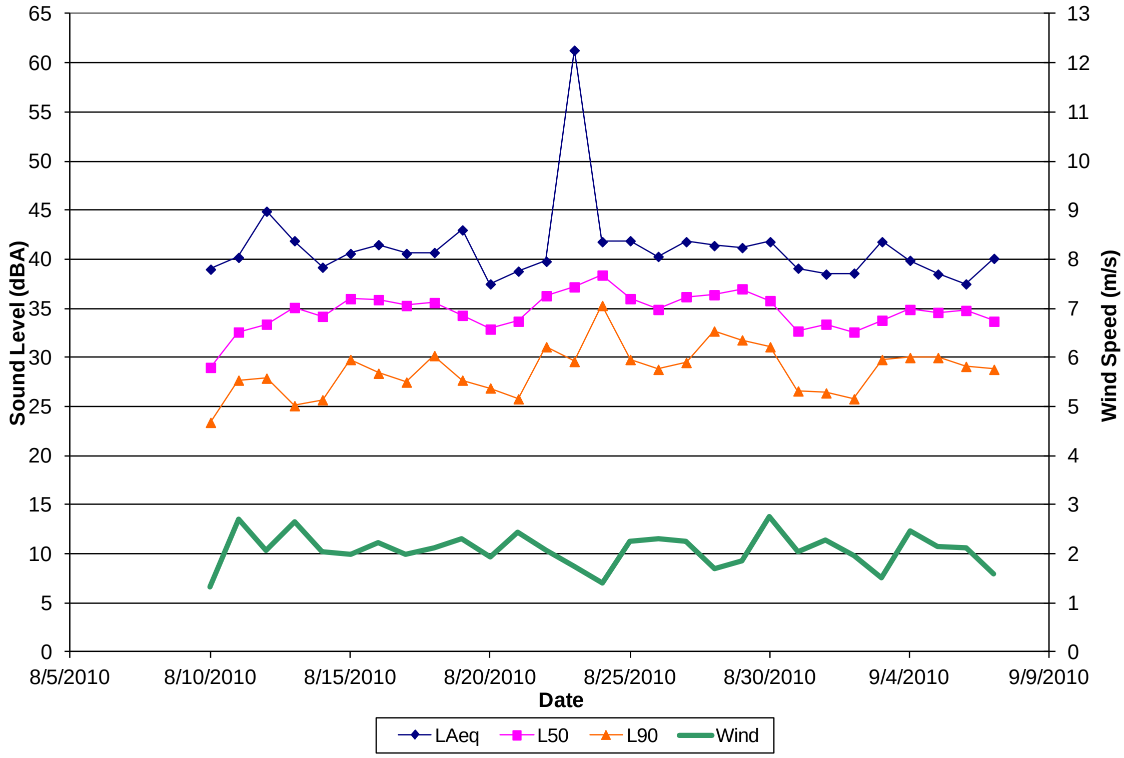

Figure 21. Daily sound levels and wind speeds for Site PETR001, summer season (2010).

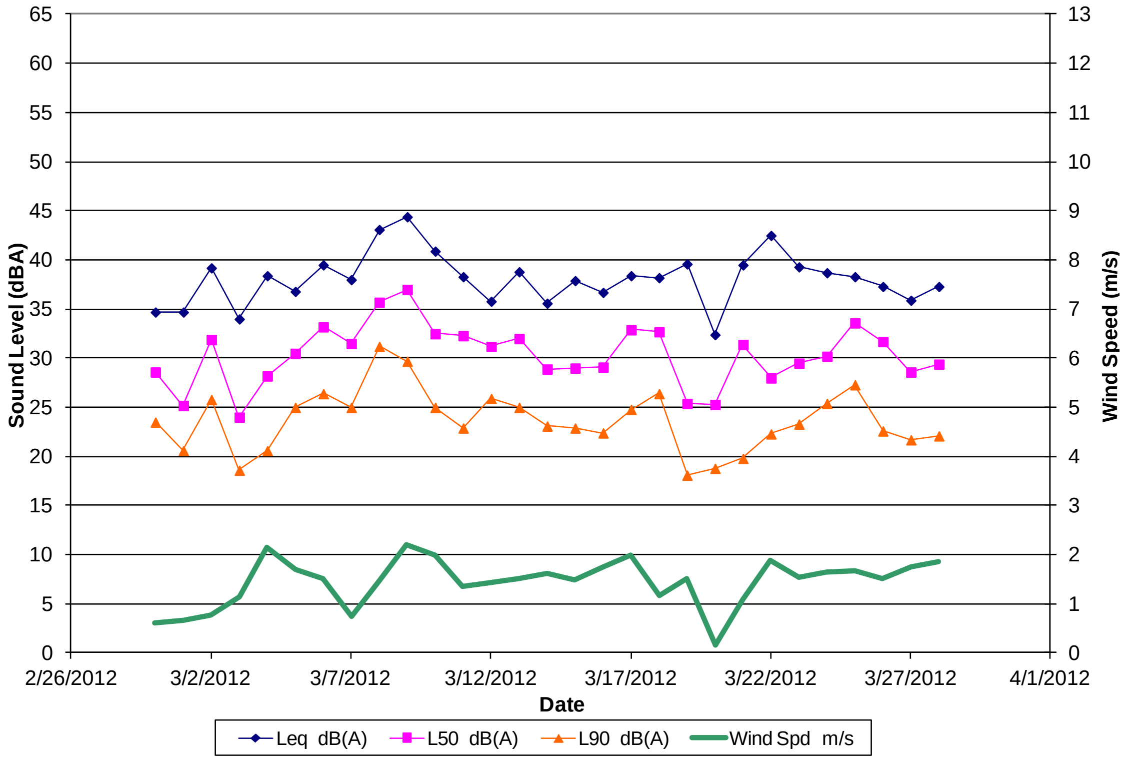

Figure 22. Daily sound levels and wind speeds for Site PETR001, winter season (2012).

