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Pu`ukohola Heiau National Historic Site, Kaloko-Honokohau National Historical Park, and Pu`uhonua o Honaunau National Historical Park: Baseline Ambient Sound Levels 2003



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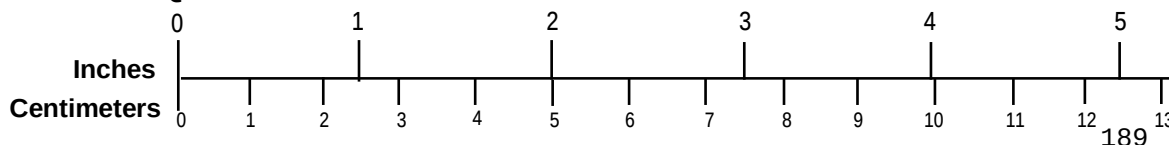
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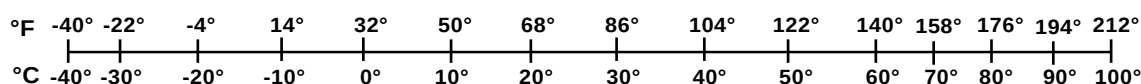
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EXECUTIVE SUMMARY

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) or Voluntary Agreements (VA) 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, exempt parks (50 or fewer annual tours), 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. 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 Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau;
- Establishing the different sound sources contributing to the baseline levels in key areas within Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau;
- Modeling sound levels in other similar areas within Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau 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 ATMPs and VAs 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)*, to assess the complete acoustical environment within the entire park. INM is a computer program used by over 700 organizations in over 50 countries to assess changes in noise impact. The INM model was recommended by the Federal Interagency Committee on Aviation Noise (FICAN) as the best-practice modeling methodology currently available for evaluating aircraft noise in national parks.^{1,2}

* As of May 2015, the Aviation Environmental Design Tool (AEDT) has replaced INM.

This document summarizes the noise measurement study undertaken to provide data about the baseline ambient noise environment in Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau, located in the state of Hawai`i (see Figure 1).



Figure 1. Location of Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau.

The FAA, with assistance of the Volpe Center's Environmental Measurement and Modeling Division, and the NPS conducted baseline ambient sound level measurements during June 2003. Approximately one week of acoustical and meteorological data were measured at multiple sites in each park. The general locations of these sites were selected with the assistance of NPS and Volpe personnel. 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 is typically 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 each park is so small, it was agreed that each park would be considered a single acoustic zone and measurement sites would be located near specific park resources. Figure 3 through Figure 5 display the locations of the final measurement sites selected.

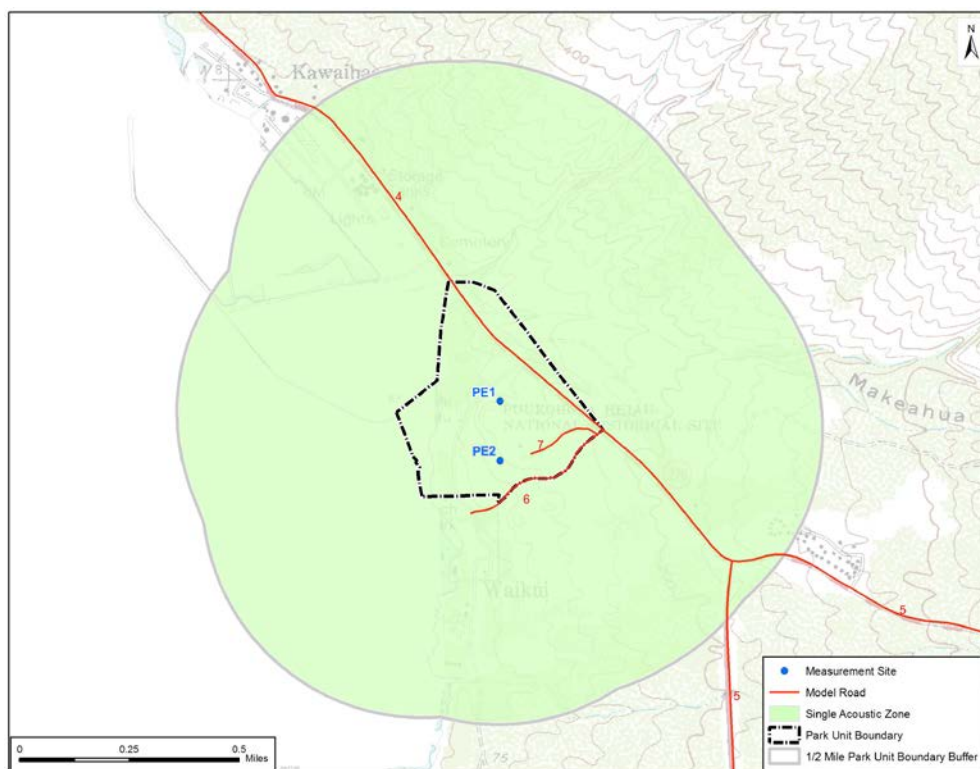


Figure 2. Acoustic zones and final measurement sites for Pu`ukohola Heiau.



Figure 3. Acoustic zones and final measurement sites for Kaloko-Honokohau.

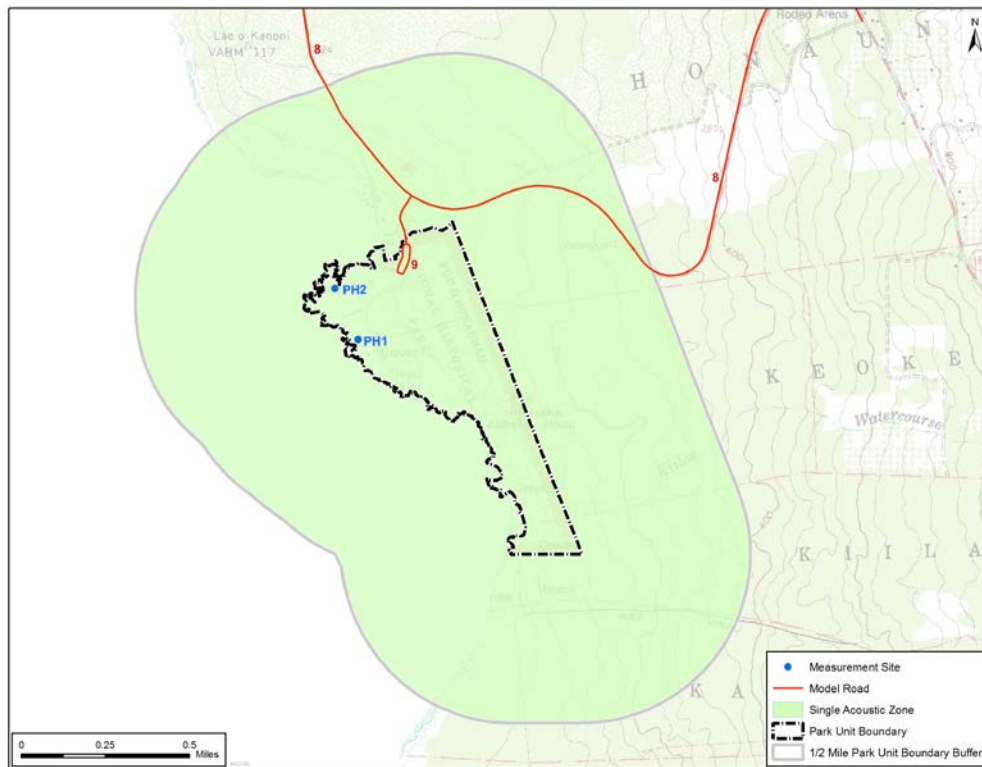


Figure 4. Acoustic zones and final measurement sites for Pu`uhonua o Honaunau.

As stated earlier, approximately one week of acoustical and meteorological data were measured at multiple sites in each park during June 2003 in each park (see Figure 6). 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 12.5 to 20,000 Hz;
- *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.

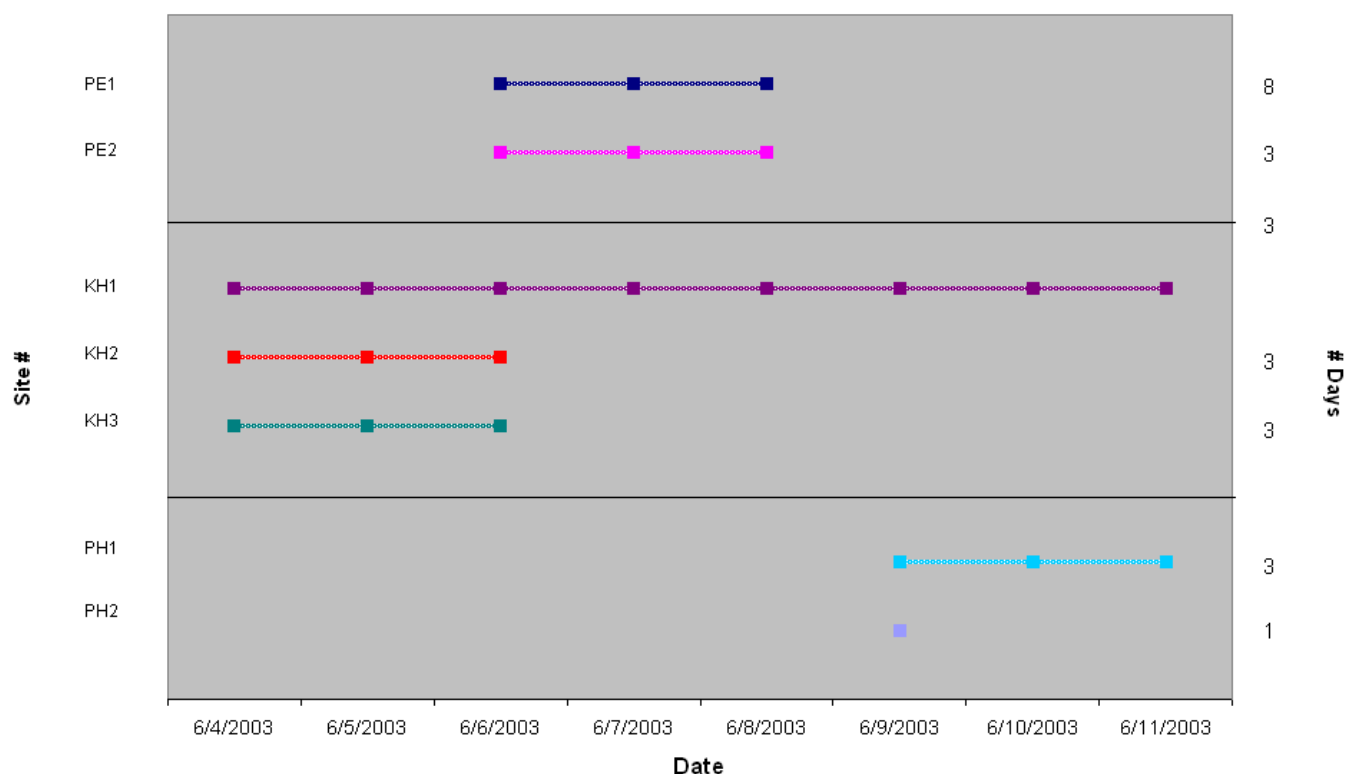


Figure 5. Baseline ambient data collection timeline.

All data analyses were performed in terms of three metrics:

- *The 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 μ Pa, 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.

In addition, because for most parks, the majority of air tour operations occur during the day, the FAA and NPS have agreed that any subsequent impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur. Accordingly, all ATMP or VA analyses will be based on daytime ambient data. For all Hawai`i parks, only data measured during the time period of 6 am to 6 pm were used. This time period is the typical operating hours for air tour operators conducting air tours in Hawai`i according to Honolulu Flight Standard District Office personnel.

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 were computed from the data. The four primary types of “ambient” used in this document are defined as follows (see Figure 7):

- *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.

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

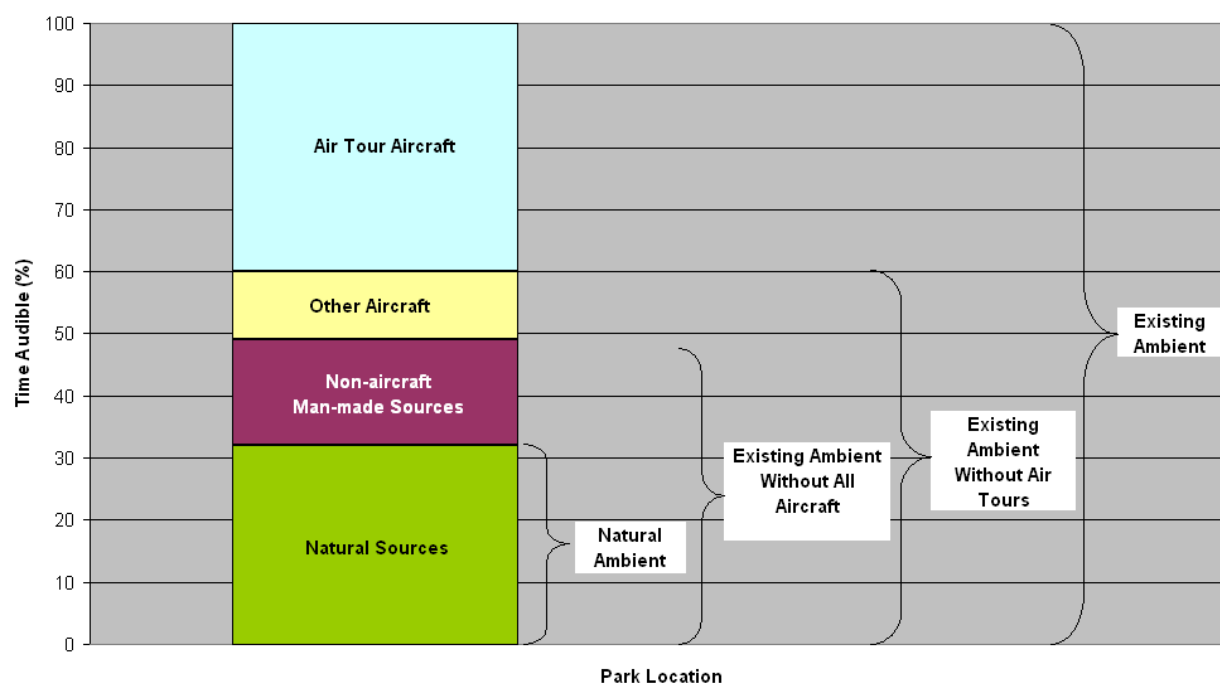


Figure 6. Graphical depiction of ambient definitions.

Table 1 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 three columns in the table are arranged as follows:

- *Park Name*: The name of the park in which the measurement site was located;
- *Site ID*: The unique two-character ID representing the site “number”; and
- *Total # Days*: The total number of days measured.

The next four primary columns define the additional types of ambient represented by the data: Existing, Existing Without Air Tours, Existing Without All Aircraft, and Natural, as defined above. Then for each type of ambient, the following data are presented: *

- *L_{Aeq}*: The equivalent, A-weighted sound level (in decibels). Presented is the energy-averaged value determined from daytime sound levels (6 am to 6 pm), taking into account the data

* As noted previously, because for most parks, the majority of air tour operations occur during the day, the FAA and NPS have agreed that any subsequent impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur. Accordingly, all ATMP or VA analyses will be based on daytime ambient data. For all Hawai`i parks, only data measured during the time period of 6 am to 6 pm were used. This time period is the typical operating hours for air tour operators conducting air tours in Hawai`i according to Honolulu Flight Standard District Office personnel.

from all days of measurements (Note: This metric was computed for the Existing Ambient only);

- *L₅₀*: The *L₅₀* sound level (in decibels) determined by the sound level exceeded 50 percent of the daytime hours (6 am to 6 pm), taking into account the data from all days of measurements;
- *L₉₀*: The *L₉₀* sound level (in decibels) determined by the sound level exceeded 90 percent of the daytime hours (6 am. to 6 pm), taking into account the data from all days of measurements; and
- *W/S*: The average wind speed (in mph). Presented is the algebraically averaged value determined from daytime sound levels (6 am to 6 pm), taking into account the data from all days of measurements.

Table 2 contains a summary of the acoustic observer data logged at each measurement site. The first six columns in the table are arranged as follows:

- *Park Name*: The name of the park in which the measurement site was located;
- *Site ID*: The unique two-character ID representing the site “number”;
- *Land Cover*: The land cover of the site in accordance with the National Land Cover Data 21-class land cover classification scheme (see Appendix E);
- *Management Zone*: The NPS management zone that the site was located in;
- *Site Category*: A designator indicating expected visitor use (with “overlook” indicating high visitor use, “short hike” indicating moderate visitor use, and “wilderness/backcountry” indicating minimal or no visitor use) in the measurement site area;
- *Total Duration (s)*: The duration in seconds of all acoustic observer logging performed at the measurement site.

The next six columns define the amount of time that different noise sources were audible to the acoustic observer:

- *Air Tour Aircraft*: The duration in seconds that air tour aircraft were audible;
- *Other Aircraft*: The duration in seconds that other aircraft (e.g., commercial, military, general aviation, and agricultural) were audible;

- *Human*: The duration in seconds that human noise sources (visitor- and mechanical-related) were audible;
- *Natural*: The duration in seconds that natural noise sources were audible;
- *% Air Tour*: The percentage of observer log time that air tour aircraft were audible; and
- *% All Aircraft*: The percentage of observer log time that all aircraft were audible (i.e., air tour and other aircraft).

In addition, Table 3 summarizes two additional metrics (per NPS request) determined using the acoustic observer logs taken during the ambient measurements:

- *Number of Events Per Hour (NEH)*: The number of air tour operations audible within a specified time period, ideally each hour during the day (where sufficient operational data exists); and
- *Noise-Free Interval (NFI)*: The length of time during which only natural sounds are audible.

The columns in the table are arranged as follows:

- *Park Name*: The name of the park in which the measurement site was located;
- *Site ID*: The unique two-character ID representing the site “number”;
- *Noise-Free Periods*: Periods of time during which only natural sounds were audible;
- *Air Tour Aircraft Events*: Periods of time during which air tour aircraft sounds were audible; and
- *Other Aircraft Events*: Periods of time during which non-air tour aircraft sounds were audible.

Table 1. Summary of measured, daytime (6 am to 6 pm), ambient sound level data.

Park Name	Site ID	# of Days	Existing L_{Aeq} (dBA)	Existing L₅₀ (dBA)	Existing L₉₀ (dBA)	Existing W/S (mph)	Existing Without Air Tours L_{Aeq} (dBA)	Existing Without Air Tours L₅₀ (dBA)	Existing Without Air Tours L₉₀ (dBA)	Existing Without Air Tours W/S (mph)	Existing Without All Aircraft L_{Aeq} (dBA)	Existing Without All Aircraft L₅₀ (dBA)	Existing Without All Aircraft L₉₀ (dBA)	Existing Without All Aircraft W/S (mph)	Natural Ambient L_{Aeq} (dBA)	Natural Ambient L₅₀ (dBA)	Natural Ambient L₉₀ (dBA)	Natural Ambient W/S (mph)
Pu`ukohola Heiau	PE1	3	40.2	36.0	31.1	1.9	37.1	35.0	31.0	2.2	36.9	35.0	31.0	2.2	34.5	34.0	31.0	2.2
Pu`ukohola Heiau	PE2	3	44.4	41.0	35.6	3.3	42.8	41.5	38.1	6.2	42.6	41.5	38.2	6.1	43.6	42.3	39.7	6.5
Kaloko-Honokohau	KH1	8	43.1	40.3	31.7	0.9	44.5	41.7	37.5	1.1	44.5	41.9	37.5	1.1	44.1	41.9	37.5	1.1
Kaloko-Honokohau	KH2	3	44.8	40.7	35.8	1.2	42.8	38.3	35.3	2.2	43.1	38.3	35.3	2.2	42.1	38.2	35.1	2.2
Kaloko-Honokohau	KH3	3	45.8	41.7	36.3	3.0	42.4	42.6	38.3	1.8	42.4	42.6	38.3	1.8	41.0	42.3	37.9	1.8
Pu`uhonua o Honaunau	PH1	3	43.1	41.1	36.8	1.1	43.4	40.4	36.7	1.9	43.4	40.4	36.7	1.9	43.5	40.4	36.7	1.9
Pu`uhonua o Honaunau	PH2	1	46.8	44.8	42.6	1.9	45.4	44.8	42.6	1.6	45.4	44.8	42.6	1.6	45.6	45.0	42.8	1.6

Table 2. Summary of acoustic observer log data. *

Park Name	Site ID	Land Cover	Management Zone	Site Category	Total Duration (s)	Seconds Audible: Aircraft Sound Sources - Air Tours	Seconds Audible: Aircraft Sound Sources - Other	Seconds Audible: Human Sound Sources	Seconds Audible: Natural Sound Sources	% Time Audible: Air Tour	% Time Audible: All Aircraft
Pu`ukohola Heiau	PE1	Bare Rock/Sand/Clay	Natural/Cultural	Overlook	3705	444	38	2562	661	12.0%	13.0%
Pu`ukohola Heiau	PE2	Shrubland	Natural/Cultural	Short Hike	4941	707	246	3383	605	14.3%	19.3%
Kaloko-Honokohau	KH1	Shrubland	Natural/Cultural	Short Hike	3201	134	215	38	2814	4.2%	10.9%
Kaloko-Honokohau	KH2	Bare Rock/Sand/Clay	Natural/Cultural	Short Hike	2515	133	259	316	1807	5.3%	15.6%
Kaloko-Honokohau	KH3	Bare Rock/Sand/Clay	Natural/Cultural	Short Hike	4869	902	126	1025	2816	18.5%	21.1%
Pu`uhonua o Honaunau	PH1	Bare Rock/Sand/Clay	Natural/Cultural	Short Hike	3328	0	0	145	3183	0.0%	0.0%
Pu`uhonua o Honaunau	PH2	Bare Rock/Sand/Clay	Natural/Cultural	Overlook	3641	36	0	1496	2109	1.0%	1.0%

* It should be noted that ideally observer logging should be performed for several hours during different time periods of the day and/or week. However, due to occasional weather, accessibility, and equipment issues, only limited observer logging were performed at each site.

Table 3. Summary of acoustic observer log data: number of events per hour and noise-free interval.

	Park Name	Site ID	Noise-Free Periods	Air Tour Aircraft Events	Other Aircraft Events
Number Periods/Events:	Pu`ukohola Heiau	PE1	33	20	9
Mean Time (minutes):	Pu`ukohola Heiau	PE1	0:00:19	0:00:36	0:00:28
Minimum Time (minutes):	Pu`ukohola Heiau	PE1	0:00:04	0:00:05	0:00:05
Maximum Time (minutes):	Pu`ukohola Heiau	PE1	0:01:14	0:02:01	0:01:22
Total Time (minutes):	Pu`ukohola Heiau	PE1	0:10:30	0:12:04	0:04:11
Number Periods/Events:	Pu`ukohola Heiau	PE2	34	4	2
Mean Time (minutes):	Pu`ukohola Heiau	PE2	0:00:20	0:01:51	0:00:19
Minimum Time (minutes):	Pu`ukohola Heiau	PE2	0:00:05	0:00:15	0:00:07
Maximum Time (minutes):	Pu`ukohola Heiau	PE2	0:00:54	0:04:21	0:00:31
Total Time (minutes):	Pu`ukohola Heiau	PE2	0:11:08	0:07:24	0:00:38
Number Periods/Events:	Kaloko-Honokohau	KH1	24	4	6
Mean Time (minutes):	Kaloko-Honokohau	KH1	0:01:57	0:00:33	0:00:36
Minimum Time (minutes):	Kaloko-Honokohau	KH1	0:00:04	0:00:22	0:00:10
Maximum Time (minutes):	Kaloko-Honokohau	KH1	0:07:39	0:00:46	0:00:54
Total Time (minutes):	Kaloko-Honokohau	KH1	0:46:56	0:02:14	0:03:35
Number Periods/Events:	Kaloko-Honokohau	KH2	27	2	13
Mean Time (minutes):	Kaloko-Honokohau	KH2	0:01:46	0:01:11	0:00:35
Minimum Time (minutes):	Kaloko-Honokohau	KH2	0:00:05	0:00:09	0:00:08
Maximum Time (minutes):	Kaloko-Honokohau	KH2	0:05:48	0:02:13	0:01:12
Total Time (minutes):	Kaloko-Honokohau	KH2	0:44:21	0:02:22	0:07:04
Number Periods/Events:	Kaloko-Honokohau	KH3	29	5	3
Mean Time (minutes):	Kaloko-Honokohau	KH3	0:01:37	0:03:00	0:00:42
Minimum Time (minutes):	Kaloko-Honokohau	KH3	0:00:11	0:00:27	0:00:32
Maximum Time (minutes):	Kaloko-Honokohau	KH3	0:09:28	0:09:09	0:00:49
Total Time (minutes):	Kaloko-Honokohau	KH3	0:46:56	0:15:02	0:02:06
Number Periods/Events:	Pu`uhonua o Honaunau	PH1	218	0	0
Mean Time (minutes):	Pu`uhonua o Honaunau	PH1	0:00:15	0:00:00	0:00:00
Minimum Time (minutes):	Pu`uhonua o Honaunau	PH1	0:00:05	0:00:00	0:00:00
Maximum Time (minutes):	Pu`uhonua o Honaunau	PH1	0:02:02	0:00:00	0:00:00
Total Time (minutes):	Pu`uhonua o Honaunau	PH1	0:53:04	0:00:00	0:00:00
Number Periods/Events:	Pu`uhonua o Honaunau	PH2	39	1	0
Mean Time (minutes):	Pu`uhonua o Honaunau	PH2	0:00:53	0:00:36	0:00:00
Minimum Time (minutes):	Pu`uhonua o Honaunau	PH2	0:00:05	0:00:36	0:00:00
Maximum Time (minutes):	Pu`uhonua o Honaunau	PH2	0:02:55	0:00:36	0:00:00
Total Time (minutes):	Pu`uhonua o Honaunau	PH2	0:35:19	0:00:36	0:00:00

As stated earlier, 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 in the park. Thus, the measured data establishes ambient sound levels in key areas within the park and is then generalized to larger areas with similar acoustical attributes, such as land cover, wind conditions, wildlife habitats, and visitor-use.

In addition to the measured ambient sound levels, the contributing effect of localized noise sources, such as waterfalls, river rapids, trains, and roads, are also considered in the development of the ambient maps. Because it is not feasible to carry out field data collection efforts in all areas of a park, the contributions of these localized sound sources 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 model 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.

All roads were modeled using the Federal Highway Administration’s Traffic Noise Model[®] (TNM). Figure 8 through Figure 10 present the resultant roadway ambient map for each park.

With four ambient types computed in terms of three metrics, the following nine composite ambient maps were developed (see Table 4). As noted earlier, the L_{Aeq} metric was computed for the Existing Ambient only.

Table 4. Nine composite ambient maps.

Metirc	Existing Ambient	Existing Ambient Without Air Tours	Existing Ambient Without All Aircraft	Natural Ambient *
L_{Aeq}	Map 1: Measured + Roadway	N/A	N/A	N/A
L₅₀	Map 2: Measured + Roadway	Map 4: Measured + Roadway	Map 6: Measured + Roadway	Map 8: Measured
L₉₀	Map 3: Measured + Roadway	Map 5: Measured + Roadway	Map 7: Measured + Roadway	Map 9: Measured

Note: The combined (Measured + Roadway) ambient were computed by using energy-addition, i.e., sound levels in decibels were converted to energy prior to addition. For a non-time-varying source, such as roadway noise, the TNM-computed L_{Aeq} sound level parameters were conservatively assumed to be equivalent to the L₅₀ and L₉₀ and, thus, used interchangeably as the “roadway” ambient.

The FAA and NPS agree on the definitions of ambient. However, because the FAA and NPS have different methodologies for assessing noise impacts, it is not clear which definition is the most appropriate. From the above nine, two ambient maps were agreed upon for use in ATMP / VA analyses:

- *Existing Ambient Without Air Tours* – Map 4 from the table above; and
- *Natural Ambient* – Map 8 from the table above.

Figure 11 through Figure 16 present the two ambient maps for each park, respectively. Section 7 presents all nine maps for each park.

* As defined in earlier, Natural Ambient includes the natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excludes all human and mechanical sounds.

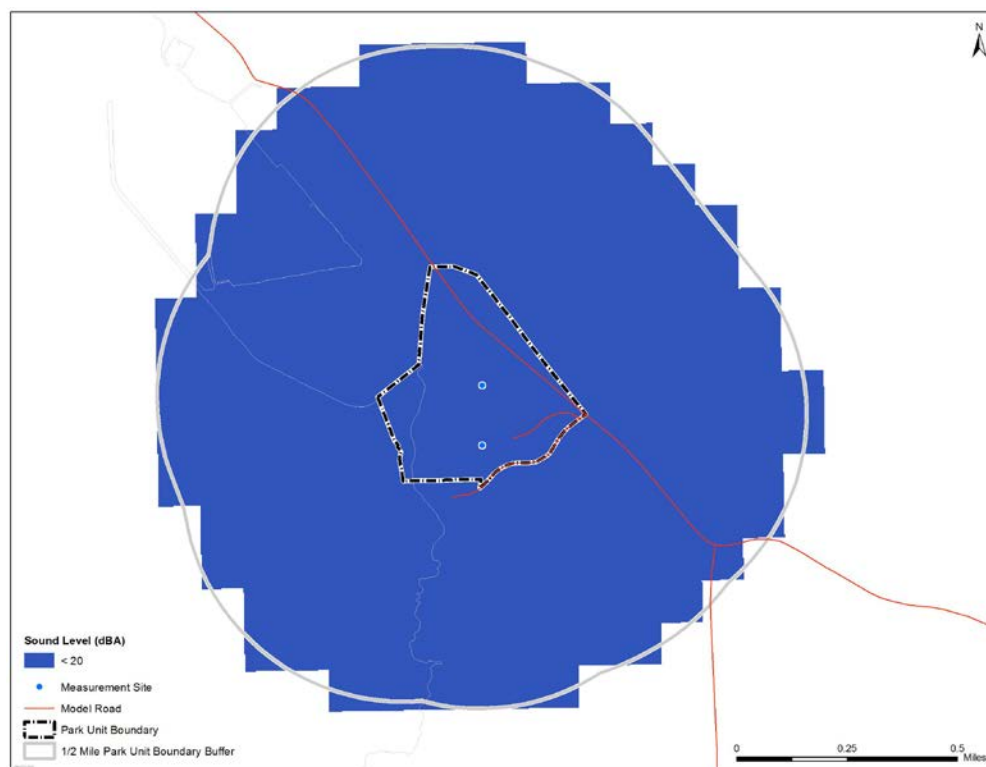


Figure 7. Roadway ambient map for Pu`ukohola Heiau.

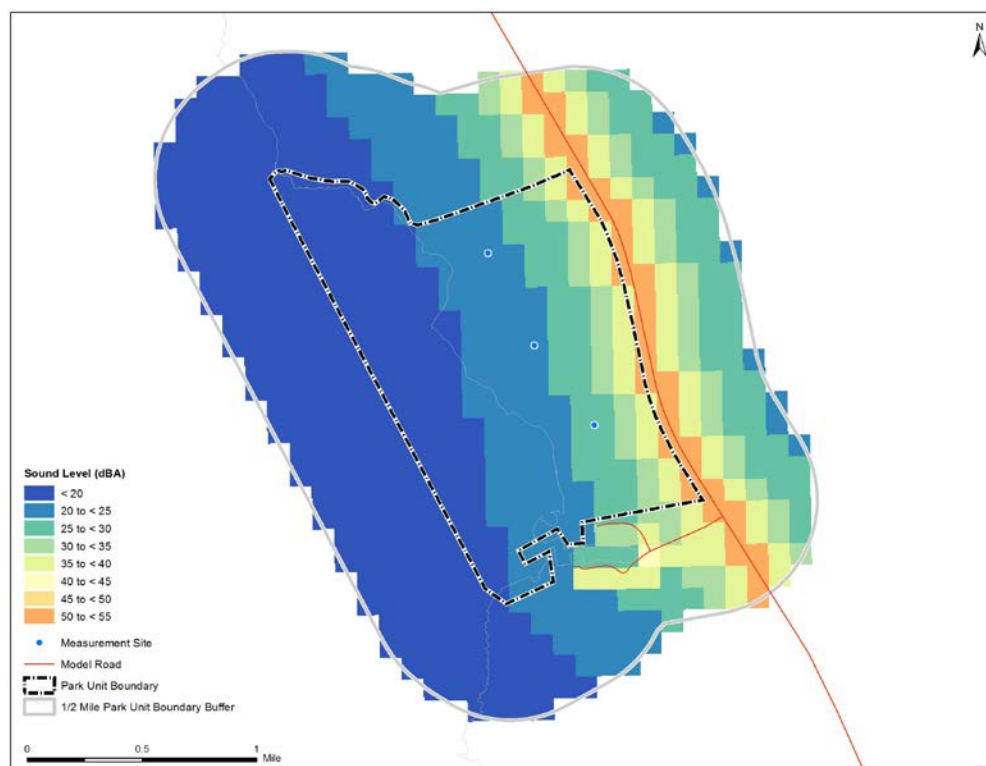


Figure 8. Roadway ambient map for Kaloko-Honokohau.

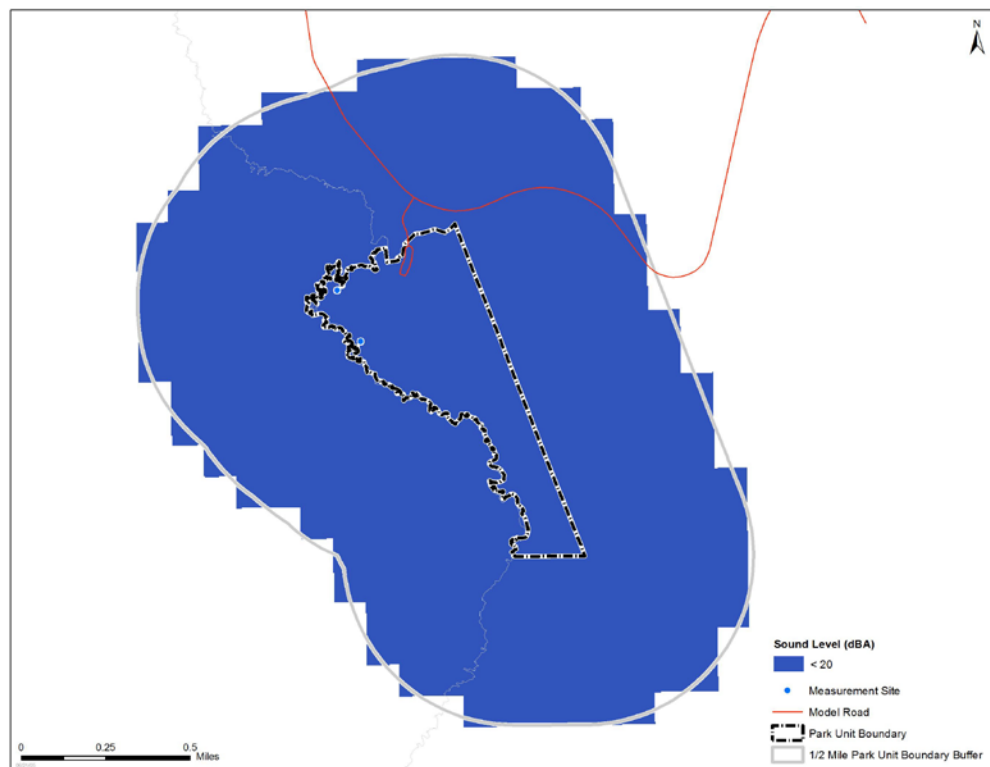


Figure 9. Roadway ambient map for Pu`uhonua o Honaunau.

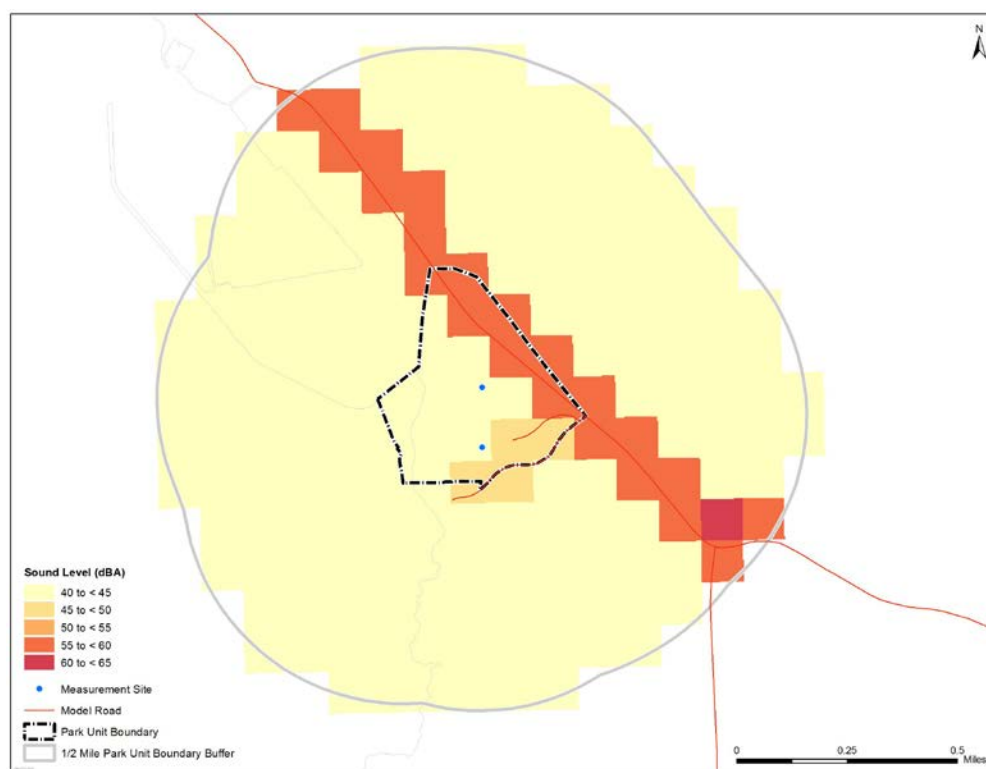


Figure 10. Baseline composite ambient map for Pu`ukohola Heiau – Existing Ambient Without Air Tours: L₅₀.

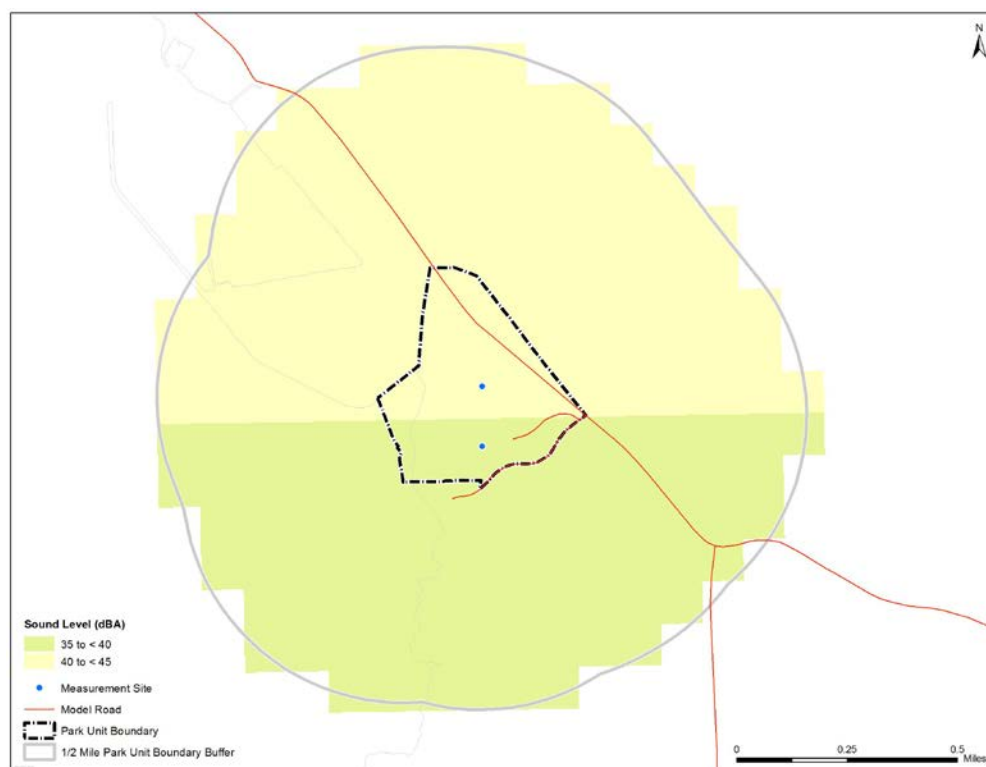


Figure 11. Baseline composite ambient map for Pu`ukohola Heiau – Natural Ambient: L₅₀.

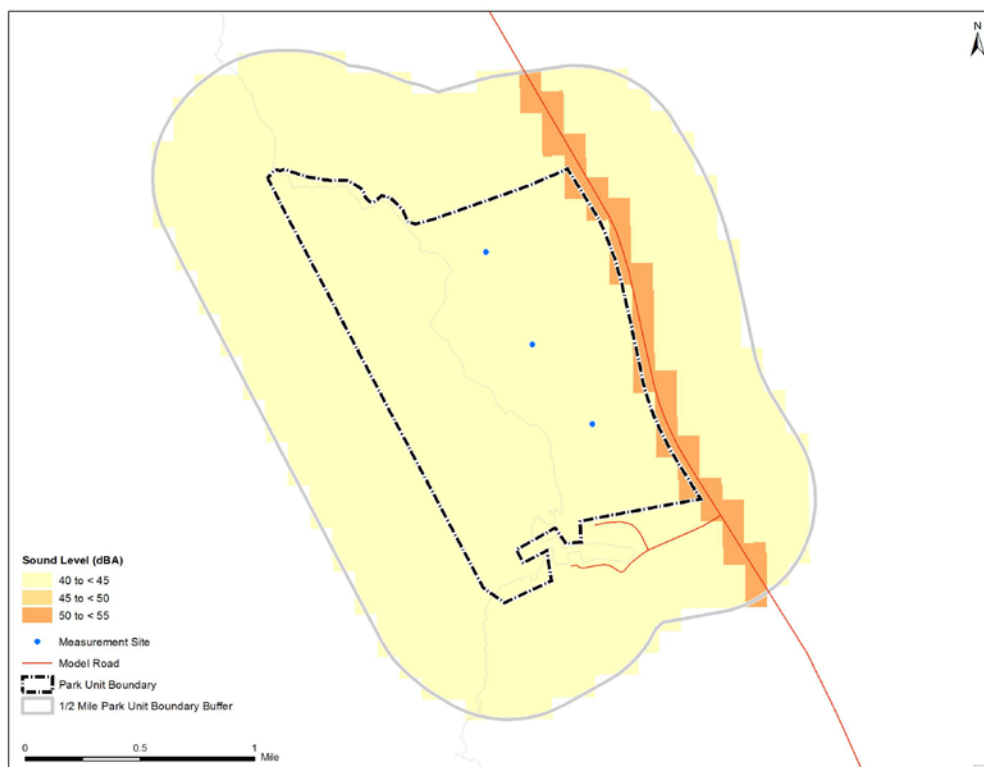


Figure 12. Baseline composite ambient map for Kaloko-Honokohau – Existing Ambient Without Air Tours: L₅₀.

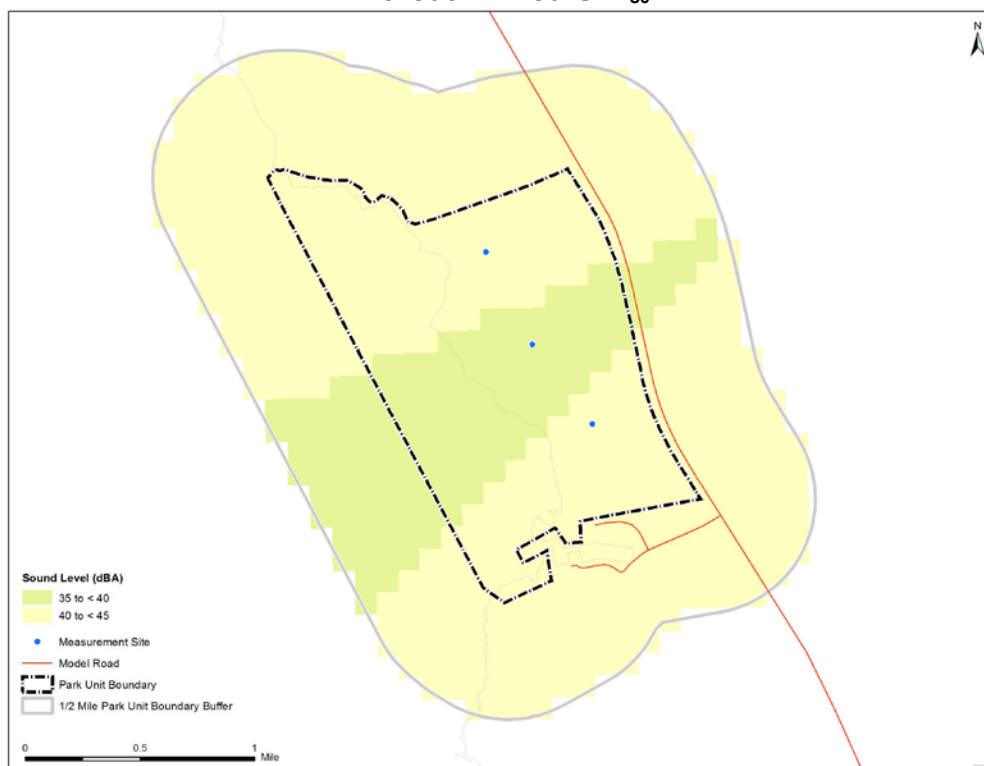


Figure 13. Baseline composite ambient map for Kaloko-Honokohau – Natural Ambient: L₅₀.

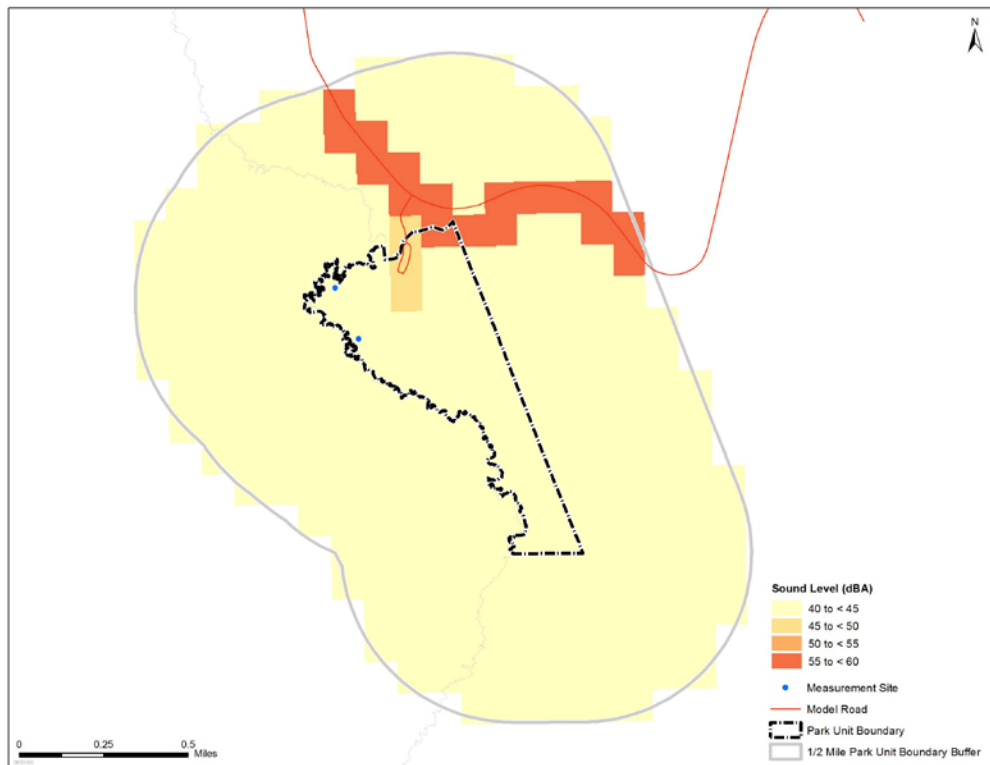


Figure 14. Baseline composite ambient map for Pu`uhonua o Honaunau – Existing Ambient Without Air Tours: L₅₀.

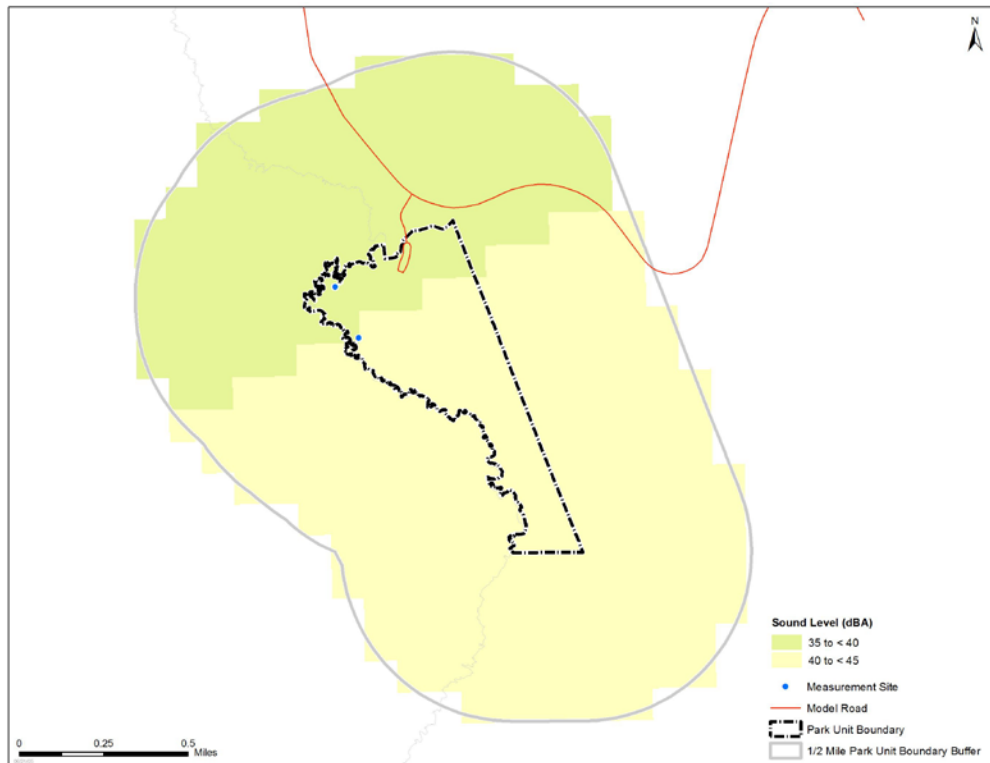


Figure 15. Baseline composite ambient map for Pu`uhonua o Honaunau – Natural Ambient: L₅₀.

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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 3 through 7.

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.

AA – Hawaiian word for jagged, rocky lava.

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 $10^{\text{LEV}/10}$, where LEV is the sound level, expressed in decibels.

AHUPUA`A – Hawaiian word for traditional sea to mountain land divisions.

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 μ Pa, the threshold of human hearing.

DOSE RESPONSE - Quantitative dose data (in this case noise data measured in the field), correlated with qualitative response data (in this case visitors' responses to a questionnaire).

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 μ Pa, the threshold of human hearing. L_{AeqT} is related to L_{AE} by the following equation:

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

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:

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

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.

HEIAU – Hawaiian word for a place of worship or a shrine.

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

KAPU – Hawaiian word ancient law against the Hawaiian gods .

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

L₉₀ - 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., L₅₀ and L₉₀.

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 Congress⁷ 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.⁸

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 model, 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.

PAHOEHOE – Hawaiian word for smooth, unbroken type of lava rock.

PALI – Hawaiian word for tall fault escarpment, cliff, steep hill or slope.

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

PHOTO-SCALING - The technique of photo-scaling relies on the geometric principle that the ratio of the lengths of the bases of two similar isosceles triangles is equal to the ratio of their heights. “Similar” in this context has the geometric meaning that the vertex angles of the isosceles triangles are equal. In photo-scaling, the first isosceles triangle has the distance from the observer to the object as the height of the triangle and the known length of the object as the triangle’s base. The second isosceles triangle has the camera/lens combination’s focal length as the height of the triangle and the length of the recorded image as the triangle’s base. This study used SAE Aerospace Information Report AIR 902 as the basis for determining the Closest Point of Approach (CPA) of an object moving relative to an observer.⁹

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.

PU`UHONUA – Hawaiian word a place of refuge.

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 17).

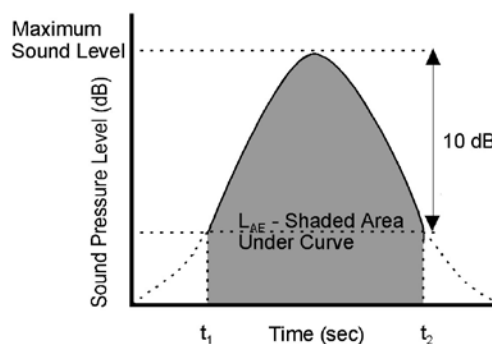


**Figure 16. Graphical representation
of L_{AE} .**

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

$$L_{AE} = 10Lg \left[\sum_{k=t_1}^{t_2} 10^{L_{AK}/10} \right] \quad (\text{dB})$$

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

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

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.

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

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).

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.¹⁰ 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. 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. Subsequent amendments exempted parks with 50 or fewer annual tours from NPATMA requirements and allowed for development of a Voluntary Agreement (VA) as an alternative to an ATMP.

The U.S. Department of Transportation, 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 and Night Skies Division, in the development of ATMPs and VAs. Approximately 85 park units have authorized air tours. These parks will either be exempt due to low annual operations (50 or fewer) or will need ATMPs or VAs developed. Some of these parks will require noise analyses, and a major component of establishing noise impacts is the determination of representative baseline sound levels, or ambient levels for each park. As it is neither economically nor expeditiously feasible to manually collect noise data under all possible conditions throughout an entire park, only through computer modeling will it be possible to assess the complete acoustical environment.

1.1 Scope

This document summarizes the baseline ambient measurement study conducted by the FAA, with assistance of the Volpe Center's Environmental Measurement and Modeling Division, and the NPS during June 2003, in Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau.

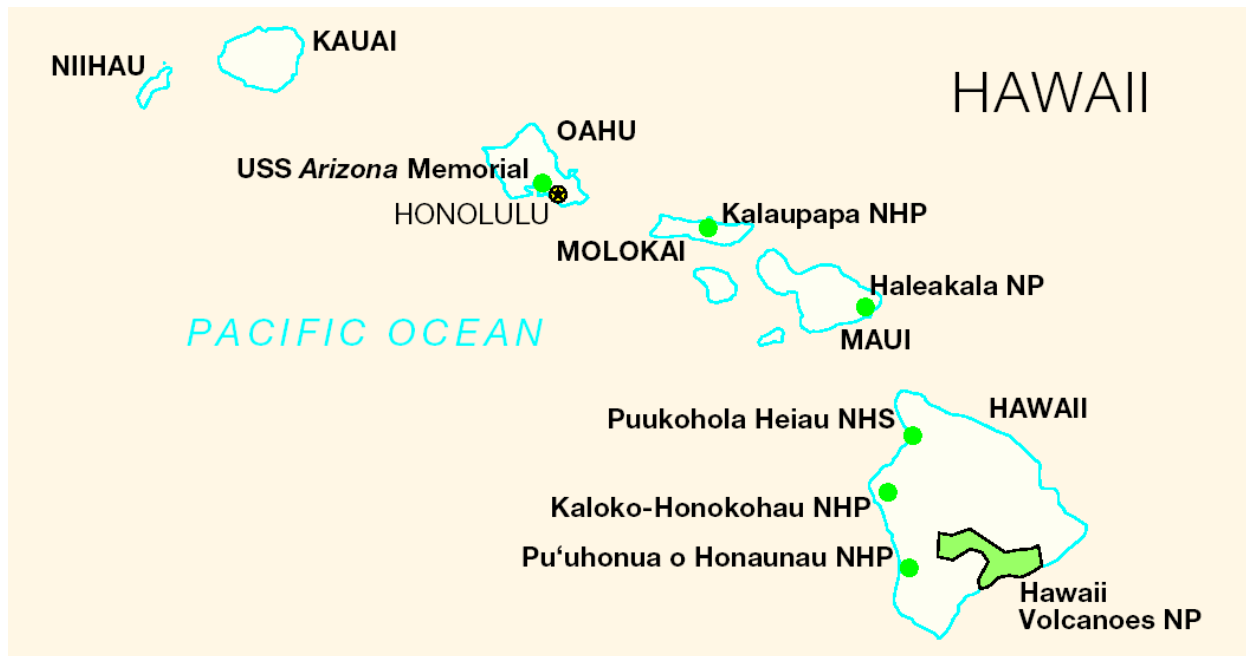


Figure 17. Location of national park units within the State of Hawai'i.

As shown in Figure 18, Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau are located on the big island of Hawai'i. A close-in view of the big island is shown in Figure 19. A more detailed description of the park can be found in Section 2 of this document.



Figure 18. Location of Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau.

1.2 Objectives

The primary objective of this study is to quantify the baseline ambient sound levels within each park to establish a foundation from which potential noise impacts can be assessed.

Approximately one week of acoustical and meteorological data were measured at multiple sites

at each 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 each park;
- Establishing the different sound sources contributing to the baseline levels in key areas within each park;
- Modeling sound levels in other similar areas within each park for which resource constraints (or other issues) do not allow for direct measurements; and
- Building a library of baseline ambient sound levels (both overall and frequency based), which may potentially be used in ATMPs or VAs to generalize baseline ambient sound levels within similar types of parks, or park areas to those encountered at each park.

The data will be used as input into the FAA's Integrated Noise Model (INM) ^{*,11} which will be used to assess the complete acoustical environment within the entire park. INM is a computer program used by over 700 organizations in over 50 countries to assess changes in noise impact. The INM model was recommended by the Federal Interagency Committee on Aviation Noise (FICAN), as the best-practice modeling methodology currently available for evaluating aircraft noise in national parks, and agreed to by the NPS and FAA. ^{Error! Bookmark not defined.,2}

In addition, an ancillary objective is to further refine an FAA- and NPS-accepted site selection and data collection protocol for use in ATMPs / VAs. The protocol is based upon the document, Draft Guidelines for the Measurement and Assessment of Low-Level Ambient Noise,¹² and discussions with the members of the FAA Western-Pacific Region and NPS Natural Sounds and Night Skies Division.

1.3 Report Organization

The presentation of this document, entitled "Pu`ukohola Heiau National Historic Site, Kaloko-Honokohau National Historical Park, and Pu`uhonua o Honaunau National Historical Park: Baseline Ambient Sound Levels 2003" begins with an executive summary and glossary. Section

^{*} As of May 2015, the Aviation Environmental Design Tool (AEDT) has replaced INM.

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 data analysis. Section 7 presents the results of the study. 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 discusses the acoustic zone analysis. All related references are presented at the end of this document.

2. SITE SELECTION

All three parks are located on the big island of Hawai`i. Pu`ukohola Heiau is located on the northwestern shore of the big island in the district of south Kohala. The *Heiau* (a place of worship or a shrine) is the one structure on the Hawaiian Islands with which the founding of the Hawaiian kingdom can be directly associated. It was built by Kamehameha I, the first Hawaiian king, as British sailor, John Young, who fought for Kamehameha, looked on. The monarchy Kamehameha built lasted 83 years. Establishment of the park was authorized by Congress in 1972, and the 86-acres national park unit preserves several historic sites.

Kaloko-Honokohau encompasses 1161 acres and is located on the western coast of the big island near the town of Kailua-Kona. The park was established as a National Historical Park in 1978 for the preservation, interpretation, and perpetuation of traditional native Hawaiian activities and culture. The park is also the site of an ancient Hawaiian settlement which encompasses portions of four different *ahupua`a* (traditional sea to mountain land divisions).

Pu`uhonua o Honaunau is located on the southwestern coast of the Big Island of Hawai`i, and preserves the site where, up until the early 19th century, Hawai`ians who broke a *kapu* (ancient law against the Hawaiian gods) and other outcasts from Hawaiian society were able to find refuge. The park was established in 1961 and includes the *Pu`uhonua* (place of refuge), a complex of archeological sites, and some reconstructed historical structures. The park's 420 acres includes a 3.7-acre detached upland parcel (called Kihapai uka, or the upland garden) located approximately along the main entrance road.¹³ The detached parcel is connected to the ocean parklands via a waterline easement across lands owned by the Bishop Estate. Thus, this chapter will describe the existing resources of the "main park parcel" and "detached park parcel" where appropriate.

Figure 20 through Figure 22 provide a general overview of the areas within each of the three parks.

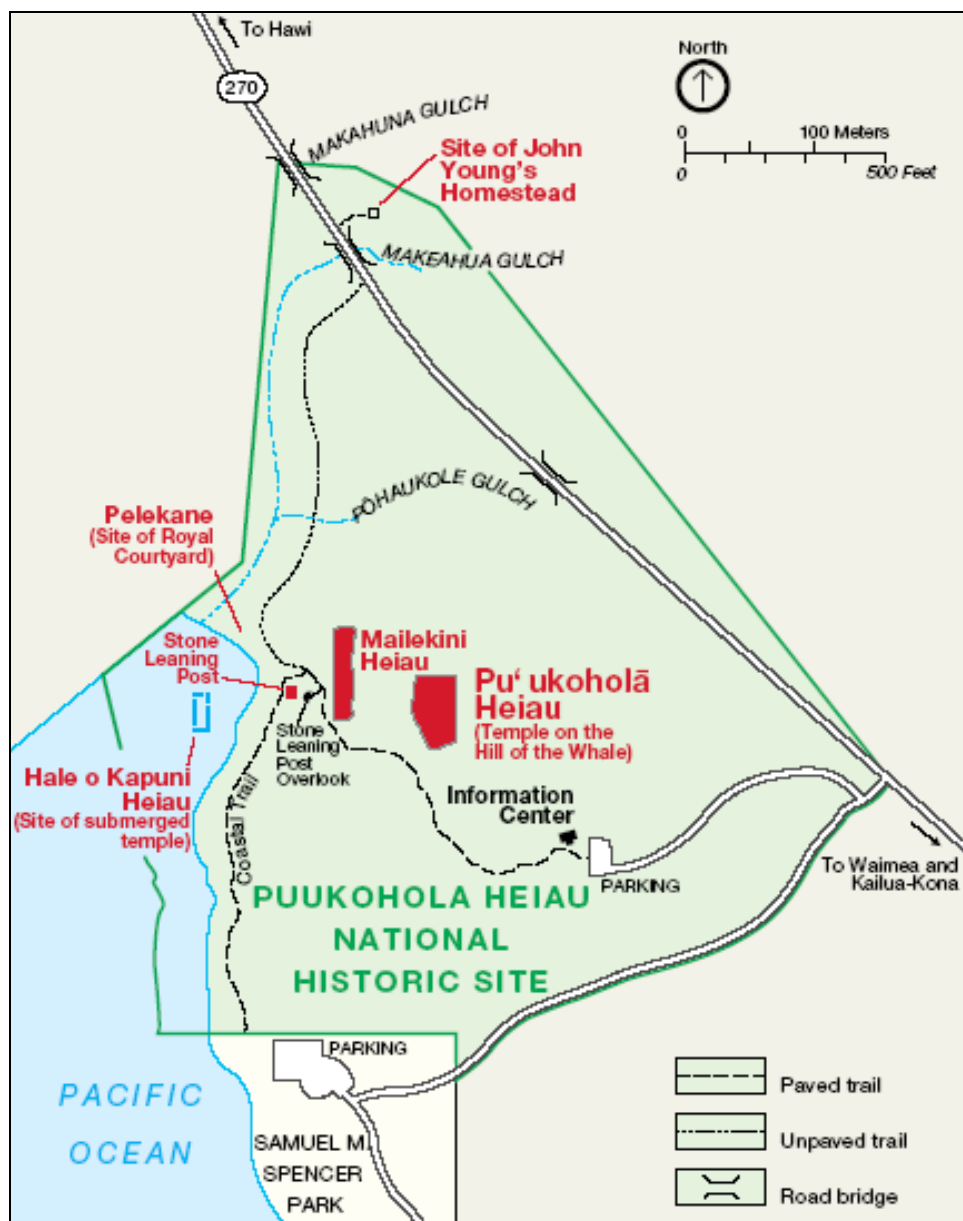


Figure 19. Overview map of Pu`ukohola Heiau.

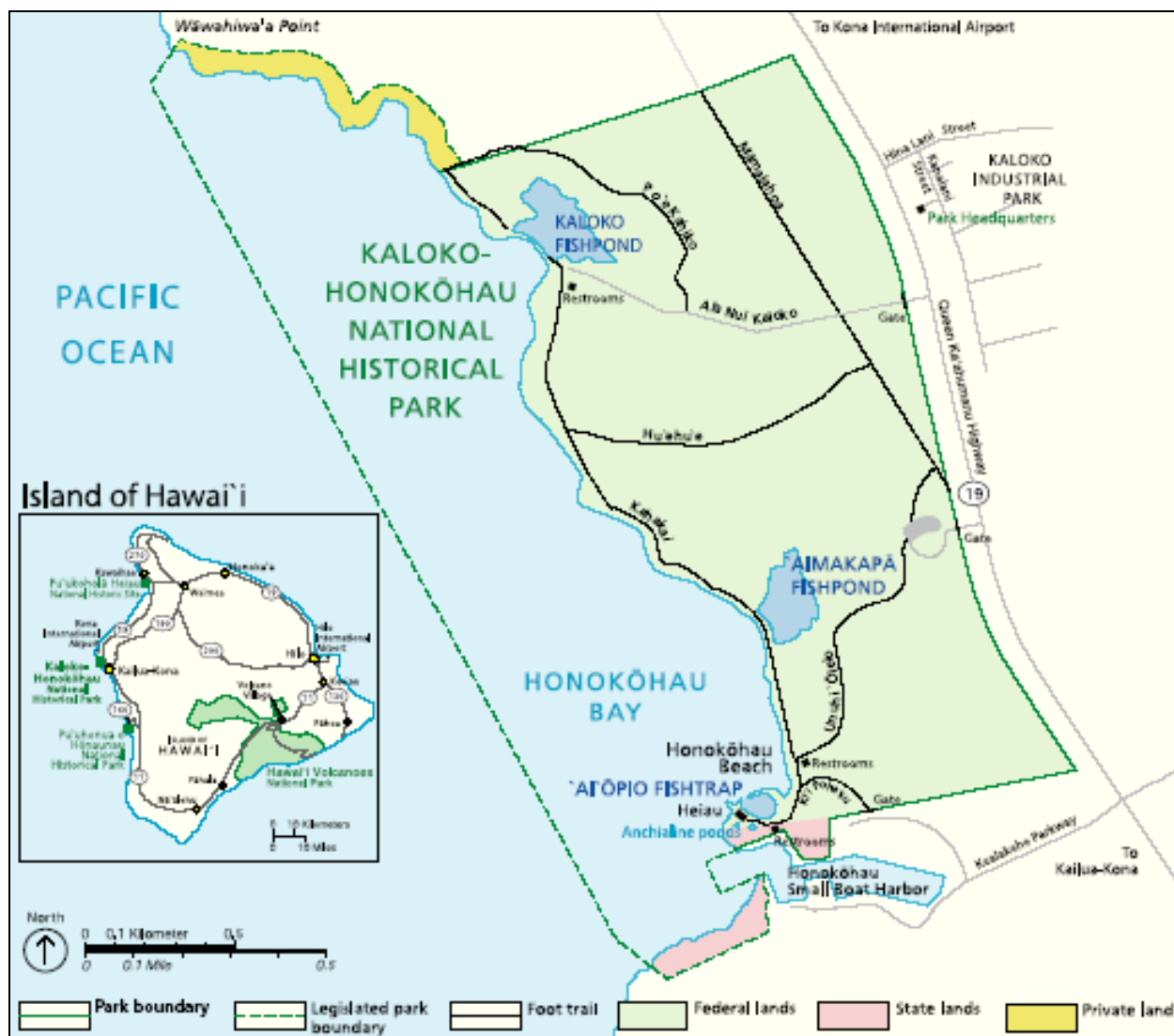


Figure 20. Overview map of Kaloko-Honokohau.

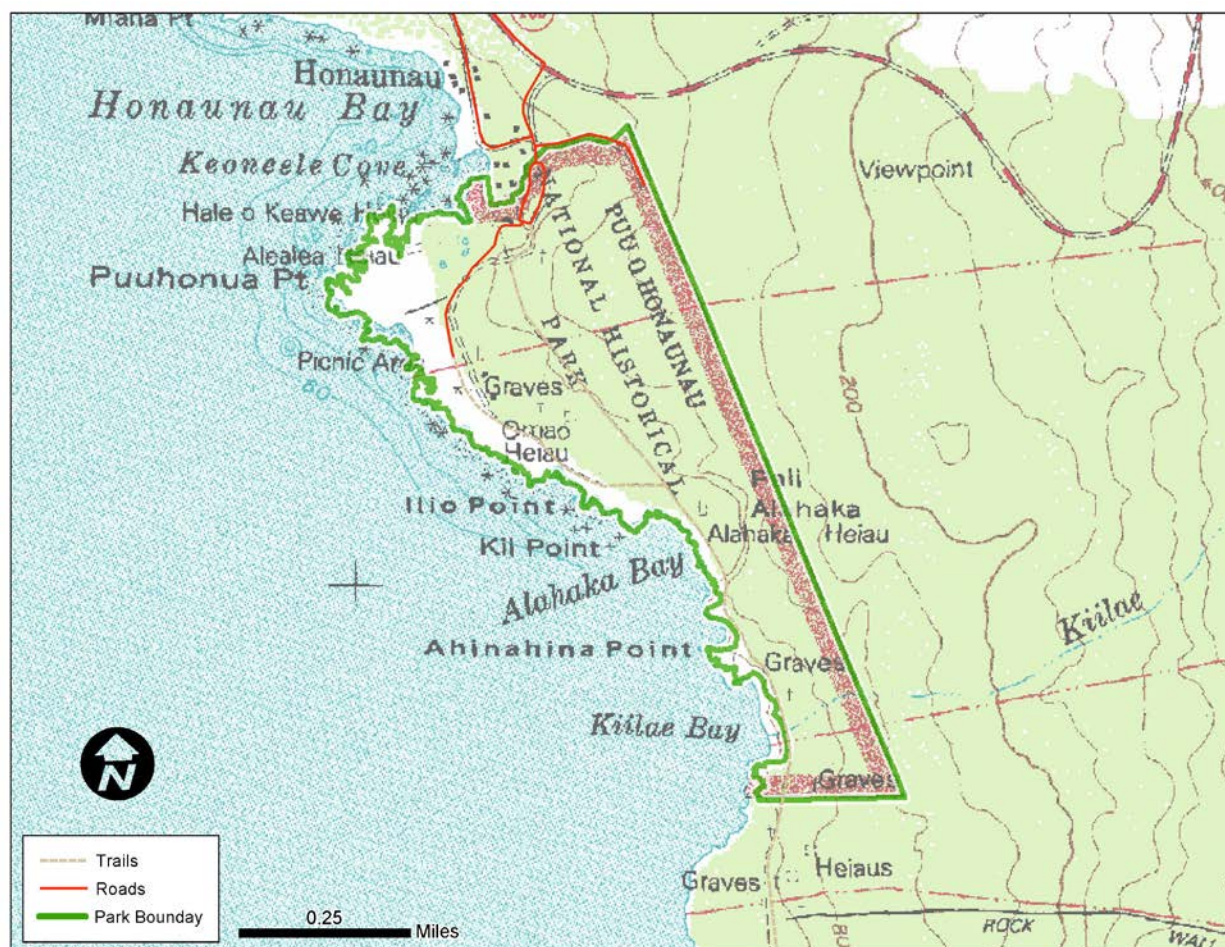


Figure 21. Overview map of Pu`uhonua o Honaunau.

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.^{14,15,16,17}

- *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 the 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 technical criteria are then combined with the following secondary criteria to determine the final sites selected (see Section 2.7):

- *Park Resources/Management Zones (see Section 2.4):* As the objective of the ATMPs and VAs 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 or VAs to reduce or eliminate 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.
- *Logistics/Access (see Section 2.7):* 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

The main plant communities that occur within Pu`ukohola are dry scrub grassland (dominated by introduced grasses and scattered introduced kiawe, or *Prosopis pallida*, trees), closed kiawe forest along the coast and in the northern part of the park (with a narrow strip of native strand plants along portions of the shoreline), and a halophytic (plants that can tolerate or thrive in alkaline soil, rich in sodium or calcium salts) community near a brackish pond.

Kaloko-Honokohau is mostly dominated by alien plants – although the coastal strand and the wetlands around the two large fishponds support vegetation in which native and Polynesian species are still prominent. Elsewhere in Kaloko-Honokohau, *pahoehoe* (smooth, unbroken type of lava rock) substrates are covered by a mixture of mostly alien grasses and shrubs. The most recent *aa* (volcanic rock consisting of angular blocks of lava with a very rough surface) flow in the center of the Kaloko-Honokohau is nearly bare of vegetation, and the 3,000-5,000 year old flow in the northern and central part of the park is also sparsely vegetated.

Nearly all of the vegetation at the main park parcel of Pu`uhonua o Honaunau is composed of alien plant species, primarily in the form of shrubs, grasses, sedges, forbs, and trailing vines.

Most of the native species are found near the shoreline of the park or as plantings near the visitor center.

Figure 23 through Figure 25 provide an overview of the general land cover in each park.

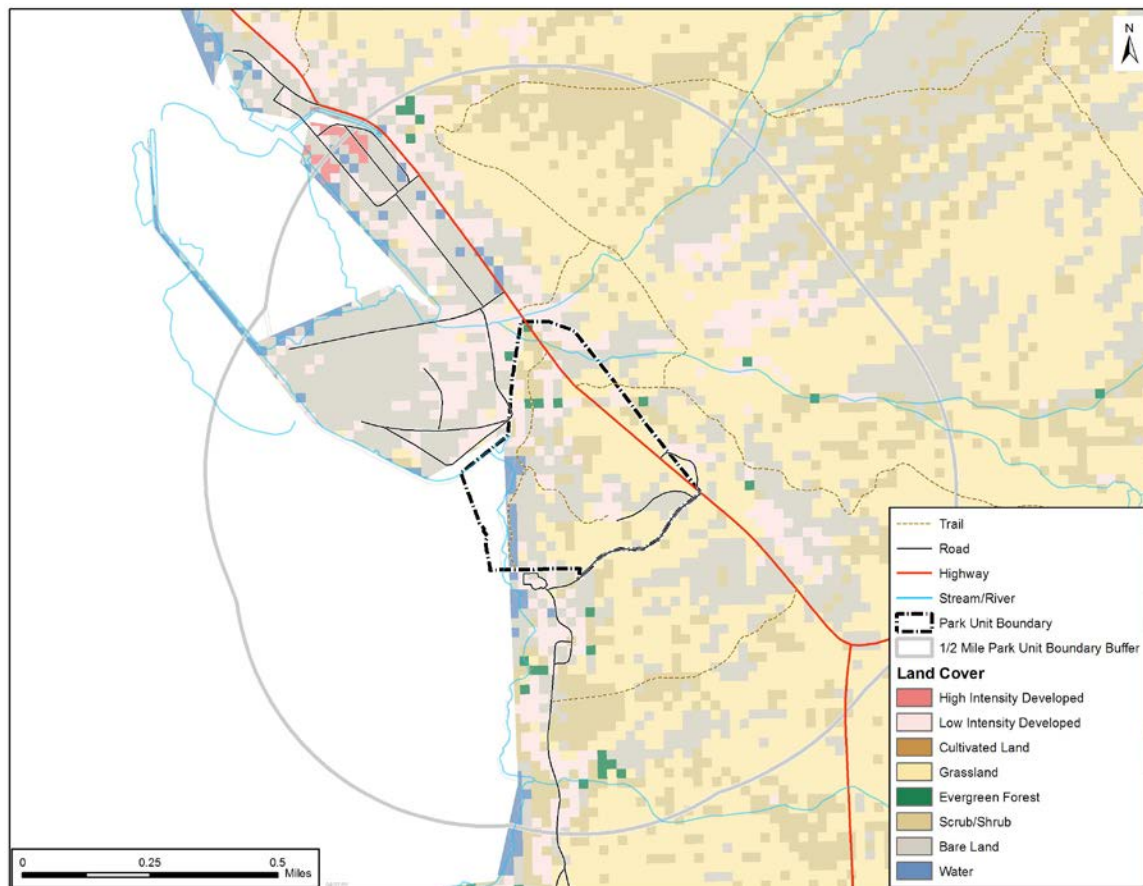


Figure 22. Land cover in Pu`ukohola Heiau.



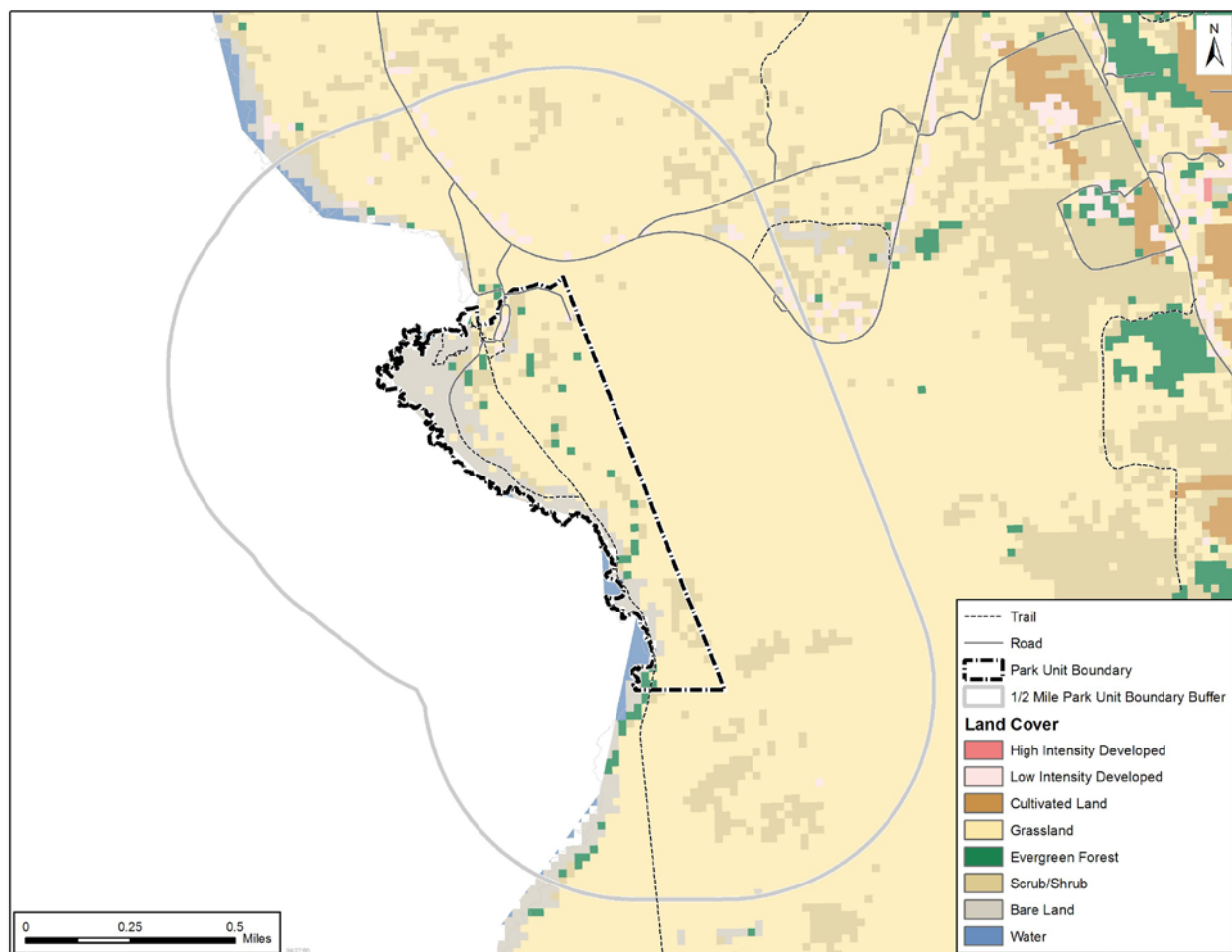


Figure 24. Land cover in Pu`uhonua o Honaunau.

2.3 Climate Conditions

The climate at all three parks is warm and relatively dry. Trade winds, and the showers they often bring, are uncommon along the Kona coast because the winds are blocked by Mauna Kea and Mauna Loa Volcanoes. There are rare periods of prolonged showers, usually occurring during winter storms that take place most frequently from December through February. Coming from the west and south, these storms bring with them high winds, high seas, and heavy rains. Tsunamis have occurred infrequently along the Kona coast.

Table 5 through Table 7 provide the monthly climate summary (averaged from 1949 through December 2004) recorded by meteorological station in the general vicinity of each park.¹⁸

Table 5. Monthly climate summary for Pu`ukohola Heiau.

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (mph)	8.0	8.3	8.5	8.4	8.2	8.2	8.4	8.5	8.2	8.1	8.1	8.2
Prevailing Direction	E	E	W	W	W	SSW	SSW	WSW	WSW	SW	S	ESE
Average Max Temp (F)	79.9	79.5	79.9	80.8	82.5	84	84.6	85.4	85.8	85.1	82.7	80.6
Average Min Temp (F)	66.4	66.2	66.7	67.2	68.4	69.2	70.3	71.2	71.4	71	69.6	67.6
Average Total Precipitation (in)	4.36	2.98	4.16	2.93	1.7	1.93	2.27	2.41	1.28	1.9	3.25	3.47
Average Total Snow Fall (in)	0	0	0	0	0	0	0	0	0	0	0	0

Table 6. Monthly climate summary for Kaloko-Honokohau.

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (mph)	8.0	8.3	8.5	8.4	8.2	8.2	8.4	8.5	8.2	8.1	8.1	8.2
Prevailing Direction	E	E	W	W	W	SSW	SSW	WSW	WSW	SW	S	ESE
Average Max Temp (F)	76.6	76.6	76.7	76.7	76.7	77.1	78.5	79.5	79.8	80	78.9	77.3
Average Min Temp (F)	58.7	58.6	59.1	60.2	61.5	62.7	63.2	63.8	63.4	62.9	61.5	59.7
Average Total Precipitation (in)	4.3	2.64	4.3	5.49	6.2	6.66	7.89	7.28	7.17	4.81	3.66	2.9
Average Total Snow Fall (in)	0	0	0	0	0	0	0	0	0	0	0	0

Table 7. Monthly climate summary for Pu`uhonua o Honaunau.

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (mph)	8.0	8.3	8.5	8.4	8.2	8.2	8.4	8.5	8.2	8.1	8.1	8.2
Prevailing Direction	E	E	W	W	W	SSW	SSW	WSW	WSW	SW	S	ESE
Average Max Temp (F)	76.3	76.4	76.8	77.3	78	78.6	79.9	80.7	80.5	80.5	79	77.3
Average Min Temp (F)	57.2	57.2	58.2	59.6	61.3	62.5	63.3	63.7	63.1	62.2	60.7	58.2
Average Total Precipitation (in)	3.33	2.38	3.52	2.99	3.45	3.28	3.86	3.85	4.26	3.5	3.39	2.77
Average Total Snow Fall (in)	0	0	0	0	0	0	0	0	0	0	0	0

2.4 Park Resources/Management Zones

Figure 26 through Figure 28 present a map of the cultural, natural, and visitor resources of each park.¹⁹ Measurement sites were chosen keeping in mind these various uses and management designations of the park lands.

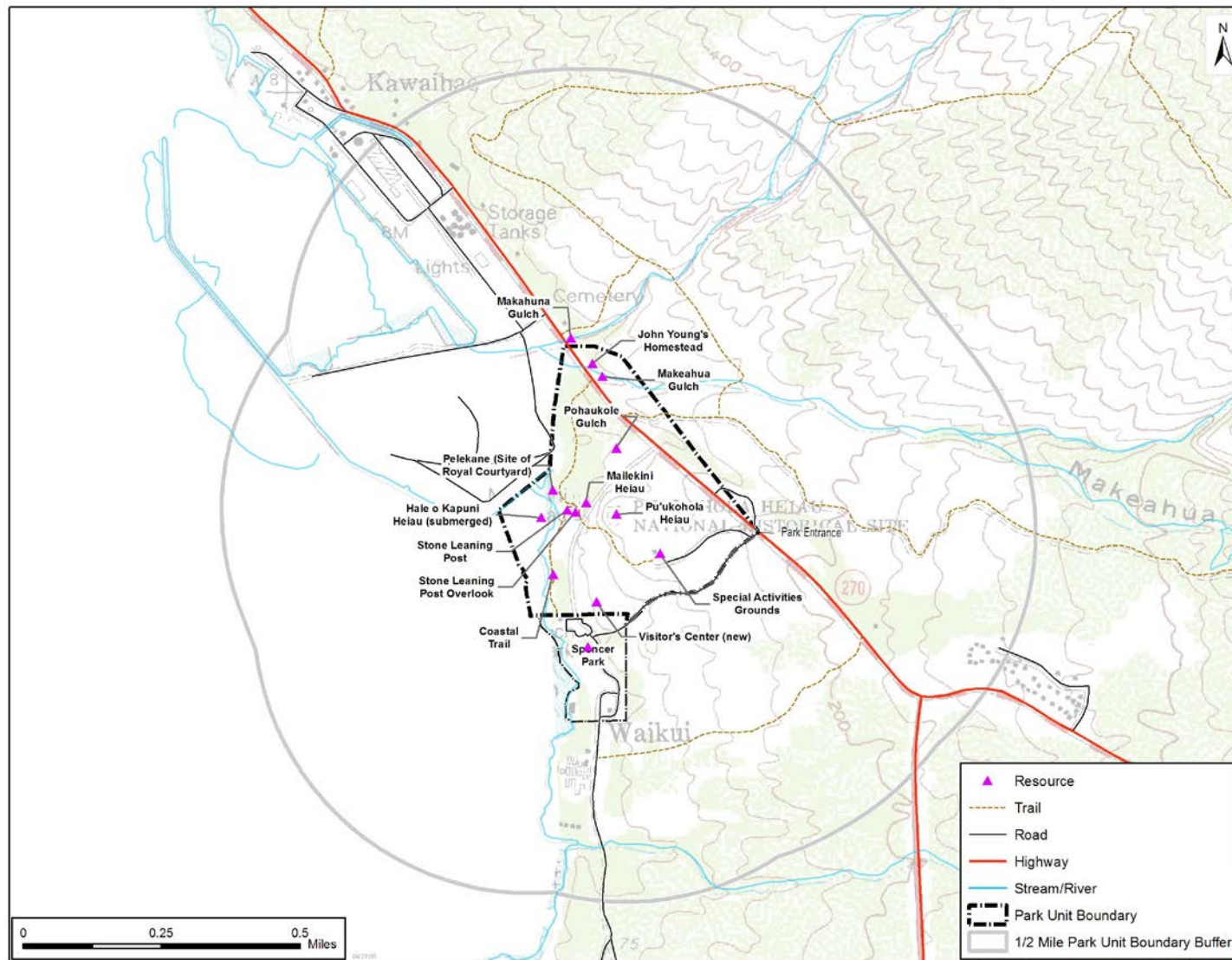


Figure 25. Natural, cultural, and visitor resources in Pu`ukohola Heiau.

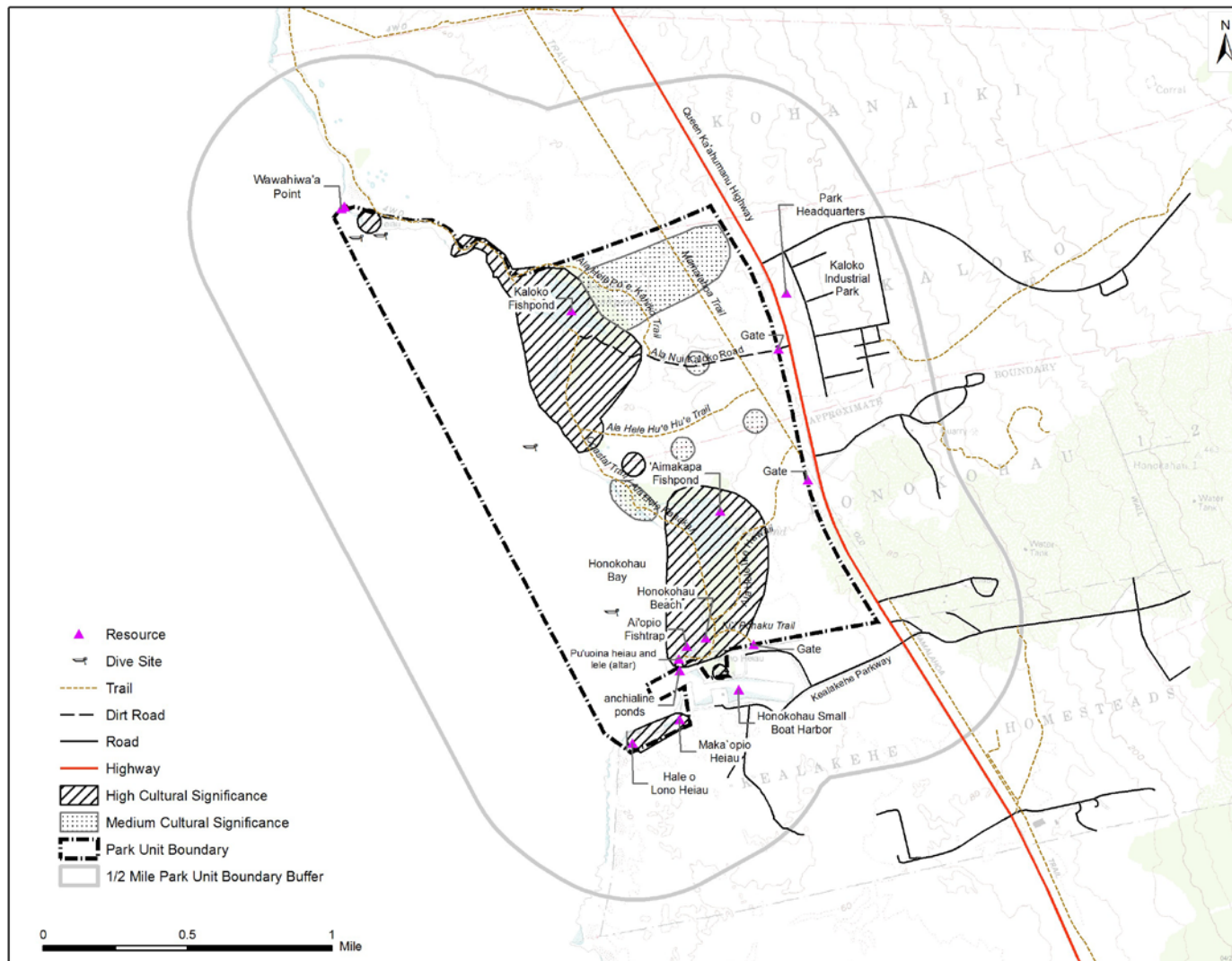


Figure 26. Natural, cultural, and visitor resources in Kaloko-Honokohau.

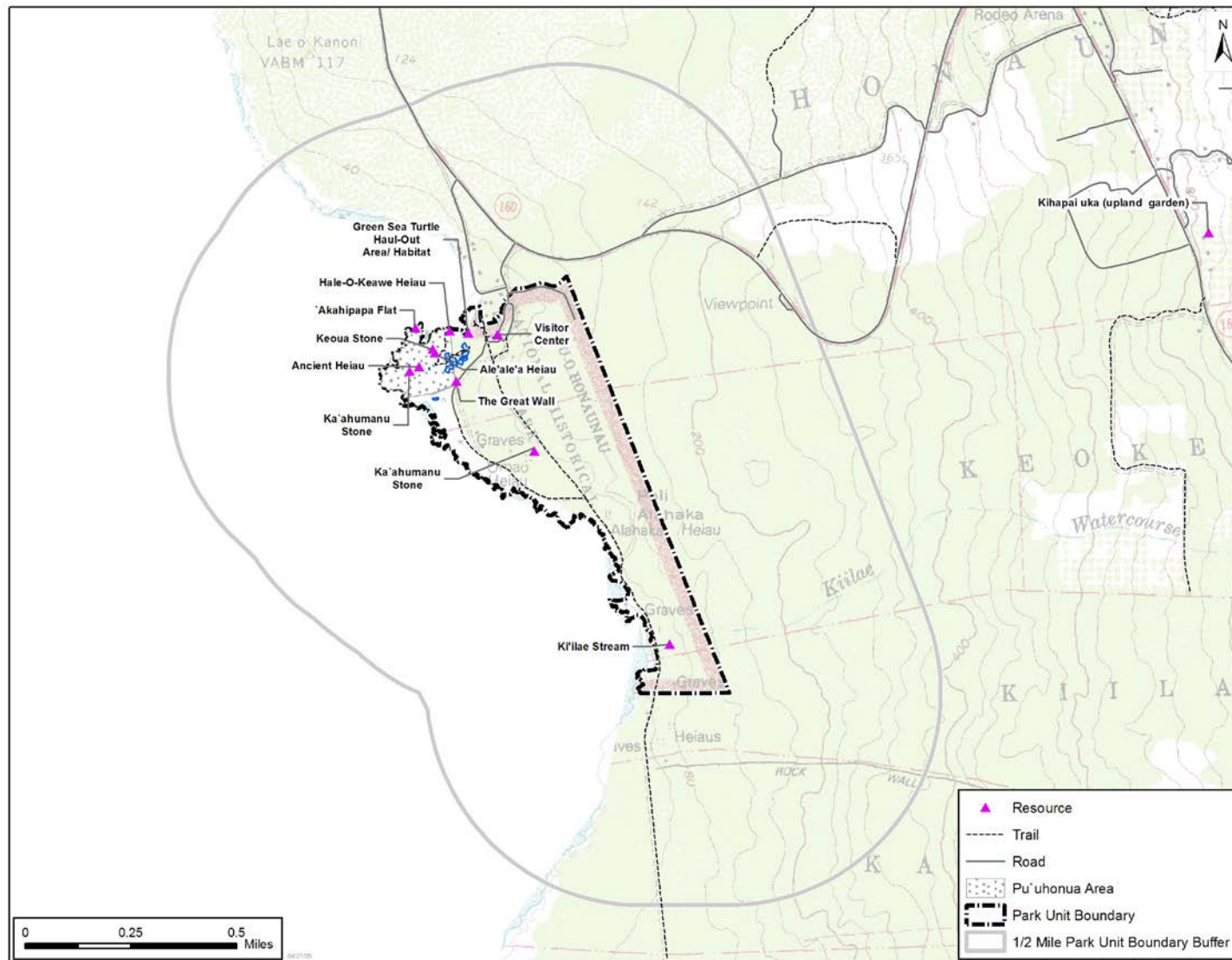


Figure 27. Natural, cultural, and visitor resources in Pu`uhonua o Honaunau.

2.5 Commercial Air Tour Flight Routes

In working with individuals, communities, private and public associations and agencies, and others to resolve issues of concern relating to sound abatement and air safety of air tours throughout Hawai`i, the FAA Flight Standards District Office (FSDO) in Honolulu, the Hawai`i Volcanoes NPS, and local air tour operators established Special Federal Aviation Regulation (SFAR) 71 Procedures Manual.²⁰ SFAR 71 prescribes visual flight rules for fixed-wing airplane and helicopter air tour flights conducted in the State of Hawai`i. The general air tour routes shown in Figure 29 below were provided by the Hawai`i FSDO.