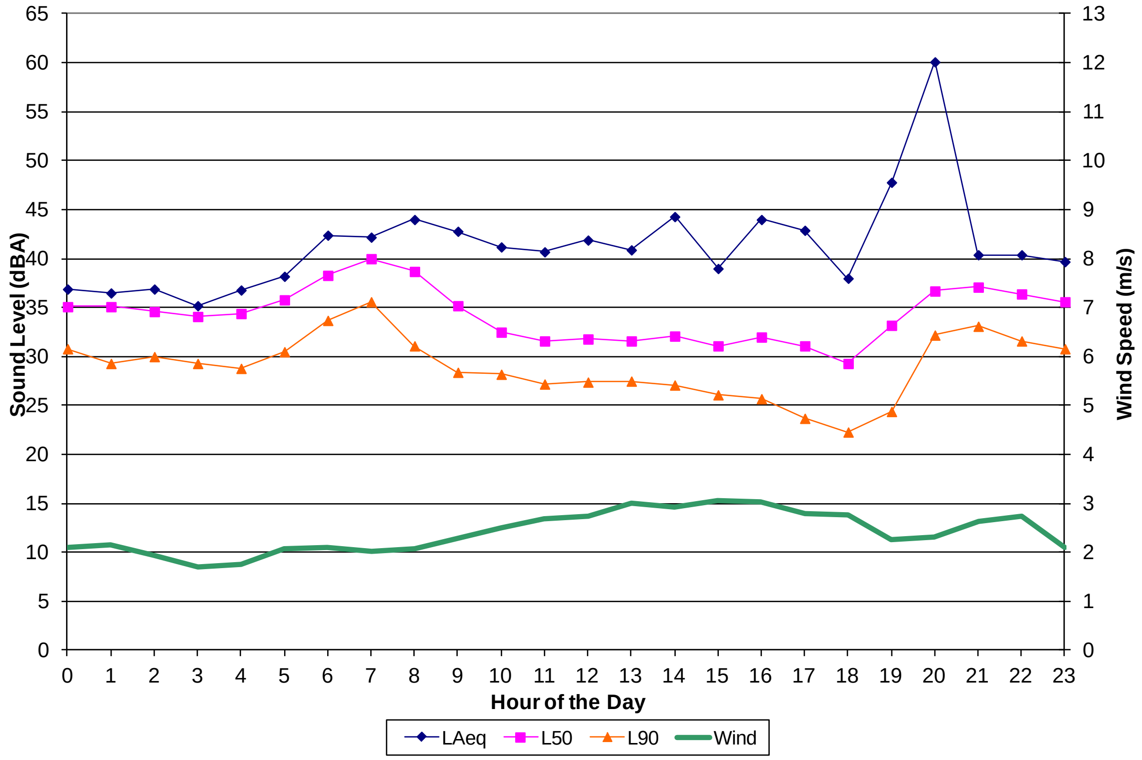

Figure 23. Hourly sound levels and wind speeds for Site PETR001, summer season (2010).

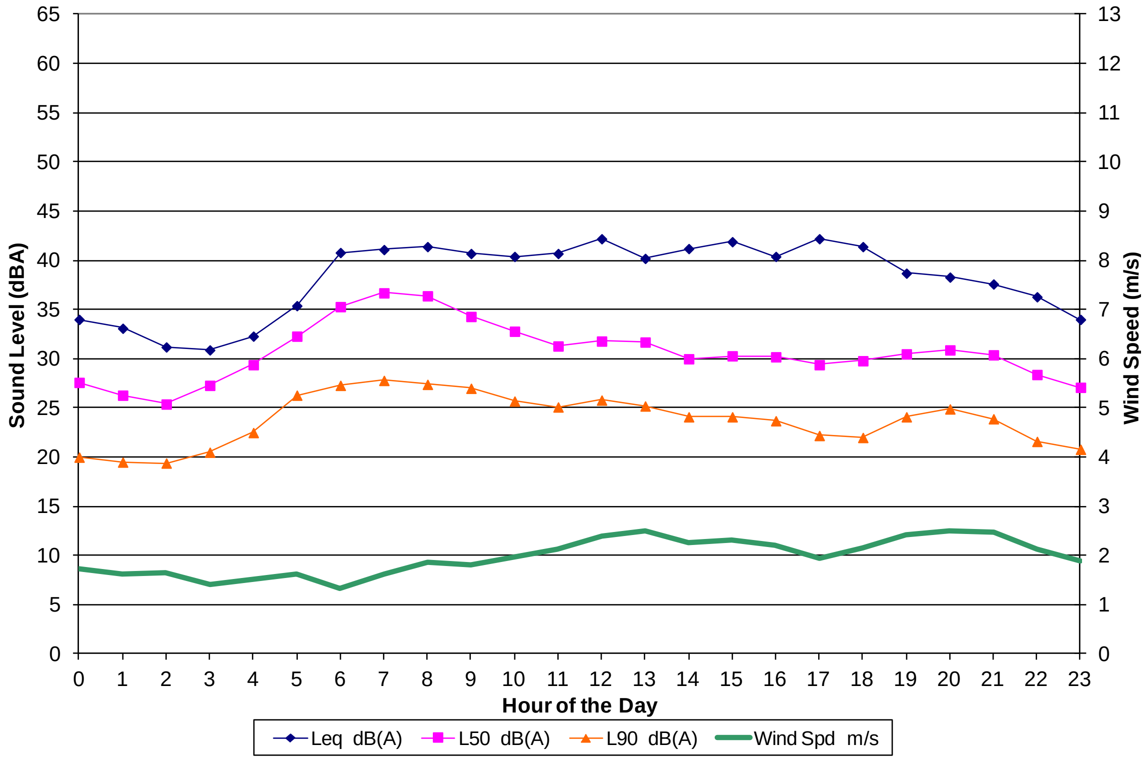

Figure 24. Hourly sound levels and wind speeds for Site PETR001, winter season (2012).

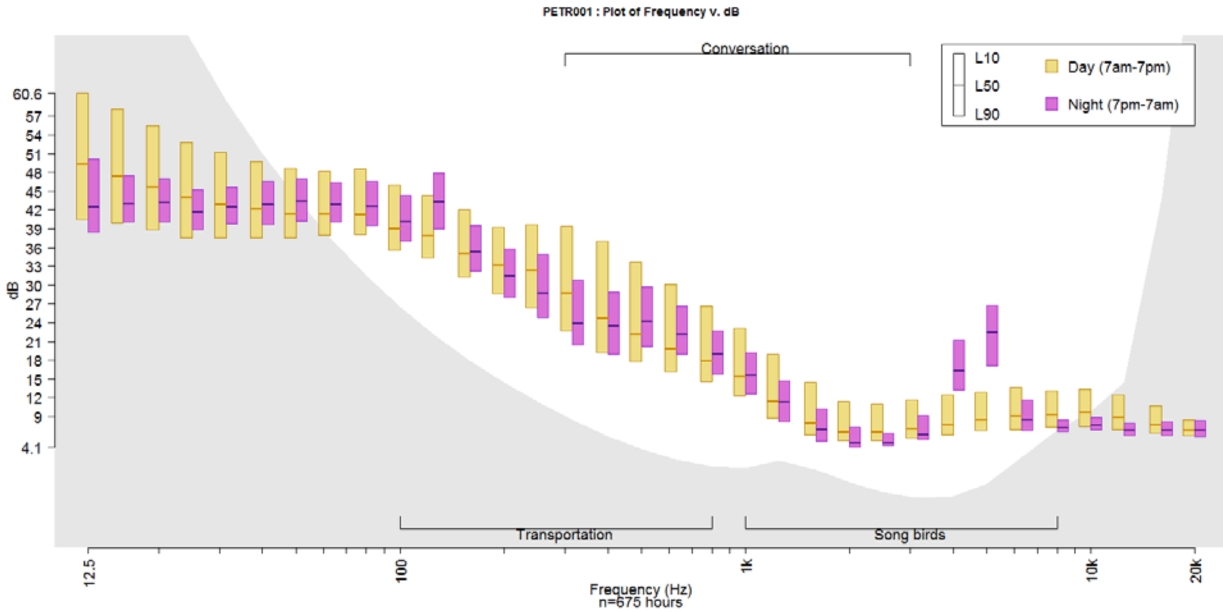

Figure 25. Sound spectrum for Site PETR001, summer season (2010).

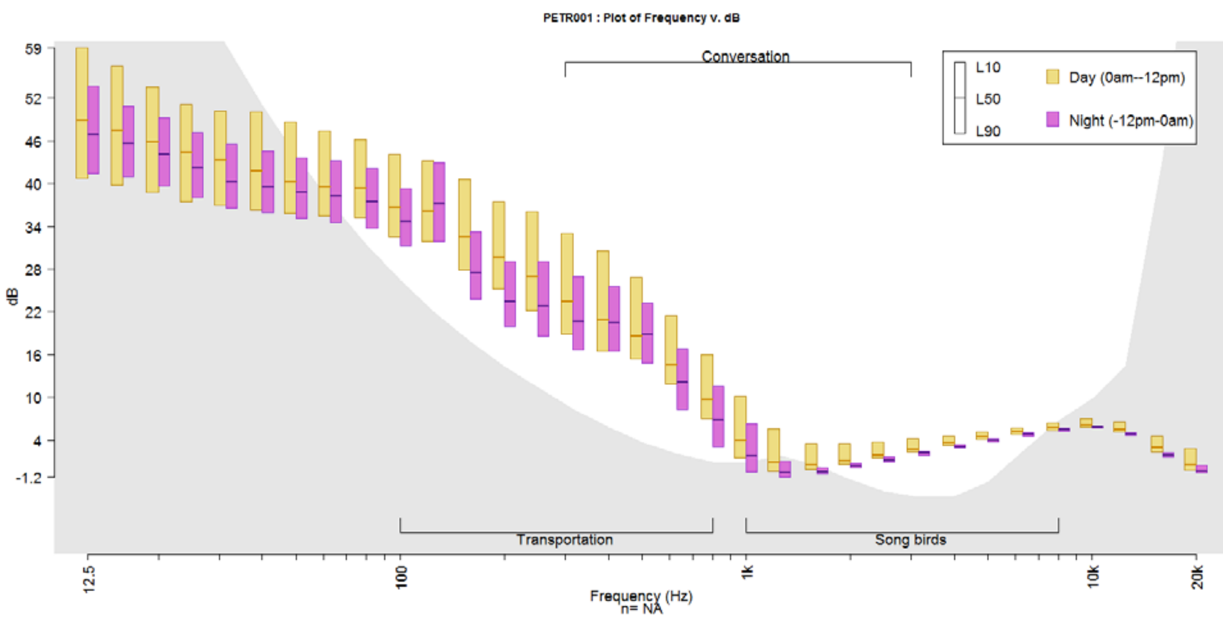

Figure 26. Sound spectrum for Site PETR001, winter season (2012).