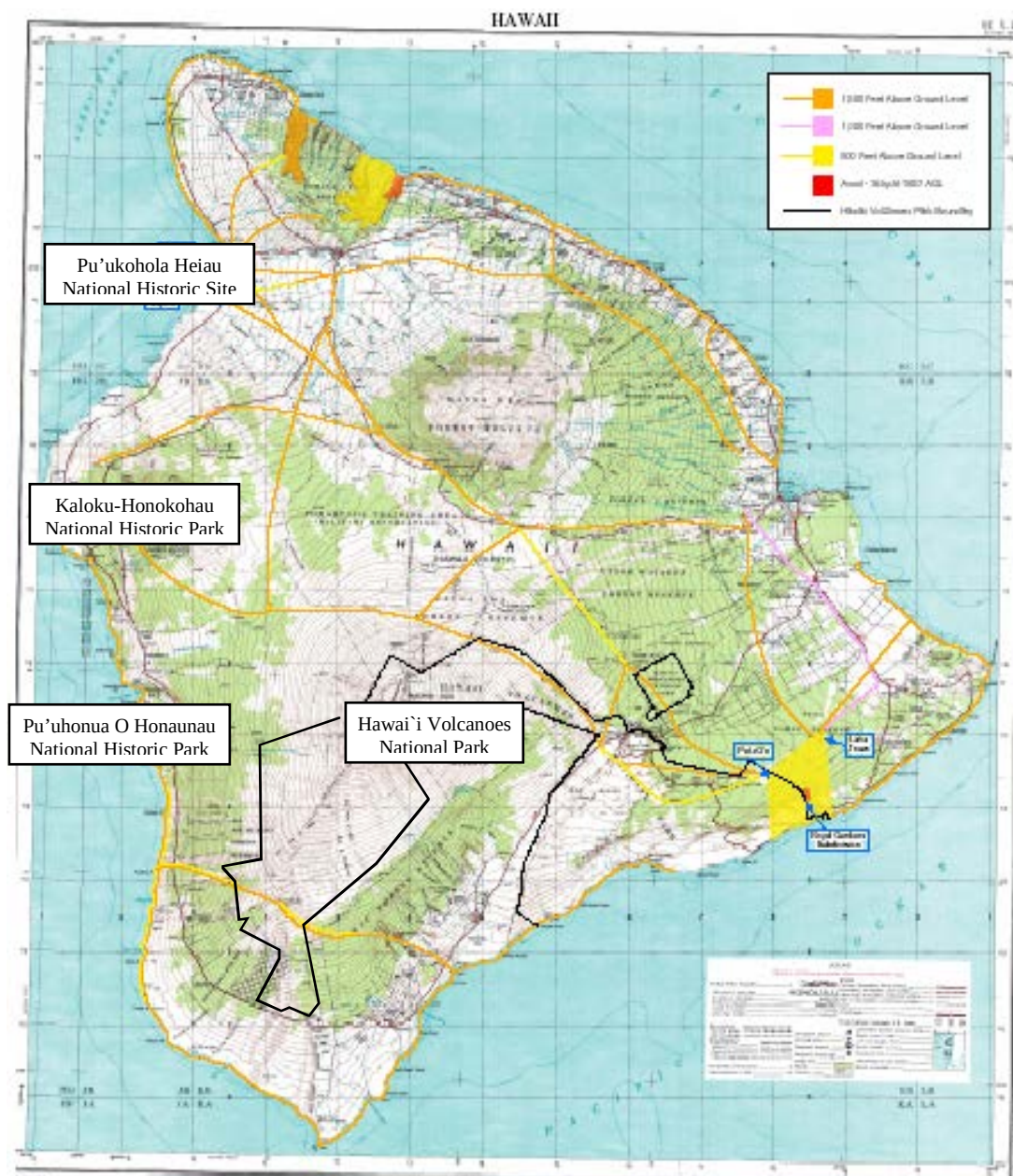


Figure 28. Air tour routes in the vicinity of Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau.

2.6 Acoustic Zones and Final Measurement Sites

Because each park is so small, it was agreed that each park would be considered a single acoustic zone and measurement sites would be located near specific park resources. Figure 30 through Figure 32 and Table 8 below summarize the final measurement sites selected. Appendix A contains individual descriptions and photographs of each measurement site location.

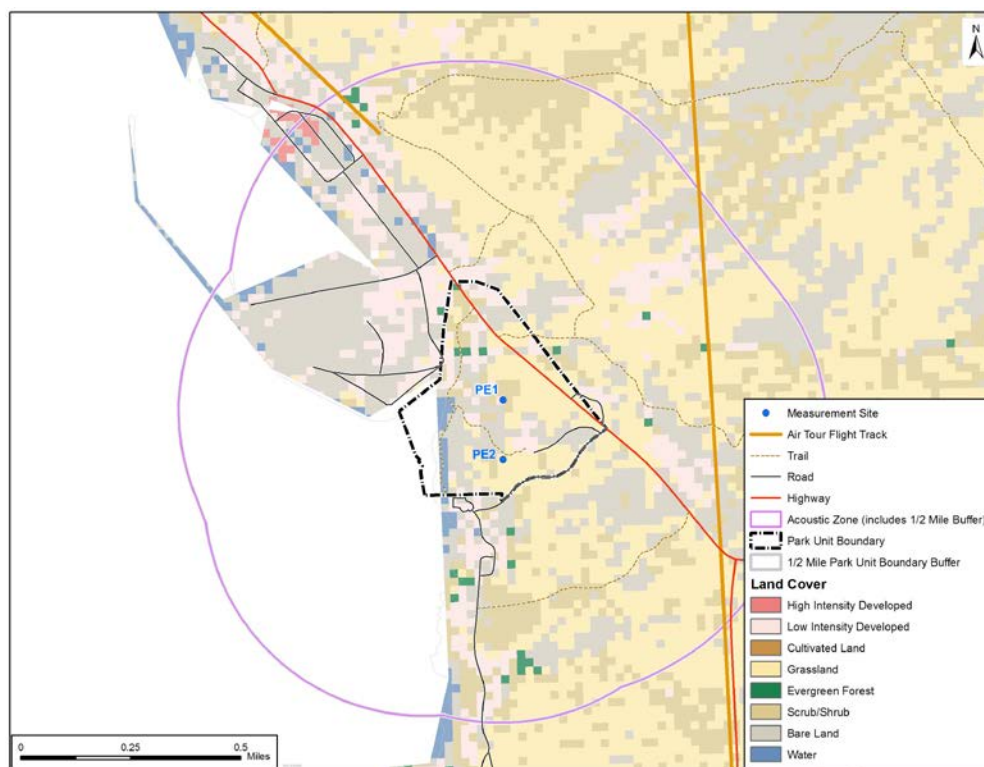


Figure 29. Final measurement sites for Pu`ukohola Heiau.

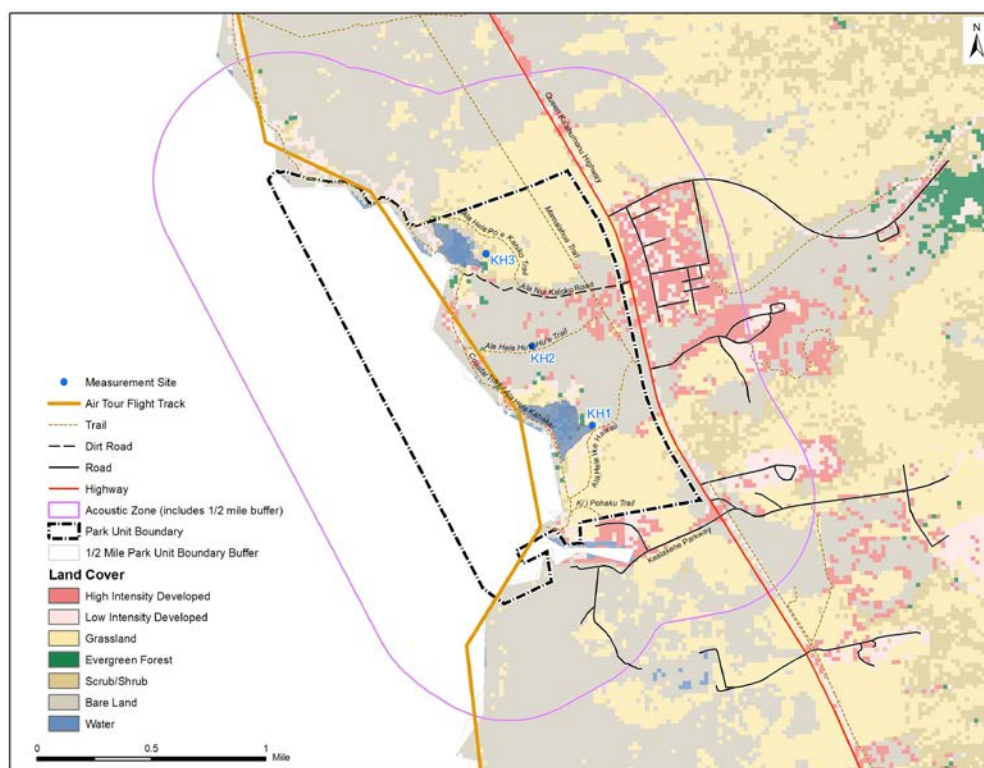


Figure 30. Final measurement sites for Kaloko-Honokohau.

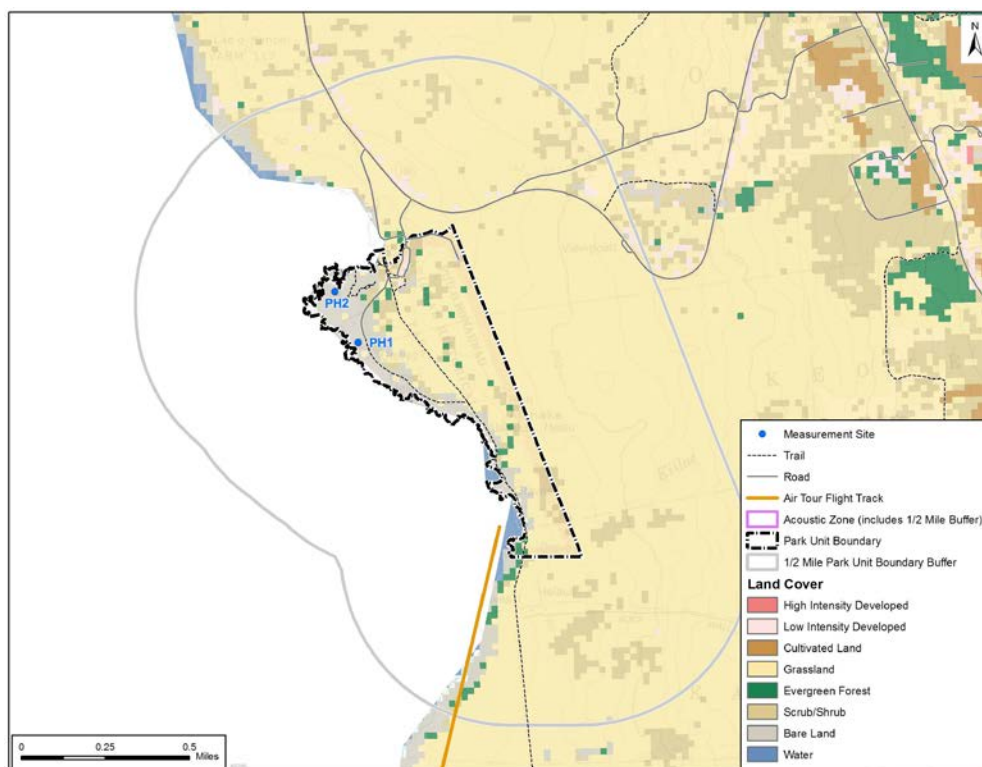


Figure 31. Final measurement sites for Pu`uhonua o Honaunau.

Table 8. Summary of measurement sites selected.

Park Name	Site #	Site Name	Vegetation/ Land Cover	Lat/Lon (decimal degrees)	Approx. Elevation	Site Category	Management Zone
Pu`ukohola Heiau	PE1	Site at Heiau	31 Bare Rock/Sand/Clay	20.0349 / 155.8243	124 ft	Overlook	Natural/Cultural
Pu`ukohola Heiau	PE2	Visitor Center Trail	51 Shrubland	20.0324 / 155.8234	109 ft	Short Hike	Natural/Cultural
Kaloko- Honokohau	KH1	`Aimakapa Fishpond	Shrubland	19.6843 / 156.0291	18 ft	Short Hike	Natural/Cultural
Kaloko- Honokohau	KH2	Hu`ehu`e Ranch Road	Bare Rock/Sand/Clay	19.6934 / 156.0390	24 ft	Short Hike	Natural/Cultural
Kaloko- Honokohau	KH3	Kaloko Fishpond	Bare Rock/Sand/Clay	19.6896 / 156.0413	16 ft	Short Hike	Natural/Cultural
Pu`uhonua o Honaunau	PH1	Mauka of 1871 Trail	31 Bare Rock/Sand/Clay	19.4622 / 155.9163	9 ft	Short Hike	Natural/Cultural
Pu`uhonua o Honaunau	PH2	Palace Grounds	31 Bare Rock/Sand/Clay	19.4242 / 155.9186	7 ft	Overlook	Natural/Cultural

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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 low-level ambient measurement system used for this study.

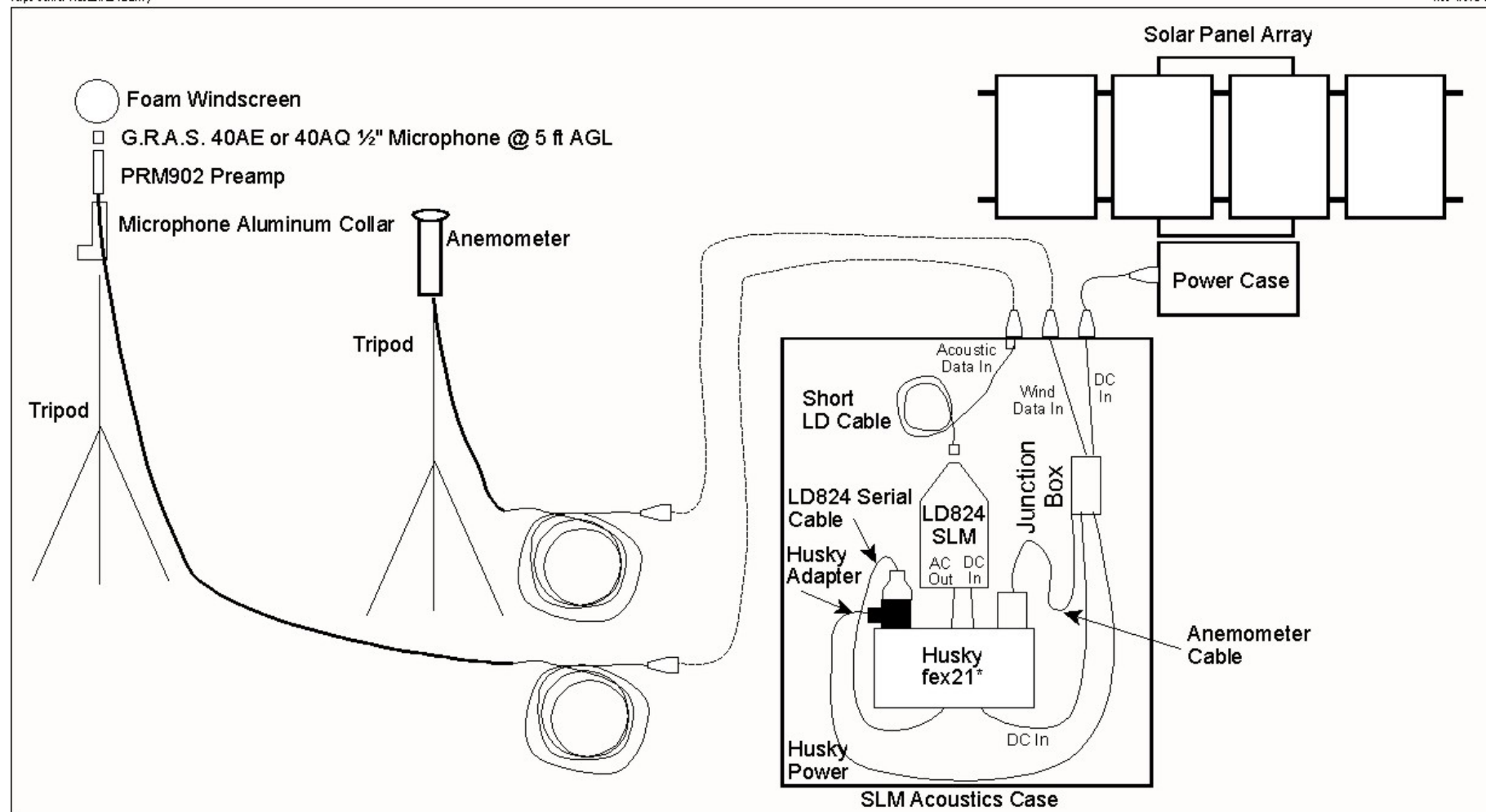
3.1 NoiseLogger™ Continuous Monitoring System

This system is a specialized measurement system used to conduct unattended, long-term (30+ days), continuous one-third 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 the system.²¹

The system uses a large diameter windscreen and a ½-inch electret condenser microphone, interfaced with a sound level meter and a Personal Digital Assistant (PDA) device 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. Figure 33 illustrates the basic components of the system.

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CL:FAA/AT&P/Equipment/Instrumentation_NoiseLogger.wpg

Figure 32. NoiseLogger™ continuous monitoring system.

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, these models of microphone function 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.

A 12-in (30 cm) diameter foam windscreen (400 pores/sq. in. porosity) custom designed by Musashi Kasei Co., Ltd. for outdoor monitoring applications was placed atop each microphone to reduce 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 one-third 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 Ultrasonic Anemometer

Two types of ultrasonic anemometers were used in this study: the Gill[™] Instruments Model WindObserver II and the FT Technologies[™] Model 702. The WindObserver II samples wind speed and direction at a rate of 40 samples per second and provides a 1-second averaged output that was stored in the Husky[™] H/PC. 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.

3.1.5 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, two marine batteries were used. The two marine batteries provided enough power to support collection of data for approximately two weeks between charges; 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 Acoustic Observer Log

During staffed measurements, a field observer continuously documented the acoustic environment at the site. 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 or Jornada hand-held computer. Using pre-programmed 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.

3.3 Other Instrumentation

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

1. *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.
2. *Pink-noise generator* - A small, portable, signal generator was used to establish the frequency response characteristics of the entire electrical system absent of the microphone.* The signal generator produces pink noise, a random signal for which the spectrum density, i.e., narrow-band signal, varies as the inverse of frequency.
3. *Microphone simulator* - A microphone simulator was used to establish the electronic noise floor of the entire electrical system absent of the microphone.
4. *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.

* Note: Frequency-response calibration was not performed on the NoiseLogger™ system, as the Husky™ Fex-21 H/PC running the NoiseLogger™ software did not display sound levels in one-third octave-band frequencies.

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4. FIELD MEASUREMENT PROCEDURES

This section presents the field measurement procedures utilized in the study. Data collection was accomplished by the NPS, Natural Sounds and Night Skies Division, personnel, who were trained by the Volpe Center during the baseline ambient measurement study at Haleakala National Park in March 2003.²² Sections 4.1 and 4.2 present a step-by-step description of the field measurement procedure, including deployment and dismantling.

4.1 NoiseLogger™ System Deployment

Figure 34 shows the NoiseLogger™ system as deployed in the field at Site PH2.



Figure 33. NoiseLogger™ system deployment; Site PH2.

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 microphone and anemometer system cables were connected to the SLM acoustic case.
4. The solar panel array was deployed facing due south to ensure maximum exposure to daytime sunlight.
5. Power to the solar array and SLM case was verified.
6. The solar panel array was secured by strapping it to the power case after power was verified and the vent knob on the front of the power case was removed and placed inside the case.
7. 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.
8. The NoiseLogger™ program was retrieved from the CompactFlash™ card, then invoked.
9. Per the program instructions, the following information/action was entered/performed:
 - a. *Site information:* The unique three-character ID representing the site “number” (e.g., PH2 for Site PH2), and the site’s name (e.g., Palace Grounds) were entered;
 - b. *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;
 - c. *Equipment information:* System component model and serial numbers (Note: Table 9 provides a summary of the system numbering convention and each system’s equipment information), and support equipment model and serial numbers (e.g., calibrator) were entered;

Table 9. Summary of NoiseLogger™ system equipment information.

System #	LD824 Serial #	Microphone Type and Serial #	Preamplifier Serial #	Anemometer Type and Serial #	Windscreen #	Used at Site
1	A0842R	40AQ #20729	1243	FT702 #2080-77	1	
2	A0843S	40AQ #25837	1276	FT702 #2080-56	2	
3	A0844T	40AQ #19879	1268	FT702 #2080-88	3	
4	A0845U	40AQ #19905	1282	FT702 #2080-68	4	
5	A1148R	40AE #24020	1643	Gill WindObserver #000528	5	KH2, PE2, PH2
6	A1149S	40AE #24021	1647	FT702 #2080-87	6	KH1
7	A1150K	40AE #24038	1678	Gill WindObserver #000524	7	
8*	A1150K	40AQ #19909	2133	Gill WindObserver #000524	7	
9	A1151L	40AE #24017	1650	FT702 #2080-58	8	
10	A1155P	40AE #24040	1630	Gill WindObserver #000525	9	
11	A1156Q	40AE #24034	1634	FT702 #2080-86	10	KH3, PE1, PH1

* Note: Systems 7 and 8 are identical except for the microphone, which was replaced during earlier measurements in Hawai'i.

- d. *System calibration:* Approximately 30 seconds of calibration signal are collected by the Husky™ H/PC;
- e. *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”) for the LD Model 824 SLM (see Table 10 below). 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.

Table 10. 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

10. 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 Measurements

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. In performing acoustic observer logging, the observer used pre-programmed macros in an automated spreadsheet to place an immediate time stamp and identify each event as 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 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 11.
2. The second field observer periodically checked the equipment and documented site details and description, including photographs of the site.
3. At the end of data collection, a post-measurement sound level calibration of the system was performed and any drift from the initial calibration was documented.
4. All instrumentation were powered down, dismantled, and packed into backpacks for removal from the site.
5. All data were downloaded and transferred onto a central computer. Data were downloaded by removing the CompactFlash™ card from the Husky™ H/PC.

Table 11. Acoustic state identifiers.

Aircraft Intrusion Sub-States	Description	Human Intrusion Sub-States	Description	Natural Sound Sub-States	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	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				
Medium Altitude	Designates medium altitude aircraft				
Low Altitude	Designates low altitude aircraft				

Note: All sound level data measured during acoustic states identified with “Human Intrusion - Measurement Team” designations are not included in the data analysis.

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5. DATA REDUCTION AND PROCESSING

Figure 35 presents a diagram of the data reduction process. Essentially, there were two types of data: (1) acoustical; and (2) meteorological. The acoustical and meteorological 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 that will be collected at the national parks.

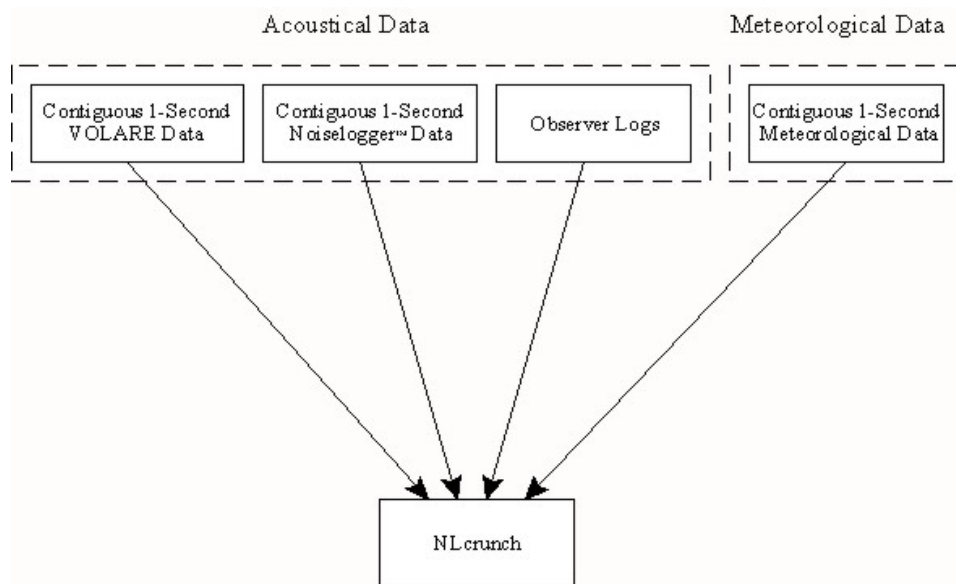


Figure 34. Flow diagram of data reduction process.

Data from the field measurement sites were transferred to a central computer. Copies of the data were then placed on DVD and sent to the Volpe Center upon completion of the measurement study.

5.1 Raw NoiseLogger™ Acoustic and Meteorological Data Reduction

No editing was required for NoiseLogger™, which contained both acoustic and meteorological data. The filename format of the raw, binary 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., “SKH1” represents Site KH1), “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.

Raw, binary 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, 1-second averaged wind speed, 1-second averaged wind direction, 1-second Z-weighted (flat or no weighting) L_{eq} , 1-second C-weighted L_{eq} , 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 typos, 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, NLcrunch Version 3.13 (dated 8/12/2005). The NLcrunch program applies several quality assurance filters and checks (Section 5.3.1), and then several adjustments (Section 5.3.2) to the acoustic data prior to detailed data reduction and analysis.

5.3.1 Data Filters

The NLcrunch program applies several quality assurance filters and checks to the acoustic data to ensure that any questionable data is identified and that only “good” data is reduced and analyzed. Following is the list of NLcrunch filters used to identify “bad” or questionable data:

- 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 average wind speeds were greater than 11 mph (5 m/s), the predetermined, acceptable, wind speed threshold (Appendix E in the Hawai`i Volcanoes measurement report details the methodology used to determine this threshold);^{23,*}
- Data whose associated 1-second Z-weighted sound levels exceeded the LD Model 824 SLM's instrumentation noise "ceiling level" for the gain setting of the instrument (see Section 4.1 for more information);
- Data whose associated one- third octave frequency band data do not deviate by at least one standard deviation (dB) across all 33 bands, typically represented by no variations in sound levels within the bands, which indicates a problem with the LD824 sample;
- Data that were measured within twenty minutes of performing calibration (to remove data potentially contaminated by field personnel handling instrumentation during the calibration process);
- Data that were measured during NPS helicopter transportation of field personnel and/or equipment to/from sites; and
- Data that were potentially contaminated by field personnel during the observer logging.

5.3.2 Data Adjustments

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

- 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;

* Available data suggests that there is a high probability of microphone-induced distortion above the wind speed threshold; however, unless such wind conditions occur more than 50 percent of the hour, exceedence metrics (L_{50} , L_{90} , and L_x) will not likely be influenced. Both the FAA and NPS acknowledge that additional research is needed to determine if a more refined approach is necessary to account for data collected during high wind conditions for ATMP and VA parks

- 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 biases of the windscreen. Appendix C presents these adjustments in detail; and
- 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 methodology 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 in the Hawai'i Volcanoes measurement report details the methodology used to determine the noise floor of each of eleven NoiseLogger™ systems, as well as the final noise-floor adjustments used during data reduction, in more detail.²³

5.3.3 Sound Level Descriptors

All ambient, sound-level data will be analyzed (see Section 6.0) in terms of the following metrics (refer to the Terminology section for definitions):

- L_{Aeq} : The A-weighted equivalent sound level and its associated $\frac{1}{3}$ -octave band un-weighted spectrum from 12.5 to 20,000 Hz.
- L_{50} : A statistical descriptor describing the sound level exceeded 50 percent of a specific time period and its associated $\frac{1}{3}$ -octave band un-weighted spectrum from 12.5 to 20,000 Hz. Note: This spectrum 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.*
- L_{90} : A statistical descriptor describing the sound level exceeded 90 percent of a specific time period and its associated $\frac{1}{3}$ -octave band un-weighted spectrum from

* This method for constructing spectra has precedent as this approach has been agreed to by the FAA and NPS for noise analyses in Grand Canyon National Park.²

12.5 to 20,000 Hz. Note: This spectrum is constructed by determining the L_{90} from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

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6. DATA ANALYSIS

In support of this study, approximately one week of acoustical and meteorological data were measured in June 2003 at multiple sites in each park. Figure 36 below shows the specific periods of time that data were collected at each site.

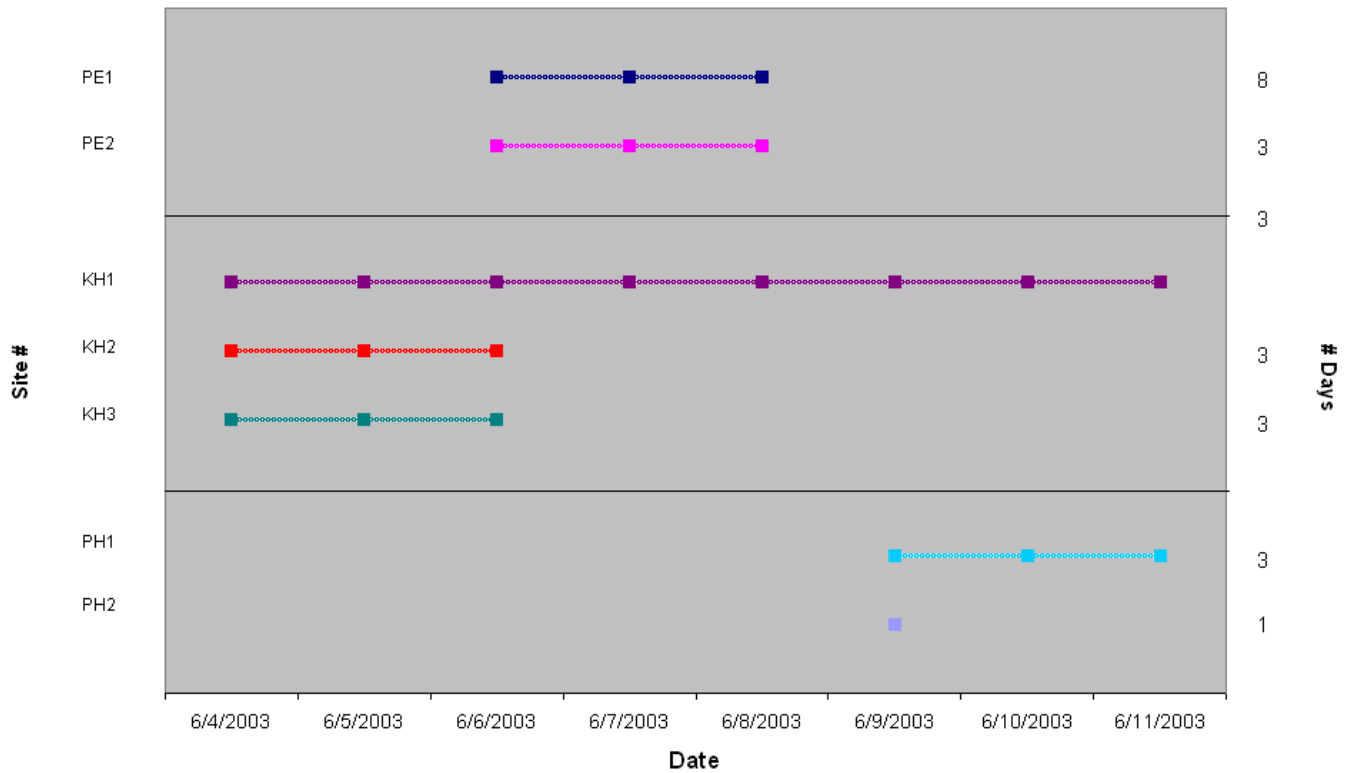


Figure 35. Baseline ambient data collection timeline.

As stated in Section 1.1, the primary objective of this study was to quantify the baseline ambient sound levels within each 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.¹² These ambient maps (along with representative one-third octave-band spectral data) will be used as input to the FAA's Integrated Noise Model (INM) or Aviation Environmental Design Tool (AEDT)²⁴. The models will be used 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.

This section discusses in detail the data analyses performed, and the process used in the development of the ambient maps that will be used as input to the model. All data analyses were performed in terms of three metrics: (1) the A-weighted equivalent sound level (L_{Aeq}) and its associated one-third octave-band spectrum (unweighted); (2) the 50-percentile exceeded sound level (L_{50}) and its associated one-third octave-band spectrum (unweighted);* and (3) the 90-percentile exceeded sound level (L_{90}) and its associated one-third octave-band spectrum (unweighted).^{*} These data were then used in the conductance of a series of analyses. Specific analyses consisted of the following:

- *Time-based Analysis (Section 6.1)* – Examine the diurnal trends of the data;
- *Acoustic Zone Analysis (Section 6.2)* – Examine the statistical similarity of the sound level data between sites;
- *Development of Ambient Maps (Section 6.3)* – Because the specific “ambient” to be used in the modeling and any subsequent impact assessment is the subject of on-going discussions between the FAA and NPS, four different ambient maps for each of the three metrics were developed from the data.

6.1 Diurnal Variability

This section discusses the diurnal trends of the data as these trends may affect how the baseline ambient will be characterized during any subsequent impact assessment. For the purpose of assessing trends in the diurnal data, average, hourly, sound levels for each site were computed by grouping the individual sound-level values from all measurement days by hour. For each hourly grouping, L_{Aeq} sound level values were weighted by the duration in seconds that hour represented,[†] and then energy-averaged over all measurement days to compute a single, average, ambient, sound-level value; L_{50} and L_{90} sound level values were algebraically averaged over all measurement days to compute a single, average, ambient, sound-level value.

* Note: As discussed in Section 5.3.3, the one-third octave-band spectra associated with the L_{50} and L_{90} are constructed by determining the L_{50} and L_{90} , respectively, from each one-third octave-band; therefore, they are not actual measured one-third octave-band spectra associated with a measurement sample. This method for constructing spectra has precedent as this approach has been agreed to by the FAA and NPS for noise analyses in Grand Canyon National Park.²

[†] Because the NLcrunch program applies several quality assurance filters and checks to the acoustic data prior to detailed data reduction and analysis, sound level values were weighted by the duration in seconds that hour represented since an hour may not necessarily be 3600 seconds.

Table 12 through Table 14 present the results for all sites computed using each of the three noise metrics (L_{Aeq} , L_{50} , and L_{90}). These data are presented graphically for each individual site in Appendix A. Note: As stated in Section 5.3, several quality assurance filters and checks (e.g., high wind filter) and then several adjustments (e.g., noise floor adjustments) were applied to the acoustic data prior to data analysis. These data are presented graphically for each individual site in Appendix A.

As summarized in Table 15, the magnitudes of the differences between daytime and the overall average, hourly, sound levels were small – on average, generally less than 3 dBA. The differences between nighttime average, hourly, sound levels as compared to the overall sound levels were larger. Sites in or near dense vegetation exhibited stronger diurnal differences between daytime and nighttime sound levels due to bird and/or insect activity.

In addition, because the majority of Hawai`i air tours operate on a daily basis between the hours of 6 am and 6 pm, the data measured during this time period (hereafter referred to as “daytime” hours) were compared to data measured outside this time period (6 pm to 6 am, hereafter referred to as “nighttime” hours). A daytime and nighttime sound level for each site was computed by grouping the individual sound-level values from all measurement days by “daytime” hours and “nighttime” hours, and then re-computing the L_{Aeq} , L_{50} , and L_{90} over all measurement days. Note: FAA and NPS have agreed that any subsequent impact assessment will be conducted using ambient sound levels during the time that the aircraft operations occur. Because the majority of Hawai`i air tours operate during the daytime, all final ambient maps (see Section 7) will be developed using daytime data. The specific hours to be defined as daytime will be park dependent. For example, a time period of 6 am to 6 pm will be used for the analyses of national parks in Hawai`i. This time period is the typical operating hours for air tour operators conducting air tours in Hawai`i according to Flight Standard District Office personnel.

Table 12. Average hourly sound levels - L_{Aeq} . (Hour of the Day*)

Site #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
PE1	37.7	34.9	39.0	40.7	41.2	43.7	42.9	38.8	39.7	39.6	40.9	40.1	38.4	42.8	41.4	41.9	39.5	41.2	37.0	35.0	38.2	41.7	40.6	36.5
PE2	42.4	40.6	50.3	39.0	46.3	42.9	44.6	42.0	43.3	41.9	43.6	43.9	43.4	46.7	47.8	43.8	44.9	44.4	44.2	44.1	41.7	41.6	40.0	38.3
KH1	41.1	38.7	34.2	39.9	35.7	41.7	42.4	43.0	42.2	43.8	44.8	43.2	44.6	44.6	43.3	43.2	43.5	43.4	42.8	46.8	43.3	47.0	42.8	41.7
KH2	42.9	42.7	42.3	42.1	43.2	45.6	46.3	45.4	43.7	43.5	46.6	43.4	46.4	47.1	43.7	43.0	43.4	42.4	44.1	45.0	46.6	46.9	43.6	47.7
KH3	44.9	41.0	39.3	39.6	41.1	43.6	44.2	44.5	42.6	47.0	46.8	42.1	49.1	49.8	49.2	46.4	44.5	44.7	45.5	46.0	47.3	48.3	46.1	46.5
PH1	41.9	45.5	42.7	42.5	44.0	48.2	42.0	41.6	43.0	38.5	43.6	44.0	43.3	44.6	44.2	42.1	39.8	41.9	39.5	37.7	43.9	41.6	42.2	41.9
PH2 [†]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	45.1	47.7	47.2	46.1	46.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 13. Average hourly sound levels - L_{50} . (Hour of the Day*)

Site #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
PE1	35.3	32.9	36.9	40.4	37.6	38.9	40.0	35.9	35.8	36.3	34.8	35.3	34.0	34.1	34.5	36.7	34.8	34.5	33.8	32.6	37.8	41.9	39.7	35.3
PE2	41.0	37.8	39.6	35.0	35.1	40.3	42.1	38.7	39.4	40.6	40.8	42.4	42.3	41.8	42.4	42.5	42.4	42.0	42.7	42.7	41.3	40.6	39.3	37.5
KH1	35.2	34.0	32.2	33.1	33.0	38.7	40.5	38.9	40.3	41.5	42.2	41.6	41.7	42.7	42.5	42.5	42.6	41.8	41.3	40.9	39.1	40.1	38.9	37.0
KH2	40.1	41.0	40.4	40.9	39.8	43.9	43.5	39.1	38.9	37.9	39.3	37.2	36.5	38.5	37.2	38.7	38.0	38.8	39.3	39.8	45.2	45.2	40.7	46.4
KH3	41.0	37.4	38.1	38.7	39.7	42.4	42.3	38.8	41.1	42.2	44.9	38.9	39.7	44.1	41.6	43.7	42.4	43.6	44.3	44.2	45.5	45.5	41.8	43.6
PH1	40.6	45.0	42.7	41.8	43.5	44.3	40.5	39.4	40.3	37.5	39.9	41.1	42.3	42.6	43.8	40.3	38.5	37.6	36.5	36.1	43.0	41.0	41.6	40.9
PH2 [†]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	44.5	44.9	45.2	44.7	44.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* As stated earlier, because the majority of Hawai`i air tours operate on a daily basis between the hours of 6 am and 6 pm, nighttime hours are shown shaded in gray.

[†] A limited amount of data was collected at this site (less than 1 day).

Table 14. Average hourly sound levels - L₉₀. (Hour of the Day*)

Site #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
PE1	31.6	30.5	31.2	35.8	29.7	32.9	34.7	31.9	31.2	32.3	31.3	31.4	30.5	30.4	30.9	32.0	31.5	31.3	30.3	29.8	32.0	38.8	38.4	32.7
PE2	38.9	34.9	32.9	31.4	29.6	34.0	38.7	35.9	36.6	38.3	38.5	40.1	40.4	39.8	40.3	40.7	40.5	40.0	40.6	40.9	39.8	39.1	37.8	35.8
KH1	31.6	30.0	28.4	29.3	30.1	35.0	37.4	36.3	37.7	39.0	40.1	39.4	39.5	40.6	40.4	40.4	40.1	39.3	39.1	37.6	36.7	36.5	36.2	33.4
KH2	37.3	37.2	38.1	38.6	37.6	41.0	40.7	35.4	36.1	35.5	36.5	34.1	34.0	35.6	34.8	36.2	35.6	36.3	37.3	37.3	43.2	41.9	36.8	42.5
KH3	34.0	33.7	35.1	35.8	37.4	39.4	40.1	36.3	38.3	39.0	41.0	36.1	35.2	38.3	37.9	41.3	39.1	40.2	41.1	41.3	42.9	42.6	38.9	39.0
PH1	38.8	40.0	40.8	39.9	40.5	40.6	38.1	36.4	37.1	35.3	37.3	38.6	40.2	40.4	41.7	38.2	36.6	34.8	34.0	33.7	39.6	39.2	40.1	38.9
PH2†	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43.0	42.8	43.4	42.4	42.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 15. Summary of day versus night diurnal trends.

Site #	Overall Average L _{Aeq} (dBA)	Overall Average L ₅₀ (dBA)	Overall Average L ₉₀ (dBA)	Daytime Hourly 7am to 7pm L _{Aeq} (dBA)	Daytime Hourly 7am to 7pm L ₅₀ (dBA)	Daytime Hourly 7am to 7pm L ₉₀ (dBA)	Nighttime Hourly 7pm to 7am L _{Aeq} (dBA)	Nighttime Hourly 7pm to 7am L ₅₀ (dBA)	Nighttime Hourly 7pm to 7am L ₉₀ (dBA)	Delta (Overall - Day) L _{Aeq} (dBA)	Delta (Overall - Day) L ₅₀ (dBA)	Delta (Overall - Day) L ₉₀ (dBA)	Delta (Overall - Night) L _{Aeq} (dBA)	Delta (Overall - Night) L ₅₀ (dBA)	Delta (Overall - Night) L ₉₀ (dBA)
PE1	40.2	36.0	31.1	40.8	35.4	31.3	39.7	36.7	30.8	-0.6	0.6	-0.2	0.5	-0.7	0.3
PE2	44.4	41.0	35.6	44.7	41.7	38.4	44.1	40.1	33.0	-0.3	-0.7	-2.8	0.3	0.9	2.6
KH1	43.1	40.3	31.7	43.5	41.8	37.7	42.7	36.9	30.0	-0.4	-1.5	-6.0	0.4	3.4	1.7
KH2	44.8	40.7	35.8	44.7	38.6	35.4	44.8	42.5	36.7	0.1	2.1	0.4	0.0	-1.8	-0.9
KH3	45.8	41.7	36.3	46.6	41.8	37.6	45.0	41.7	35.0	-0.8	-0.1	-1.3	0.8	0.0	1.3
PH1	43.1	41.1	36.8	42.5	40.4	36.8	43.4	41.8	36.8	0.6	0.7	0.0	-0.3	-0.7	0.0
PH2†	46.8	44.8	42.6	46.8	44.8	42.6	N/A	N/A	N/A	0.0	0.0	0.0	N/A	N/A	N/A
									Average	-0.2	0.2	-1.4	0.3	0.2	0.8

* As stated earlier, because the majority of Hawai`i air tours operate on a daily basis between the hours of 6 am and 6 pm, nighttime hours are shown shaded in gray.

† A limited amount of data was collected at this site (less than 1 day).

6.2 Acoustic Zones

As stated earlier in Section 2.6, it is anticipated that the use of acoustic zones as representative units, within which data can be collected and grouped (by land cover, wildlife activity, visitor-use, wind and seasonality, etc) may be extrapolated within large, homogeneous regions of a particular park, to similar areas within a park, and possibly between similar regions in other parks. In developing acoustic zones, land cover and climate/ecological domain appear to be the two most important technical factors influencing ambient sound levels in a national park since these factors are 1) related to the natural sources present in the area and 2) affect how sound waves propagate from source to receiver (Note: Appendix D discusses the analysis methodology in greater detail). This effort continues the work that began in Hawai`i Volcanoes National Park to examine the use of acoustic zones for ATMP and VA park ambient studies.²³ As discussed in Section 2.6, because each park is so small, it was agreed that each park would be considered a single acoustic zone and measurement sites would be located near specific park resources.

The following comparisons were performed to statistically assess ambient data collected at a pair of sites that were: (1) located in the same park (acoustic zone), (2) had the same land cover class/subclass (per NLCD), or (3) experienced similar levels of visitor-use. As new ambient data are collected in parks with additional land cover types and within other ecological divisions, it is anticipated that the analysis of acoustic zones may be expanded to a larger scale, possibly nationwide.

Figure 37 presents the results of comparing ambient data collected at pairs of sites within each park. From this analysis, there is statistical evidence to support the transferability of ambient data hypothesis. Sites within all three parks showed similarity (KH1, KH2, KH3, PE1, PH1).

Acoustic Zone	Site ID	KH1	KH2	KH3	PE1	PE2	PH1	PH2
KAHO	KH1		S	SS	S	S	S	F
KAHO	KH2			S	S	S	S	F
KAHO	KH3				S	S	S	F
PUHE	PE1					F	S	F
PUHE	PE2						S	F
PUHO	PH1							F
PUHO	PH2							

Figure 36. Data transferability within each park.

Note 1: SS = Both tests passed, i.e., data showed strong similarity.

F = Both tests failed, i.e., data were not similar.

S = One test passed, i.e., data showed some similarity.

Note 2: Cells highlighted in yellow indicate pairs of sites within the same park.

Figure 38 presents the results of comparing ambient data collected at pairs of sites within the three parks, located in the same land cover class/subclass (per National Land Cover Database, or NLCD, as discussed in Appendix D). From this analysis, some data similarities can be seen for shrubland (KH1 and PE2) and bare rock/sand/clay sites (KH2, KH3, and PE1), which support the transferability of ambient data hypothesis. However, human influence may have played a more dominant role than natural features in these sites.

NLCD Land Cover Classification	Site ID	KH1	KH2	KH3	PE1	PE2	PH1	PH2
51 Shrubland	KH1		S	SS	S	S	S	F
31 Bare Rock/Sand/Clay	KH2			S	S	S	S	F
31 Bare Rock/Sand/Clay	KH3				S	S	S	F
31 Bare Rock/Sand/Clay	PE1					F	S	F
51 Shrubland	PE2						S	F
31 Bare Rock/Sand/Clay	PH1							F
31 Bare Rock/Sand/Clay	PH2							

Figure 37. Data comparisons for land cover.

Note 1: SS = Both tests passed, i.e., data showed strong similarity.

F = Both tests failed, i.e., data were not similar.

S = One test passed, i.e., data showed some similarity.

Note 2: Cells highlighted in yellow indicate pairs of sites with the same land cover classification.

Figure 39 presents the results of comparing ambient data collected at pairs of sites within the three parks with similar levels of estimated visitor activity. Short-hike sites, which tend to experienced medium visitor-use showed strong similarity, but high visitor use sites did not show similarity. These results tend to support the conclusion that the ambient sound levels at park locations were primarily driven by two factors, natural-eco factors and the influence of visitor activity.

Visitor-Use	Site ID	KH1	KH2	KH3	PE1	PE2	PH1	PH2
Short Hike	KH1		S	SS	S	S	S	F
Short Hike	KH2			S	S	S	S	F
Short Hike	KH3				S	S	S	F
Overlook	PE1					F	S	F
Short Hike	PE2						S	F
Short Hike	PH1							F
Overlook	PH2							

Figure 38. Data comparisons for visitor-use.

Note 1: SS = Both tests passed, i.e., data showed strong similarity.