6.2 Site PETR002 – Volcano Vista

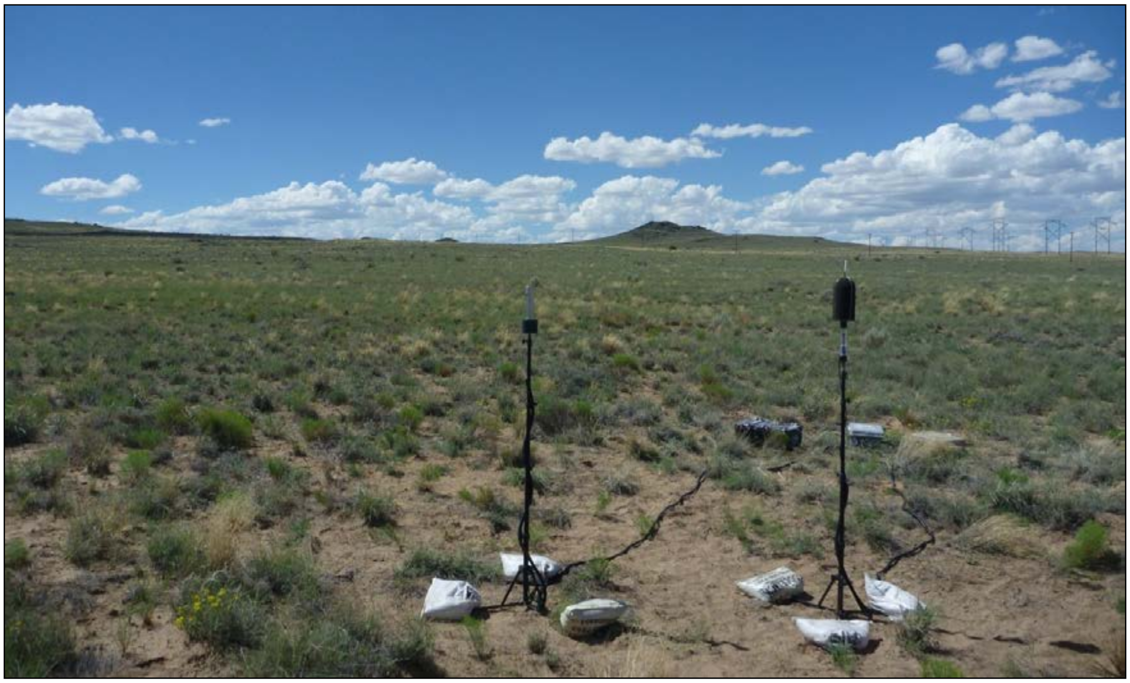

Figure 27. Photograph of Site PETR002, summer season (2010).

Figure 28. Photograph of Site PETR002, winter season (2012).

The PETR002 Volcano Vista site was located in the backcountry near an urban area. The system was deployed in a large, exposed mesa-like area with sandy soil, desert scrub, and no nearby tree vegetation. The measurement system collected data from August 9, 2010 to September 7, 2010 to represent the summer season and February 29, 2012 to April 2, 2012 to represent the winter season. The vegetation near the measurement system consisted of desert and sparse vegetation at an altitude of 1,738 meters above sea level. Daytime sources of sound included birds, insects, wind-, and water-related sounds. This site is within two miles of an urban area, therefore city sounds are audible on occasion (vehicles, aircraft).

Off-site review of recorded audio data showed aircraft were audible 49% of daytime hours during summer 2010; 40% of daytime and 8% of nighttime hours during winter 2012. Other human-related sounds were audible 4% of the summer 2010 daytime hours; 2% of daytime and 14% of nighttime hours during winter 2012. The period of time where no human sounds were audible is called the "noise-free" component of the soundscape. Noise-free time periods accounted for 47% of summer 2010 daytime hours; 58% of daytime and 78% of nighttime hours during winter 2012. Natural sounds audible at this site, which could have occurred concurrently with human sounds, included wind, bird vocalizations, and insects.

The overall median daytime sound level for this site was 30.9 dBA during summer 2010 and 33.4 dBA during winter 2012. Daily (twenty-four hour) median sound levels (L_{50}) ranged from 26 to 34 dBA during the summer and 29 to 38 dBA during the winter. The summer measurements included several loud days. A loud day occurred on 8/23/10 and was due to a heavy storm that included winds, rain and thunder. An additional loud day occurred on 9/3/10 and was due to aircraft operations in the vicinity.

Hourly median sound levels during summer 2010 varied from 25 dBA to 35 dBA with louder hourly sound levels occurring in the morning due to persistent insect activity during these hours. Hourly median sound levels during winter 2012 ranged from 29 to 40 dBA.

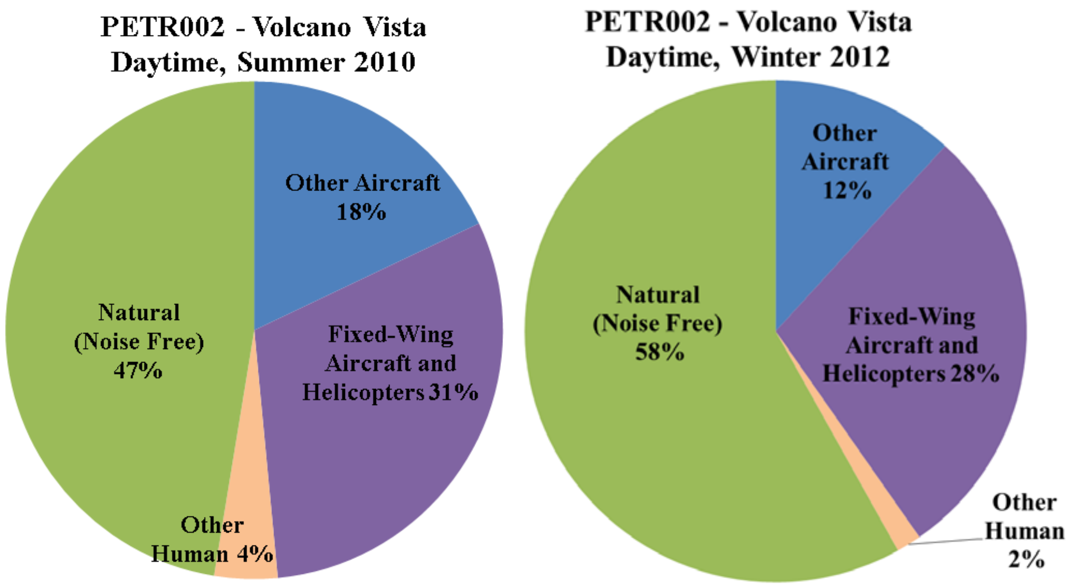

Figure 29. Distribution of daytime sound sources audible (off-site listening) for Site PETR002, summer season (2010) (left) and winter season (2012) (right).

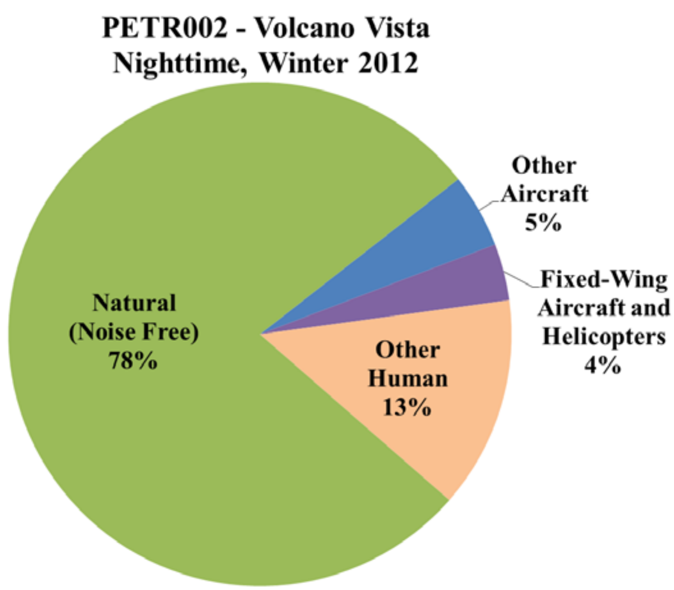

Figure 30. Distribution of nighttime sound sources audible (off-site listening) for Site PETR002, winter season (2012) (summer season results unavailable).

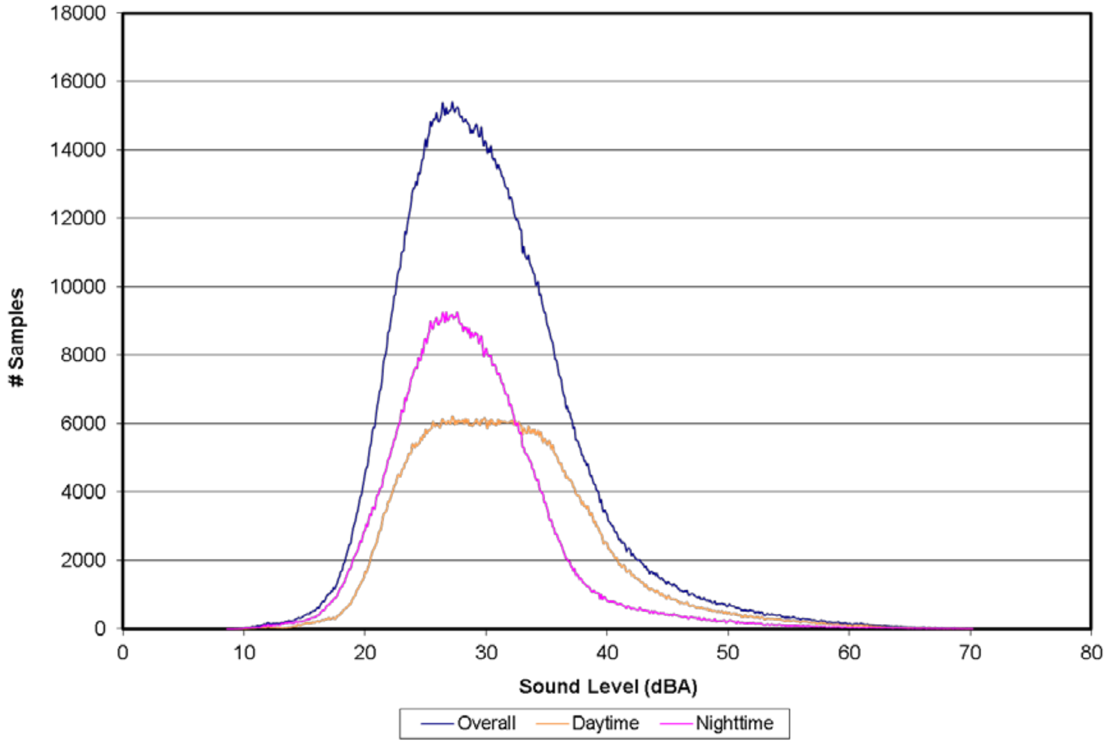

Figure 31. Distribution of sound level data for Site PETR002, summer season (2010).

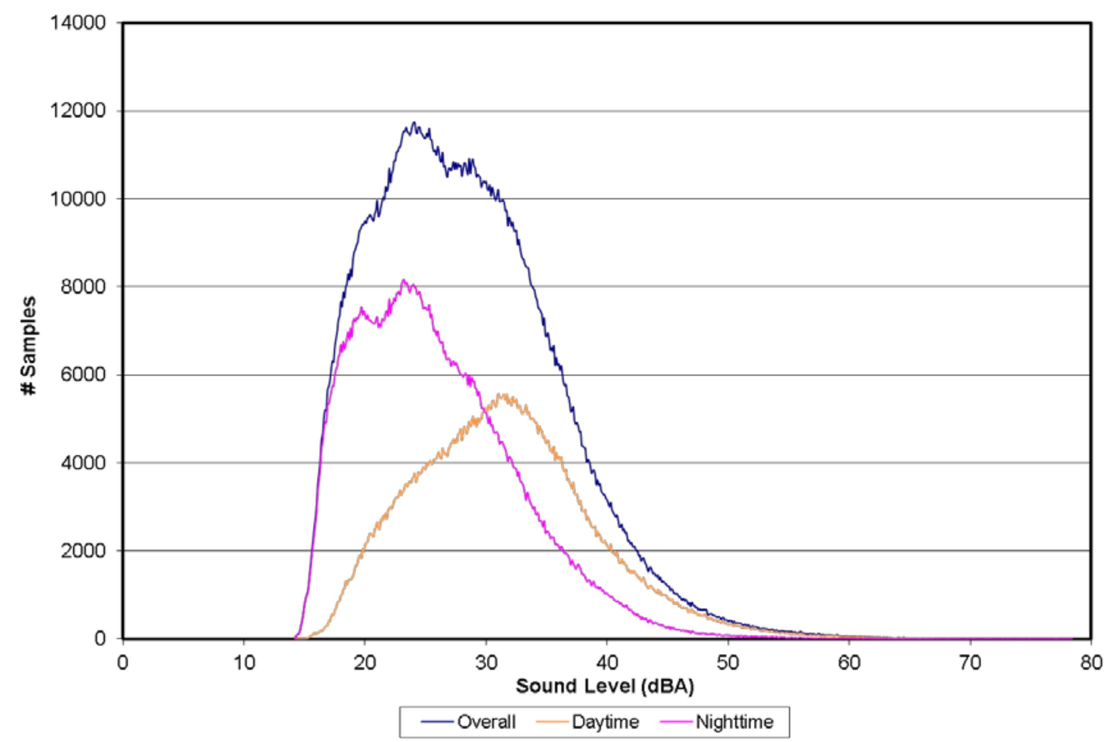

Figure 32. Distribution of sound level data for Site PETR002, winter season (2012).