F = Both tests failed, i.e., data were not similar.

S = One test passed, i.e., data showed some similarity.

Note 2: Cells highlighted in yellow indicate pairs of sites with the same visitor-use classification.

6.3 Development of Ambient Maps

Over the past decade, several definitions of ambient noise have been adopted by different organizations depending on their application.^{7,14,15,25} In fact, a review of the acoustical issues regarding the measurement of ambient data has been the subject of on-going discussions between the FAA and NPS.^{26,27} This includes which metric will be used to describe ambient (e.g., L_{Aeq} , L_{50} , or L_{90}). The FAA, NPS, and Volpe agree on the definitions of ambient. However, because the FAA and NPS have different methodologies for assessing noise impacts, it is not clear which definition is the most appropriate. The four types of “ambient” used in this report are defined as follows (see Figure 40):

- *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

* Note: 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.

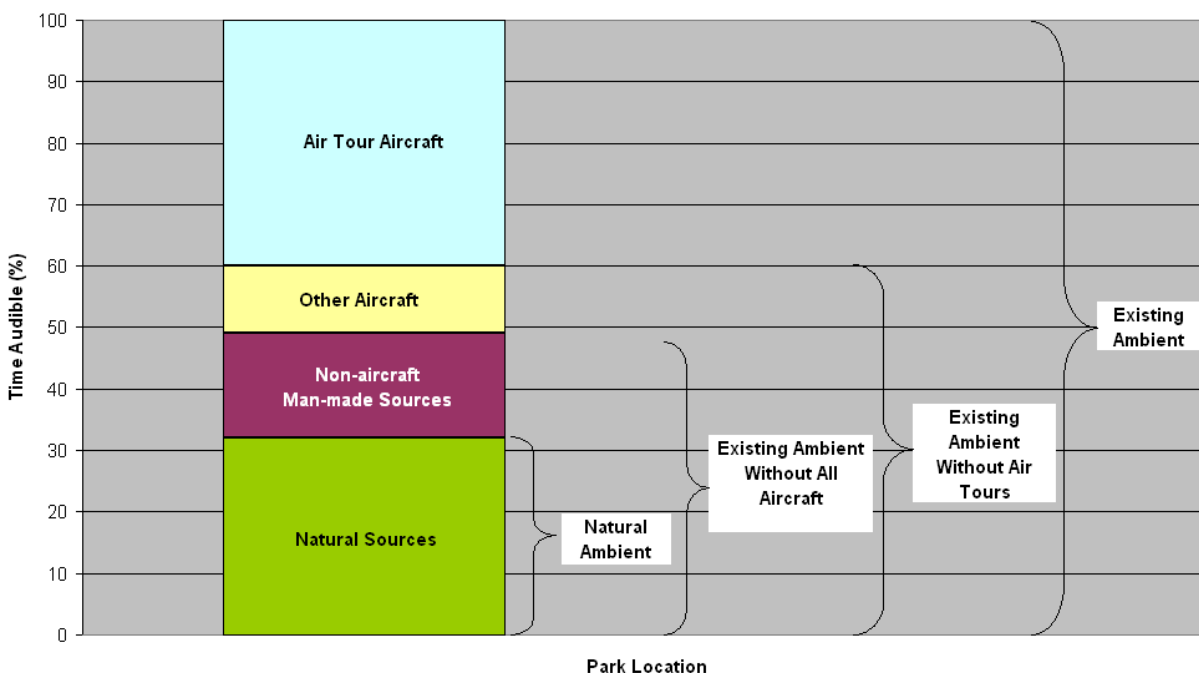


Figure 39. Graphical depiction of ambient definitions.

Nine ambient sound level values were initially computed for every measurement site (four primary types of ambient for each of three metrics) as listed in Table 16. Note: The L_{Aeq} metric was computed for the Existing Ambient only.

Table 16. Matrix of ambient maps.

Metric	Existing Ambient	Existing Ambient Without Air Tours	Existing Ambient Without All Aircraft	Natural Ambient
L_{Aeq}	Map 1	N/A	N/A	N/A
L_{50}	Map 2	Map 4	Map 6	Map 8
L_{90}	Map 3	Map 5	Map 7	Map 9

6.3.1 Computation of Existing, Traditional, Cumulative Traditional, and Natural Ambients

The FAA/Volpe/NPS are developing standards for computing ambient sound levels in National Parks. Because different sound sources often overlap in both frequency and

amplitude, there is currently no practical method to separate acoustic energy of human-caused sounds from that of natural sounds. Working closely with the NPS,²⁸ a methodology was developed to utilize short-term measurement data, collected with detailed acoustic state logs, to develop short-term distributions of ambient data as a function of acoustic state, and apply these short-term distributions to the long-term data. The objectives of the methodology were:

- To obtain a percentile statistical value from the short-term data (commonly referred to as L_x), which corresponds to each of the ambient types, and apply that statistical measure to the long-term data. The assumption is that the statistical measure (*not the level*) is representative of what would be obtained over the long term. Note: The actual ambient level would be based on the long-term data, and the short-term data would only be used to determine the statistical index; and
- To obtain a spectral shape from the short-term data, which corresponds to each of the ambient types, and adjust the shape (up or down in level) based on the L_x value derived from the long-term data.

The developed methodology was comprised of the following steps:

1. Using the A-weighted sound level data derived from the short-term, one-second, one-third octave-band data, in concert with the acoustic state observer logs, compute the L_{50} for each of the four primary ambients, based on the definitions presented in Section 6.0.
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 determine what L_x corresponds to the L_{50} for each of the three ambients from Step 1 above.
3. Sort, high-to-low, the long-term NoiseLogger™ data collected at a site and based on the L_x values determined in Step 2 above for each ambient type, determine the corresponding level from the long-term data. For example, if from Step 2 above, it is determined that at a particular site, the L_{50} Natural ambient corresponds to an L_{65} of the short-term data, then determine the sound level which corresponds to an L_{65} ,

taking into account all of the long-term data. The result will be a long term, A-weighted ambient sound level for each of the four ambients.

4. Determine a spectrum adjustment factor for each ambient type by subtracting the L_x value from Step 3 from the energy-averaged spectrum (A-weighted and summed) derived in Step 1. Note the two values being subtracted would be overall, A-weighted values, not one-third octave-band values. But the resultant factor is appropriate to apply to one-third octave-bands (see Step 5).
5. Apply the factor derived in Step 4 to the level in each one-third octave-band from Step 1 above to calibrate the spectrum based on the long-term sound levels. This will ensure the ambient A-weighted sound level from the long-term data is consistent with the spectrum, after A-weighting and summation.

It should be noted that the above approach can result in some quiet Natural Ambient data being removed from the sub-sample and thus potentially over-estimating the resultant ambient. This results in ambient sound levels for the sub-sample occasionally being greater (generally less than 1 dB) than Existing Ambient sound levels, which is a logically impossible outcome, because the uncensored data represents the summed contributions of natural and human-caused ambient sounds. Such small differences will have a negligible effect on the modeling results. Both agencies acknowledge that the methods are imperfect, and additional research is on-going to develop better methodology for these calculations.

The final ambient maps are a composite of one-third octave-band spectral data, including contributions from ambient measurements, as well as contributions from modeled roadways and other localized sound sources (see Section 6.3.2). The ambient maps, along with aircraft source and schedule data, provide the input parameters utilized by the model 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.

6.3.2 Other Considerations

In addition to the measured ambient sound levels, the contributing effect of localized noise sources, such as roads, river rapids, and train tracks, should be considered in the development of the ambient maps. Specifically, the estimated drop-off rate, reflecting a continuous decrease in sound level as a function of increasing distance from each road, was computed using the Federal Highway Administration's Traffic Noise Model[®] (TNM).²⁹ The following assumptions were made in using TNM:

- **Traffic Volumes** – The annual traffic volume was provided by the NPS Public Use Statistics Office (<http://www2.nature.nps.gov/stats/>). Hourly volume is estimated by dividing the annual volume by 365 days and 12 hours per day, which assumes the majority of traffic in a park occurs between 6 am and 6 pm – an assumption consistent with the typical operational hours that the majority of Hawai'i air tours conduct air tours. Table 17 through Table 19 present the TNM traffic volume input for each of the parks.

Table 17. TNM traffic volume input for Pu`ukohola Heiau.

Vehicle Type	Annual Volume	Hwy 270** Hourly Volume	Hwy 19** Hourly Volume	Park Road to Spencer Park*** Hourly Volume	Park Road to Visitor Center*** Hourly Volume
		56	56	28	28
Buses	110	0	0	0	0
Heavy Trucks*	7,395	2	2	0	0

* Note 1: It was conservatively assumed that 3% of traffic on highways is heavy trucks and no trucks (or a insignificant number) entered the park.

** Note 2: It was assumed all traffic entering the park would use both Highway 270 and Highway 19.

*** Note 3: As a visitor has two destination choices (Spencer Park and Visitor Center) upon entering the park, it was assumed traffic would be split between the two.

Table 18. TNM traffic volume input for Kaloko-Honokohau.

Vehicle Type	Annual Volume	Hwy 19** Hourly Volume	Kealakehe Pkwy to Harbor*** Hourly Volume	Kealakehe Pkwy to Park Entrance*** Hourly Volume
		18	9	9
Buses	0	0	0	0
Heavy Trucks*	2,355	1	0	0

* Note 1: It was conservatively assumed that 3% of traffic on highways is heavy trucks and no trucks (or a insignificant number) entered the park.

** Note 2: It was assumed all traffic entering the park would use Highway 19.

*** Note 3: As a visitor has two destination choices (a nearby Harbor and the park entrance) from Kealakehe Parkway off Highway 19, it was assumed traffic would be split between the two.

Table 19. TNM traffic volume input for Pu`uhonua o Honaunau.

Vehicle Type	Annual Volume	Hourly Volume Hwy160** Hourly Volume	Hourly Volume Park Road ** Hourly Volume
Autos	596,961	136	136
Buses	333	0	0
Heavy Trucks*	17,909	4	0

* Note 1: It was conservatively assumed that 3% of traffic on highways is heavy trucks and no trucks (or a insignificant number) entered the park.

** Note 2: It was assumed all traffic entering the park would use Highway 160.

- *Traffic Speeds* – For Pu`ukohola Heiau, an average speed of 45 mph (72.4 kph), 55 mph (88.5 kph), 25 mph (40.2 kph), 15 mph (24.1 kph) were used for four roads, respectively. For Kaloko-Honokohau, an average speed of 55 mph, 15 mph, and 25 mph, were used for three roads, respectively. For Pu`uhonua o Honaunau, an average speed of 45 mph and 15 mph were used for two roads, respectively.
- *Ground Impedance* – Because much of the land cover in vicinity of the roads in all three parks was rocky shrubland, a moderately hard acoustical ground impedance was assumed using an effective flow resistivity of 1000 cgs/rayls.

6.3.3 Assignment of Ambient Sound Levels

As stated earlier in the previous section, a comprehensive grid was created in the development of a composite map of ambient sound levels throughout the park (including contributions from ambient measurements, as well as contributions from modeled roadways). The process of assigning ambient noise to each grid point location was a time-consuming, but relatively straightforward process, using a Geographical Information System (GIS) in concert with software developed by the Volpe Center. The program performs the following actions:

- Define the input “objects”:
 - o Define the park boundary in Universal Transverse Mercator (UTM)* coordinates to set the initial grid area boundary.[†]
 - o Divide the park into a regular grid of points at a desired spacing using a Digital

* The UTM system provides coordinates on a world wide flat grid for easy manipulation in GIS applications.

[†] Because NPATMA 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.

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 these three parks, a grid spacing of 500 ft (152.4 m) was used.

- o Define the acoustic zone boundaries in UTM coordinates.
- o Define the location of each measurement site. Within a particular acoustic zone, the distance to the nearest measurement site was calculated and assigned to each grid point within that acoustic zone.
- o Define the location of localized noise sources (i.e., the roads in each park were defined). The distance to each road was calculated and assigned to each grid point.
- 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 for each ambient type and metric (9 combinations as discussed in Section 6.3).
- Assign a “roadway” ambient sound level (and its associated one-third octave-band, unweighted spectrum) to each grid point using the drop-off rates determined by TNM using the input parameters discussed in Section 6.3.2.
- Compute a combined “measured” and “roadway” ambient (and spectra), as appropriate, at each grid point (see Table 20). The resultant ambient maps are presented in Section 7.

Table 20. Determination of final, composite ambient sound levels at each grid point.

Metric	Existing Ambient	Existing Ambient Without Air Tours	Existing Ambient Without All Aircraft	Natural Ambient*
L_{Aeq}	Measured + Roadway	N/A	N/A	N/A
L₅₀	Measured + Roadway	Measured + Roadway	Measured + Roadway	Measured
L₉₀	Measured + Roadway	Measured + Roadway	Measured + Roadway	Measured

Note: The combined (Measured + Roadway) ambient were computed by using energy-addition, i.e., sound levels in decibels were converted to energy prior to addition. For a non-time-varying source, such as roadway noise, the TNM-computed L_{Aeq} sound level parameters were conservatively assumed to be equivalent to the L₅₀ and L₉₀ and, thus, used interchangeably as the “roadway” ambient.

* As defined in Section 6.3, Natural Ambient includes the natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excludes all human and mechanical sounds.

7. RESULTS

This section presents a detailed discussion of the results of the study. Included is an overall summary of the final, ambient sound levels for each measurement site, and the final, ambient, sound level maps developed in support of this study for input into the FAA’s Integrated Noise Model (INM) or Aviation Environmental Design Tool (AEDT).

Table 21 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 three columns in the table are arranged as follows:

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

The next four primary columns define the additional types of ambient represented by the data: Existing, Existing Without Air Tours, Existing Without All Aircraft, and Natural, as defined in Section 6.3. Then for each type of ambient, the following data are presented: *

- *L_{Aeq}*: The equivalent, A-weighted sound level (in decibels). Presented is the energy-averaged value determined from daytime sound levels (6 a.m. to 6 p.m.), taking into account the data from all days of measurements (Note: This metric was computed for the Existing Ambient only);
- *L₅₀*: The L₅₀ sound level (in decibels) determined by the sound level exceeded 50 percent of the daytime hours (6 a.m. to 6 p.m.), taking into account the data from all days of measurements;
- *L₉₀*: The L₉₀ sound level (in decibels) determined by the sound level exceeded 90 percent of the daytime hours (6 a.m. to 6 p.m.), taking into account the data from all days of measurements; and

* As noted in Section 6.1, the FAA and NPS have agreed that any subsequent impact assessment should be conducted using ambient sound levels during the time that the aircraft operations occur. Because the majority of Hawai`i air tours operate during the daytime, all final ambient maps will be developed using daytime data. The specific hours to be defined as daytime will be park dependent. For example, a time period of 6 am to 6 pm were used for the analyses of the 6 national parks in Hawai`i. This time period is the typical operating hours for air tour operators conducting air tours in Hawai`i according to Flight Standard District Office personnel.

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- **W/S:** The average wind speed (in mph). Presented is the algebraically averaged value determined from daytime sound levels (6 am to 6 pm), taking into account the data from all days of measurements.

Figure 41 through Figure 44 present the data in Table 21. Summary of measured, daytime (6 am to 6 pm), ambient sound level data, graphically for each ambient type. Figure 45 and Figure 46 present the data graphically for each metric. ***(Note: For comparison purposes, Table 22 contains a summary of the ambient, sound level data for the entire measurement period, where daytime and nighttime hours were included.)*** Table 23 presents the associated spectral data for the two ambient maps agreed upon for use in ATMP / VA analyses: Existing Ambient Without Air Tours (L_{50}) and Natural Ambient (L_{50}).

Table 24 and Figure 47 contain a summary of the acoustic observer data logged at each measurement site. As discussed in Section 6.3.1, this data was used to determine short-term distributions of ambient data from the measurement data collected during the acoustic observer logging as function of acoustic state, and apply these short-term distributions to the long-term data to develop the four types of ambient defined in Section 6.0. The first six columns in the table are arranged as follows:

- **Acoustic Zone:** The acoustic and management zone in which the measurement site was located;
 - **Site ID:** The unique two-character ID representing the site “number”;
 - **Land Cover:** The land cover of the site in accordance with the National Land Cover Data 21-class land cover classification scheme;
 - **Management Zone:** The NPS management zone that the site was located in;
 - **Site Category:** A designator indicating expected visitor use (with “overlook” indicating high visitor use, “short hike” indicating moderate visitor use, and “wilderness/backcountry” indicating minimal or no visitor use) in the measurement site area;
 - **Total Duration (s):** The duration in seconds of all acoustic observer logging performed at the measurement site.
-

The next six columns define the amount of time that different noise sources were audible to the acoustic observer:

- *Air Tour Aircraft*: The duration in seconds that air tour aircraft were audible;
- *Other Aircraft*: The duration in seconds that other aircraft (e.g., commercial, military, general aviation, and agricultural) were audible;
- *Human*: The duration in seconds that human noise sources (visitor- and mechanical-related) were audible;
- *Natural*: The duration in seconds that natural noise sources were audible;
- *% Air Tour*: The percentage of observer log time that air tour aircraft were audible; and
- *% All Aircraft*: The percentage of observer log time that all aircraft were audible (i.e., air tour and other aircraft).

In addition, Table 25 summarizes two additional metrics (per NPS request) determined using the acoustic observer logs taken during the ambient measurements:

- *Number of Events Per Hour (NEH)*: The number of air tour operations audible within a specified time period, ideally each hour during the day (where sufficient operational data exists); and
- *Noise-Free Interval (NFI)*: The length of time during which only natural sounds are audible.

The columns in the table are arranged as follows:

- *Acoustic Zone*: The acoustic and management zone in which the measurement site was located;
- *Site ID*: The unique two-character ID representing the site “number”;
- *Noise-Free Periods*: Periods of time during which only natural sounds were audible;
- *Air Tour Aircraft Events*: Periods of time during which air tour aircraft sounds were audible; and
- *Other Aircraft Events*: Periods of time during which non-air tour aircraft sounds were audible.

Figure 48 through Figure 77 present the roadway ambient maps and the resultant, nine, baseline ambient maps for each park, respectively, as above in Table 21.

Table 21. Summary of measured, daytime (6 am to 6 pm), ambient sound level data.

Park Name	Site ID	# of Days	Existing L_{Aeq} (dBA)	Existing L₅₀ (dBA)	Existing L₉₀ (dBA)	Existing W/S (mph)	Existing Without Air Tours L_{Aeq} (dBA)	Existing Without Air Tours L₅₀ (dBA)	Existing Without Air Tours L₉₀ (dBA)	Existing Without Air Tours W/S (mph)	Existing Without All Aircraft L_{Aeq} (dBA)	Existing Without All Aircraft L₅₀ (dBA)	Existing Without All Aircraft L₉₀ (dBA)	Existing Without All Aircraft W/S (mph)	Natural Ambient L_{Aeq} (dBA)	Natural Ambient L₅₀ (dBA)	Natural Ambient L₉₀ (dBA)	Natural Ambient W/S (mph)
Pu`ukohola Heiau	PE1	3	40.2	36.0	31.1	1.9	37.1	35.0	31.0	2.2	36.9	35.0	31.0	2.2	34.5	34.0	31.0	2.2
Pu`ukohola Heiau	PE2	3	44.4	41.0	35.6	3.3	42.8	41.5	38.1	6.2	42.6	41.5	38.2	6.1	43.6	42.3	39.7	6.5
Kaloko-Honokohau	KH1	8	43.1	40.3	31.7	0.9	44.5	41.7	37.5	1.1	44.5	41.9	37.5	1.1	44.1	41.9	37.5	1.1
Kaloko-Honokohau	KH2	3	44.8	40.7	35.8	1.2	42.8	38.3	35.3	2.2	43.1	38.3	35.3	2.2	42.1	38.2	35.1	2.2
Kaloko-Honokohau	KH3	3	45.8	41.7	36.3	3.0	42.4	42.6	38.3	1.8	42.4	42.6	38.3	1.8	41.0	42.3	37.9	1.8
Pu`uhonua o Honaunau	PH1	3	43.1	41.1	36.8	1.1	43.4	40.4	36.7	1.9	43.4	40.4	36.7	1.9	43.5	40.4	36.7	1.9
Pu`uhonua o Honaunau	PH2	1	46.8	44.8	42.6	1.9	45.4	44.8	42.6	1.6	45.4	44.8	42.6	1.6	45.6	45.0	42.8	1.6

Table 22. Summary of measured ambient sound level data (daytime and nighttime hours included).

Park Name	Site ID	# of Days	Existing L_{Aeq} (dBA)	Existing L₅₀ (dBA)	Existing L₉₀ (dBA)	Existing W/S (mph)	Existing Without Air Tours L₅₀ (dBA)	Existing Without Air Tours L₉₀ (dBA)	Existing Without Air Tours W/S (mph)	Existing Without All Aircraft L₅₀ (dBA)	Existing Without All Aircraft L₉₀ (dBA)	Existing Without All Aircraft W/S (mph)	Natural Ambient L₅₀ (dBA)	Natural Ambient L₉₀ (dBA)	Natural Ambient W/S (mph)
Pu`ukohola Heiau	PE1	3	40.2	36.0	31.1	1.9	35.9	30.7	2.2	35.9	30.7	2.2	34.5	30.7	2.2
Pu`ukohola Heiau	PE2	3	44.4	41.0	35.6	3.3	40.7	34.6	6.2	40.7	35.1	6.1	41.6	38.4	6.5
Kaloko-Honokohau	KH1	8	43.1	40.3	31.7	0.9	40.0	31.3	1.1	40.3	31.3	1.1	40.3	31.3	1.1
Kaloko-Honokohau	KH2	3	44.8	40.7	35.8	1.2	40.2	35.7	2.2	40.2	35.7	2.2	39.9	35.5	2.2
Kaloko-Honokohau	KH3	3	45.8	41.7	36.3	3.0	42.7	37.4	1.8	42.7	37.4	1.8	42.4	36.8	1.8
Pu`uhonua o Honaunau	PH1	3	43.1	41.1	36.8	1.1	41.1	36.6	1.9	41.1	36.6	1.9	41.1	36.6	1.9
Pu`uhonua o Honaunau	PH2	1	46.8	44.8	42.6	1.9	44.8	42.6	1.6	44.8	42.6	1.6	45.0	42.8	1.6

Table 23. Summary of measured, daytime (6 am to 6 pm), ambient sound level spectral data: Existing ambient without air tours.*

Frequency (Hz)	Site PE1	Site PE2	Site KH1	Site KH2	Site KH3	Site PH1	Site PH2
12.5	39.9	51.5	36.0	41.9	46.3	38.0	42.2
16	41.6	49.1	36.8	42.7	44.0	38.5	42.8
20	42.1	46.7	37.8	43.3	40.6	38.5	43.2
25	43.1	45.2	39.8	41.3	35.8	39.4	44.8
31	43.3	45.1	40.8	41.5	32.4	39.3	44.6
40	43.6	44.8	42.3	41.1	30.4	38.9	45.1
50	43.2	44.0	42.5	40.0	29.6	36.3	44.6
63	44.3	44.9	42.6	40.3	32.0	36.2	44.8
80	44.0	44.8	42.7	39.8	35.0	32.8	44.2
100	42.1	41.3	43.8	34.2	34.3	31.5	43.6
125	36.8	37.5	42.5	31.7	33.5	30.1	42.9
160	33.2	33.9	39.2	29.4	34.3	29.6	40.6
200	31.3	32.4	34.3	29.0	34.2	30.0	39.2
250	29.5	31.2	32.9	29.0	34.8	32.1	36.8
315	26.8	30.8	33.1	29.3	35.5	32.9	34.4
400	27.8	31.9	34.6	30.0	36.0	33.7	33.5
500	26.4	33.6	35.6	30.1	36.1	34.3	34.0
630	24.7	33.8	35.6	30.0	35.9	33.7	34.7
800	23.5	32.3	34.3	29.3	35.1	32.3	34.5
1000	23.4	31.3	33.1	28.9	33.9	30.7	34.5
1250	21.8	30.2	30.0	27.7	31.8	28.6	33.8
1600	19.0	29.2	26.2	26.0	29.3	27.6	33.4
2000	16.6	28.4	22.2	23.7	26.2	26.2	32.6
2500	14.6	28.4	18.4	21.7	22.8	24.4	31.6
3150	14.0	27.2	14.9	20.8	20.7	20.7	30.9
4000	12.7	24.0	12.3	21.8	14.6	19.7	29.3
5000	10.6	21.1	9.4	19.7	10.5	16.6	25.9
6300	7.6	19.6	7.3	17.0	11.0	12.9	24.1
8000	8.4	18.1	3.5	12.3	8.6	9.3	19.4
10000	10.0	17.9	3.1	10.0	8.2	8.6	14.4
12500	6.5	16.2	4.7	9.2	7.4	4.6	9.6
16000	6.1	12.2	6.8	6.5	5.8	3.9	5.3
20000	4.9	4.5	5.7	6.1	2.7	1.0	4.6

* As discussed in Section 5.3.3, the spectral data associated with the L₅₀ exceedence level is constructed by determining the L₅₀ 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 24. Summary of measured, daytime (6 am to 6 pm), ambient sound level spectral data: Natural ambient.*

Frequency (Hz)	Site PE1	Site PE2	Site KH1	Site KH2	Site KH3	Site PH1	Site PH2
12.5	40.2	52.8	36.1	41.9	45.7	38.0	42.2
16	41.7	50.3	36.9	42.5	43.6	38.5	42.6
20	42.3	47.8	38.0	43.1	40.0	38.5	43.3
25	43.1	45.7	40.0	41.1	35.3	39.4	44.9
31	43.5	46.0	41.0	41.2	31.8	39.3	44.5
40	42.9	45.3	42.4	40.9	30.1	38.9	45.0
50	41.7	44.4	42.4	40.0	29.3	36.4	44.6
63	42.8	44.6	42.8	40.4	31.9	36.2	44.7
80	42.7	45.0	42.9	39.8	34.6	32.8	43.9
100	41.2	42.8	43.9	34.0	34.4	31.6	43.4
125	35.7	38.5	42.7	31.6	33.3	30.1	42.7
160	32.2	34.5	39.4	29.2	34.1	29.6	40.5
200	30.6	32.7	34.5	28.9	33.9	30.0	39.2
250	28.5	31.7	33.1	28.8	34.4	32.1	36.6
315	26.0	31.5	33.3	29.2	35.2	32.9	34.4
400	27.4	32.6	34.9	30.0	35.7	33.7	33.6
500	25.9	34.3	35.9	30.1	35.8	34.3	34.0
630	24.0	34.5	35.8	29.9	35.6	33.6	34.6
800	23.1	33.0	34.5	29.2	34.8	32.3	34.4
1000	23.3	31.9	33.3	28.8	33.6	30.7	34.5
1250	21.6	31.0	30.2	27.7	31.3	28.6	33.8
1600	18.8	30.2	26.4	26.0	28.5	27.6	33.6
2000	16.4	29.4	22.3	23.7	25.5	26.2	33.1
2500	14.6	29.2	18.5	21.7	21.9	24.4	32.1
3150	14.0	27.8	15.0	20.8	20.0	20.7	31.5
4000	12.6	24.9	12.4	21.8	14.0	19.7	29.9
5000	10.7	22.3	9.5	19.6	10.5	16.7	26.1
6300	7.5	20.9	7.4	17.1	10.6	13.2	24.1
8000	8.3	19.6	3.7	12.2	8.3	9.4	19.6
10000	9.9	19.4	3.0	10.1	8.0	8.7	14.5
12500	7.5	17.7	4.9	9.3	7.2	4.6	10.0
16000	6.3	13.6	7.0	6.6	5.6	3.9	5.3
20000	4.7	5.9	5.9	6.2	2.5	1.0	4.6

* As discussed in Section 5.3.3, the spectral data associated with the L₅₀ exceedence level is constructed by determining the L₅₀ from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

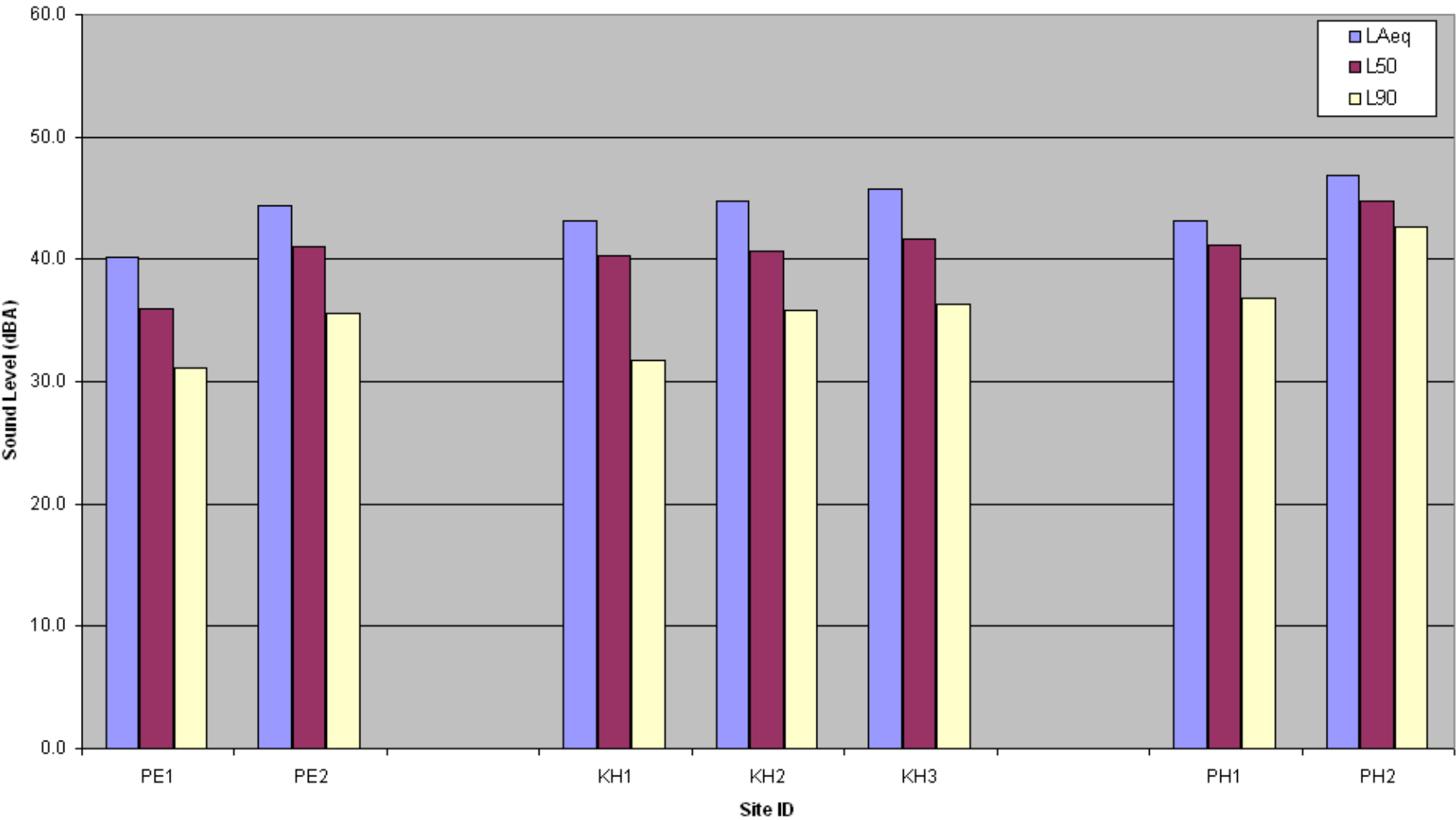


Figure 40. Summary of measured ambient sound level data – Existing Ambient (L_{Aeq}, L₅₀, L₉₀).

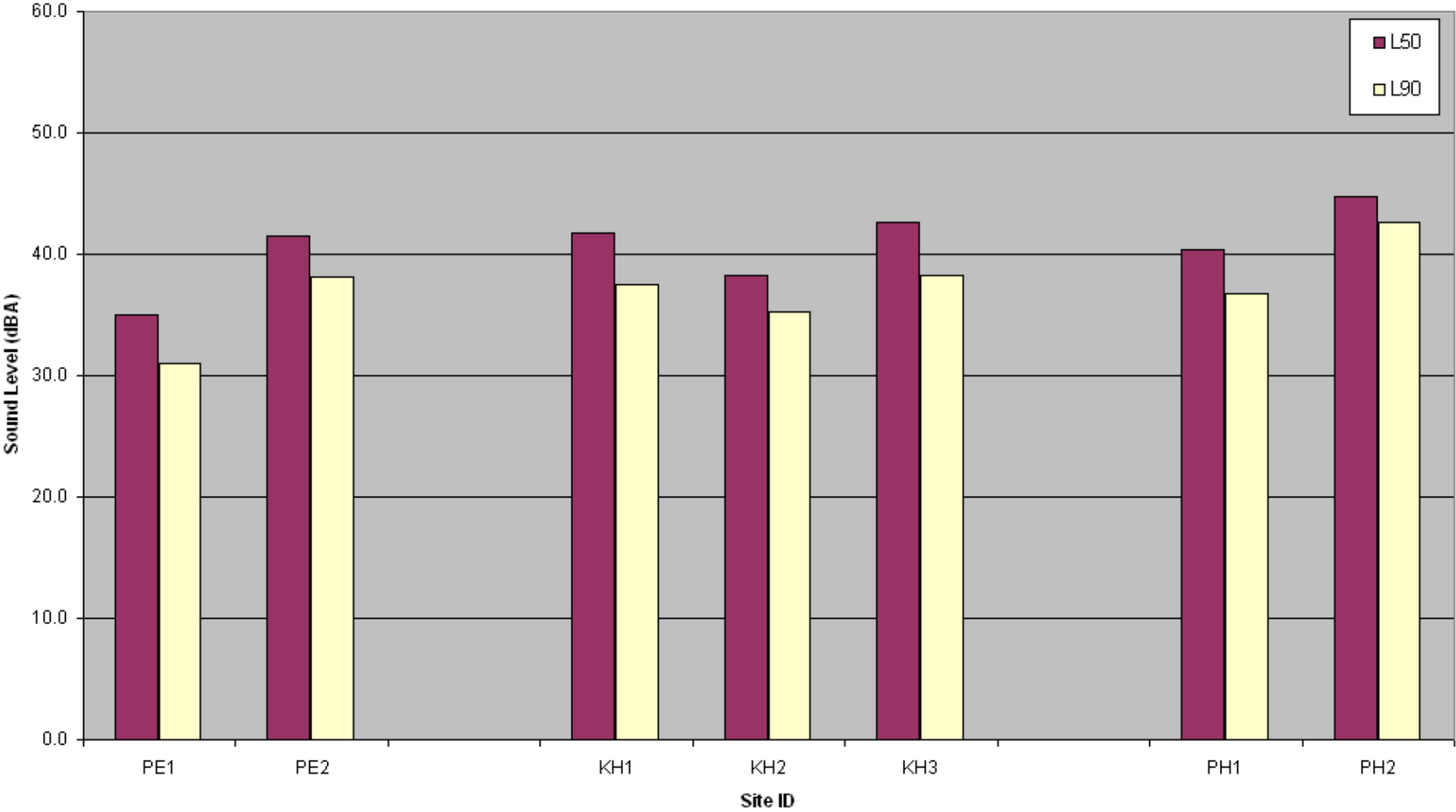


Figure 41. Summary of measured ambient sound level data – Existing Ambient Without Air Tours (L₅₀, L₉₀).

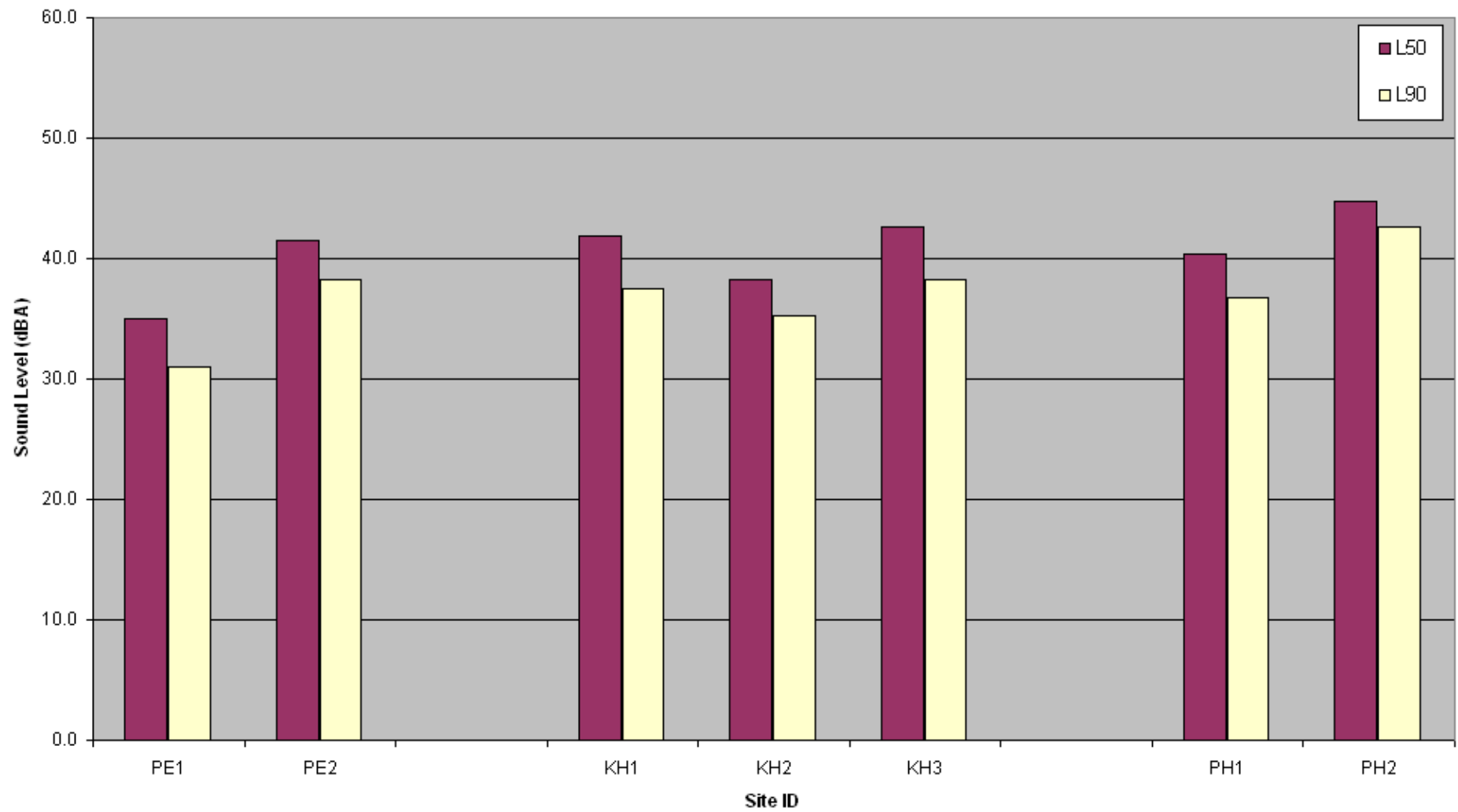


Figure 42. Summary of measured ambient sound level data – Existing Ambient Without All Aircraft (L₅₀, L₉₀).

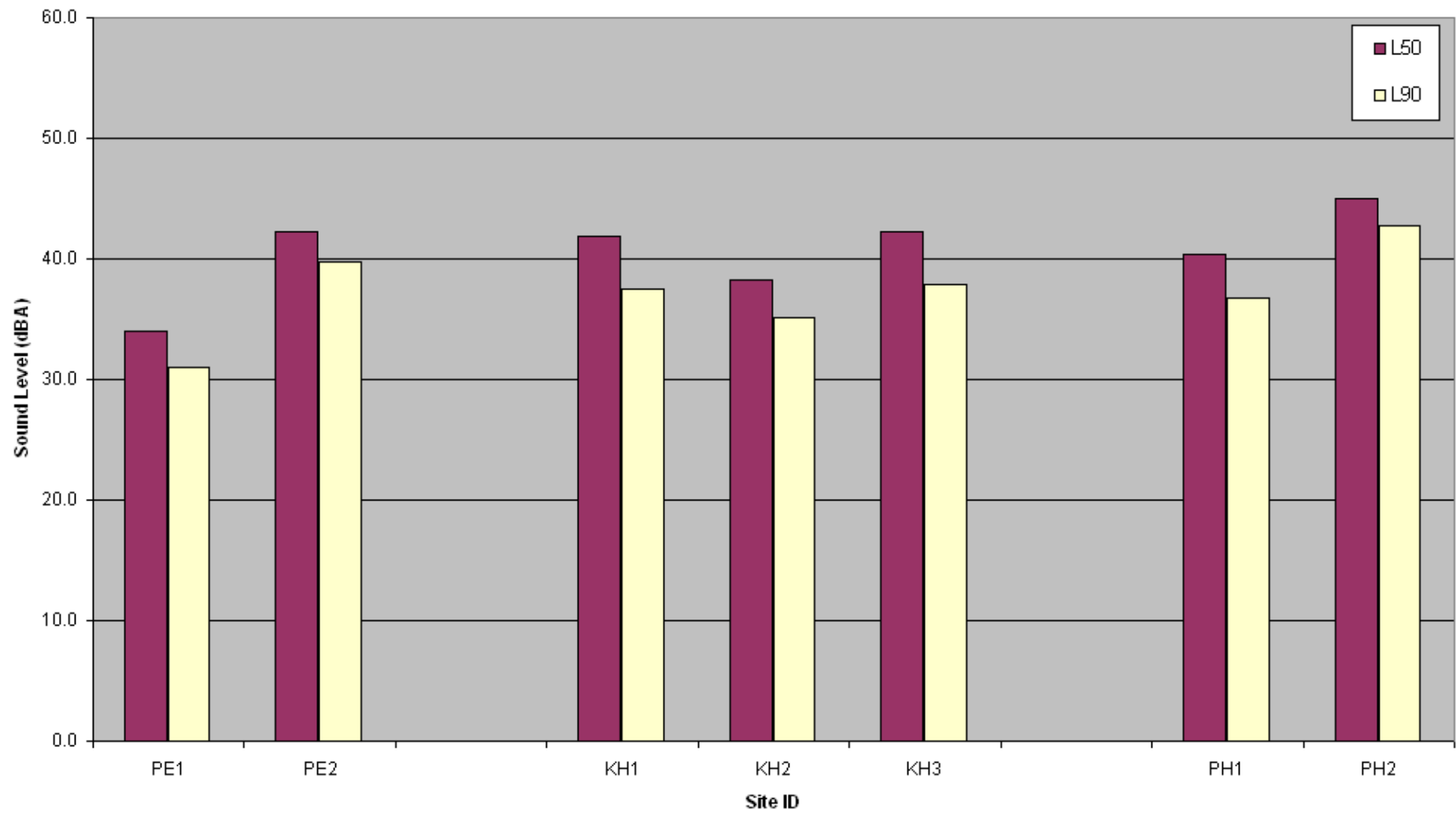


Figure 43. Summary of measured ambient sound level data – Natural Ambient (L₅₀, L₉₀).

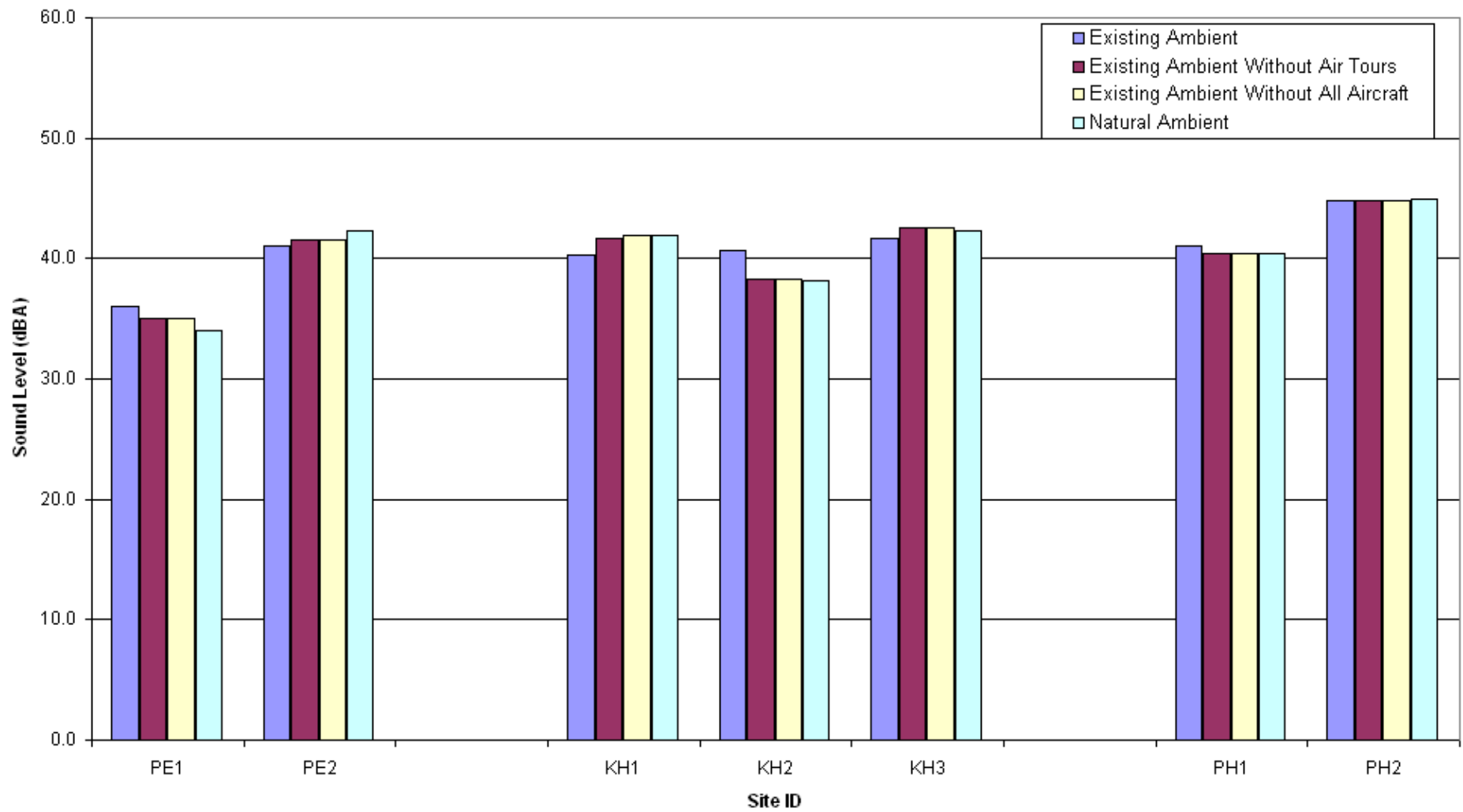


Figure 44. Summary of measured ambient sound level data – L₅₀.

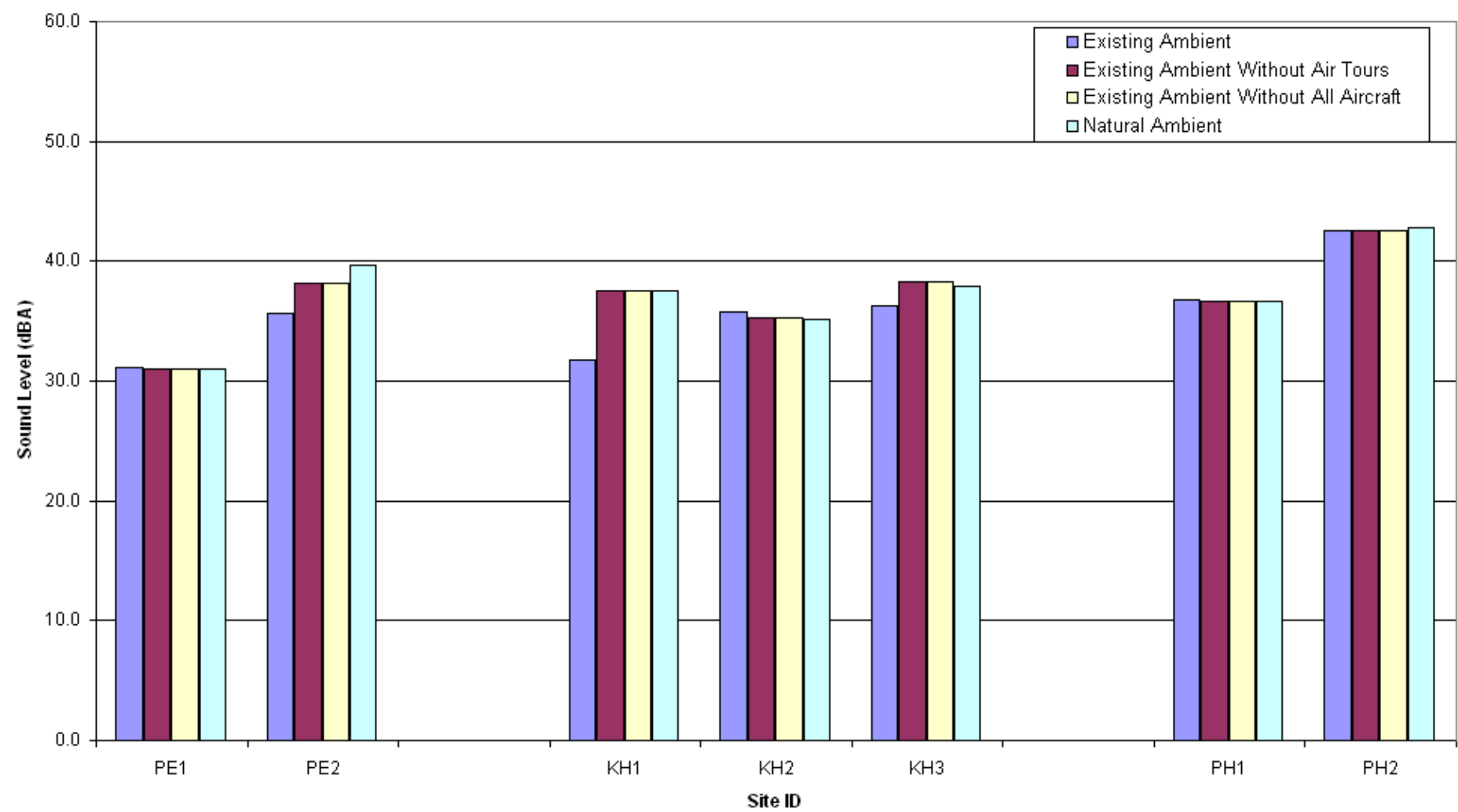


Figure 45. Summary of measured ambient sound level data – L₉₀.

Table 25. Summary of acoustic observer log data. *

Park Name	Site ID	Land Cover	Management Zone	Site Category	Total Duration (s)	Seconds Audible: Aircraft Sound Sources - Air Tours	Seconds Audible: Aircraft Sound Sources - Other	Seconds Audible: Human Sound Sources	Seconds Audible: Natural Sound Sources	% Time Audible: Air Tour	% Time Audible: All Aircraft
Pu`ukohola Heiau	PE1	Bare Rock/Sand/Clay	Natural/Cultural	Overlook	3705	444	38	2562	661	12.0%	13.0%
Pu`ukohola Heiau	PE2	Shrubland	Natural/Cultural	Short Hike	4941	707	246	3383	605	14.3%	19.3%
Kaloko-Honokohau	KH1	Shrubland	Natural/Cultural	Short Hike	3201	134	215	38	2814	4.2%	10.9%
Kaloko-Honokohau	KH2	Bare Rock/Sand/Clay	Natural/Cultural	Short Hike	2515	133	259	316	1807	5.3%	15.6%
Kaloko-Honokohau	KH3	Bare Rock/Sand/Clay	Natural/Cultural	Short Hike	4869	902	126	1025	2816	18.5%	21.1%
Pu`uhonua o Honaunau	PH1	Bare Rock/Sand/Clay	Natural/Cultural	Short Hike	3328	0	0	145	3183	0.0%	0.0%
Pu`uhonua o Honaunau	PH2	Bare Rock/Sand/Clay	Natural/Cultural	Overlook	3641	36	0	1496	2109	1.0%	1.0%

* It should be noted that ideally observer logging should be performed for several hours during different time periods of the day and/or week. However, due to occasional weather, accessibility, and equipment issues, only limited observer logging were performed at each site.

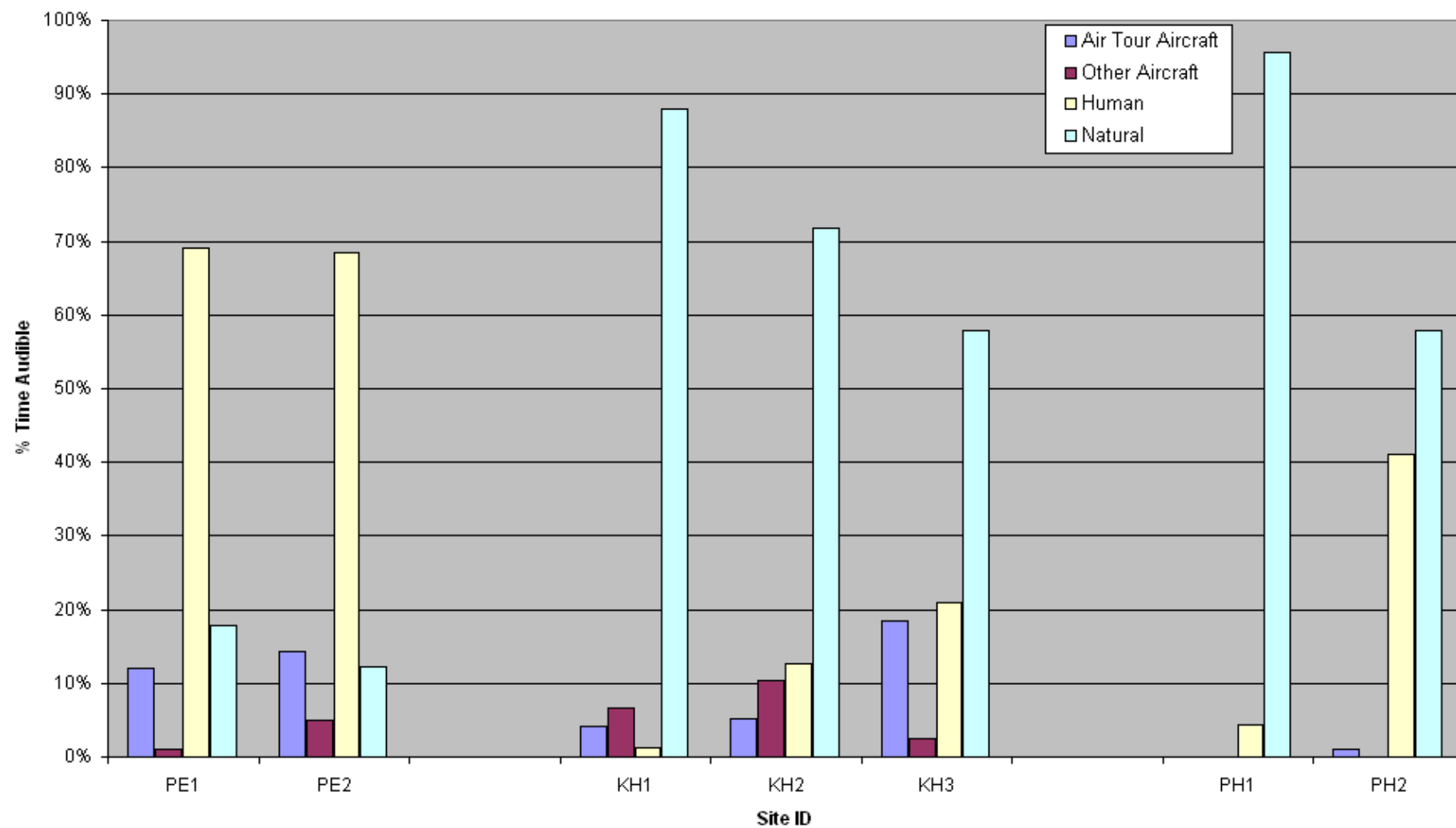


Figure 46. Summary of acoustic observer log data.

Table 26. Summary of acoustic observer log data: number of events per hour and noise-free interval.

	Park Name	Site ID	Noise-Free Periods	Air Tour Aircraft Events	Other Aircraft Events
Number Periods/Events:	Pu`ukohola Heiau	PE1	33	20	9
Mean Time (minutes):	Pu`ukohola Heiau	PE1	0:00:19	0:00:36	0:00:28
Minimum Time (minutes):	Pu`ukohola Heiau	PE1	0:00:04	0:00:05	0:00:05
Maximum Time (minutes):	Pu`ukohola Heiau	PE1	0:01:14	0:02:01	0:01:22
Total Time (minutes):	Pu`ukohola Heiau	PE1	0:10:30	0:12:04	0:04:11
Number Periods/Events:	Pu`ukohola Heiau	PE2	34	4	2
Mean Time (minutes):	Pu`ukohola Heiau	PE2	0:00:20	0:01:51	0:00:19
Minimum Time (minutes):	Pu`ukohola Heiau	PE2	0:00:05	0:00:15	0:00:07
Maximum Time (minutes):	Pu`ukohola Heiau	PE2	0:00:54	0:04:21	0:00:31
Total Time (minutes):	Pu`ukohola Heiau	PE2	0:11:08	0:07:24	0:00:38
Number Periods/Events:	Kaloko-Honokohau	KH1	24	4	6
Mean Time (minutes):	Kaloko-Honokohau	KH1	0:01:57	0:00:33	0:00:36
Minimum Time (minutes):	Kaloko-Honokohau	KH1	0:00:04	0:00:22	0:00:10
Maximum Time (minutes):	Kaloko-Honokohau	KH1	0:07:39	0:00:46	0:00:54
Total Time (minutes):	Kaloko-Honokohau	KH1	0:46:56	0:02:14	0:03:35
Number Periods/Events:	Kaloko-Honokohau	KH2	27	2	13
Mean Time (minutes):	Kaloko-Honokohau	KH2	0:01:46	0:01:11	0:00:35
Minimum Time (minutes):	Kaloko-Honokohau	KH2	0:00:05	0:00:09	0:00:08
Maximum Time (minutes):	Kaloko-Honokohau	KH2	0:05:48	0:02:13	0:01:12
Total Time (minutes):	Kaloko-Honokohau	KH2	0:44:21	0:02:22	0:07:04
Number Periods/Events:	Kaloko-Honokohau	KH3	29	5	3
Mean Time (minutes):	Kaloko-Honokohau	KH3	0:01:37	0:03:00	0:00:42
Minimum Time (minutes):	Kaloko-Honokohau	KH3	0:00:11	0:00:27	0:00:32
Maximum Time (minutes):	Kaloko-Honokohau	KH3	0:09:28	0:09:09	0:00:49
Total Time (minutes):	Kaloko-Honokohau	KH3	0:46:56	0:15:02	0:02:06
Number Periods/Events:	Pu`uhonua o Honaunau	PH1	218	0	0
Mean Time (minutes):	Pu`uhonua o Honaunau	PH1	0:00:15	0:00:00	0:00:00
Minimum Time (minutes):	Pu`uhonua o Honaunau	PH1	0:00:05	0:00:00	0:00:00
Maximum Time (minutes):	Pu`uhonua o Honaunau	PH1	0:02:02	0:00:00	0:00:00
Total Time (minutes):	Pu`uhonua o Honaunau	PH1	0:53:04	0:00:00	0:00:00
Number Periods/Events:	Pu`uhonua o Honaunau	PH2	39	1	0
Mean Time (minutes):	Pu`uhonua o Honaunau	PH2	0:00:53	0:00:36	0:00:00
Minimum Time (minutes):	Pu`uhonua o Honaunau	PH2	0:00:05	0:00:36	0:00:00
Maximum Time (minutes):	Pu`uhonua o Honaunau	PH2	0:02:55	0:00:36	0:00:00
Total Time (minutes):	Pu`uhonua o Honaunau	PH2	0:35:19	0:00:36	0:00:00

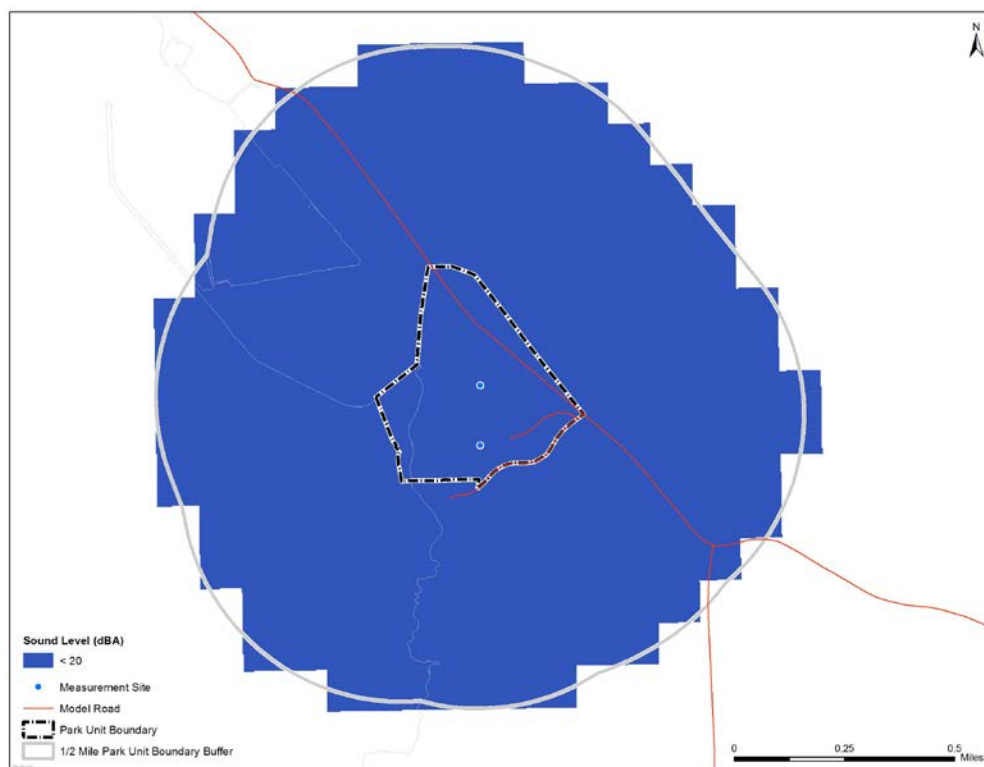


Figure 47. Roadway ambient map for Pu`ukohola Heiau.

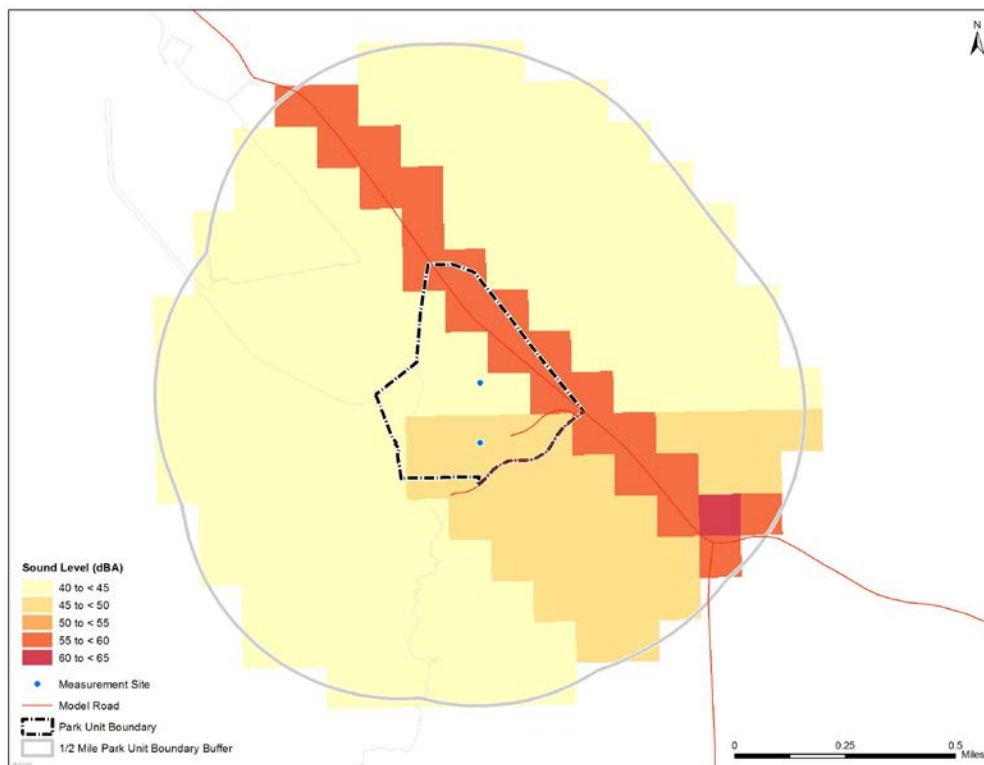


Figure 48. Baseline ambient map for Pu`ukohola Heiau – Existing Ambient: L_{Aeq} .

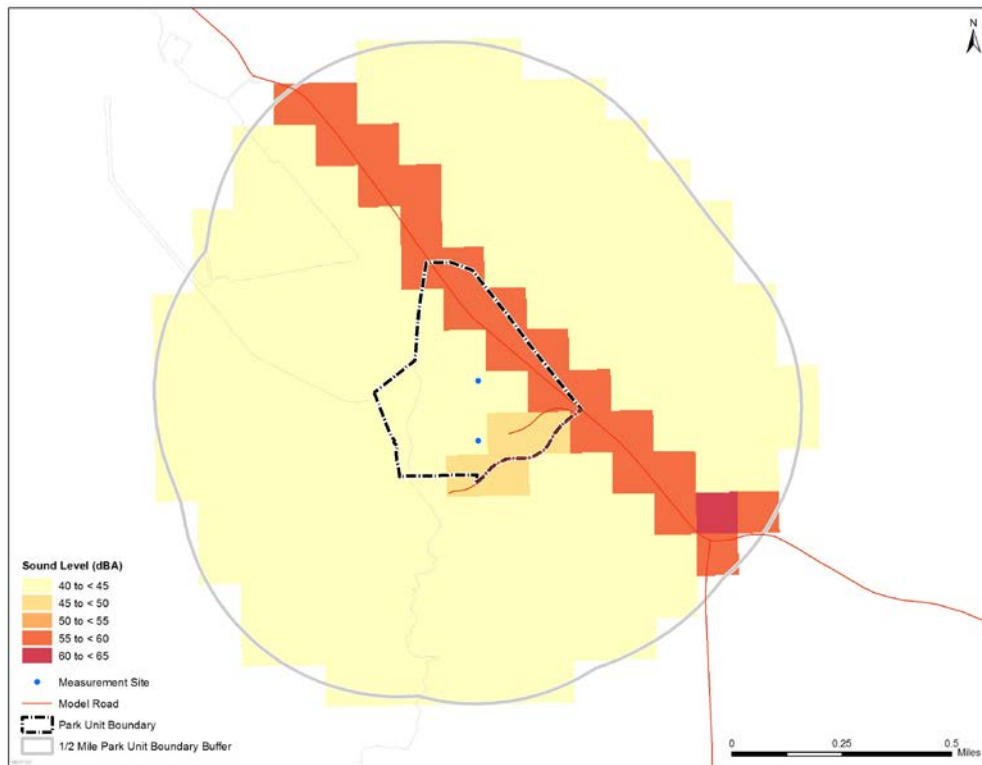


Figure 49. Baseline ambient map for Pu`ukohola Heiau – Existing Ambient: L₅₀.

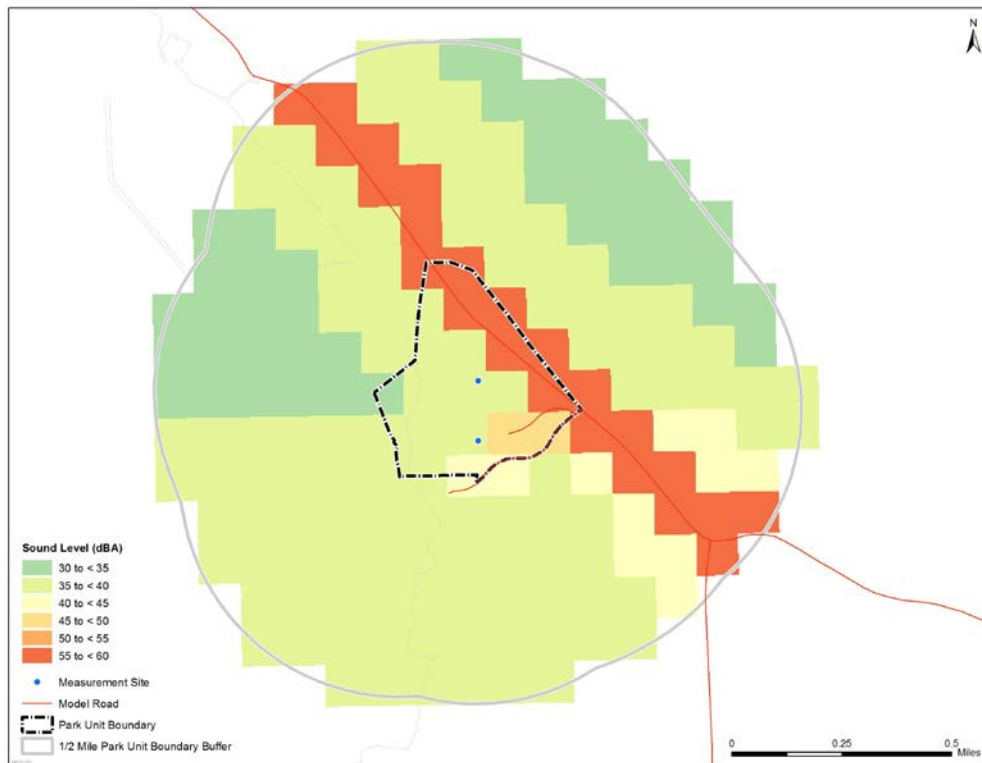


Figure 50. Baseline ambient map for Pu`ukohola Heiau – Existing Ambient: L₉₀.

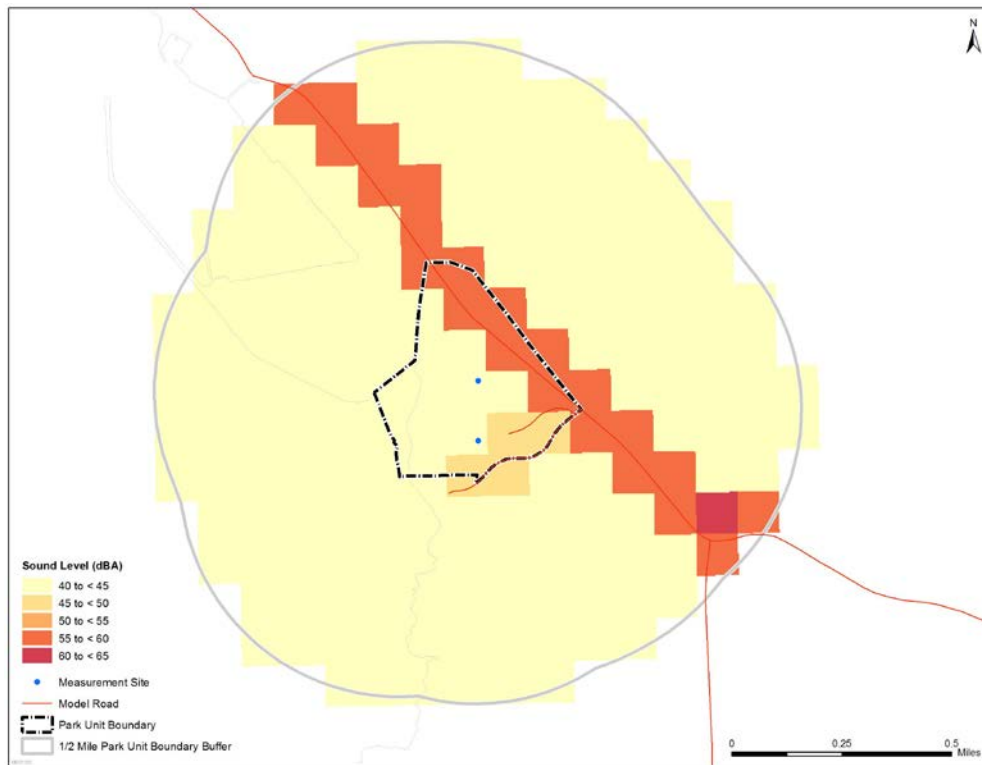


Figure 51. Baseline ambient map for Pu`ukohola Heiau – Existing Ambient Without Air Tours: L₅₀.

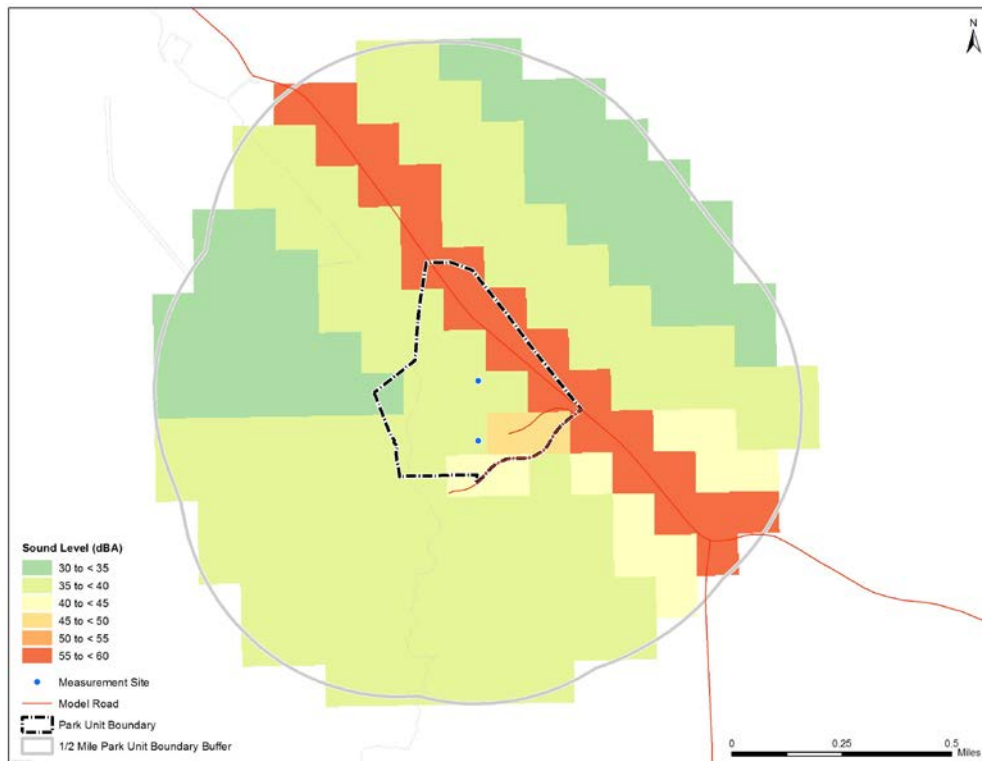


Figure 52. Baseline ambient map for Pu`ukohola Heiau – Existing Ambient Without Air Tours: L₉₀.

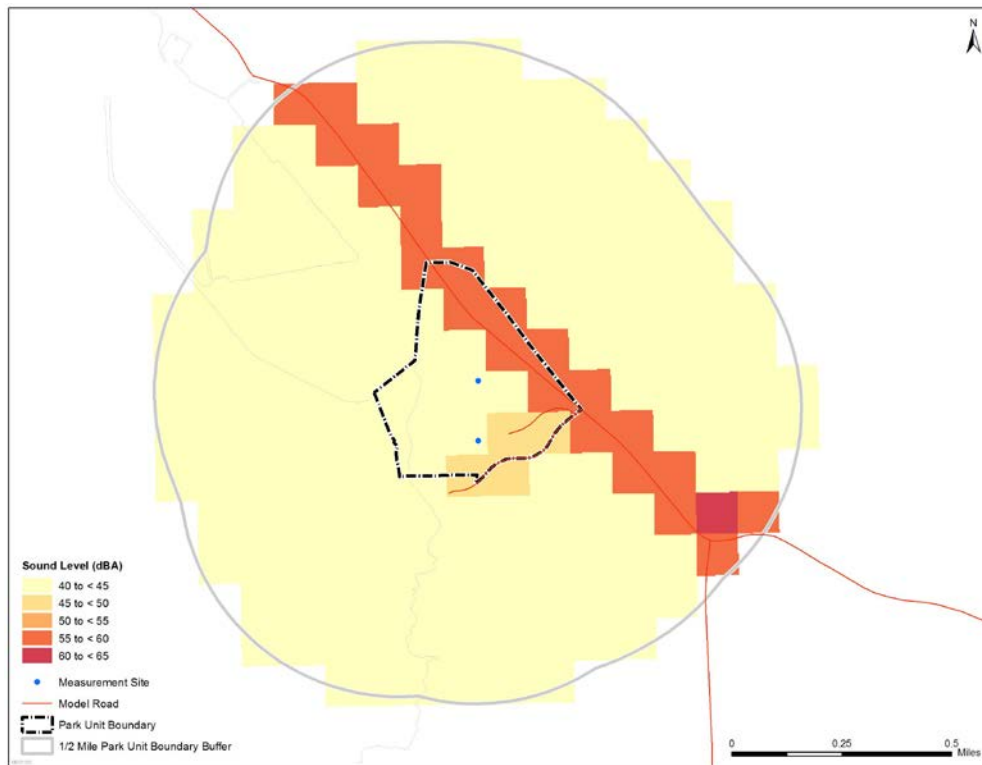


Figure 53. Baseline ambient map for Pu`ukohola Heiau – Existing Ambient Without All Aircraft: L₅₀.

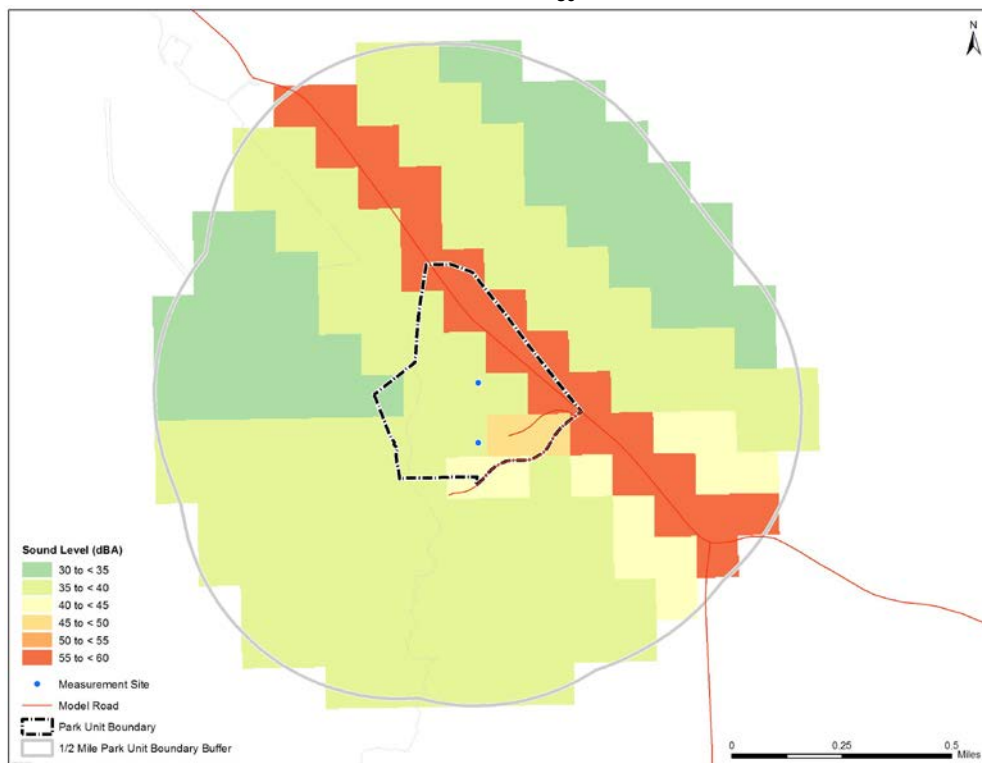


Figure 54. Baseline ambient map for Pu`ukohola Heiau – Existing Ambient Without All Aircraft: L₉₀.

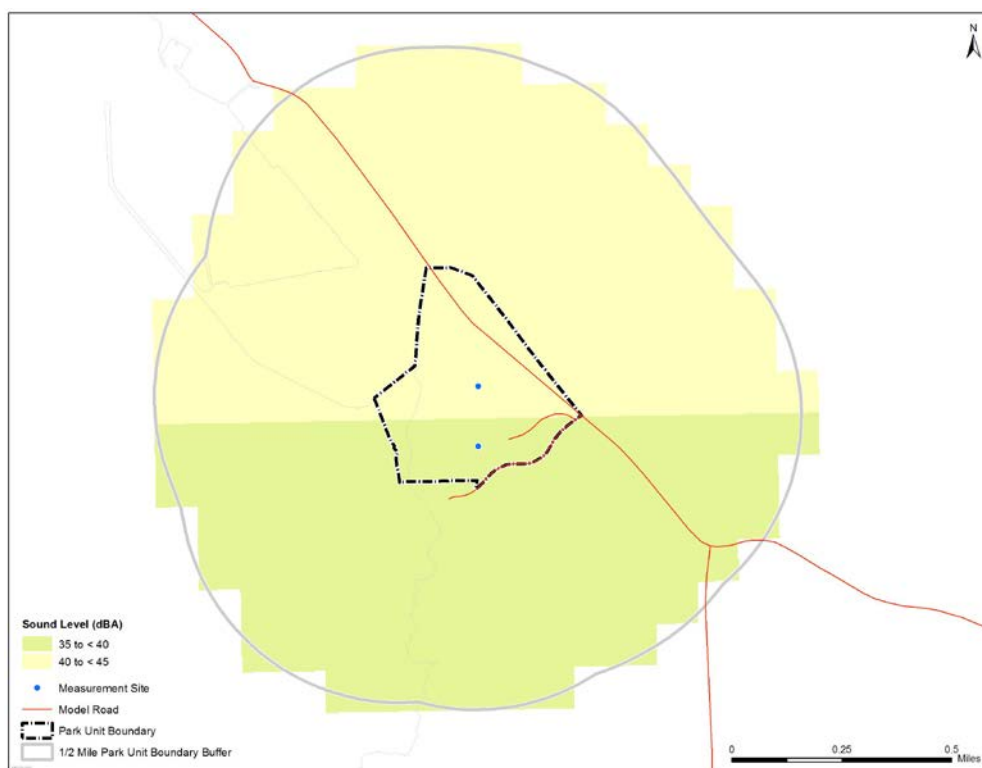


Figure 55. Baseline ambient map for Pu`ukohola Heiau – Natural Ambient: L₅₀.

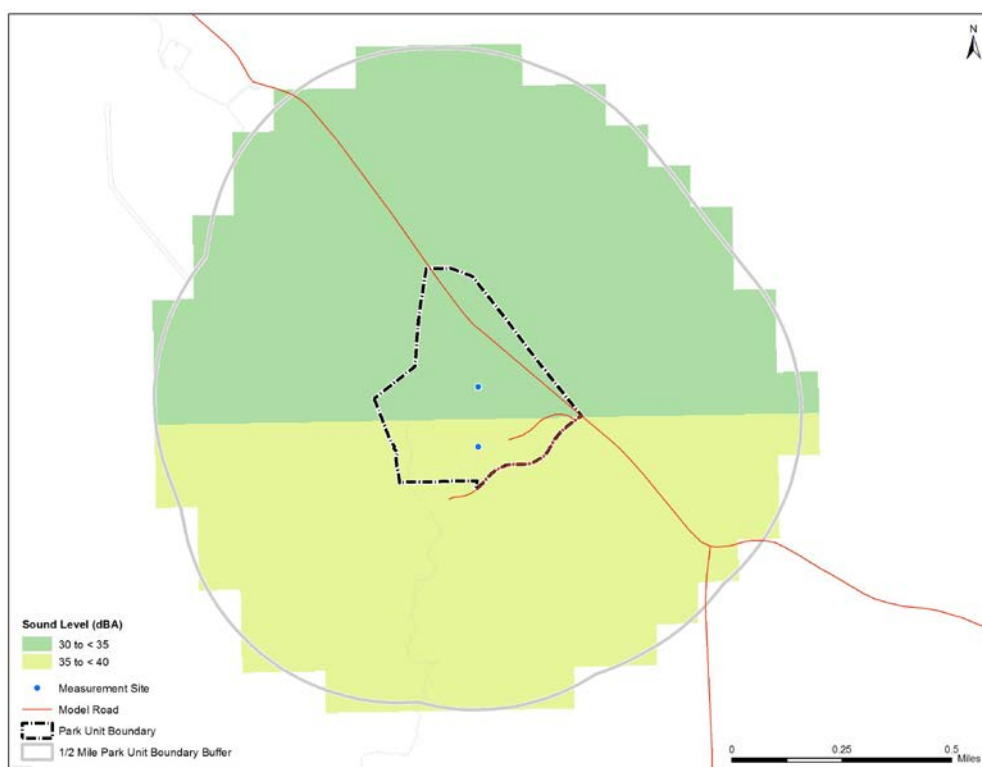


Figure 56. Baseline ambient map for Pu`ukohola Heiau – Natural Ambient: L₉₀.

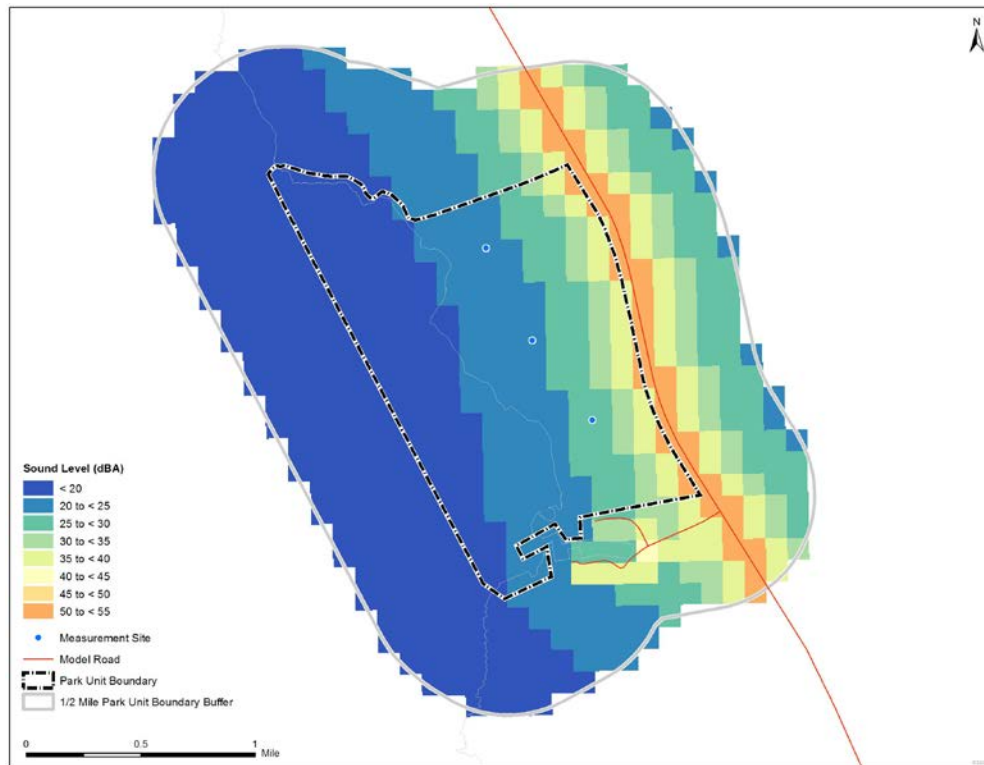


Figure 57. Roadway ambient map for Kaloko-Honokohau.

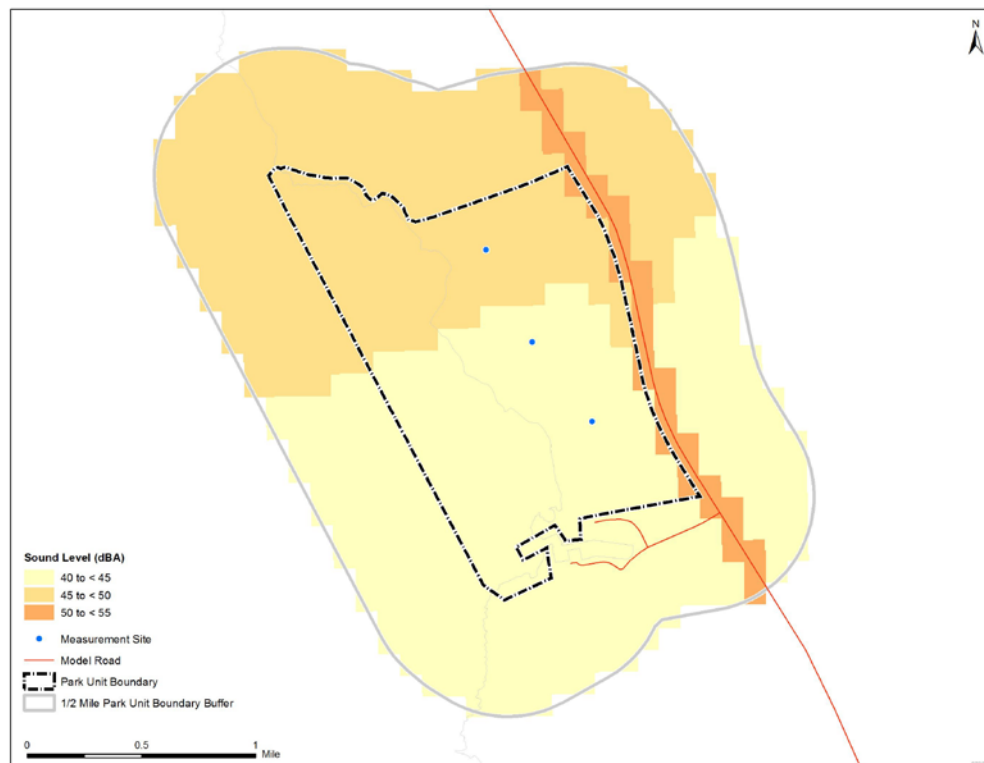


Figure 58. Baseline ambient map for Kaloko-Honokohau – Existing Ambient: L_{Aeq} .

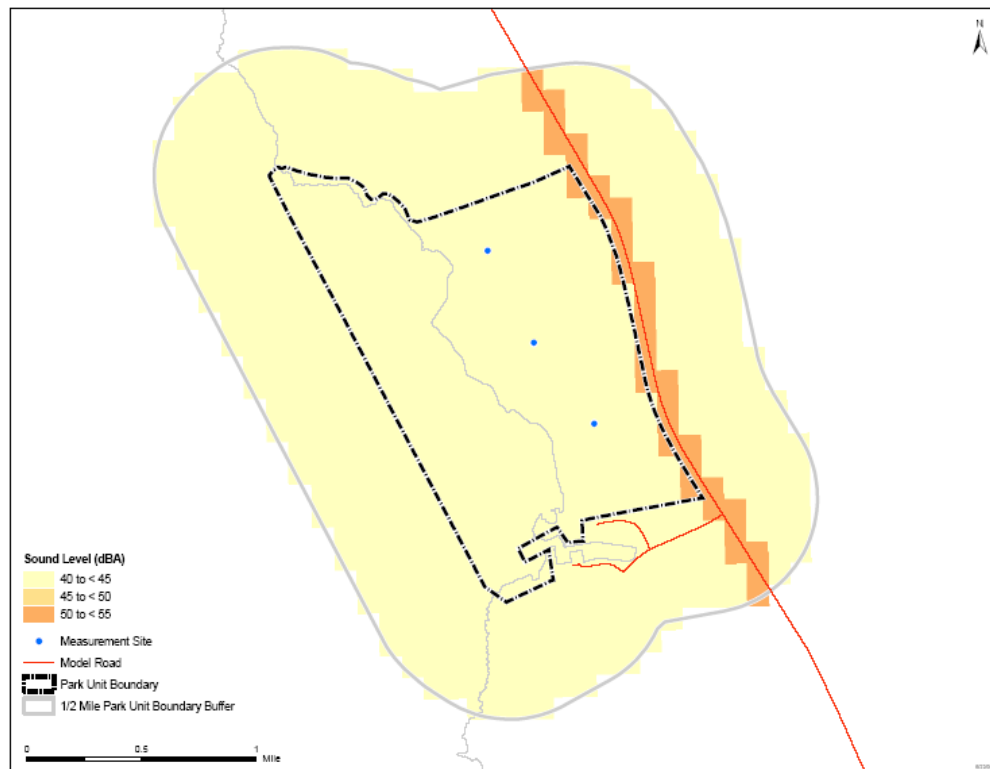


Figure 59. Baseline ambient map for Kaloko-Honokohau – Existing Ambient: L₅₀.

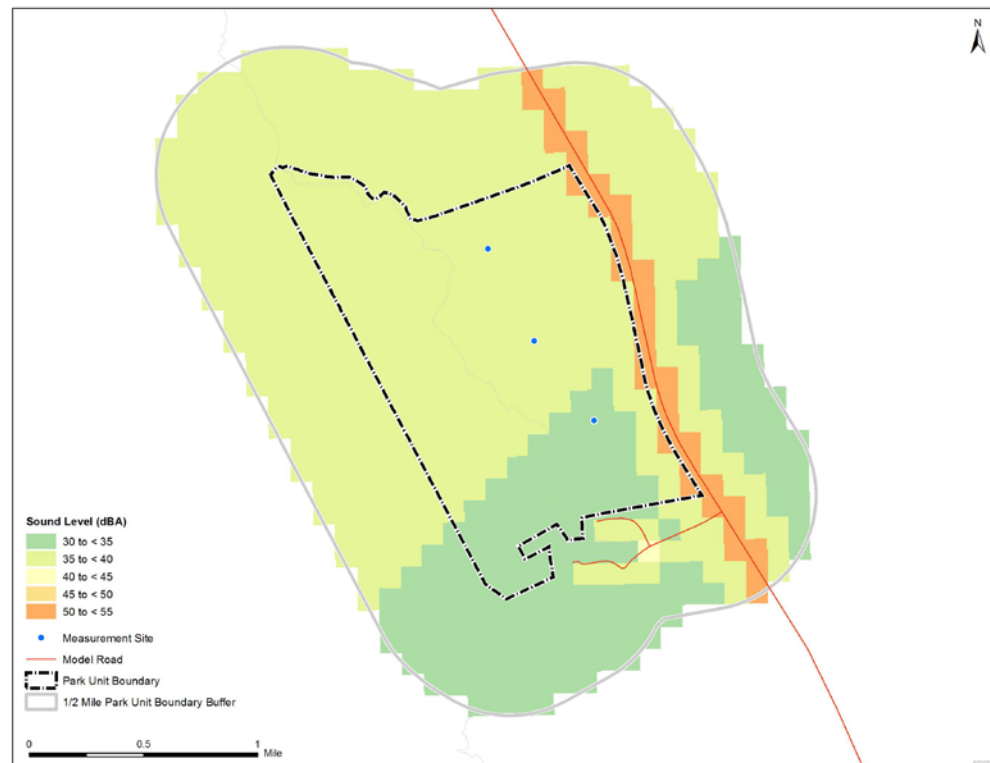


Figure 60. Baseline ambient map for Kaloko-Honokohau – Existing Ambient: L₉₀.

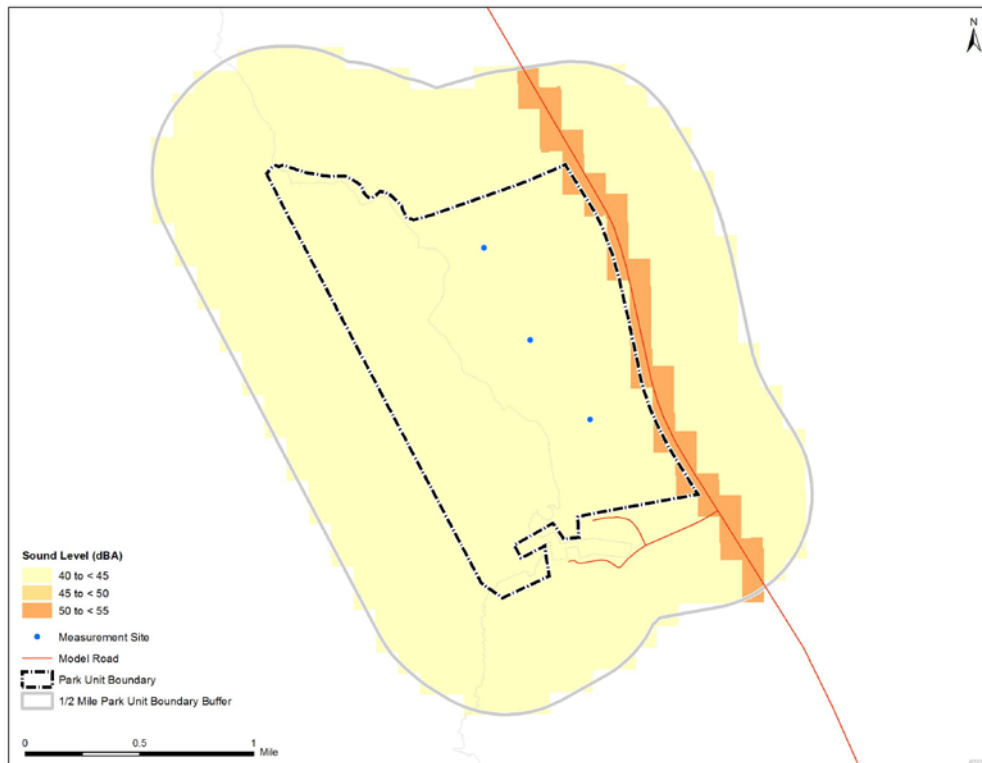


Figure 61. Baseline ambient map for Kaloko-Honokohau – Existing Ambient Without Air Tours: L₅₀.



Figure 62. Baseline ambient map for Kaloko-Honokohau – Existing Ambient Without Air Tours: L₉₀.

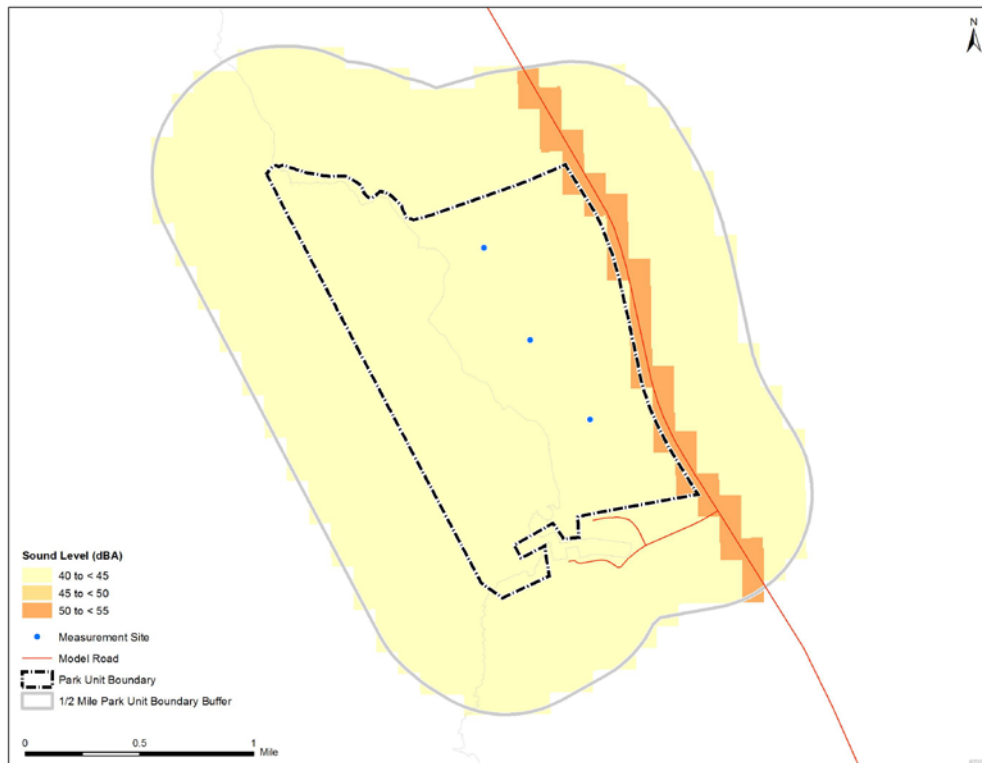


Figure 63. Baseline ambient map for Kaloko-Honokohau – Existing Ambient Without All Aircraft: L₅₀.



Figure 64. Baseline ambient map for Kaloko-Honokohau – Existing Ambient Without All Aircraft: L₉₀.

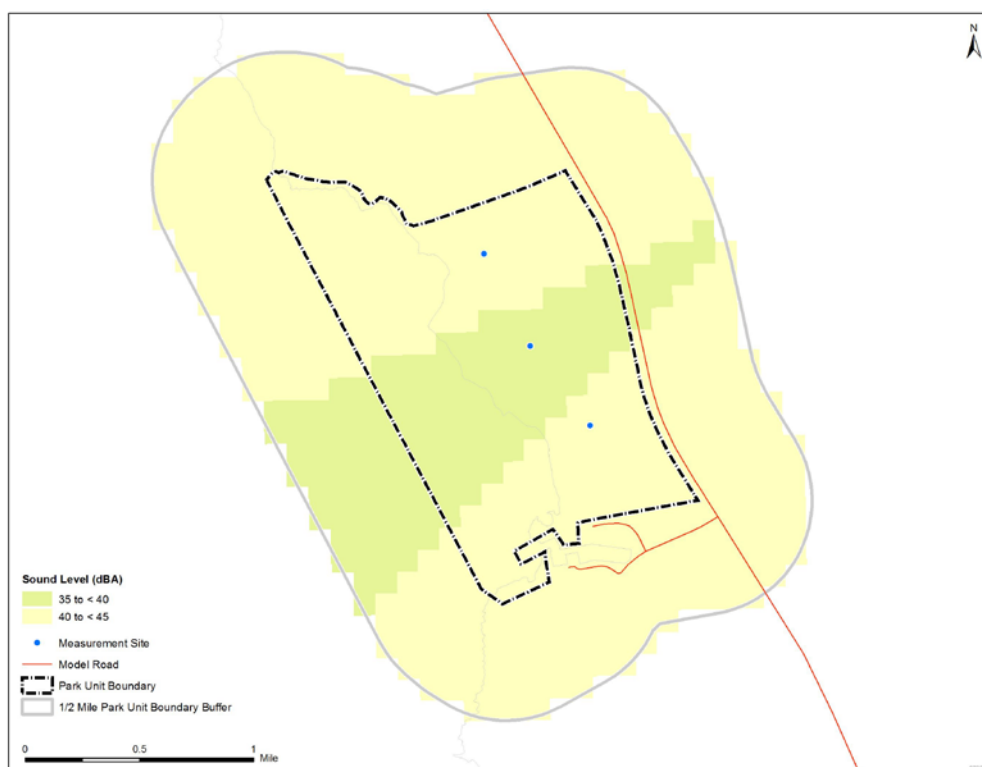


Figure 65. Baseline ambient map for Kaloko-Honokohau – Natural Ambient: L₅₀.

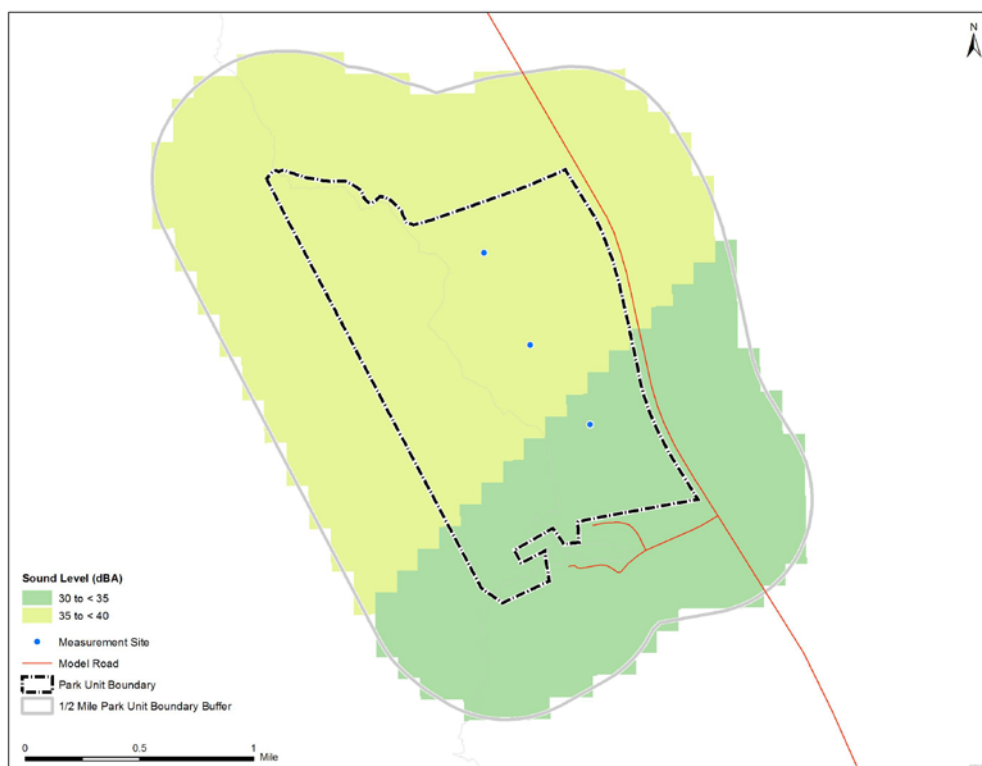


Figure 66. Baseline ambient map for Kaloko-Honokohau – Natural Ambient: L₉₀.

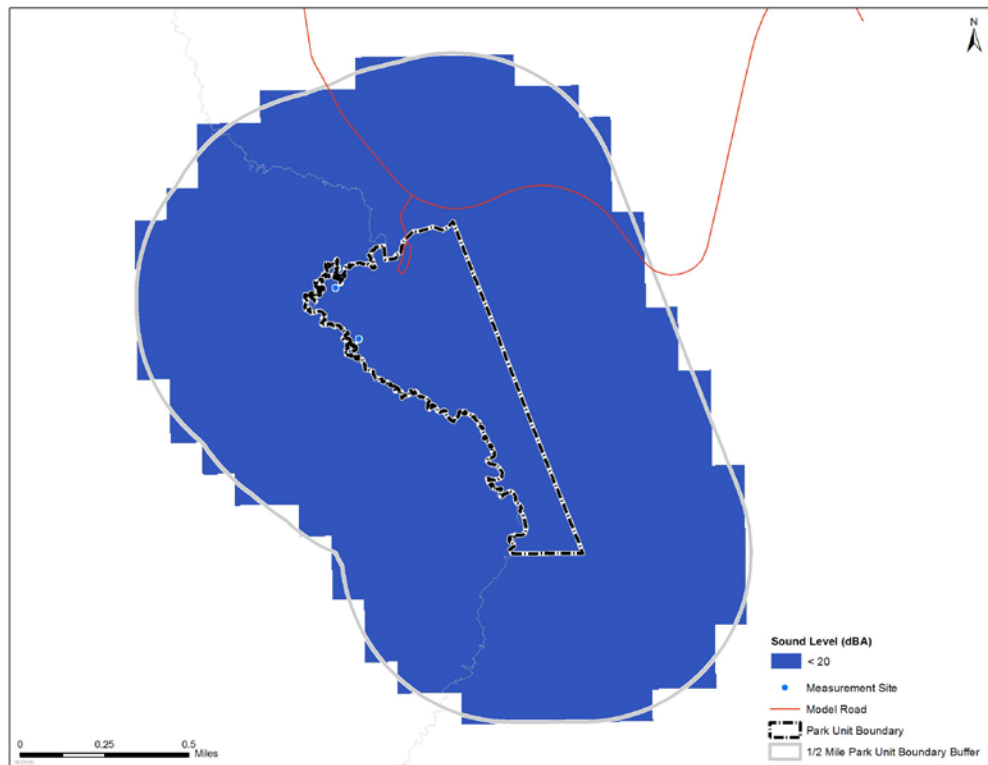


Figure 67. Roadway ambient map for Pu`uhonua o Honaunau.

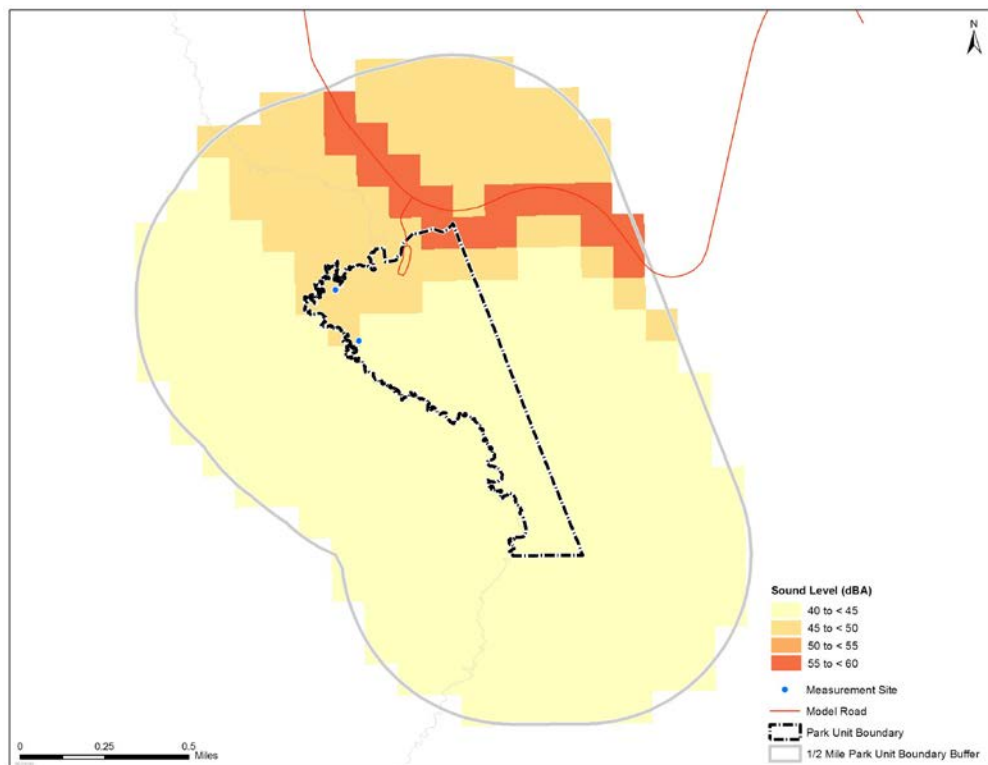


Figure 68. Baseline ambient map for Pu`uhonua o Honaunau – Existing Ambient: L_{Aeq} .

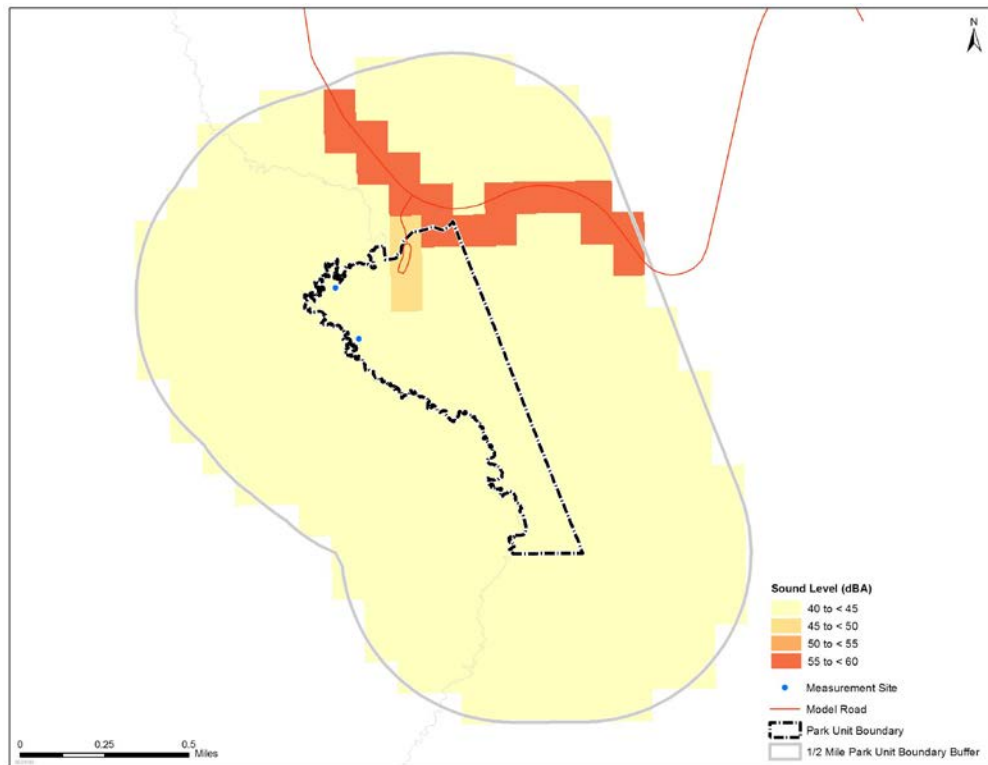


Figure 69. Baseline ambient map for Pu`uhonua o Honaunau – Existing Ambient: L₅₀.

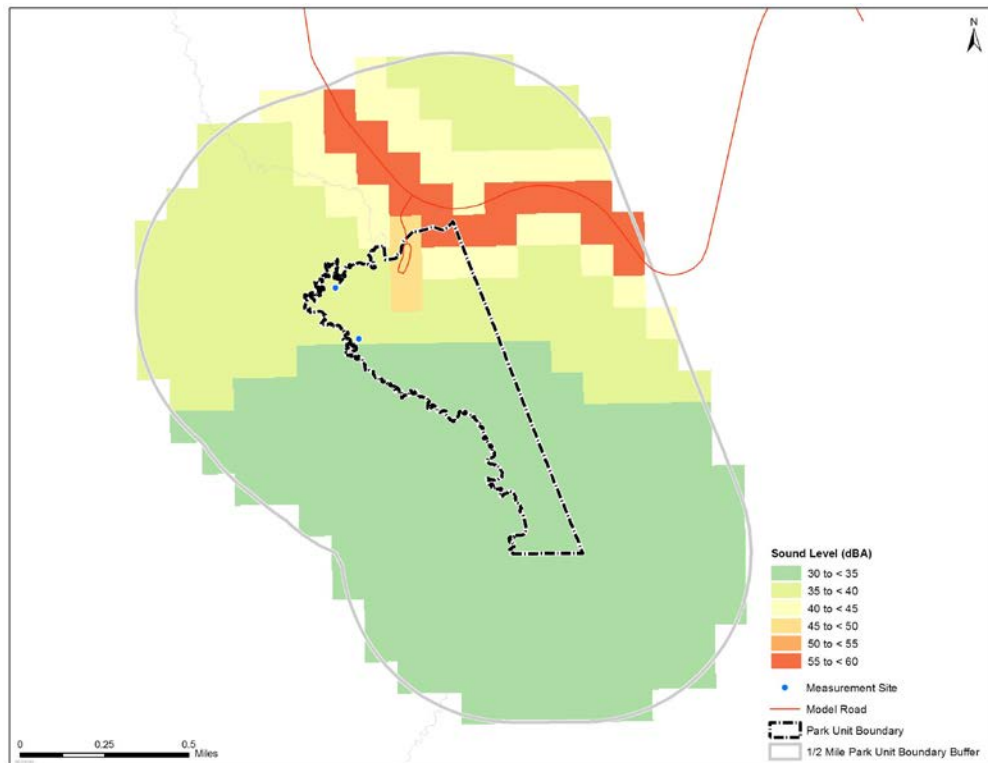


Figure 70. Baseline ambient map for Pu`uhonua o Honaunau – Existing Ambient: L₉₀.

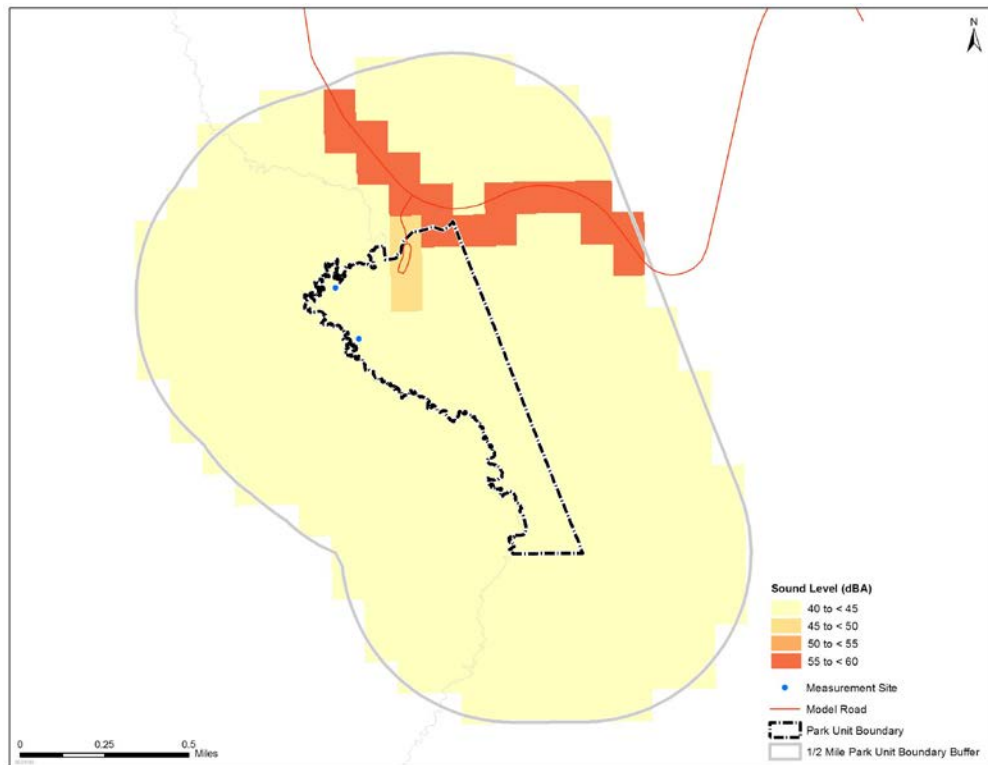


Figure 71. Baseline ambient map for Pu`uhonua o Honaunau – Existing Ambient Without Air Tours: L₅₀.

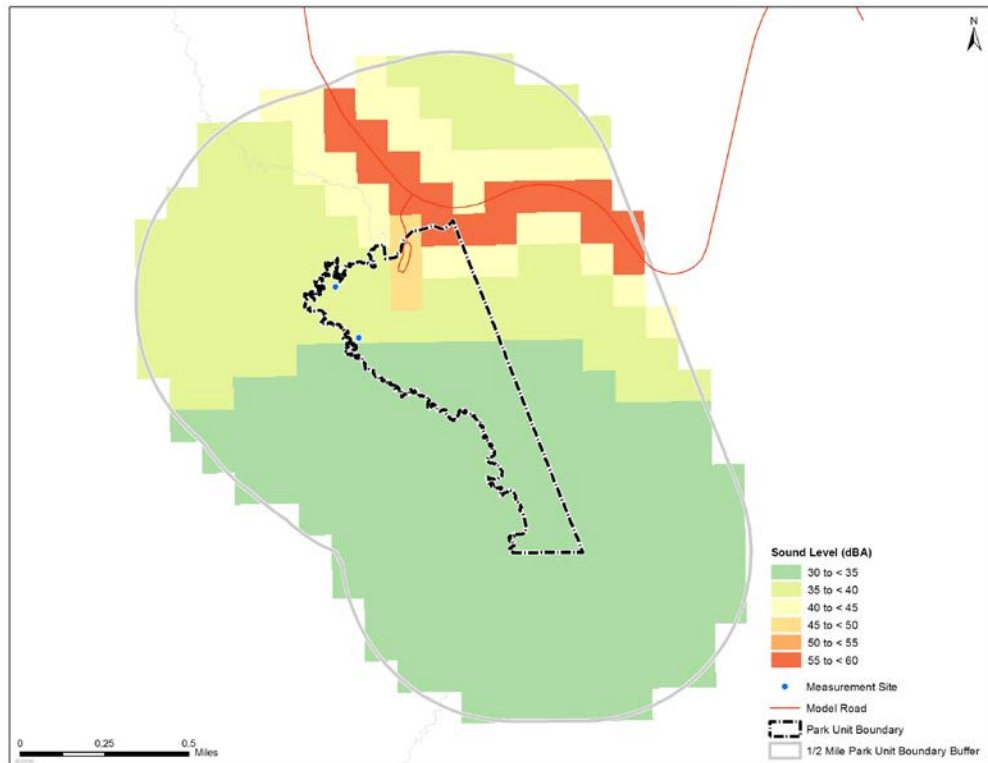


Figure 72. Baseline ambient map for Pu`uhonua o Honaunau – Existing Ambient Without Air Tours: L₉₀.

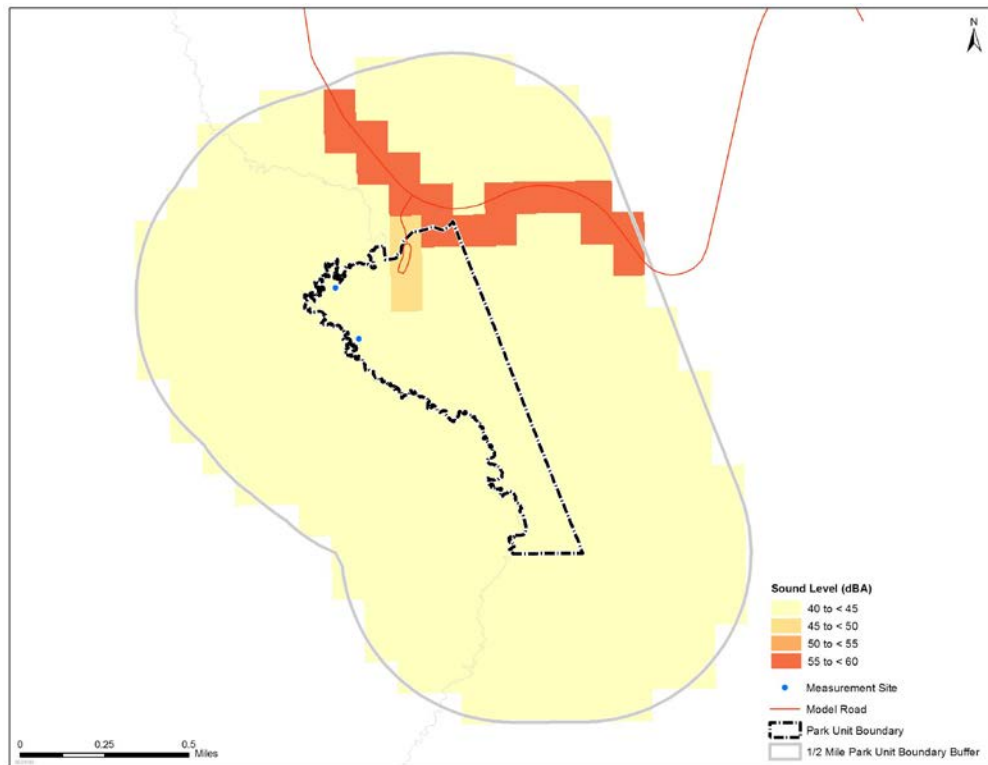


Figure 73. Baseline ambient map for Pu`uhonua o Honaunau – Existing Ambient Without All Aircraft: L₅₀.

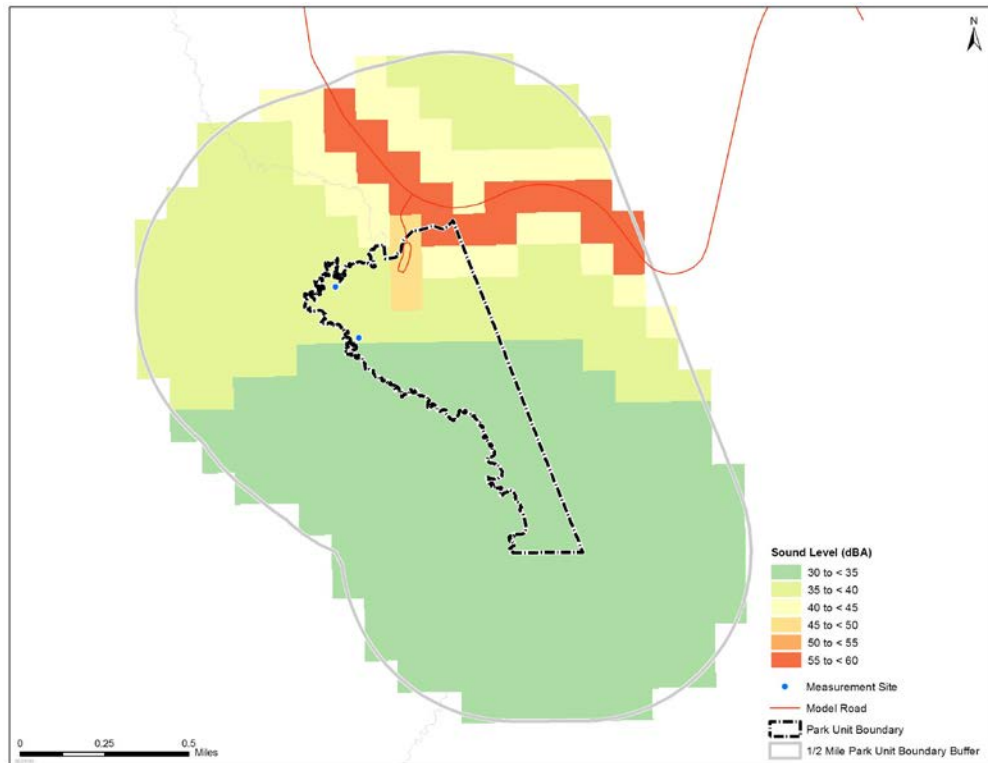


Figure 74. Baseline ambient map for Pu`uhonua o Honaunau – Existing Ambient Without All Aircraft: L₉₀.

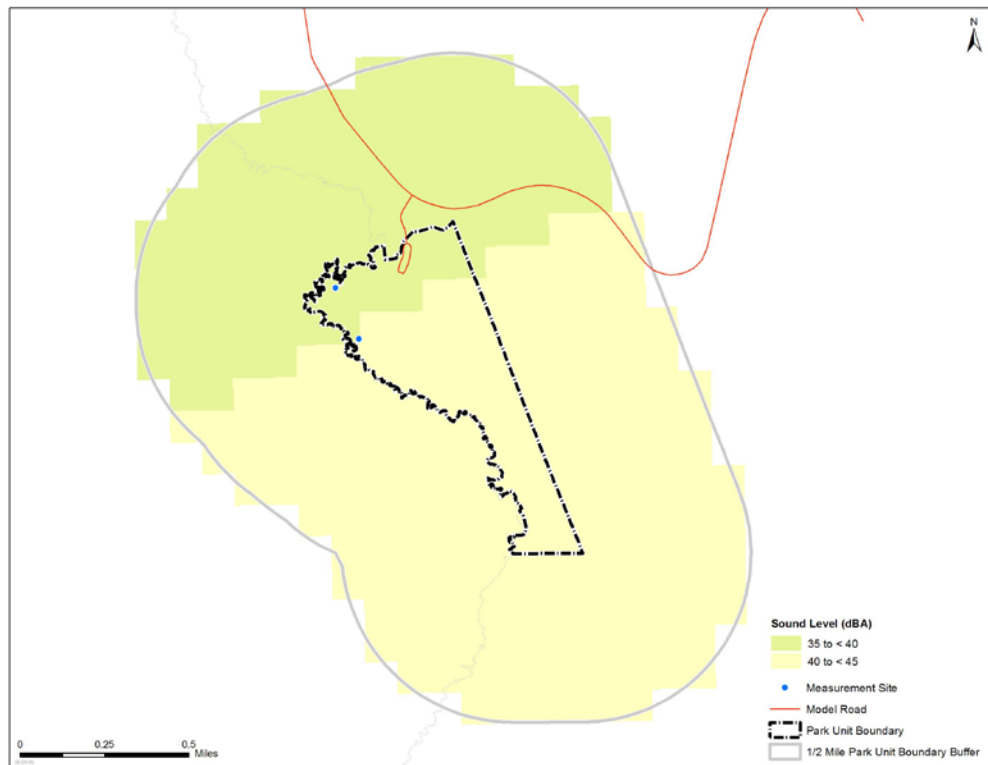


Figure 75. Baseline ambient map for Pu`uhonua o Honaunau – Natural Ambient: L₅₀.

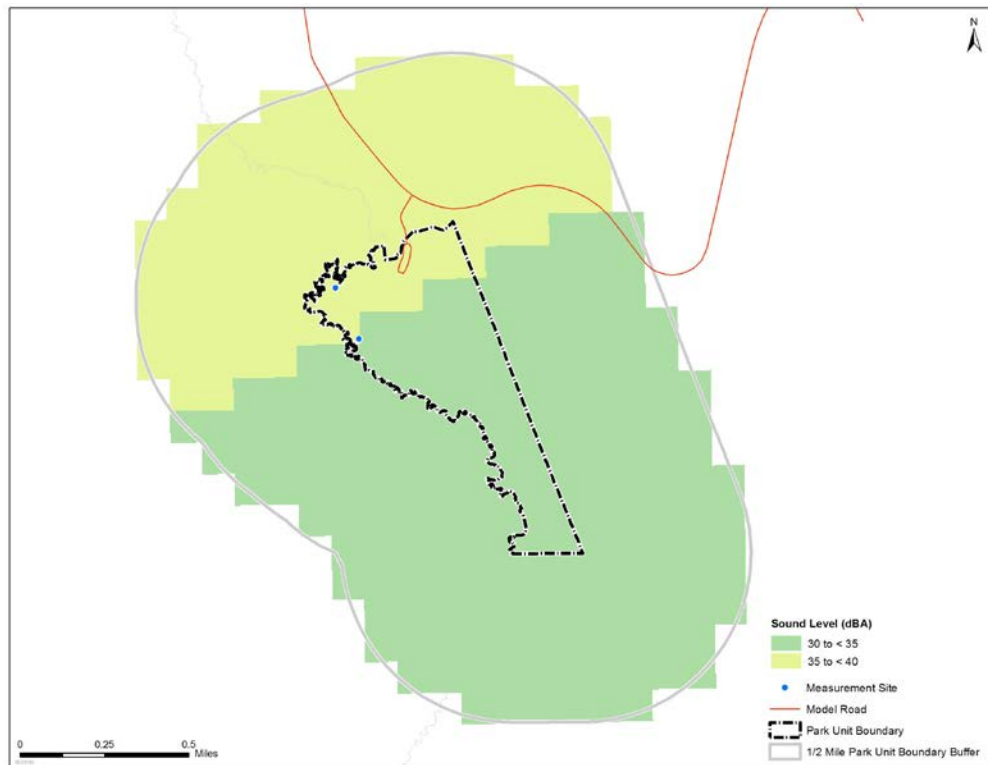


Figure 76. Baseline ambient map for Pu`uhonua o Honaunau – Natural Ambient: L₉₀.

APPENDIX A. MEASUREMENT SITE DETAILS

The measurement sites for each park are shown in Figure 78 through Figure 80 and described here in detail.

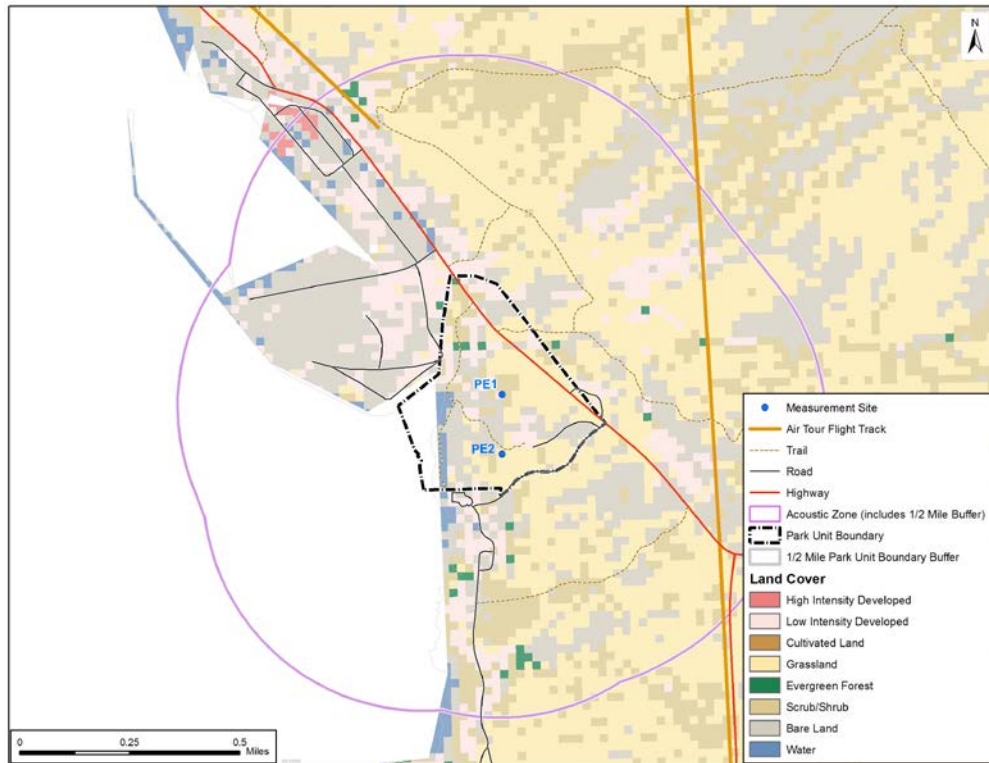


Figure 77. Final measurement sites for Pu'ukohola Heiau.

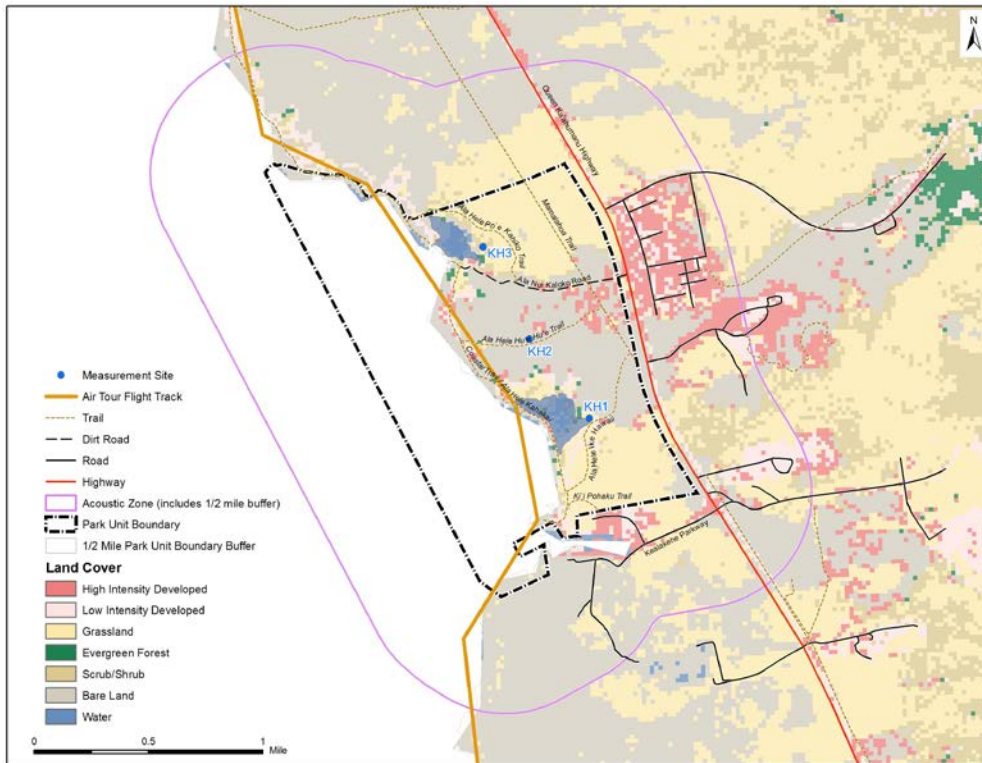


Figure 78. Final measurement sites for Kaloko-Honokohau.

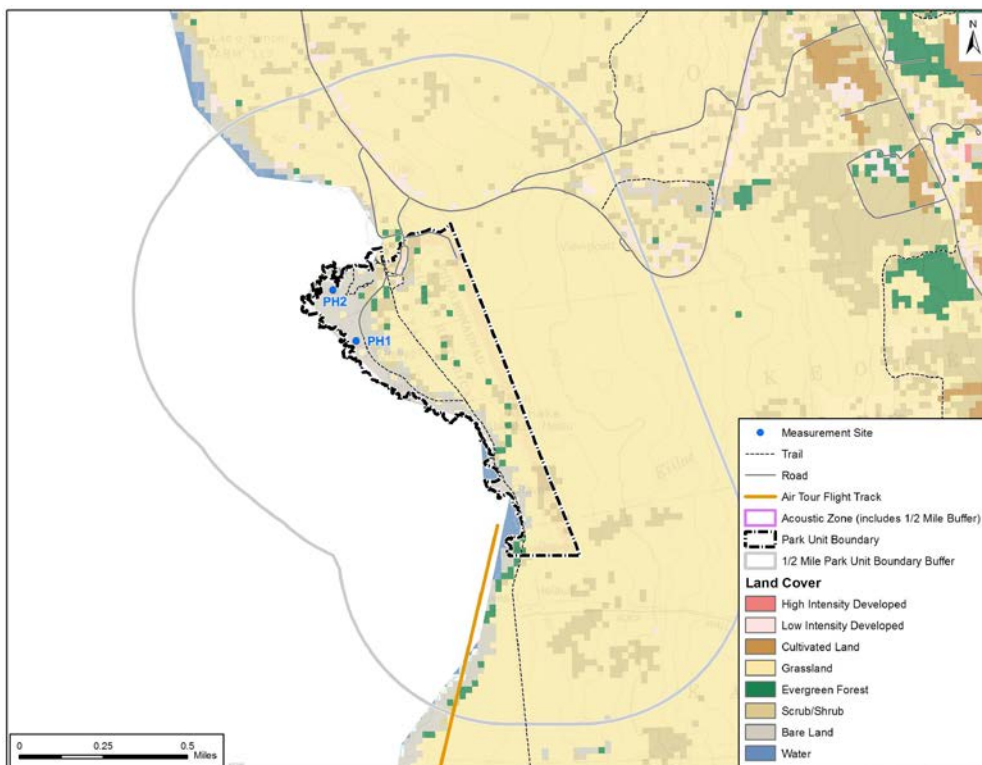


Figure 79. Final measurement sites for Pu`uhonua o Honaunau.

For each site, the following are included:

- A table providing site description and arranged as follows:
 - *Site ID*: The unique two-character ID representing the site “number”;
 - *Site Name*: The name of the site;
 - *# Measurement Days and Dates*: The total number of days measured and the dates the measurements started and ended, respectively;
 - *System # and Type*: The numeric identifier of the continuous monitoring system used at the site (see Table 9 in Section 4.1);
 - *Latitude/Longitude (decimal degrees)*: The latitudinal and longitudinal location of the site in decimal degrees;
 - *Approximate Elevation (ft)*: The elevation of the site above mean sea level (MSL) in feet;
 - *Ecological Domain*: The geographic ecosystem unit of the site (see also Appendix D);
 - *Ecological Division*: The geographic ecosystem subunit of the site (see also Appendix D);
 - *Land Cover Class*: The land cover class of the site in accordance with the National Land Cover Data (NLCD) 21-class land cover classification scheme (see also Appendix D);
 - *Land Cover Subclass*: The land cover subclass of the site in accordance with the National Land Cover Data (NLCD) 21-class land cover classification scheme (see also Appendix D);
 - *Management Zone*: The NPS management zone that the site was located in (see also Section 2.5); and
 - *Site Category*: A designator indicating expected visitor use (with “overlook” indicating high visitor use, “short hike” indicating moderate visitor use, and “backcountry” indicating minimal or no visitor use) in the measurement site area.
 - A photograph of the area;
 - A graphic presenting the daily A-weighted sound levels using three hourly A-weighted metrics (L_{Aeq} , L_{50} , and L_{90} - refer to the Terminology section for definitions), as well as average daily wind speeds over the entire measurement period.
 - A graphic presenting average, hourly sound level data using three hourly A-weighted metrics (L_{Aeq} , L_{50} , and L_{90} - refer to the Terminology section for definitions), as well as average hourly wind speeds; and
-

- A graphic presenting distribution plots of the number of samples of each sound pressure level measured during the daytime hours, and during the nighttime hours. The average wind speed for each hour is also plotted.

Note: As stated in Section 5.3, several quality assurance filters and checks (e.g., high wind filter) and then several adjustments (e.g., noise floor adjustments) were applied to the acoustic data prior to data analysis. Additional discussion on the use of ecological domains/divisions and land cover categories to correlate data in accordance with acoustic zone analyses can be found in Section 6.2.

A.1 Pu`ukohola Heiau: Site PE1

Table 27. Site PE1: description.

Site ID	PE1
Site Name	Site at Heiau
# Measurement Days and Dates	3 days – June 6 to June 8, 2003
System # and Type	5 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.0349 / 155.8243
Approximate Elevation (ft)	124
Ecological Domain (see Appendix D)	(400) Humid Neotropical
Ecological Division (see Appendix D)	(412) Hawaiian Highlands
Land Cover Class (see Appendix D)	(3) Barren
Land Cover Subclass (see Appendix D)	(31) Bare Rock/Sand/Clay
Management Zone (see Section 2.5)	Natural/Cultural
Site Category (see Section 2.5.1)	Overlook

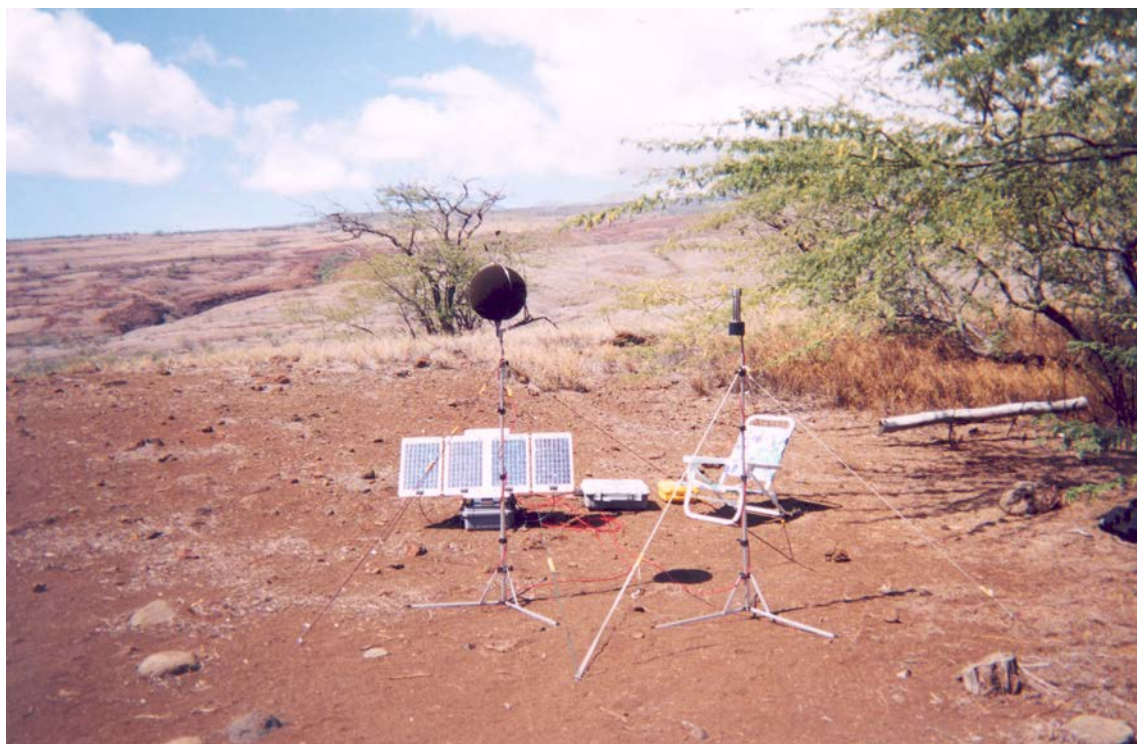


Figure 80. Site PE1: Description and photograph.

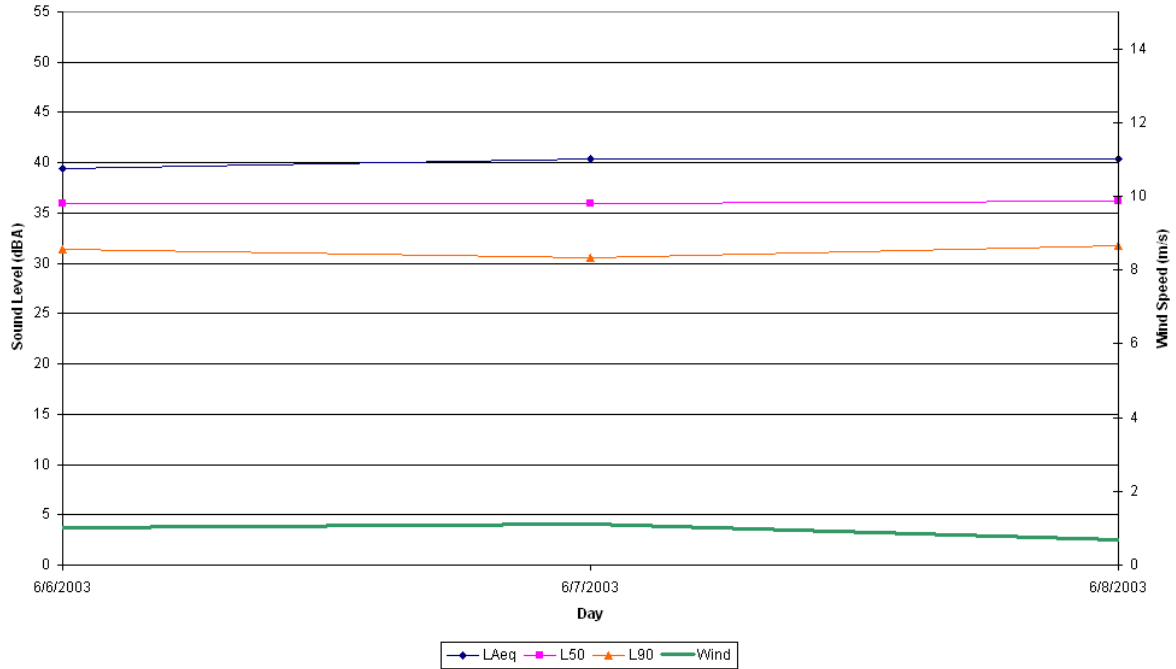


Figure 81. Daily sound levels and wind speeds: Site PE1.

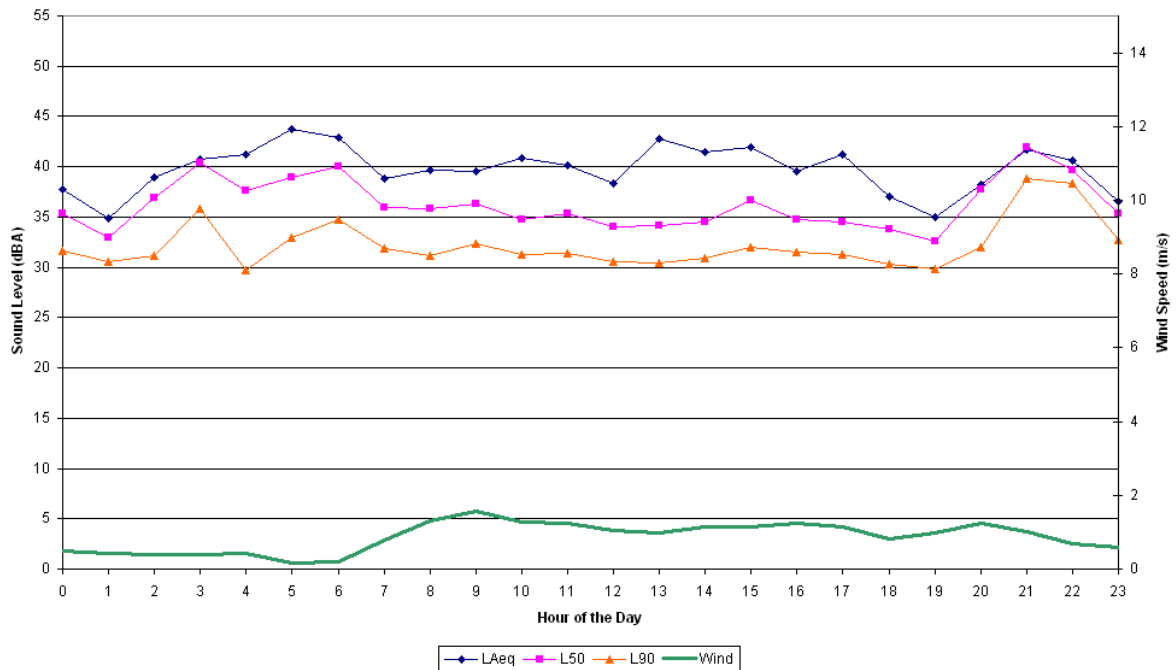


Figure 82. Average hourly sound levels and wind speeds: Site PE1.

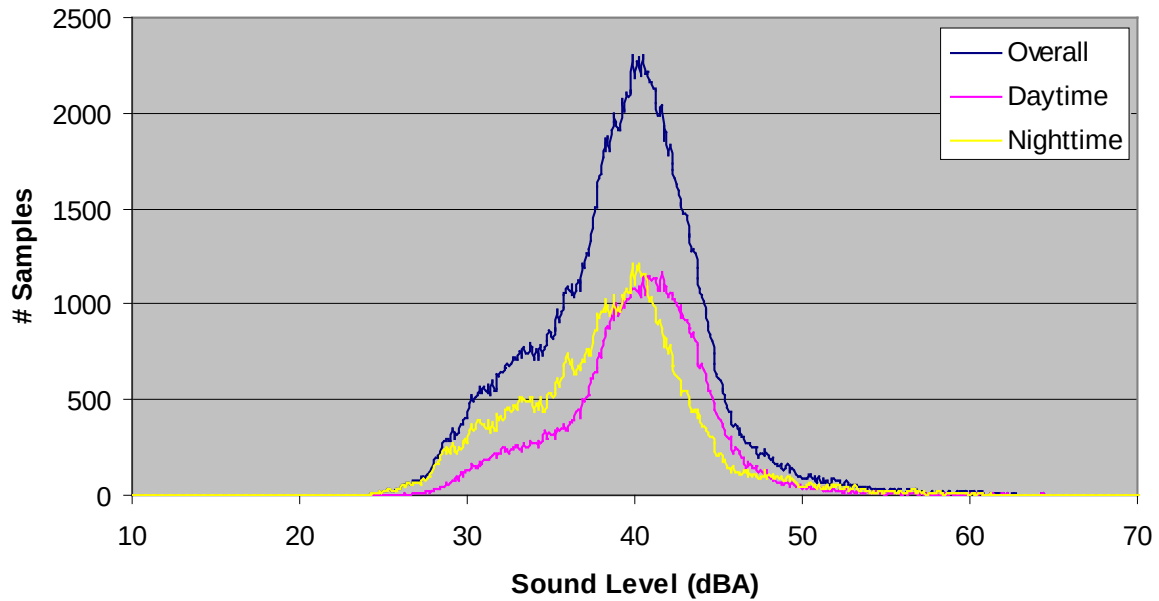


Figure 83. Distribution of data: Site PE1.

This data distribution at this site shows that the sound levels during both the daytime and nighttime were roughly equivalent, which leads to the conclusion that this site experienced primarily natural sounds.

A.2 Pu`ukohola Heiau: Site PE2**Table 28. Site PE2: description.**

Site ID	PE2
Site Name	Visitor Center Trail
# Measurement Days and Dates	3 days – June 6 to June 8, 2003
System # and Type	11 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.0324 / 155.8234
Approximate Elevation (ft)	109
Ecological Domain (see Appendix D)	(400) Humid Neotropical
Ecological Division (see Appendix D)	(412) Hawaiian Highlands
Land Cover Class (see Appendix D)	(5) Shrubland
Land Cover Subclass (see Appendix D)	(51) Shrubland
Management Zone (see Section 2.5)	Natural/Cultural
Site Category (see Section 2.5.1)	Short Hike

**Figure 84. Site PE2: Description and photograph.**

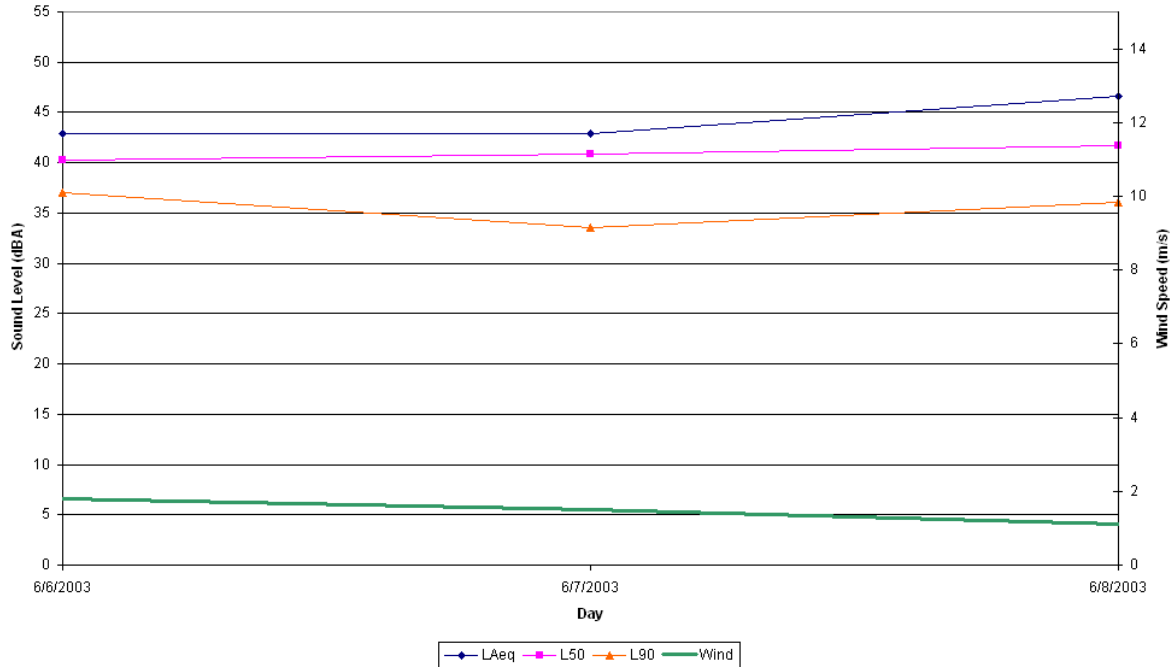


Figure 85. Daily sound levels and wind speeds: Site PE2.

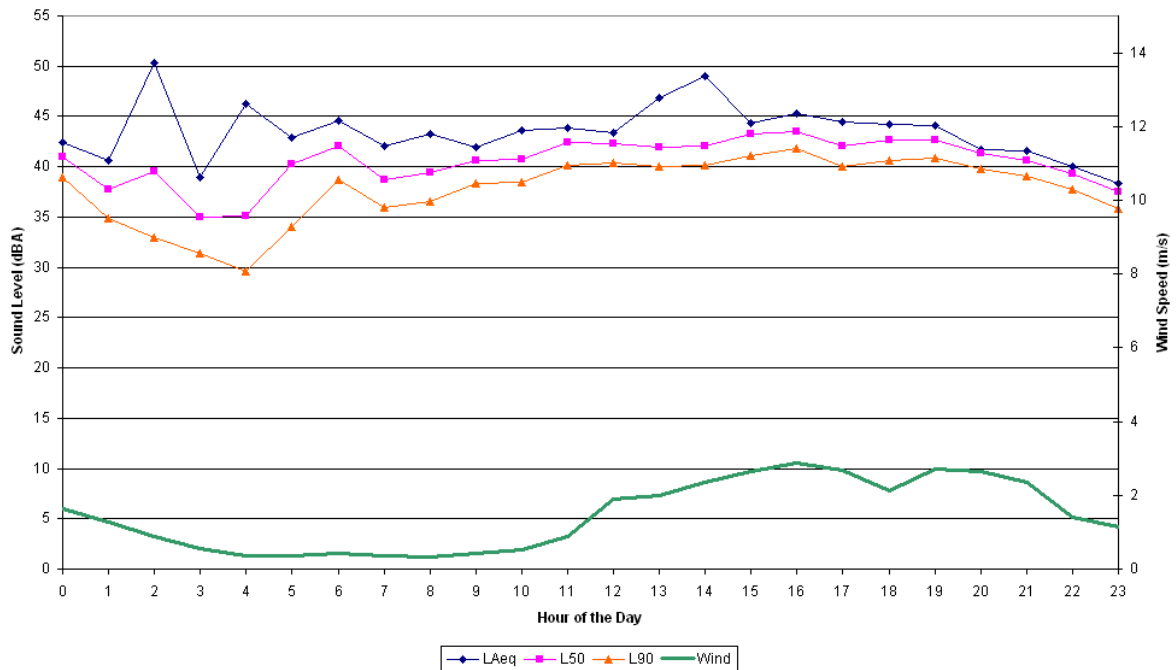


Figure 86. Average hourly sound levels and wind speeds: Site PE2.

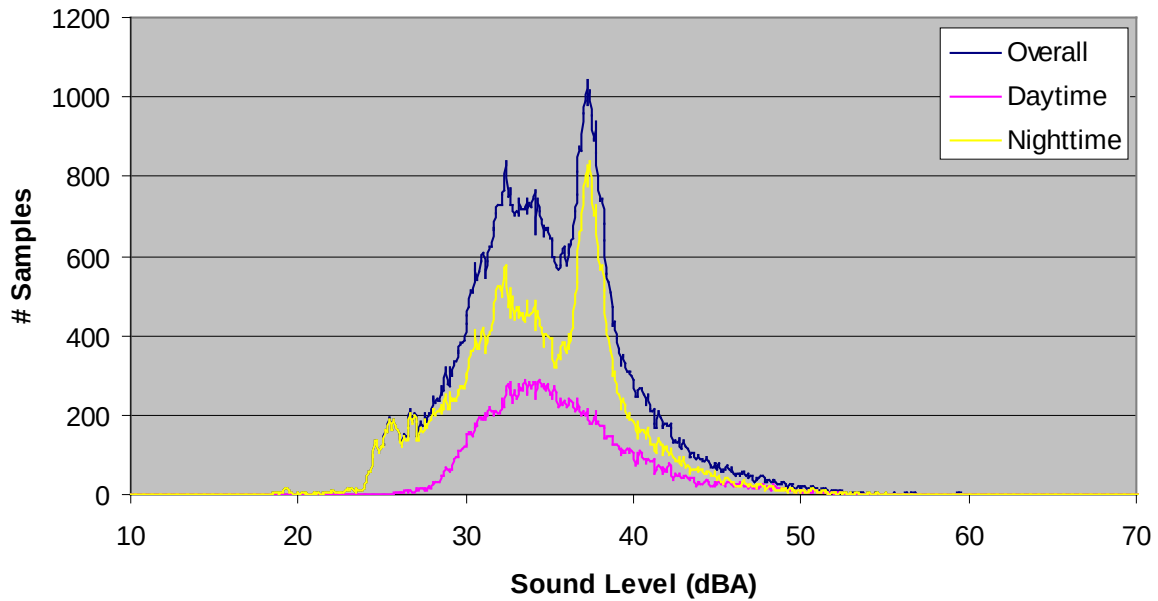


Figure 87. Distribution of data: Site PE2.

This site is characterized by natural sounds with a few aircraft events. The double peaks during the nighttime are evidence of nocturnal wildlife activity (insects or birds).

A.3 Kaloko-Honokohau: Site KH1

Table 29. Site KH1: description.

Site ID	KH1
Site Name	`Aimakapa Fishpond
# Measurement Days and Dates	8 days – June 4 to June 11, 2003
System # and Type	6 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	19.6844 / 156.0291
Approximate Elevation (ft)	18
Ecological Domain (see Appendix D)	(400) Humid Neotropical
Ecological Division (see Appendix D)	(412) Hawaiian Highlands
Land Cover Class (see Appendix D)	(5) Shrubland
Land Cover Subclass (see Appendix D)	(51) Shrubland
Management Zone (see Section 2.5)	Natural/Cultural
Site Category (see Section 2.5.1)	Short Hike



Figure 88. Site KH1: Description and photograph.

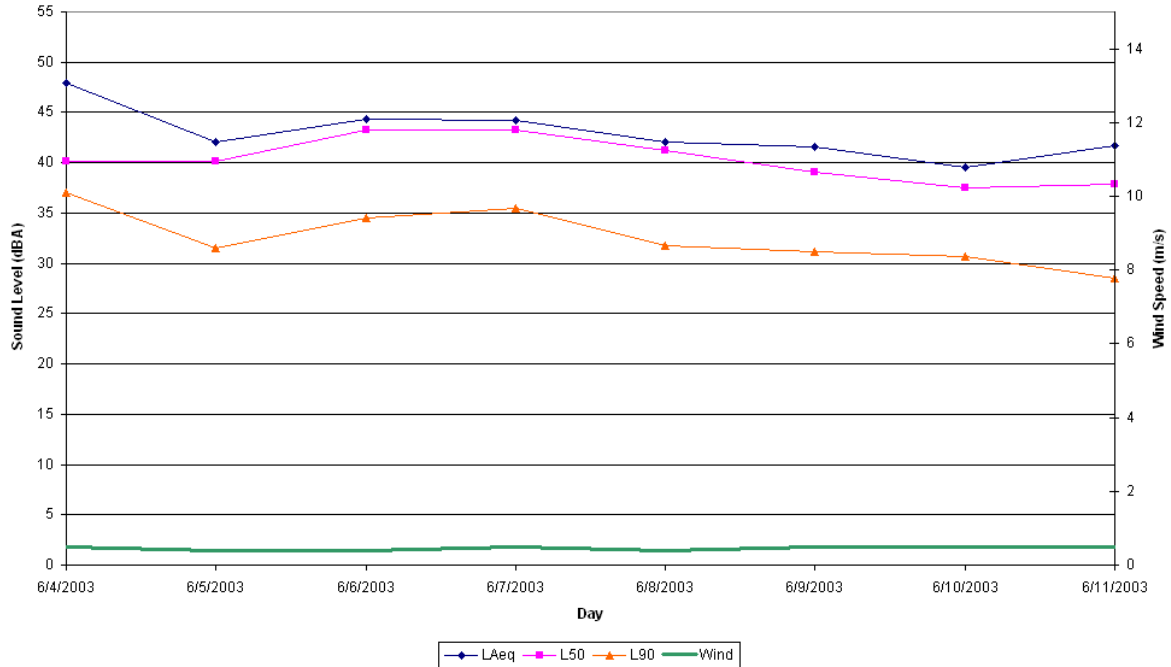


Figure 89. Daily sound levels and wind speeds: Site KH1.

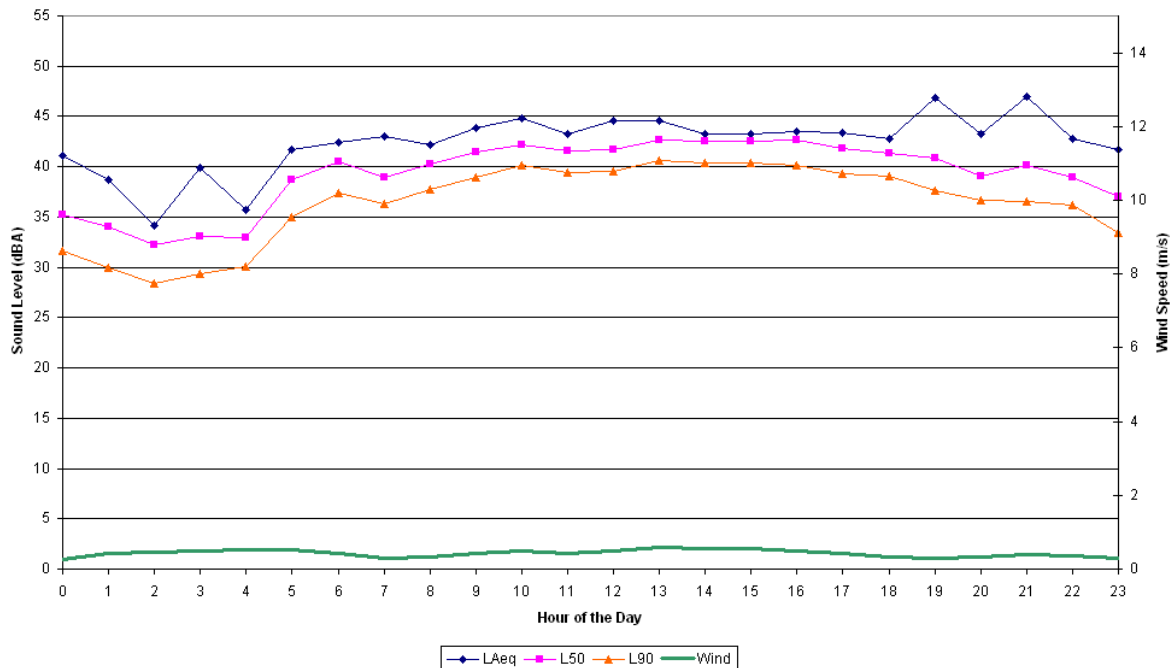


Figure 90. Average hourly sound levels and wind speeds: Site KH1.

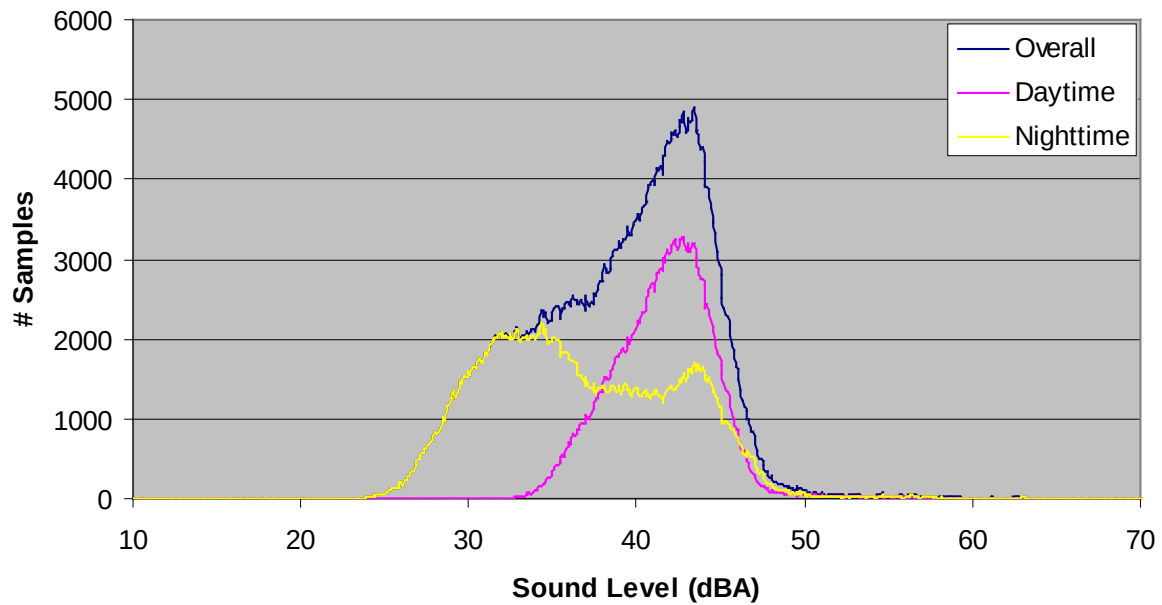


Figure 91. Distribution of data: Site KH1.

This site is characterized by natural sounds with a few aircraft events. The double peaks during the nighttime are evidence of nocturnal wildlife activity (insects or birds).

A.4 Kaloko-Honokohau: Site KH2**Table 30. Site KH2: description.**

Site ID	KH2
Site Name	Hu`ehu`e Ranch Road
# Measurement Days and Dates	3 days – June 4 to June 6, 2003
System # and Type	5 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	19.6934 / 156.0390
Approximate Elevation (ft)	24
Ecological Domain (see Appendix D)	(400) Humid Neotropical
Ecological Division (see Appendix D)	(412) Hawaiian Highlands
Land Cover Class (see Appendix D)	(3) Bare Rock/Sand/Clay
Land Cover Subclass (see Appendix D)	(31) Bare Rock/Sand/Clay
Management Zone (see Section 2.5)	Natural/Cultural
Site Category (see Section 2.5.1)	Short Hike

**Figure 92. Site KH2: Description and photograph (Note: System not shown).**

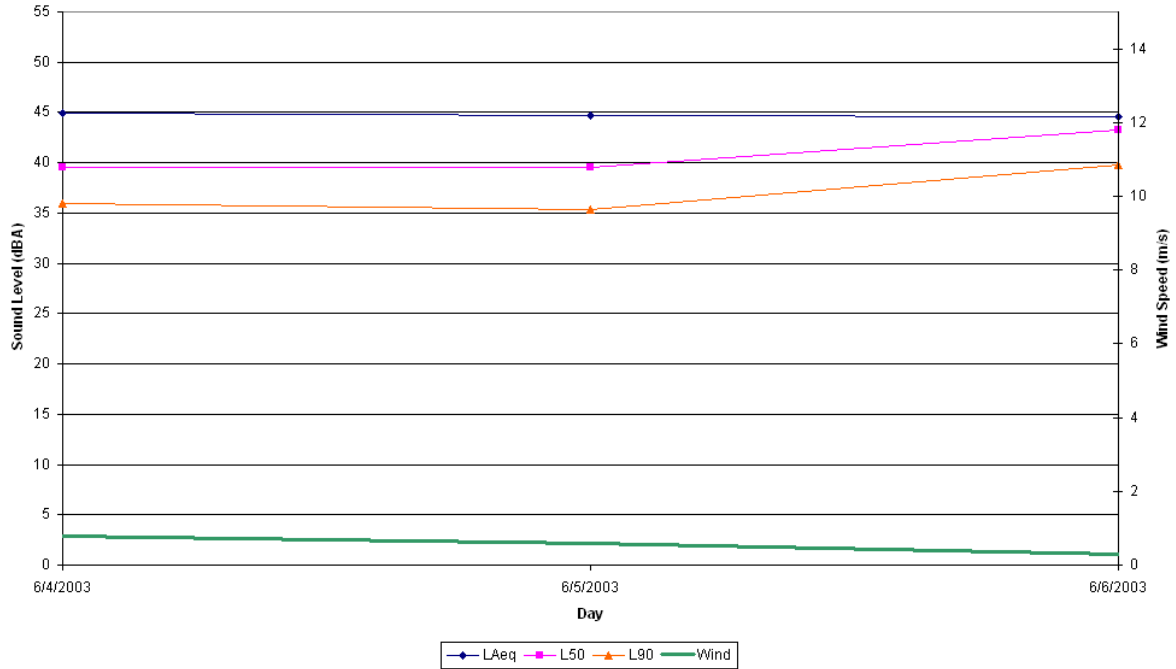


Figure 93. Daily sound levels and wind speeds: Site KH2.

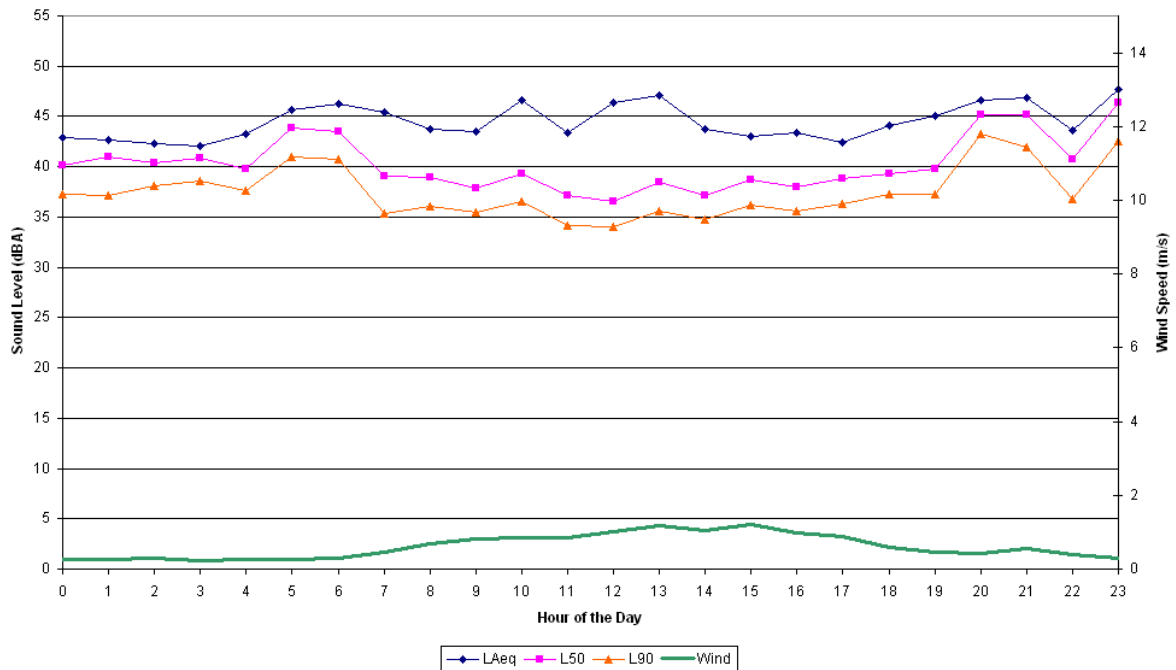


Figure 94. Average hourly sound levels and wind speeds: Site KH2.

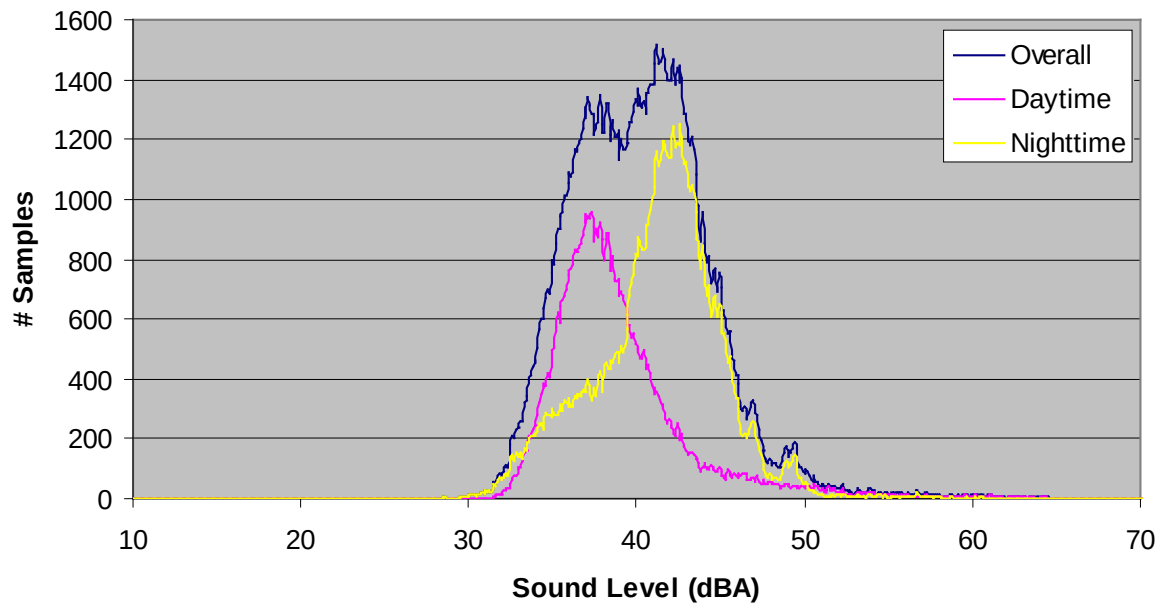


Figure 95. Distribution of data: Site KH2.

This site is characterized by natural sounds with some aircraft events during the day. The nighttime distribution looks like it is influenced by louder sound sources than the daytime levels.

A.5 Kaloko-Honokohau: Site KH3**Table 31. Site KH3: description.**

Site ID	KH3
Site Name	Kaloko Fishpond
# Measurement Days and Dates	3 days – June 4 to June 6, 2003
System # and Type	11 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	19.6896 / 156.0413
Approximate Elevation (ft)	16
Ecological Domain (see Appendix D)	(400) Humid Neotropical
Ecological Division (see Appendix D)	(412) Hawaiian Highlands
Land Cover Class (see Appendix D)	(3) Bare Rock/Sand/Clay
Land Cover Subclass (see Appendix D)	(31) Bare Rock/Sand/Clay
Management Zone (see Section 2.5)	Natural/Cultural
Site Category (see Section 2.5.1)	Short Hike

**Figure 96. Site KH3: Description and photograph (Note: System not shown).**

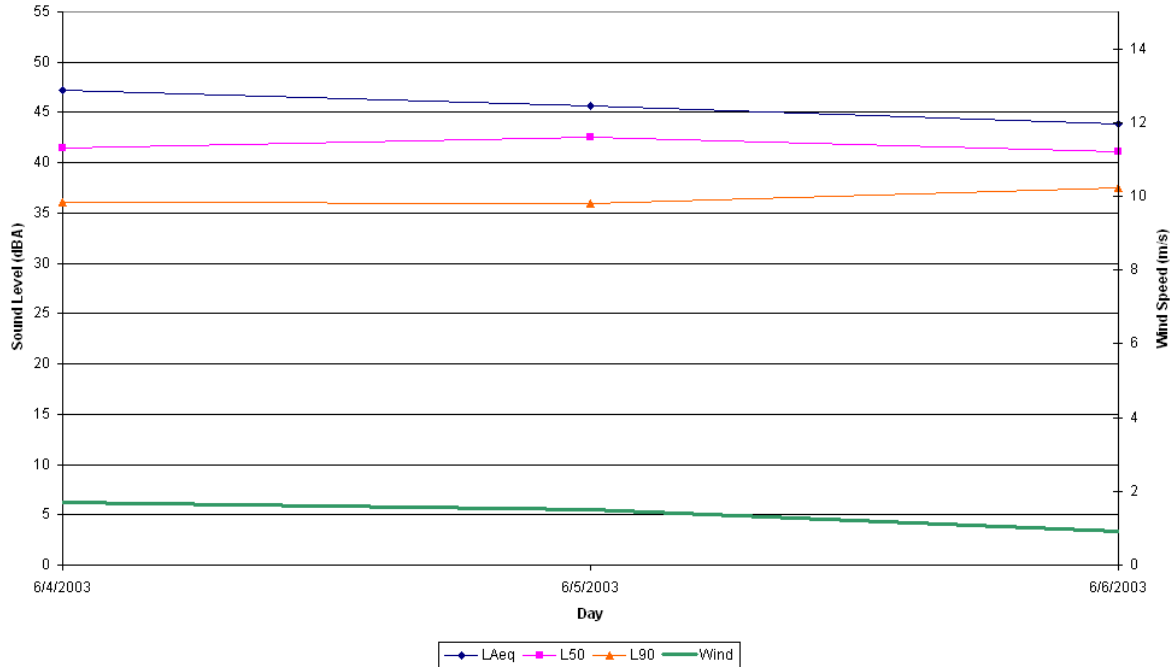


Figure 97. Daily sound levels and wind speeds: Site KH3.

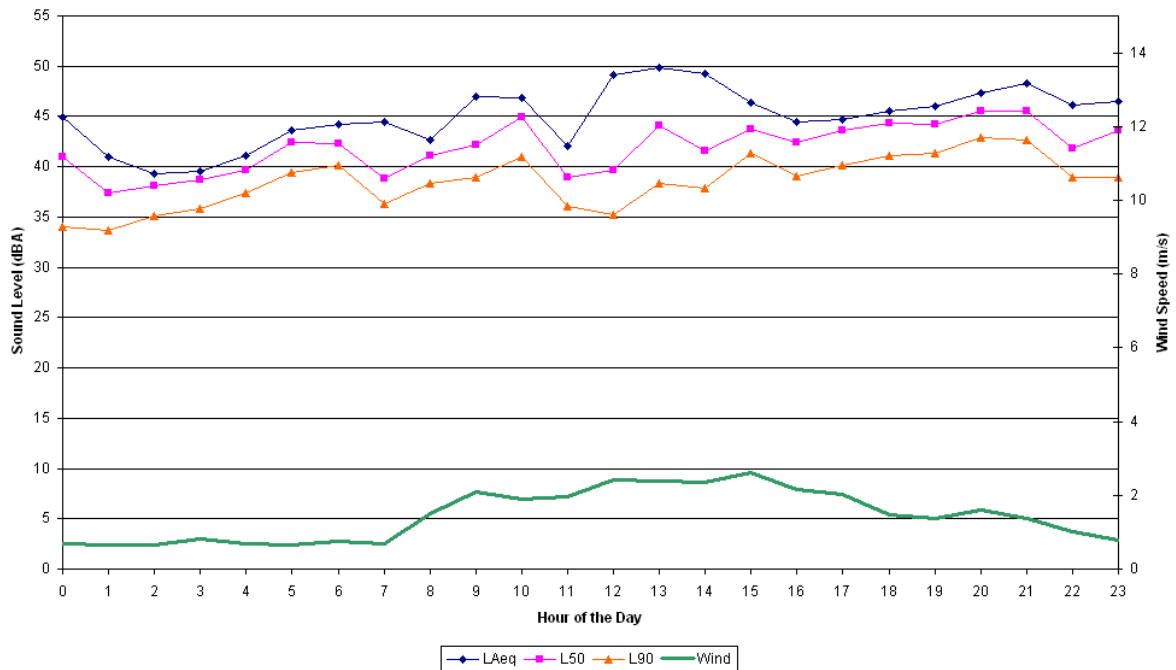


Figure 98. Average hourly sound levels and wind speeds: Site KH3.

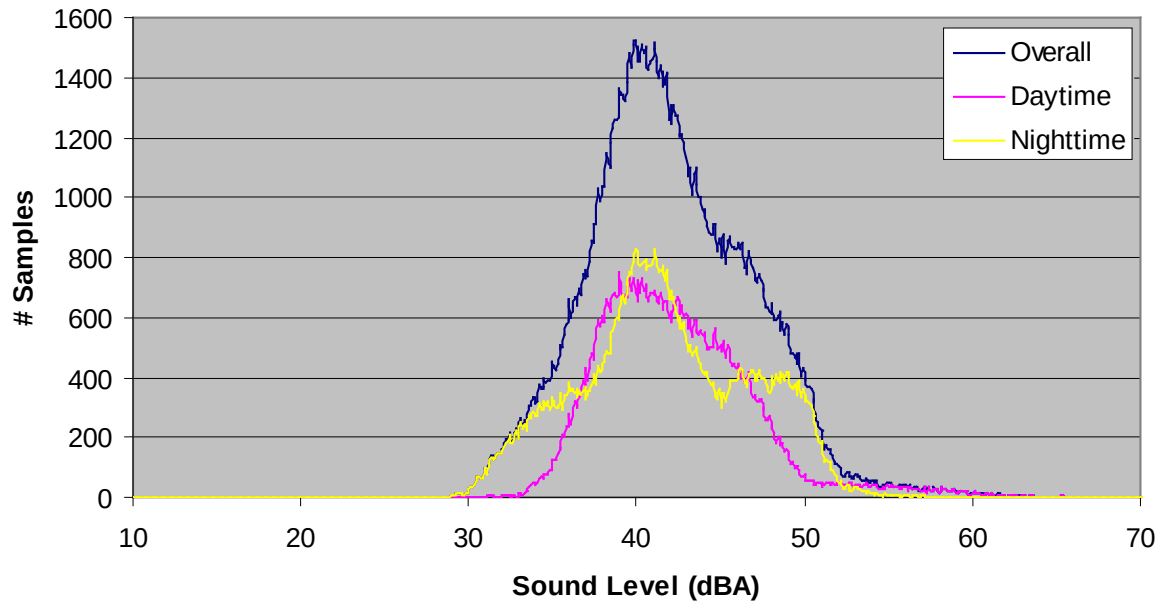


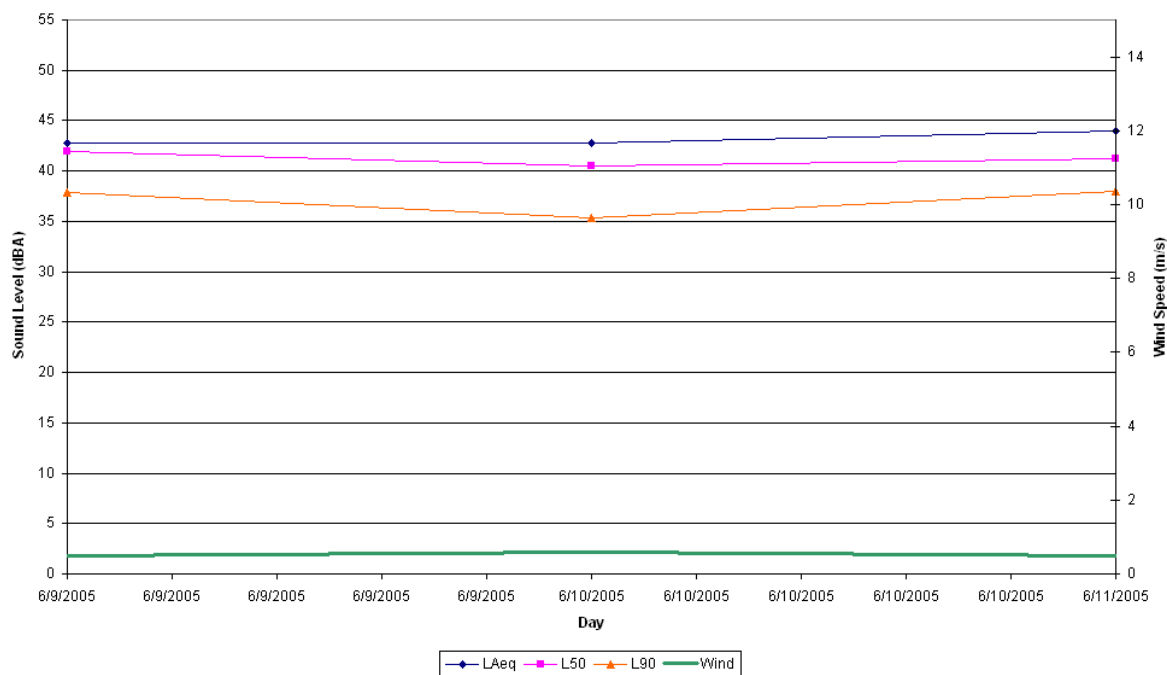
Figure 99. Distribution of data: Site KH3.

This site is characterized by natural sounds with some aircraft events during the day. The nighttime distribution is somewhat unusual and appears as if different sources were active during different hours of the night.

A.6 Pu`uhonua o Honaunau: Site PH1**Table 32. Site PH1: description.**

Site ID	PH1
Site Name	Mauka of 1871 Trail
# Measurement Days and Dates	3 days – June 9 to June 11, 2003
System # and Type	11 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	19.4622 / 155.9163
Approximate Elevation (ft)	9
Ecological Domain (see Appendix D)	(400) Humid Neotropical
Ecological Division (see Appendix D)	(412) Hawaiian Highlands
Land Cover Class (see Appendix D)	(3) Barren
Land Cover Subclass (see Appendix D)	(31) Bare Rock/Sand/Clay
Management Zone (see Section 2.5)	Natural/Cultural
Site Category (see Section 2.5.1)	Short Hike

Note: Photograph not available.

**Figure 100. Daily sound levels and wind speeds: Site PH1.**

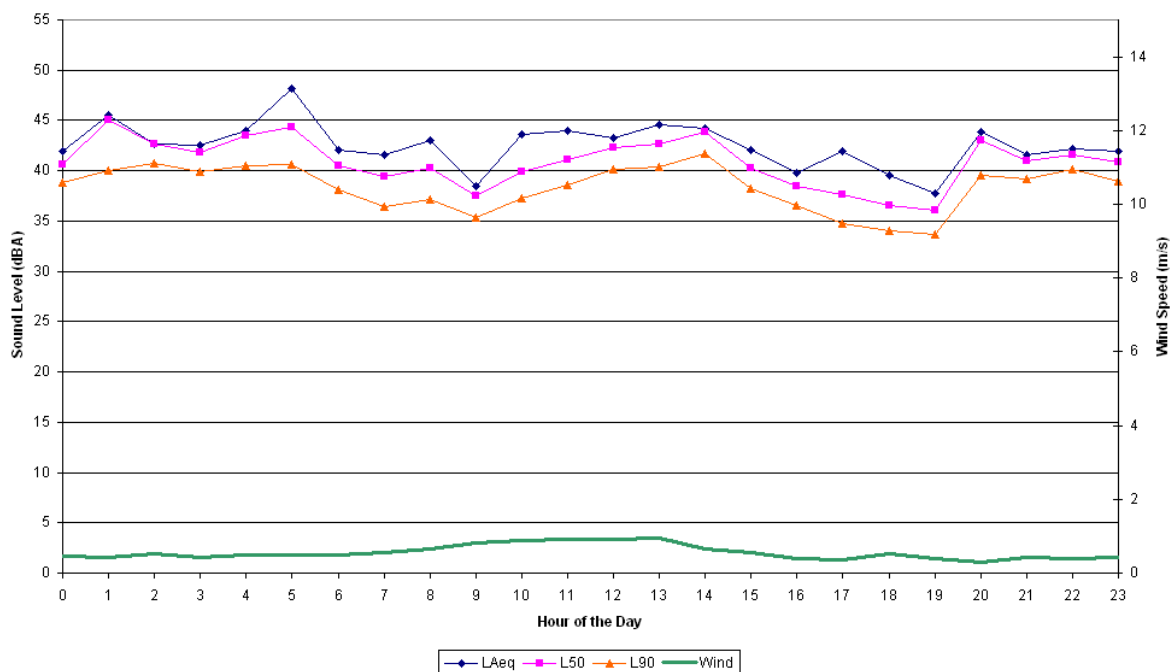


Figure 101. Average hourly sound levels and wind speeds: Site PH1.

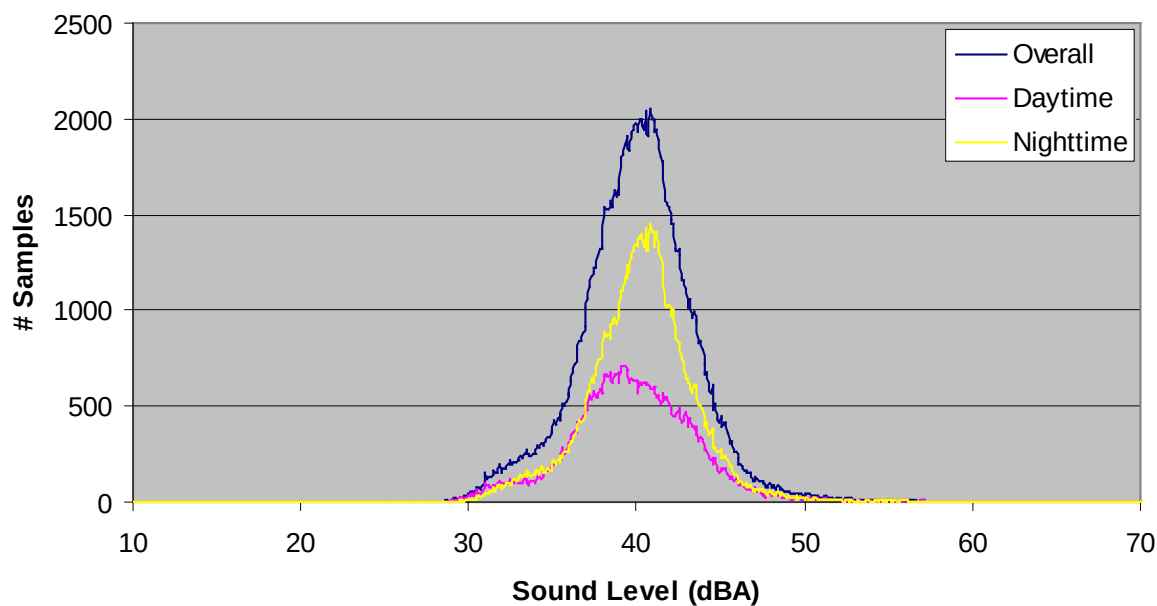


Figure 102. Distribution of data: Site PH1.

This site is characterized by natural sounds with some aircraft events. There is nothing unusual about the distribution, which is centered at 40 dBA.

A.7 Pu`uhonua o Honaunau: Site PH2**Table 33. Site PH2: description.**

Site ID	PH2
Site Name	Palace Grounds
# Measurement Days and Dates	1 day – June 9, 2003
System # and Type	5 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	19.4242 / 155.9186
Approximate Elevation (ft)	7
Ecological Domain (see Appendix D)	(400) Humid Neotropical
Ecological Division (see Appendix D)	(412) Hawaiian Highlands
Land Cover Class (see Appendix D)	(3) Barren
Land Cover Subclass (see Appendix D)	(31) Bare Rock/Sand/Clay
Management Zone (see Section 2.5)	Natural/Cultural
Site Category (see Section 2.5.1)	Short Hike

**Figure 103. Site PH2: Description and photograph.**

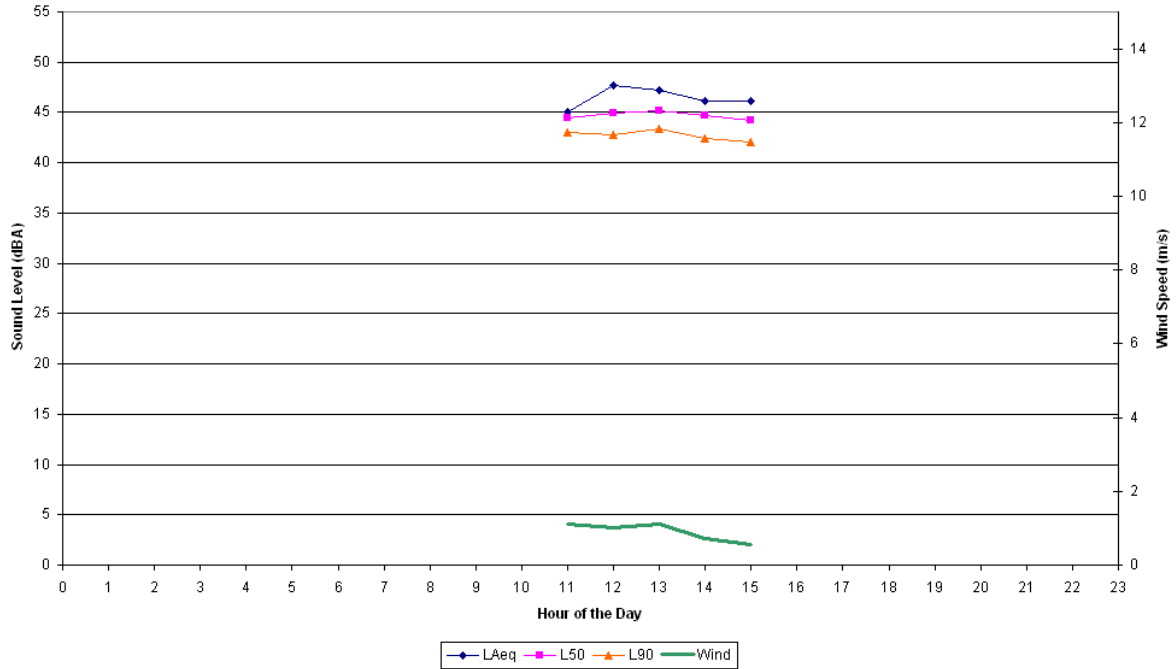


Figure 104. Average hourly sound levels and wind speeds: Site PH2.

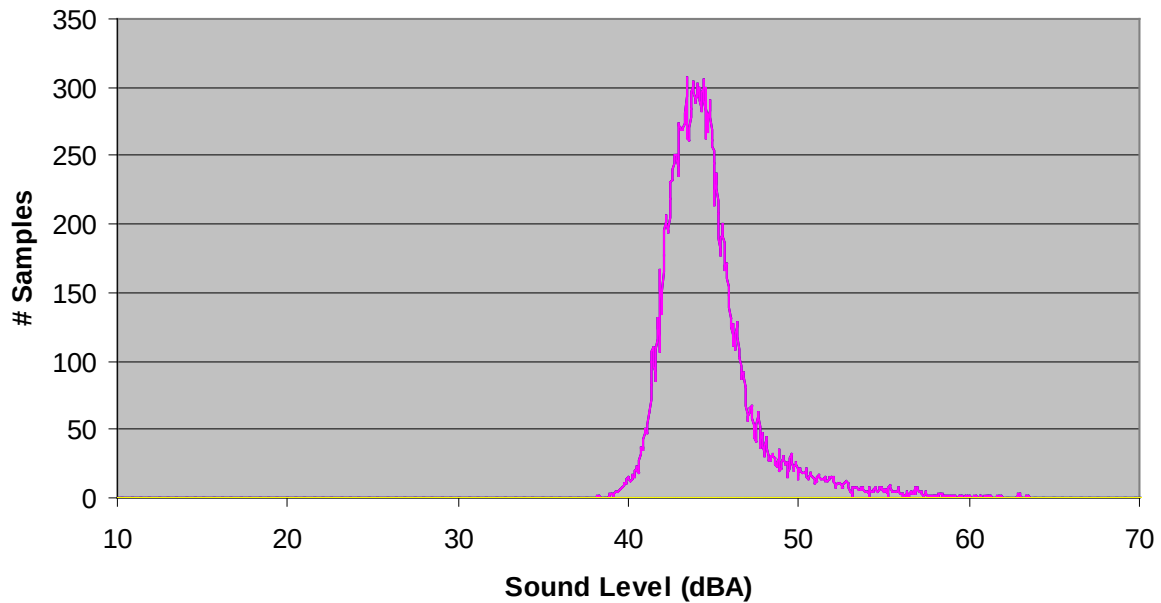


Figure 105. Distribution of data: Site PH2.

This was a one-day measurement with several distant aircraft events occurring around 1 pm. There is nothing unusual about the distribution. Because this was a single day site, only daytime data was collected.

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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 3.1 discusses the systems' component instrumentation in more detail.

B.1 Overview

The NoiseLogger™ system is a specialized measurement system used to conduct unattended, long-term (30+ days), continuous 1/3-octave band noise measurements in outdoor environments. It is compact, light, rugged, and can run for days with external battery power, or continuously with solar panels, thus, making the system able to store more data than any known portable system. Table 33 and Figure 107 illustrate the basic components of the system.

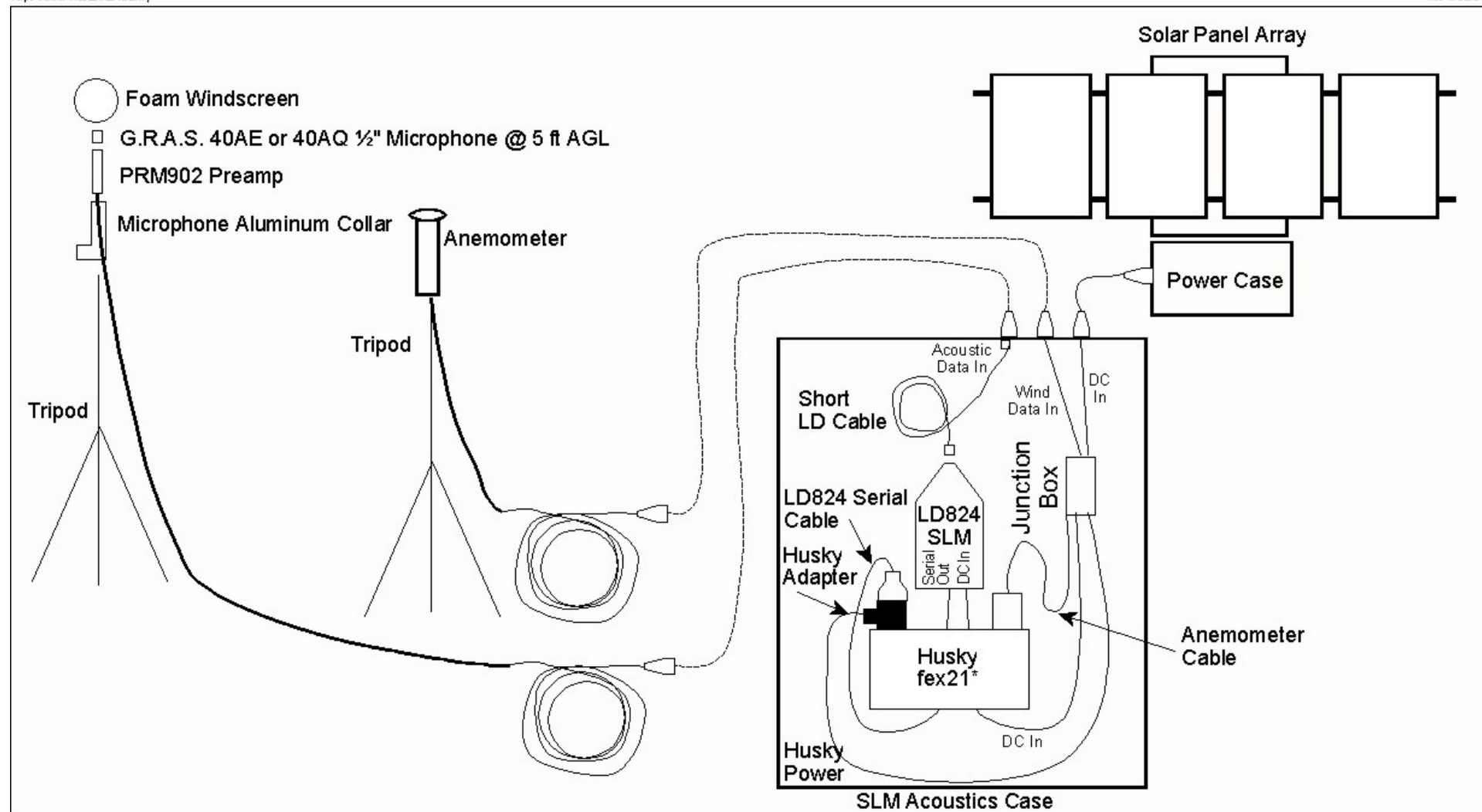
B.2 Instrumentation List

Table 34. NoiseLogger™ system instrumentation list.

Subsystem	Components
Microphone System	GRAS 40AQ or 40AE ½-inch Microphone PRM902 Preamp Microphone Cable with 7-pin Connector Large Foam Windscreen
Windscreen System	Gill WindObserver II Anemometer <i>or</i> FT702 Ultrasonic Anemometer Anemometer Cable with 6-pin Connector
Recorder System	LD824 Sound Level Meter Husky fex21 Computer 128-MB Flash Cards
Power System	2 17-AH Gell Cells 1 Solar Panel Array
Ancillary Equipment	Garmin GPS Plus III Unit B&K 4231 Calibrator Microphone Simulator

Volpe Center Acoustics Facility

Rev 4/28/04



CL:FAA/AT&P/Equipment/Instrumentation_NoiseLogger.vpp

Figure 106. NoiseLogger™ continuous monitoring system.

B.2 Deployment

1. Locate an approximate 5x5 ft area that is both relatively flat and at least 50 ft (15 m) from reflective objects.
2. Carefully unpack the system backpacks.

B.2.1 Wind Sensor System

1. Extend tripod so that the legs are flat on the ground.
2. Attach anemometer (see Figure 108) to tripod.
 - a. If using a Gill WindObserver II anemometer, connect one end of anemometer cable (red cable, black connector, 6-pin connector with twist locking collar) to the base of the anemometer. Mount anemometer on tripod.
 - b. If using a FT702 anemometer, the 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.
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.

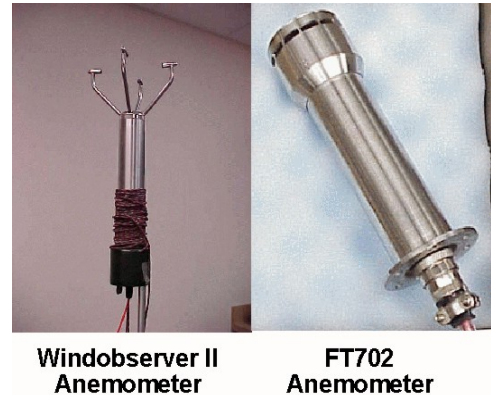


Figure 107. Gill WindObserver II and FT702 anemometers.

B.2.2 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 106).
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 108.
Microphone/preamp
assembly.

B.2.3 Power System

1. Unfold the metal panel and carefully remove solar panels. Align panels one through four from left to right (see Figure 110). 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.

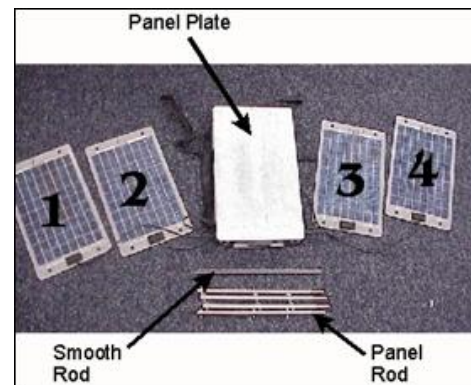


Figure 109. Unpack solar panel
array

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 111).
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.”

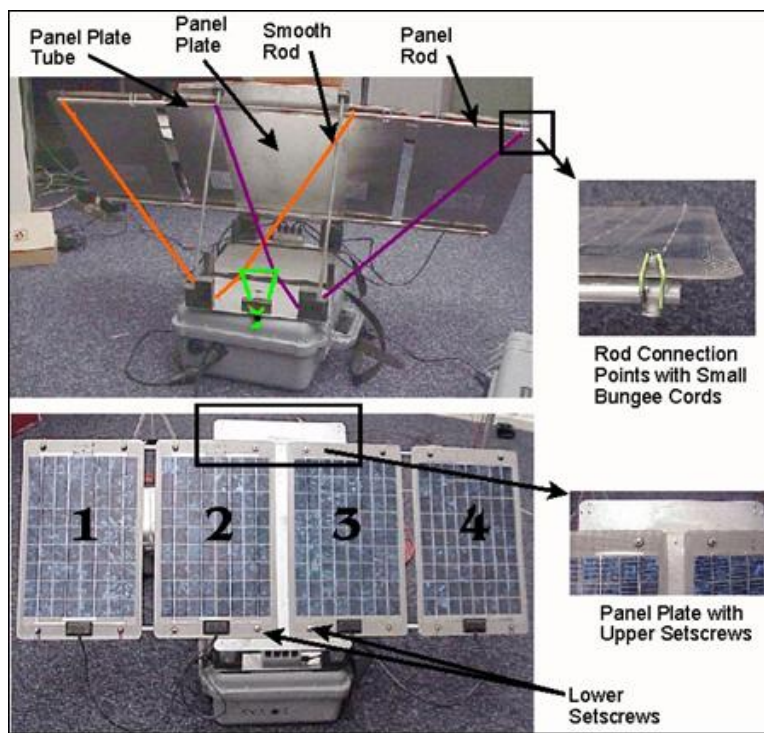


Figure 110. Solar panel array setup.

6. Tighten the “X” pattern by pulling the small string loop at the base of the “X” and raising the tension knob (see Figure 112).
7. Insert the two lower panel rods into the tubes at the bottom of the “panel plate.”



Figure 111. Close-in view of string tensioner.

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.

B.3 Operation

B.3.1 NoiseLogger™ Startup

1. Open SLM acoustics case. Remove top foam piece.
2. Verify connections as shown in Figure 113, 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.

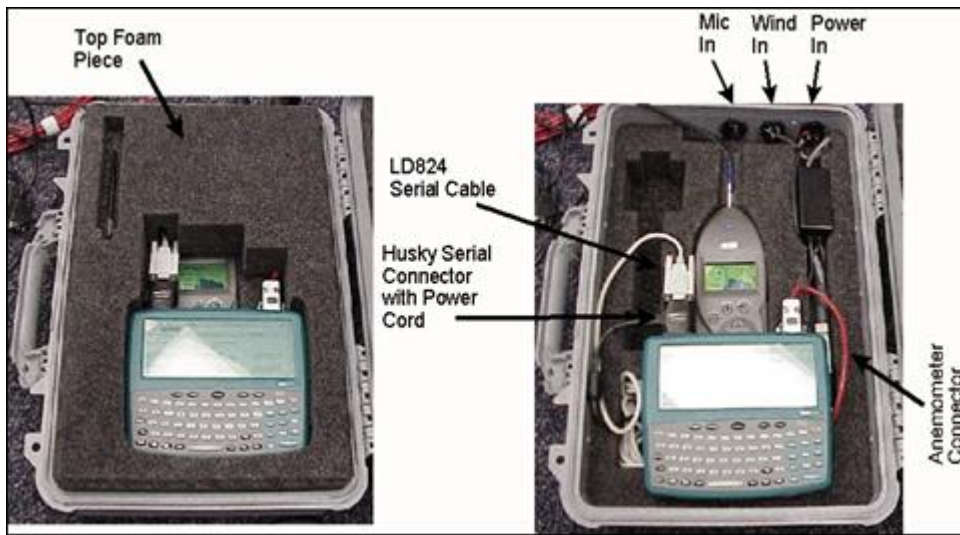


Figure 112. SLM acoustics case.

3. 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.
4. 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.
5. 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.
6. Reset/reboot the Husky™ by pressing both the contrast and brightness buttons on either side of the power button.
7. Using the red tip of the stylus, select "My Handheld PC" icon on the desktop.
8. 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.
9. An "About NoiseLogger" dialog is displayed. Select OK.
10. Per the program instructions, enter a unique three-character ID representing the site "number" (e.g., PH2 for Site PH2), and the site's name (e.g., Palace Grounds).
11. Select "Equipment Info" and proceed to the GPS Synchronization (Section B.3.2).

B.3.2 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.3.3.

B.3.3 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.
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.3.4.

B.3.4 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 114). 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.
6. Verify that the LD824 is responding to the calibration process (a sound level of



Figure 113. System calibration.

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.3.5 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.4 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 34 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 35. 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.5 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 $\frac{1}{4}$ 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. 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.3.4).
10. Start data collection (see Section B.4).

B.6 System Dismantling

B.6.1 SLM Acoustics Case

1. Verify that the computer is powered down. Disconnect 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.6.2 Wind Sensor System

1. Remove anemometer from tripod.
 - a. If a Gill WindObserver anemometer was used, lift anemometer off tripod and disconnect the anemometer cable from the base of the anemometer.
 - b. If a FT702 anemometer was used, 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.6.3 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.6.4 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 115).
16. Close panel plate over the top of the stack of panels and secure with black straps.



Figure 114. 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.

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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.

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 35 and Figure 116). It should be noted that systems 1-4 and 8 used GRAS Model 40AQ microphones, while the other systems used GRAS Model 40AE microphones (see Table 9 in Section 4.1).

* 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).

Table 36. Microphone frequency responses by system number.

Frequency (Hz)	1	2	3	4	5	6	7	8	9	10	11
12.5	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
20	-0.06	0	0.14	-0.03	-0.03	0.06	0	0.05	-0.03	0.03	-0.03
25	0.05	0	0.05	-0.1	0.06	0.1	-0.01	0.11	0.02	0.02	-0.05
31	-0.04	0	0.05	0.01	0.02	-0.01	0	0.01	0.01	-0.01	-0.01
40	-0.03	0	0.01	0	-0.01	-0.01	0.01	0.02	0.04	-0.01	0.02
50	-0.04	0	-0.03	0	0.03	0.01	0	0.01	0.02	0.01	-0.01
63	-0.06	0	0.04	0.04	0	0.01	0	0	0.03	0.02	0.04
80	-0.04	0	0	0.02	0.01	0.03	-0.02	0.01	0.01	0	0.01
100	-0.03	0	0.02	0	0.03	0.01	0.01	0	0	-0.01	0
125	-0.04	0	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.03
160	-0.04	0	0	0.02	-0.04	0.01	0.01	0	0	0	0
200	-0.04	0	-0.01	0.01	0.04	0.03	0	0.01	0.01	-0.01	-0.01
250	0	0	0	0	0	0	0	0	0	0	0
315	-0.04	0	0.01	0	0.02	0.01	-0.01	0.02	-0.01	0	-0.01
400	-0.04	0	0	0.02	0	0.01	0	0.01	-0.02	-0.02	-0.01
500	-0.04	0	0	0.03	-0.02	-0.01	-0.01	0	-0.02	-0.03	0.05
630	-0.05	-0.032	0	0.01	-0.04	-0.02	-0.01	0.01	-0.03	-0.04	-0.05
800	-0.05	-0.003	0.01	0.01	-0.05	-0.04	-0.04	0.01	-0.06	-0.06	-0.06
1000	-0.04	-0.009	0.01	0.01	-0.04	-0.03	0	0.02	-0.06	-0.09	-0.06
1250	-0.05	-0.006	0.01	0.01	-0.06	-0.05	-0.03	0	-0.08	-0.17	-0.09
1600	-0.06	0.001	0	0.02	-0.18	-0.09	-0.07	0.03	-0.15	-0.22	-0.13
2000	-0.07	0.037	0.03	0.03	-0.29	-0.18	-0.14	0	-0.26	-0.36	-0.25
2500	-0.09	0.067	0.04	0.04	-0.47	-0.33	-0.27	0.02	-0.43	-0.52	-0.41
3150	-0.6	0.123	0.14	0.11	-0.71	-0.49	-0.42	0.05	-0.65	-0.88	-0.63
4000	-0.1	0.068	0.18	0.12	-1.09	-0.86	-0.74	0.06	-1.05	-1.34	-1.04
5000	-0.14	0.006	0.25	0.15	-1.5	-1.31	-1.13	0.15	-1.55	-1.88	-1.61
6300	-0.12	0.217	0.48	0.25	-1.91	-1.8	-1.6	0.28	-2.09	-2.38	-2.14
8000	0.17	0.504	0.83	0.66	-2.11	-2.19	-2.05	0.77	-2.4	-2.62	-2.74
10000	-0.15	0.744	1.06	0.22	-2.15	-2.57	-2.67	0.62	-2.96	-2.97	-3.47
12500	-1.57	0.858	-0.3	-1.59	-2.86	-3.33	-3.73	-0.62	-3.82	-3.32	-4.73
16000	-2.83	-0.366	-1.71	-3.18	-4.12	-3.87	-4.77	-2.03	-4.6	-4.02	-6.15
20000	-6.31	-3.45	-5.34	-6.27	-8.13	-5.63	-8.21	-6.19	-7.75	-8.06	-9.61

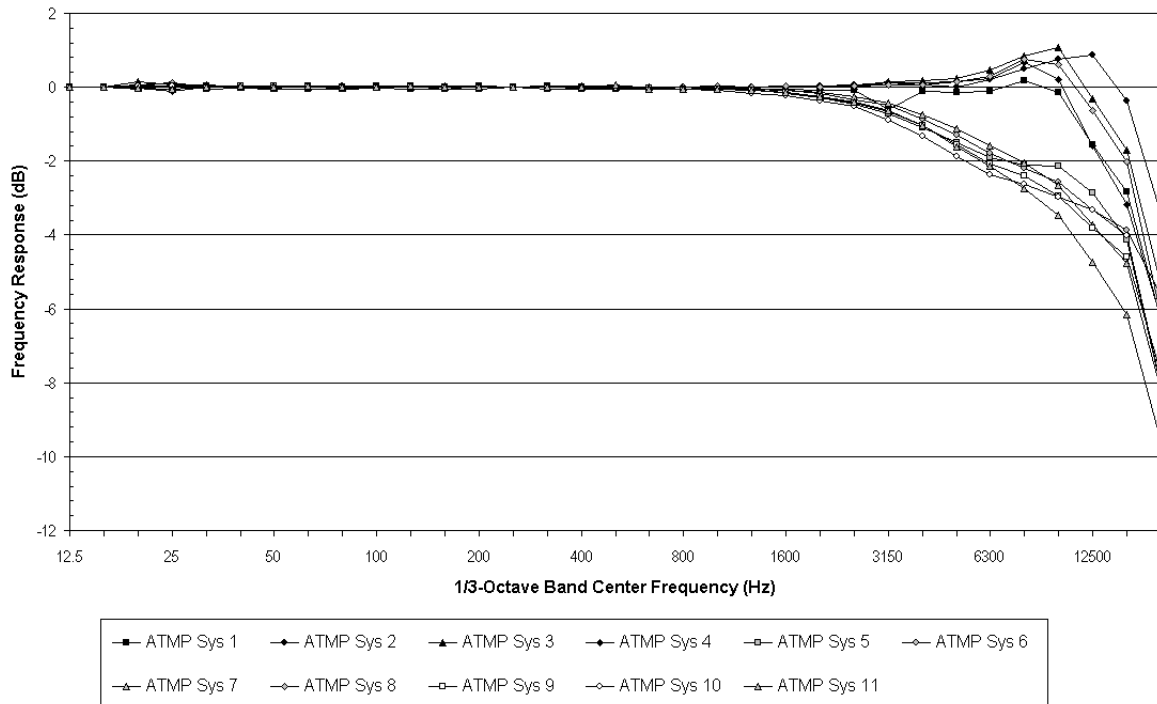


Figure 115. Microphone frequency responses (see Table 9 in Section 4.1).

C.2 Windscreen Frequency Response Adjustments

As discussed in Section 3.1.1, a 12-in (30-cm) diameter foam windscreen (400 pores/sq. in. porosity), custom designed by Musashi Kasei Co., Ltd. for outdoor sound monitoring applications was placed atop each microphone to reduce the effects of wind-generated noise at the microphone diaphragm. The windscreens used in this study were manufactured in two batches – the first batch was used on the NoiseLogger™ systems 1 to 4, and the second batch was used with systems 5 to 11. The attenuation of both sets of windscreens was measured utilizing a diffuse sound source and is shown as a function of frequency in Table 36 and Figure 117.³⁰

Table 37. Windscreen frequency responses by system number.

Frequency (Hz)	1	2	3	4	5	6	7	8	9	10	11
12.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
125	0.07	0.07	0.07	0.07	0.09	0.09	0.09	0.09	0.09	0.09	0.09
160	0.16	0.16	0.16	0.16	0.03	0.03	0.03	0.03	0.03	0.03	0.03
200	0.17	0.17	0.17	0.17	0.11	0.11	0.11	0.11	0.11	0.11	0.11
250	0.09	0.09	0.09	0.09	0.13	0.13	0.13	0.13	0.13	0.13	0.13
315	0.24	0.24	0.24	0.24	0.21	0.21	0.21	0.21	0.21	0.21	0.21
400	0.44	0.44	0.44	0.44	0.28	0.28	0.28	0.28	0.28	0.28	0.28
500	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
630	0.57	0.57	0.57	0.57	0.24	0.24	0.24	0.24	0.24	0.24	0.24
800	0.40	0.40	0.40	0.40	0.21	0.21	0.21	0.21	0.21	0.21	0.21
1000	0.16	0.16	0.16	0.16	-0.41	-0.41	-0.41	-0.41	-0.41	-0.41	-0.41
1250	-0.46	-0.46	-0.46	-0.46	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02
1600	-0.85	-0.85	-0.85	-0.85	-1.35	-1.35	-1.35	-1.35	-1.35	-1.35	-1.35
2000	-1.09	-1.09	-1.09	-1.09	-1.40	-1.40	-1.40	-1.40	-1.40	-1.40	-1.40
2500	-1.13	-1.13	-1.13	-1.13	-2.01	-2.01	-2.01	-2.01	-2.01	-2.01	-2.01
3150	-1.26	-1.26	-1.26	-1.26	-2.28	-2.28	-2.28	-2.28	-2.28	-2.28	-2.28
4000	-1.66	-1.66	-1.66	-1.66	-2.66	-2.66	-2.66	-2.66	-2.66	-2.66	-2.66
5000	-2.14	-2.14	-2.14	-2.14	-2.93	-2.93	-2.93	-2.93	-2.93	-2.93	-2.93
6300	-2.51	-2.51	-2.51	-2.51	-3.57	-3.57	-3.57	-3.57	-3.57	-3.57	-3.57
8000	-3.05	-3.05	-3.05	-3.05	-4.13	-4.13	-4.13	-4.13	-4.13	-4.13	-4.13
10000	-3.74	-3.74	-3.74	-3.74	-5.04	-5.04	-5.04	-5.04	-5.04	-5.04	-5.04
12500	-4.16	-4.16	-4.16	-4.16	-5.76	-5.76	-5.76	-5.76	-5.76	-5.76	-5.76
16000	-4.64	-4.64	-4.64	-4.64	-6.53	-6.53	-6.53	-6.53	-6.53	-6.53	-6.53
20000	-6.15	-6.15	-6.15	-6.15	-7.18	-7.18	-7.18	-7.18	-7.18	-7.18	-7.18

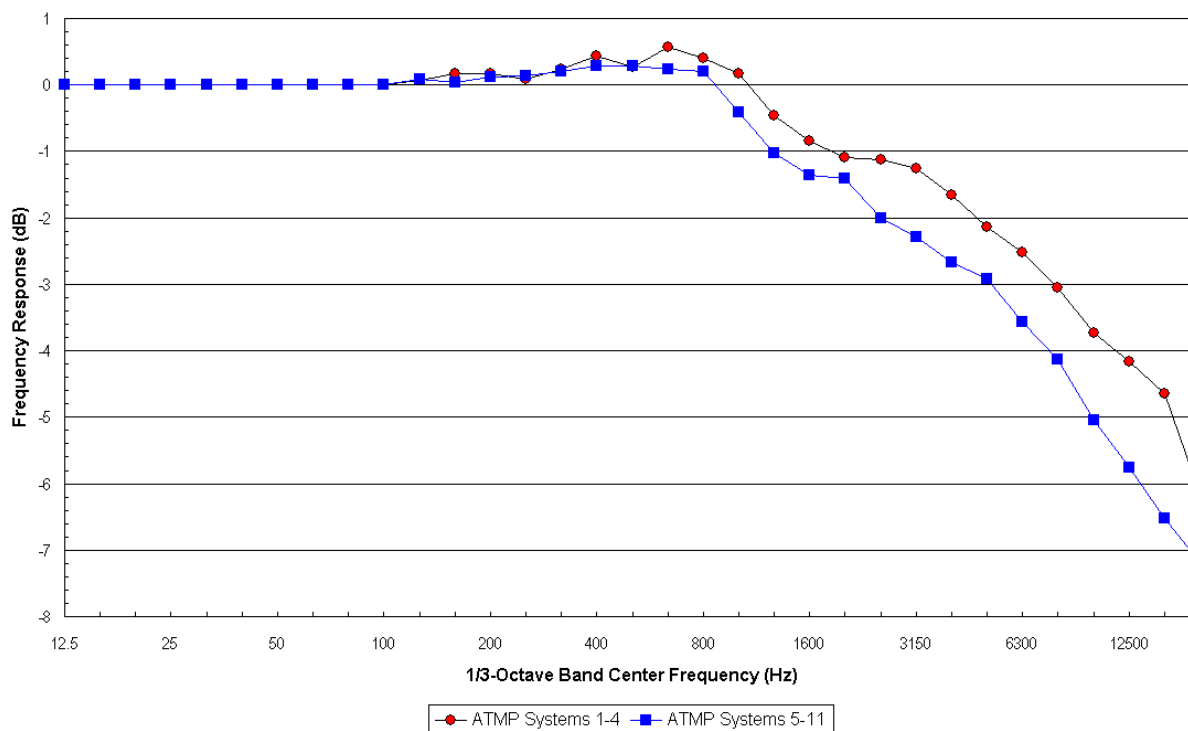


Figure 116. Windscreen frequency responses.

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APPENDIX D. ACOUSTIC ZONE ANALYSIS

Many parks, particularly those within similar ecosystems have similar physical, biological and meteorological parameters – including land cover, wildlife activity, visitor-use, wind and seasonality. Therefore, one would expect that their baseline ambient sound levels would also be similar, thus, allowing for the potential transferability of baseline ambient data within large, homogeneous regions of a particular park and possibly between similar regions in other parks. This effort continues the work that began in Hawai'i Volcanoes National Park.²³

The concept of transferability of data is currently a working hypothesis.³¹ An area of justified concern is the reliability of transferred ambient data in the dynamic outdoor environment of a national park - be it data from one area of a park to another area within the same park, or data from one park to a completely different park. It is presently hypothesized that after a critical mass of baseline ambient sound level data have been collected, it will be statistically viable to begin generalizing data measured in one park to regions possessing similar attributes in other parks. What is not currently known, however, is how many park measurement studies will be needed to achieve statistical reliability and scientific defensibility of ambient data as this type of effort has never been attempted before. The transferability hypothesis, if proven sound, will not preclude measurements entirely in other parks, but it should greatly reduce the scope of required measurements. It is anticipated that some baseline ambient sound level measurements will be necessary in all parks. The purpose of a limited measurement campaign (probably a few days in even the later parks included in the ATMP / VA program) is to statistically prove the hypothesis of transferability of baseline ambient sound level data on a park-by-park basis, and, as important, secure public acceptance of the environmental compliance documents prepared for individual parks.

In developing acoustic zones within a national park,* land cover (Section D.1) and climate/ecological domain (Section D.2) are the two most important technical factors influencing

* The number of initial acoustic zones within a particular park will be primarily determined by land cover and climate regions within that park, and not park size. Acoustic zones may then be further subdivided based on factors such as park management zones, visitor-use, and wildlife habitats. For example, Hawai'i Volcanoes National Park is approximately 400 square miles with an estimated 9 acoustic zones based on land cover and topographical information. Badlands, a slightly larger park at almost 500 square miles possessed uniformity of land cover and topography over much of the park, but was divided into 3 acoustic zones based on park management zones.

ambient sound levels as they are the two most significant factors affecting how sound waves propagate from source to receiver.³²

D.1 Land Cover

The vegetative land cover within a park is one of the key attributes affecting the acoustics. Land cover directly affects how sounds propagate from a source to a receiver. Sounds typically propagate with little attenuation over acoustically hard surfaces (e.g., bare rocks or water) as opposed to acoustically soft surfaces (e.g., grassy fields or dense trees). 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. (see Table 37).³³ The land cover distribution using the NLCD categories for Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau is shown in Table 38. This classification approach has been closely coordinated with NPS personnel.*

Table 38. National Land Cover Database (NLCD) characterization classes/subclasses.

Land Cover Class	Land Cover Subclass	Description
Water	11 Open Water	All areas of open water, generally with less than 25% cover of vegetation/land cover.
Water	12 Perennial Ice/Snow	All areas characterized by year-long surface cover of ice and/or snow.
Developed	21 Low Intensity Residential	All areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80% of the cover. Vegetation may account for 20 to 70% of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
Developed	22 High Intensity Residential	Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20% of the cover. Constructed materials account for 80 to 100% of the cover.
Developed	23 Commercial/Industrial/Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

* 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.

Land Cover Class	Land Cover Subclass	Description
Barren	31 Bare Rock/Sand/ Clay	Perennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.
Barren	32 Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Barren	33 Transitional	Areas of sparse vegetative cover (less than 25% of cover) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).
Forested Upland	41 Deciduous Forest	Areas dominated by trees where 75% Or more of the tree species shed foliage simultaneously in response to seasonal change.
Forested Upland	42 Evergreen Forest	Areas dominated by trees where 75% or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Forested Upland	43 Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75% of the cover present.
Shrubland	51 Shrubland	Areas dominated by shrubs; shrub canopy accounts for 25-100% of the cover. Shrub cover is generally greater than 25% when tree cover is less than 25%. Shrub cover may be less than 25% in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25% and shrubs cover exceeds the cover of the other life forms.
Non-Natural Woody	61 Orchards/Vineyards/ Other	Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.
Herbaceous Upland Natural/Semi-natural Vegetation	71 Grasslands/ Herbaceous	Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25%, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.
Herbaceous Planted/Cultivated	81 Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Herbaceous Planted/Cultivated	82 Row Crops	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Herbaceous Planted/Cultivated	83 Small Grains	Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.
Herbaceous Planted/Cultivated	84 Fallow	Areas used for the production of crops that do not exhibit visible vegetation as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.
Herbaceous Planted/Cultivated	85 Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.
Wetlands	91 Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100% of the cover and the soil or substrate is periodically saturated with or covered with water.
Wetlands	92 Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100% of the cover and the soil or substrate is periodically saturated with or covered with water.

Table 39. Land cover subclass distribution in Pu`ukohola Heiau, Kaloko-Honokohau, and Pu`uhonua o Honaunau.

Land Cover Class	Land Cover Subclass	Area in Pu`ukohola Heiau (Sq. Mi)	Area in Kaloko- Honokohau (Sq. Mi)	Area in Pu`uhonua o Honaunau (Sq. Mi.)
Water	11 Open Water	0.0	0.0	0.0
Water	12 Perennial Ice/Snow	0.0	0.0	0.0
Developed	21 Low Intensity Residential	0.2	0.1	0.0
Developed	22 High Intensity Residential	0.0	0.3	0.0
Developed	23 Commercial/Industrial/Transportation	0.0	0.0	0.0
Barren	31 Bare Rock/Sand/Clay	0.3	1.9	0.1
Barren	32 Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0
Barren	33 Transitional	0.0	0.0	0.0
Forested Upland	41 Deciduous Forest	0.0	0.0	0.0
Forested Upland	42 Evergreen Forest	0.0	0.0	0.0
Forested Upland	43 Mixed Forest	0.0	0.0	0.0
Shrubland	51 Shrubland	0.1	0.1	0.0
Non-Natural Woody	61 Orchards/Vineyards/Other	0.0	0.0	0.0
Herbaceous Upland Natural/Semi-natural Vegetation	71 Grasslands/Herbaceous	0.6	1.1	1.4
Herbaceous Planted/Cultivated	81 Pasture/Hay	0.0	0.0	0.0
Herbaceous Planted/Cultivated	82 Row Crops	0.0	0.0	0.0
Herbaceous Planted/Cultivated	83 Small Grains	0.0	0.0	0.0
Herbaceous Planted/Cultivated	84 Fallow	0.0	0.0	0.0
Herbaceous Planted/Cultivated	85 Urban/Recreational Grasses	0.0	0.0	0.0
Wetlands	91 Woody Wetlands	0.0	0.0	0.0
Wetlands	92 Emergent Herbaceous Wetlands	0.0	0.0	0.0
	Total *	1.2	3.5	1.5

D.2 Climate and Ecological Domain

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. Thus, different climate regions (or ecological domains) of the U.S. have to be considered. The organization, NatureServe, and its natural heritage program members, with funding from The Nature Conservancy, have completed the first working classification of terrestrial ecological systems in the United States, southern

* Because NPATMA applies to all commercial air tour operations within the ½-mile outside the boundary of a national park, these numbers include these areas. Therefore, the total area of all land cover types is larger than the total area of the park.

Alaska, and adjacent portions of Mexico and Canada. The ecological divisions of North America used in association with NatureServe are shown in Figure 115.³⁴ Note: Hawai`i is not shown in this figure. Its ecological division is #412 (Hawaiian Highlands). With the goal of potentially facilitating future data transferability between parks, all baseline acoustic data collected thus far have been organized by ecological division. This approach has been closely coordinated with NPS personnel.*

* 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.

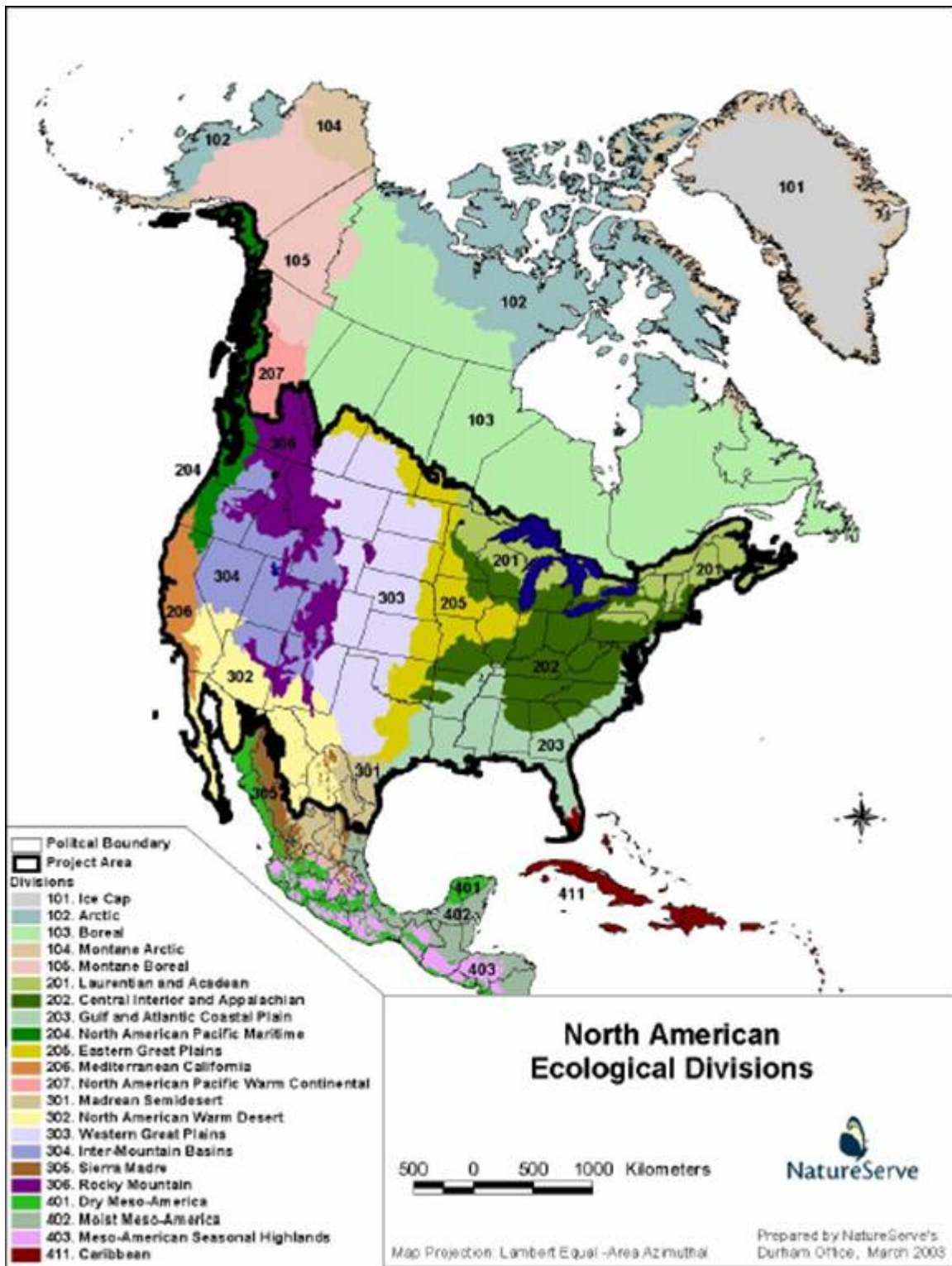


Figure 117. NatureServe ecological divisions of North America.*

* Hawai'i is not shown in this figure. Its ecological division is #412 (Hawaiian Highlands).

D.3 Statistical Tests for Data Transferability

The site transferability hypothesis seeks to show that similar locations within a national park have similar acoustic features. This provides a means to estimate ambient acoustic features of large regions of a national park that are economically infeasible to monitor with sound level equipment. Two statistical methods were used to evaluate the site transferability hypothesis: Regression Analysis (see Section D.3.1) and the Kolmogorov-Smirnoff (K-S) Statistic (see Section D.3.2). These two methods were used in tandem to assess acoustic similarity. If a site combination passed both methods it was considered strong evidence that the sites were similar. If a site combination failed both methods, it was an indication that the sites were different. Cases where one method indicated similarity and the other method was contradictory were evaluated individually and a final decision was made after review of the results and pertinent site information.

D.3.1 Regression Analysis

Although sound-level data, whose associated wind speed was greater than 5 m/s (see Section 5.3.1), were not used in data analyses, it was still considered likely that wind speed would affect the hourly L_{50} sound levels. An analysis of the Pearson Correlations confirmed this, indicating that the correlation between hourly L_{50} and hourly average wind speed is significant at the majority of sites.

Because sound levels at each site were found to be dependant upon wind speed, any attempt to find statistical similarity between sites needs to take the wind variable into consideration. Therefore, site comparisons were conducted by regressing L_{50} on wind speed using a third order polynomial, fitted with a weighted, least-squares regression,^{*} and including a dummy site variable. The significance of this site variable was then used to answer the question, “Can the variation in hourly L_{50} be explained, not only by wind speed, but also by site-specific characteristics?” If the site variable was not significant, it can be said that none of the variation in L_{50} can be explained by site. If none of the

^{*} This regression was also conducted taking into account the fact that the hourly L_{50} data is also highly correlated over time. In other words, a sample from the 10:00 hour is highly correlated with a sample from the 9:00 hour and from the 11:00 hour. Due to this correlation, the number of degrees of freedom used in this regression was not based on the number of hourly L_{50} data points, which were measured. Rather, the number of degrees of freedom was based on the number of days over which the measurements were conducted

variation can be explained by site, then there is statistically no difference between sites. The site variable was considered statistically significant if its p-level was 0.05 or less. The p-level represents the probability of error in accepting the observed result as valid.

D.3.2 Kolmogorov-Smirnoff (K-S) Statistic

The Kolmogorov-Smirnoff (K-S) method evaluates two different cumulative distribution functions (cdf) and computes the probability that they are the same distribution.³⁵ This test is a nonparametric alternative to the t-test for independent samples. The implementation of this method uses the overall, hourly distributions of the measured sound pressure levels. The K-S statistic was computed for each daytime hour. If a majority (more than 50 percent) of the daytime hours pass the K-S test, then the sites were considered equivalent.

Using the above tests, the following comparisons were performed to statistically assess ambient data collected at a pair of sites within each park that were: (1) located in the same acoustic zone, (2) had the same land cover class/subclass (per NLCD), or (3) experienced similar levels of visitor-use. Section 6.2 presents the results.

As new ambient data are collected in parks with additional land cover types and within other ecological divisions, it is anticipated that the analysis of acoustic zones may be expanded to a larger scale, possibly nationwide.

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