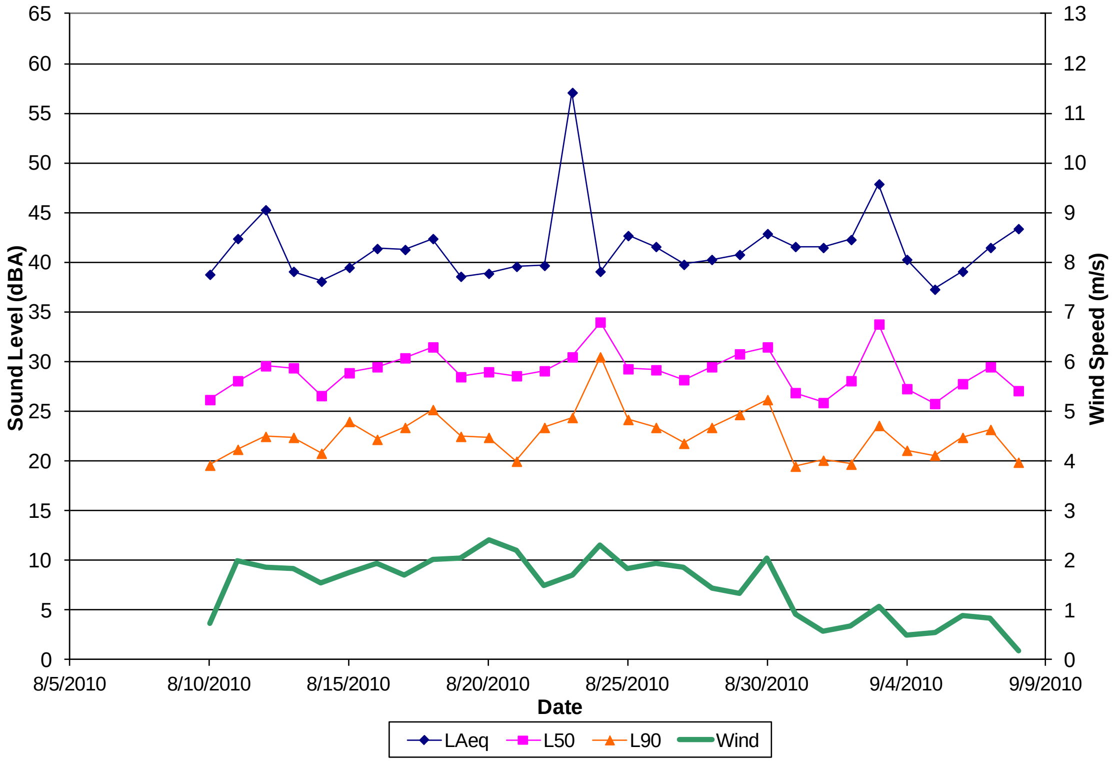

Figure 33. Daily sound levels and wind speeds for Site PETR002, summer season (2010).

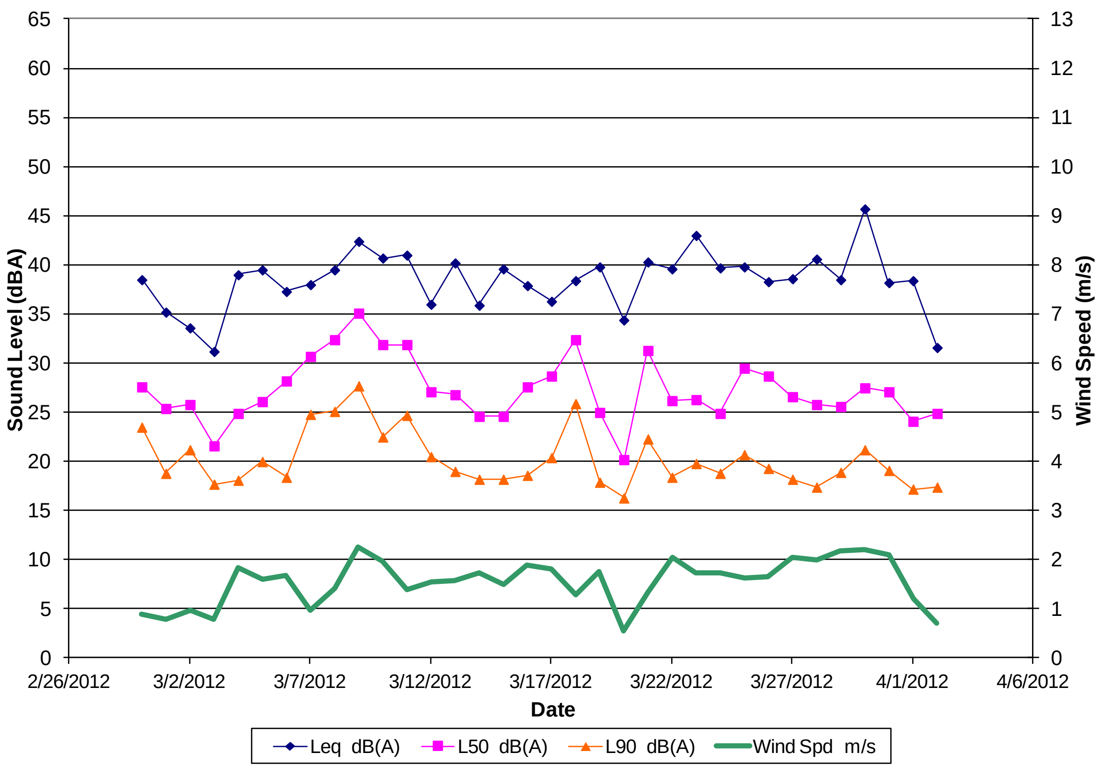

Figure 34. Daily sound levels and wind speeds for Site PETR002, winter season (2012).

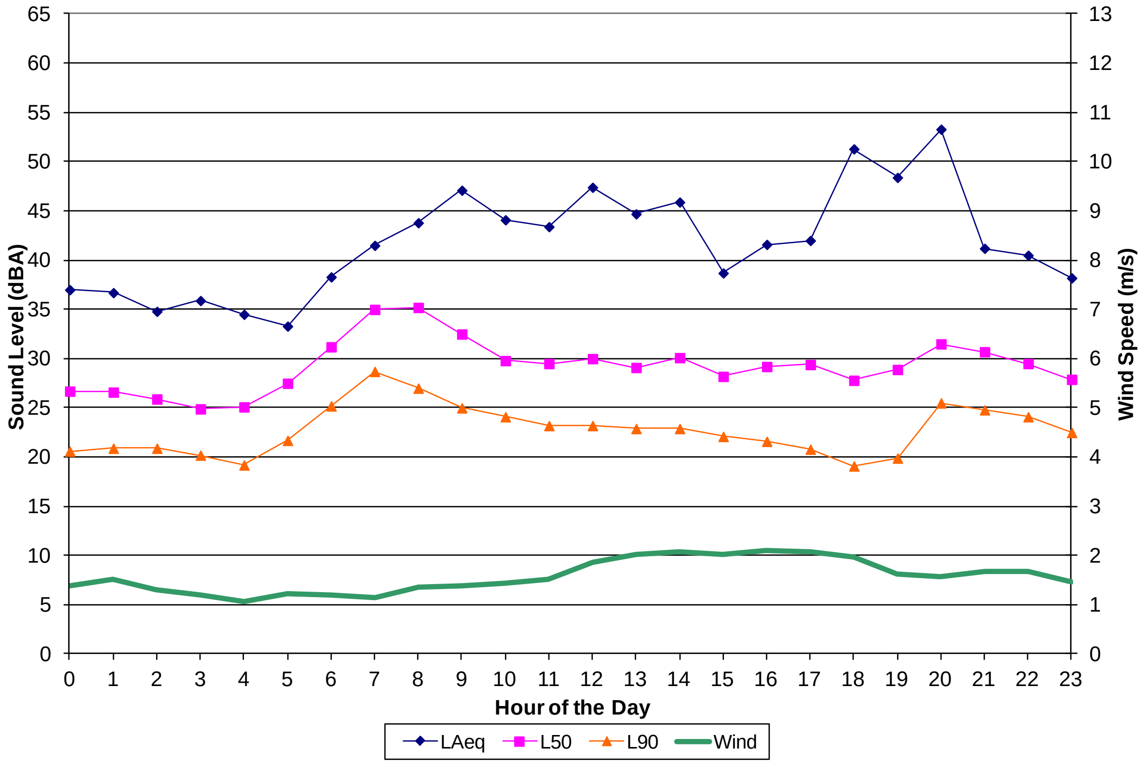

Figure 35. Hourly sound levels and wind speeds for Site PETR002, summer season (2010).

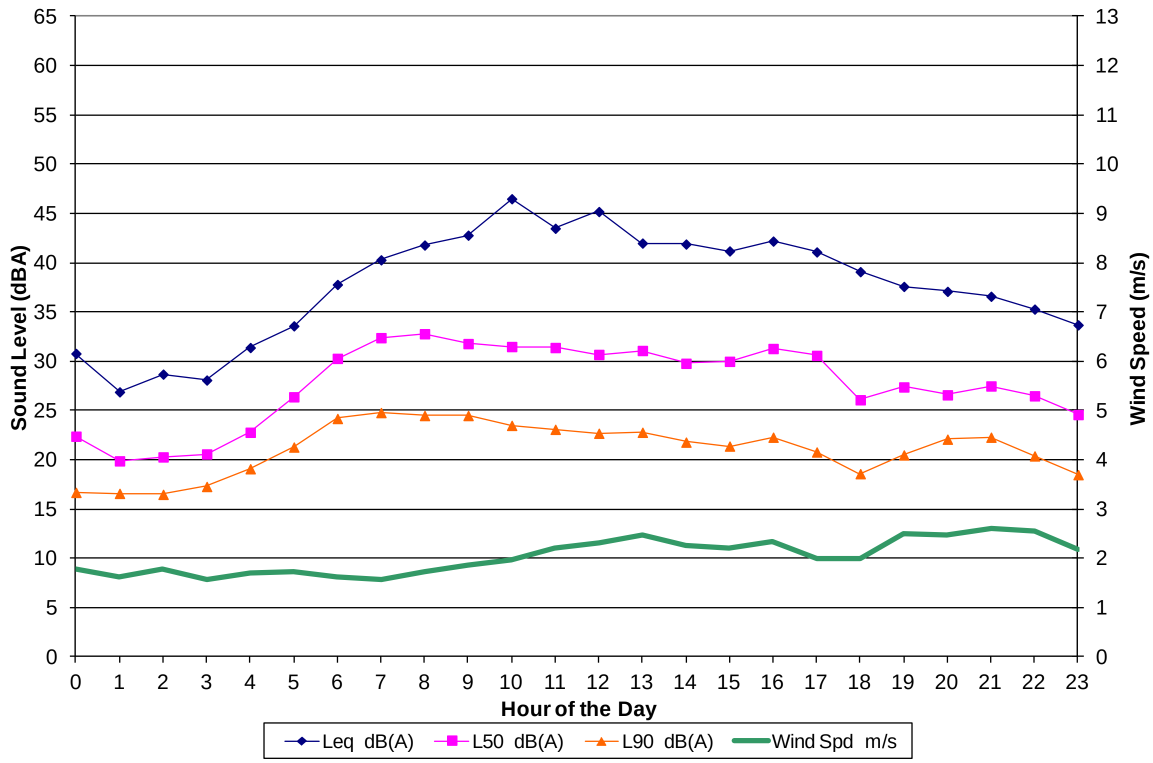

Figure 36. Hourly sound levels and wind speeds for Site PETR002, winter season (2012).

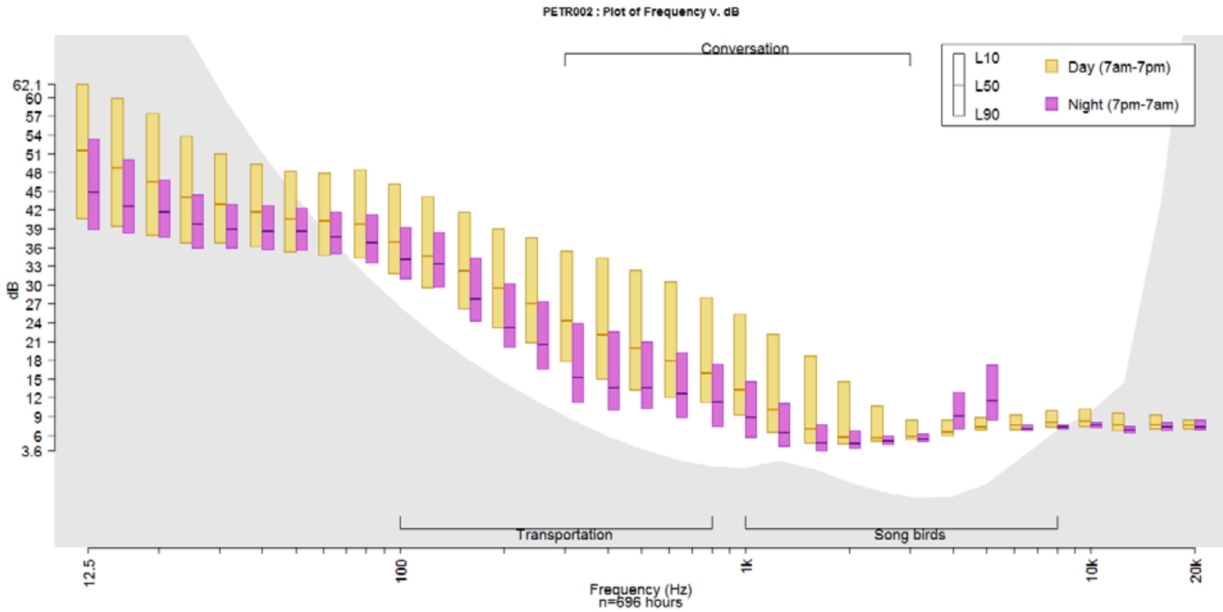

Figure 37. Sound spectrum for Site PETR002, summer season (2010).

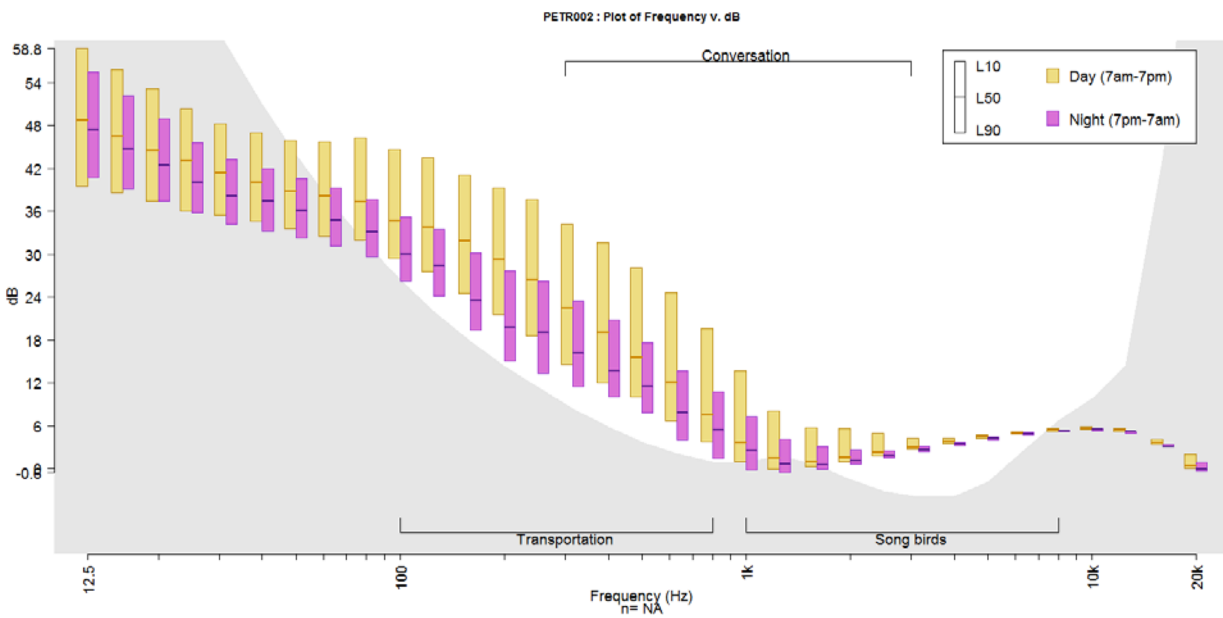

Figure 38. Sound spectrum for Site PETR002, winter season (2012).

Literature Cited

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

Berglund, B., Lindvall, T. and Schwela, D.H (Eds.). Guidelines for Community Noise, World Health Organization, Geneva: 1999.

Environmental Protection Agency. Information on Levels of Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety, March 1974. http://www.fican.org/pages/noise_speech.html (accessed 30 September 2013)

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.

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.

Haralabidis Alexandros S., et. al., "Acute effects of night-time noise exposure on blood pressure in populations living near airports" European Heart Journal Advance Access, Published online February 12, 2008.

Homer, C. C. Huang, L. Yang, B. Wylie and M. Coan. "Development of a 2001 National Landcover Database for the United States" Photogrammetric Engineering and Remote Sensing, Vol. 70, No. 7, July 2004, pp. 829-840.

Lee, C., 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.

National Park Service. 2013a. Petroglyph National Monument: Acoustical Monitoring 2010. Natural Resource Technical Report NPS/NRSS/NRTR—2013/687. National Park Service, Fort Collins, Colorado.

National Park Service. 2013b. National Park Service Visitor Use Statistics website. https://irma.nps.gov/Stats/ (accessed 28 October 2013).

National Park Service. 2014. Petroglyph National Monument website. http://www.nps.gov/PETR (accessed 12 February 2014).

New Mexico Department of Transportation. 2013. Statewide Planning Bureau website. http://www.dot.state.nm.us/en/Planning.html#Data (accessed 30 November 2013).

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

Rapoza, A., 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.

NPS 354/127129, November 2014

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov