



U.S. Department of Transportation
Federal Aviation Administration



U.S. Department of Interior
National Park Service

DOT-VNTSC-FAA-06-09
DOT/FAA/AEE/2016-06

Haleakalā National Park: Baseline Ambient Sound Levels 2003



NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof. This report does not constitute a standard, specification, or regulation.

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

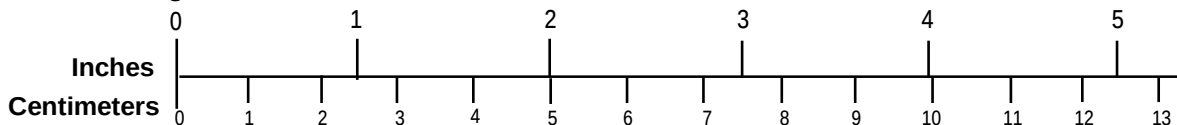
REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 2016		3. REPORT TYPE AND DATES COVERED Final Report
4. TITLE AND SUBTITLE Haleakalā National Park: Baseline Ambient Sound Levels 2003		5. FUNDING NUMBERS FP-01/CS077		
6. AUTHOR(S) Cynthia S.Y. Lee, Gregg G. Fleming, Christopher J. Roof, John M. MacDonald, Christopher J. Scarpone, Andrew R. Malwitz, and Gary Baker				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology John A. Volpe National Transportation Systems Center Environmental Measurement and Modeling Division, V-324 Cambridge, MA 02142-1093		8. PERFORMING ORGANIZATION REPORT NUMBER DOT-VNTSC-FAA-06-09		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Aviation Administration Western-Pacific Regional Office Washington, DC 20591		10. SPONSORING/MONITORING AGENCY REPORT NUMBER DOT/FAA/AEE/2016-06		
11. SUPPLEMENTARY NOTES FAA Program Managers: Barry Brayer, Brian Armstrong, and Steve May (AWP, Western-Pacific Regional Office)				
12a. DISTRIBUTION/AVAILABILITY STATEMENT			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The Federal Aviation Administration (FAA), with the cooperation of the National Park Service (NPS) and assistance of the U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) is developing Air Tour Management Plans (ATMP) 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, Rocky Mountain National Park, exempt park units (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 FAA, with the assistance of the Volpe Center's Environmental Measurement and Modeling Division, and the NPS conducted baseline ambient sound level measurements during the period February 27 through May 27, 2003 in Haleakalā National Park. In total, 165 days of acoustical and meteorological data were measured at ten sites throughout the park. This document summarizes the results of the noise measurement study.				
14. SUBJECT TERMS Aircraft noise, air tours, ambient, acoustic zones, noise impact, noise, Hawai'i, Air Tour Management Plan, ATMP, National Park			15. NUMBER OF PAGES 207	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT	

METRIC/ENGLISH CONVERSION FACTORS

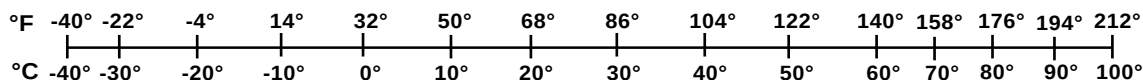
ENGLISH TO METRIC

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

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



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

Updated 6/17/98

ACKNOWLEDGEMENTS

The authors of this report wish to express their sincere gratitude to all who helped make this a successful study. The coordination and support provided by the Federal Aviation Administration (FAA), Western-Pacific Regional Office, and National Park Service (NPS), Natural Sounds and Night Skies Division, proved invaluable. We would also like to thank Don Hamilton (FAA Flight Standards District Office) and Don Reeser and his entire team at Haleakalā National Park. Additionally, we thank Sarah Creachbaum (NPS Natural Sounds and Night Skies Division) and Peter Graves (Hawai`i Volcanoes NPS) for their invaluable assistance in the maintenance and downloading of the acoustic systems throughout the two-month measurement period.

Page left blank intentionally.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
ACKNOWLEDGEMENTS	v
TABLE OF CONTENTS	vii
LIST OF FIGURES	xi
LIST OF TABLES	xv
EXECUTIVE SUMMARY	xvii
TERMINOLOGY	xxxv
1. INTRODUCTION.....	1
1.1 Scope.....	1
1.2 Objectives	2
1.3 Report Organization.....	3
2. SITE SELECTION	5
2.1 Site Selection Criteria	6
2.2 Vegetation/Land Cover	7
2.3 Climate Conditions	8
2.4 Park Resources/Management Zones	9
2.4.1 Visitor Use Areas	12
2.4.2 Wildlife Resource Areas	12
2.4.3 Cultural and Historic Resource Areas.....	13
2.5 Commercial Air Tour Flight Routes	13
2.6 Haleakalā Acoustic Zones.....	14
2.7 Logistics/Access	16
2.7.1 Access	16
2.7.2 Duration of Measurements.....	17

3.	INSTRUMENTATION	21
3.1	NoiseLogger™ Continuous Monitoring System	21
3.1.1	Microphone System	21
3.1.2	Sound Level Meter (SLM).....	22
3.1.3	Handheld Personal Computer	22
3.1.4	Ultrasonic Anemometer	22
3.1.5	Solar Panel Array	23
3.2	NoiseLogger Plus™ Continuous Monitoring System	23
3.3	Volpe Low-Amplitude Recording Equipment (VoLARE) System	26
3.3.1	Microphone System	26
3.3.2	Sound Level Meter (SLM).....	26
3.3.3	Digital Audio Tape (DAT) Recorder	27
3.4	Acoustic Observer Log	29
3.5	Aircraft Photo-scaling System	29
3.6	Other Instrumentation	30
4.	FIELD MEASUREMENT PROCEDURES.....	31
4.1	NoiseLogger™ and NoiseLogger Plus™ System Deployment.....	31
4.2	VoLARE System Deployment.....	36
4.3	Measurements	38
5.	DATA REDUCTION AND PROCESSING	41
5.1	Raw NoiseLogger™ and NoiseLogger Plus™ Acoustic and Meteorological Data Reduction	41
5.2	Raw VoLARE Acoustic Data Reduction.....	42
5.3	Acoustic Observer Log Data Reduction	43
5.4	Slant Range Data Reduction	43
5.5	Data Processing.....	44
5.5.1	Data Filters.....	44
5.5.2	Data Adjustments.....	45
5.5.3	Sound Level Descriptors.....	46

6.	DATA ANALYSIS	47
6.1	Diurnal Variability	48
6.2	Acoustic Zones.....	52
6.3	Measurement Duration.....	55
6.4	Development of Ambient Maps.....	58
6.4.1	Computation of Ambients.....	60
6.4.2	Other Considerations	62
6.4.3	Assignment of Ambient Sound Levels	63
7.	RESULTS	65
APPENDIX A. MEASUREMENT SITE DETAILS		93
A.1	Site P01 – Haleakalā Crater Measurement Site	96
A.2	Site P02 – West Rim Crater Measurement Site	99
A.3	Site P03 – Kipahulu Coastal Measurement Site	102
A.4	Site ST4 – Kaupo Gap Measurement Site	105
A.5	Site ST5 – Haleakalā Crater Measurement Site.....	108
A.6	Site ST6 – Haleakalā Crater Measurement Site.....	111
A.7	Site ST7 – West Rim Crater Measurement Site.....	114
A.8	Site ST8 – Kipahulu Coastal Measurement Site.....	117
A.9	Site ST9 – Upper Kipahulu Valley Measurement Site	119
A.10	Site ST10 – Kipahulu Coastal Measurement Site.....	122
APPENDIX B. NOISELOGGER™ AND NOISELOGGER PLUS™ CONTINUOUS SYSTEM REFERENCE		125
B.1	Overview.....	125
B.2	Instrumentation List	125
B.2	Deployment.....	128
B.2.1	Wind Sensor System	128
B.2.2	Microphone System	129
B.2.3	Power System.....	129
B.3	Operation.....	131

B.3.1	NoiseLogger™ Startup	131
B.3.2	NoiseLogger Plus™ Startup	133
B.3.3	GPS Synchronization	135
B.3.4	Equipment Information	135
B.3.5	Calibration.....	136
B.3.6	System Integrity Check.....	137
B.4	Data Collection	138
B.5	Data Download	139
B.6	System Dismantling.....	141
B.6.1	SLM Acoustics Case.....	141
B.6.2	Wind Sensor System	141
B.6.3	Microphone System	141
B.6.4	Power System.....	142
 APPENDIX C. INSTRUMENTATION FREQUENCY RESPONSE ADJUSTMENTS .		145
C.1	Microphone Frequency Response Adjustments.....	145
C.2	Windscreen Frequency Response Adjustments	147
 APPENDIX D. SLANT RANGE PHOTO ANALYSIS.....		149
 APPENDIX E. ACOUSTIC ZONE ANALYSIS		153
E.1	Land Cover.....	154
E.2	Climate and Ecological Domain	156
E.3	Statistical Tests for Data Transferability	158
E.3.1	Regression Analysis.....	158
E.3.2	Kolmogorov-Smirnoff (K-S) Statistic	159
 REFERENCES.....		161

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
Figure 1. Location of Haleakalā.....	xviii
Figure 2. Acoustic zones and final measurement sites for Haleakalā.....	xx
Figure 3. Baseline ambient data collection timeline for each site.	xxi
Figure 4. Graphical depiction of ambient definitions.	xxiii
Figure 5. Roadway ambient map.	xxxii
Figure 6. Baseline composite ambient map – Existing Ambient Without Air Tours: L ₅₀	xxxiii
Figure 7. Baseline composite ambient map – Natural Ambient: L ₅₀	xxxiv
Figure 8. Graphical representation of L _{AE}	xl
Figure 9. Location of Haleakalā.....	2
Figure 10. Overview map of Haleakalā.	5
Figure 11. Land cover in Haleakalā.	8
Figure 12. Noise-sensitive areas in Haleakalā.	11
Figure 13. Air tour routes in the vicinity of Haleakalā.	14
Figure 14. Acoustic zones for Haleakalā.	16
Figure 15. Final measurement sites for Haleakalā.	19
Figure 16. NoiseLogger™ continuous monitoring system.....	24
Figure 17. NoiseLogger Plus™ continuous monitoring system.....	25
Figure 18. Volpe Low-Amplitude Recording Equipment (VoLARE) system.	28
Figure 19. NoiseLogger™ system deployment; Site ST7.	35
Figure 20. NoiseLogger Plus™ system deployment; Site P03.....	36
Figure 21. VoLARE microphone system deployment; Site ST9.....	37
Figure 22. VoLARE recording system deployment; Site ST9.	38
Figure 23. Flow diagram of data reduction process.....	41
Figure 24. Baseline ambient data collection timeline for each site.	47
Figure 25. Acoustic zones and measurement sites for Haleakalā.	53
Figure 26. Data transferability within acoustic zones.....	54
Figure 27. Data comparisons for land cover.....	54
Figure 28. Data comparisons for visitor-use.....	55

Figure 29. Summary of L ₅₀ results for all permanent measurement sites.....	57
Figure 30. Summary of L ₉₀ results for all permanent measurement sites.....	57
Figure 31. Graphical depiction of ambient definitions.	59
Figure 32. Summary of measured ambient sound level data – Existing Ambient (L _{Aeq} , L ₅₀ , L ₉₀).	71
Figure 33. Summary of measured ambient sound level data – Existing Ambient Without Air Tours (L ₅₀ , L ₉₀).	72
Figure 34. Summary of measured ambient sound level data – Existing Ambient Without All Aircraft (L ₅₀ , L ₉₀).	73
Figure 35. Summary of measured ambient sound level data – Natural Ambient (L ₅₀ , L ₉₀).	74
Figure 36. Summary of measured ambient sound level data – L ₅₀	75
Figure 37. Summary of measured ambient sound level data – L ₉₀	76
Figure 38. Summary of acoustic observer log data.....	79
Figure 39. Roadway ambient map.	82
Figure 40. Baseline ambient map – Existing Ambient: L _{Aeq}	83
Figure 41. Baseline ambient map – Existing Ambient: L ₅₀	84
Figure 42. Baseline ambient map – Existing Ambient: L ₉₀	85
Figure 43. Baseline ambient map – Existing Ambient Without Air Tours: L ₅₀	86
Figure 44. Baseline ambient map – Existing Ambient Without Air Tours: L ₉₀	87
Figure 45. Baseline ambient map – Existing Ambient Without All Aircraft: L ₅₀	88
Figure 46. Baseline ambient map – Existing Ambient Without All Aircraft: L ₉₀	89
Figure 47. Baseline ambient map – Natural Ambient: L ₅₀	90
Figure 48. Baseline ambient map – Natural Ambient: L ₉₀	91
Figure 49. Final measurement sites for Haleakalā.	93
Figure 50. Site P01: Description and photograph.	96
Figure 51. Daily sound levels and wind speeds: Site P01.	97
Figure 52. Average hourly sound levels and wind speeds: Site P01.	97
Figure 53. Distribution of data: Site P01.	98
Figure 54. Site P02: Description and photograph.	99
Figure 55. Daily sound levels and wind speeds: Site P02.	100
Figure 56. Average hourly sound levels and wind speeds: Site P02.	100

Figure 57. Distribution of data: Site P02.	101
Figure 58. Site P03: Description and photograph.	102
Figure 59. Daily sound levels and wind speeds: Site P03.	103
Figure 60. Average hourly sound levels and wind speeds: Site P03.	103
Figure 61. Data distributions: Site P03.	104
Figure 62. Site ST4: Description and photograph.	105
Figure 63. Daily sound levels and wind speeds: Site ST4.	106
Figure 64. Average hourly sound levels and wind speeds: Site ST4.*	106
Figure 65. Data distributions: Site ST4.	107
Figure 66. Site ST5: Description and photograph (Note: System not shown).	108
Figure 67. Daily sound levels and wind speeds: Site ST5.	109
Figure 68. Average hourly sound levels and wind speeds: Site ST5.	109
Figure 69. Data distributions: Site ST5.	110
Figure 70. Site ST6: Description and photograph.	111
Figure 71. Daily sound levels and wind speeds: Site ST6.	112
Figure 72. Average hourly sound levels and wind speeds: Site ST6.	112
Figure 73. Data distributions: Site ST6.	113
Figure 74. Site ST7: Description and photograph.	114
Figure 75. Daily sound levels and wind speeds: Site ST7.	115
Figure 76. Average hourly sound levels and wind speeds: Site ST7.	115
Figure 77. Data distributions: Site ST7.	116
Figure 78. Site ST8: Description and photograph (Note: System not shown).	117
Figure 79. Site ST9: Description and photograph.	119
Figure 80. Daily sound levels and wind speeds: Site ST9.	120
Figure 81. Average hourly sound levels and wind speeds: Site ST9.*	120
Figure 82. Data distributions: Site ST9.	121
Figure 83. Site ST10: Description and photograph (Note: System not shown).	122
Figure 84. Average hourly sound levels and wind speeds: Site ST10.	123
Figure 85. Data distributions: Site ST10.	123
Figure 86. NoiseLogger™ continuous monitoring system.	126
Figure 87. NoiseLogger Plus™ continuous monitoring system.	127

Figure 88. Gill WindObserver II and FT702 anemometers.....	128
Figure 89. Microphone/preamp assembly.....	129
Figure 90. Unpack solar panel array.....	129
Figure 91. Solar panel array setup.	130
Figure 92. Close-in view of string tensioner.....	130
Figure 93. SLM acoustics case.	132
Figure 94. NoiseLogger Plus™ Fujitsu™ computer.	133
Figure 95. System calibration.	136
Figure 96. Packing the solar panel array.....	143
Figure 97. Microphone frequency responses (see Table 7 in Section 4.1).	146
Figure 98. Windscreen frequency responses.	148
Figure 99. Comparison of measured and predicted aircraft sound levels.....	151
Figure 100. NatureServe ecological divisions of North America.....	157

LIST OF TABLES

<u>Table</u>	<u>Page</u>
Table 1. Summary of measured, daytime (6 am to 6 pm), ambient sound level data.....	xxvii
Table 2. Summary of acoustic observer log data.....	xxviii
Table 3. Summary of acoustic observer log data: number of events per hour and noise-free interval.	xxix
Table 4. Nine composite ambient maps.....	xxxi
Table 5. Monthly climate summary for Haleakalā.	9
Table 6. Summary of measurement sites selected for Haleakalā.....	20
Table 7. Summary of NoiseLogger™ and NoiseLogger Plus™ system equipment information.	33
Table 8. LD Model 824 SLM sound level range and associated gain setting and ceiling level..	33
Table 9. Acoustic state identifiers.....	40
Table 10. Average hourly sound levels - L_{Aeq} (Hour of the Day).....	50
Table 11. Average hourly sound levels - L_{50} (Hour of the Day).	50
Table 12. Average hourly sound levels - L_{90} (Hour of the Day).	51
Table 13. Summary of day versus night diurnal trends.	51
Table 14. Matrix of ambient maps.....	60
Table 15. TNM traffic volume input.....	62
Table 16. Determination of final, composite ambient sound levels at each grid point.....	64
Table 17. Summary of measured, daytime (6 am to 6 pm), ambient sound level data.....	69
Table 18. Summary of measured, daytime (6 am to 6 pm), ambient sound level spectral data. .	69
Table 19. Summary of measured ambient sound level data (daytime and nighttime hours included).	77
Table 20. Summary of acoustic observer log data.....	78
Table 21. Summary of acoustic observer log data: number of events per hour and noise-free interval.	80
Table 22. Site P01: description.	96
Table 23. Site P02: description.	99
Table 24. Site P03: description.	102

Table 25. Site ST4: description.....	105
Table 26. Site ST5: description.....	108
Table 27. Site ST6: description.....	111
Table 28. Site ST7: description.....	114
Table 29. Site ST8: description.....	117
Table 30. Site ST9: description.....	119
Table 31. Site ST10: description.....	122
Table 32. NoiseLogger™ and NoiseLogger Plus™ system instrumentation list.	125
Table 33. LD Model 824 SLM sound level range and associated gain setting and ceiling level.	139
Table 34. Microphone frequency responses by system number.	145
Table 35. Windscreen frequency responses by system number.	147
Table 36. Summary of computed slant range data.....	150
Table 37. Comparison of measured and INM-predicted aircraft sound levels.	150
Table 38. National Land Cover Database (NLCD) characterization classes/subclasses.	154
Table 39. Land cover subclass distribution in Haleakalā.	155

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 Hawai`i Volcanoes;
- Establishing the different sound sources contributing to the baseline levels in key areas within Hawai`i Volcanoes;
- Modeling sound levels in other similar areas within Hawai`i Volcanoes 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 for the baseline ambient noise environment in Haleakalā National Park (Haleakalā) located in the state of Hawai`i (see Figure 1).



Figure 1. Location of Haleakalā.

The FAA, with assistance of the Volpe Center’s Environmental Measurement and Modeling Division, and the NPS conducted baseline ambient sound level measurements during the period of February 27 through May 27, 2003 – 165 days of acoustical and meteorological data were measured at ten sites throughout the park. These sites were selected during multiple teleconferences between the FAA, the NPS, the Volpe Center, and Haleakalā NPS 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 was accomplished by identifying acoustically representative regions for which data could be collected and stratified, i.e., “acoustic zones.” These data could then be applied to other regions in the park possessing similar attributes, which will affect acoustics, such as land cover, wind conditions, and wildlife habitats.

The land cover in Haleakalā is approximately 25 percent bare rock/sand/clay, 30 percent evergreen forest, 27 percent shrubland, and 18 percent grassland, resulting in four, primary acoustic zones. The four zones were then further subdivided based on other factors. These factors affect the acoustics and how NPS manages different areas within the park. The resultant agreed-upon five acoustic zones were as follows:

- West Rim Crater (Zone 1);
- Haleakalā Crater (Zone 2);
- Kaupo Gap (Zone 3);
- Kipahulu Coastal (Zone 4); and
- Upper Kipahulu Valley (Zone 5).

In discussions with Haleakalā NPS personnel, because there is little climatic seasonal variation in Hawai`i as compared with other U.S. national parks, a minimum of one week of continuous, 24-hour measurements at each site was recommended, with up to two weeks being preferred. To validate this recommendation and provide guidance for adequate measurement duration for use in future parks, it was agreed that: (1) one site within each of three key acoustic zones would include data collection on a long-term basis, i.e., longer than 2 weeks up to the entire measurement study duration of approximately 1 month (permanent sites, designated with the letter “P” in Figure 3); and (2) additional sites placed within each zone would include data collection on a short-term basis, i.e., one to two weeks (mobile sites designated with the letters “ST” in Figure 3). For example, Sites P01 and ST5 indicate a permanent system and a mobile system, respectively, in Zone 1 (Haleakalā Crater). Figure 2 displays the locations of the acoustic zones and the final measurement sites selected.

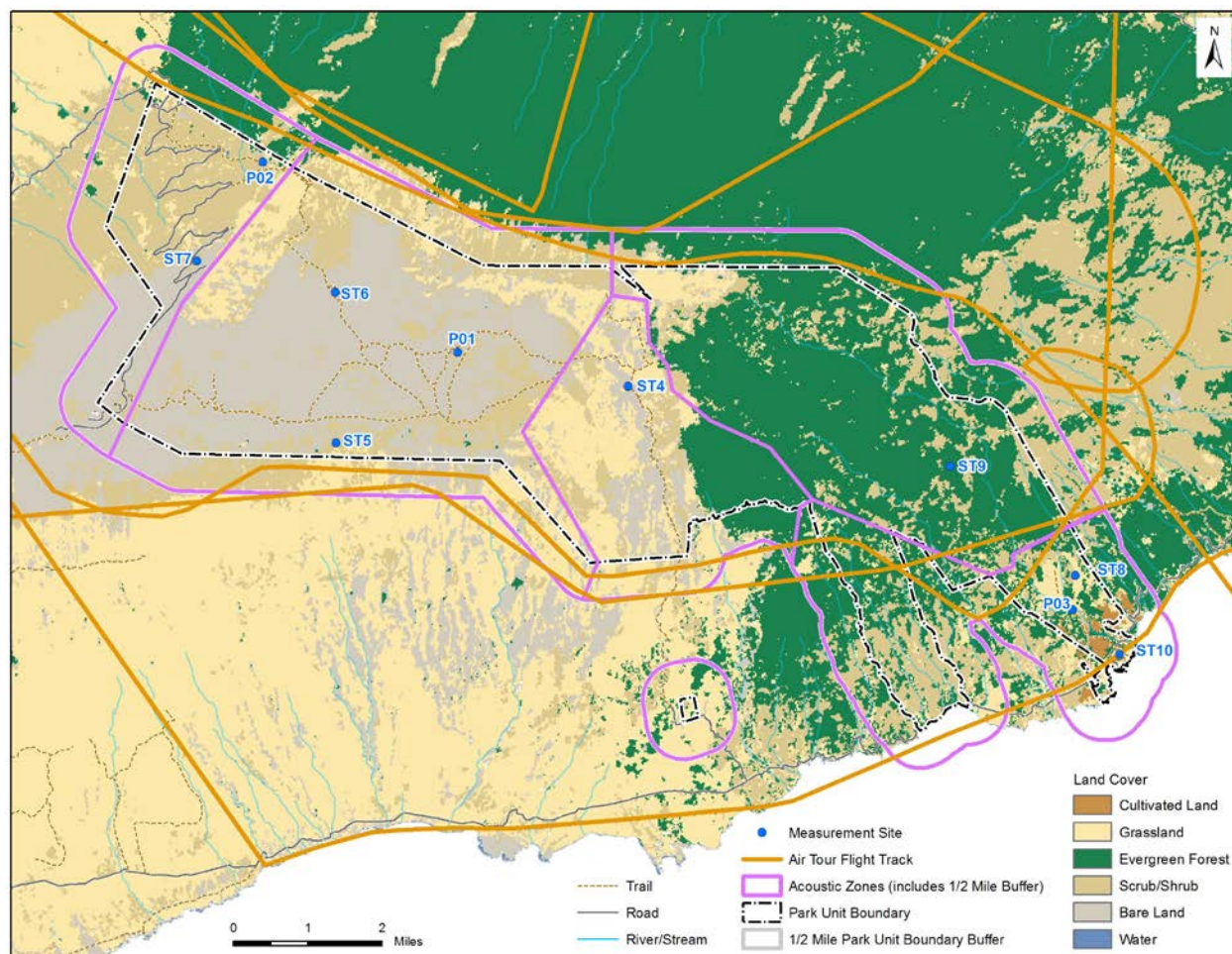


Figure 2. Acoustic zones and final measurement sites for Haleakalā.

As stated earlier, in total, 165 days of acoustical and meteorological data were measured at ten sites throughout Haleakalā during the period February 27 through May 27, 2003 (see Figure 3). Note: Sites within the same acoustic zones are shown in like colors.

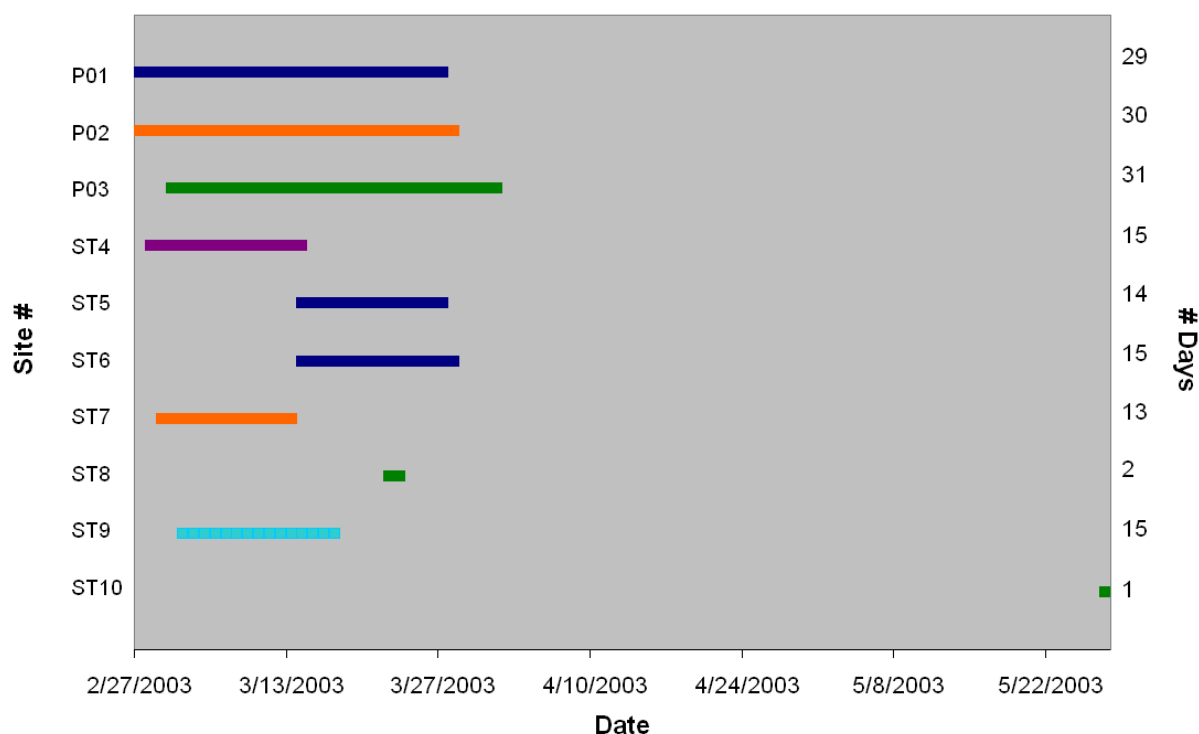


Figure 3. Baseline ambient data collection timeline for each site.

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 hierarchical 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.

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 and VA analyses will be based on daytime ambient data. For Haleakalā, 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 4):

- *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.

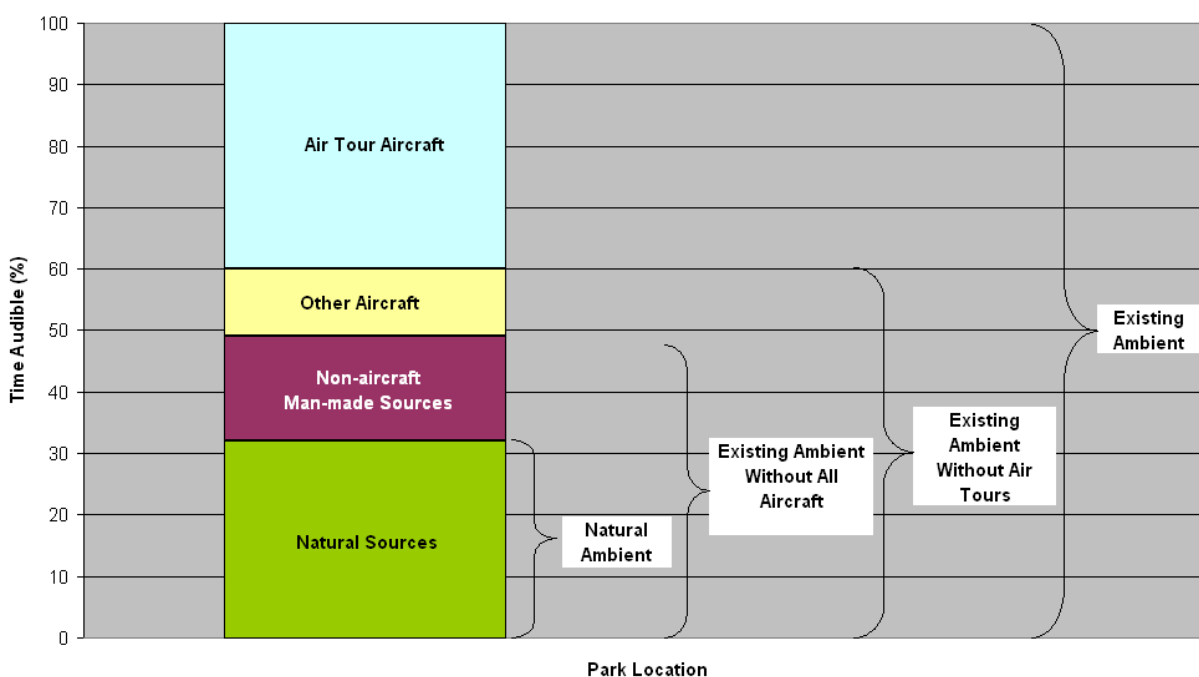


Figure 4. Graphical depiction of ambient definitions.

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:

- *Acoustic Zone*: The acoustic and management zone in which the measurement site was

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

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 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:

- *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”;

* 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 analyses will be based on daytime ambient data. For Haleakalā, 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.

- *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 summarize 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.

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

Acoustic Zone	Site ID	Total # Days	Existing L _{Aeq} (dBA)	Existing L ₅₀ (dBA)	Existing L ₉₀ (dBA)	Existing W/S (mph)	Existing Without Air Tours L ₅₀ (dBA)	Existing Without Air Tours L ₉₀ (dBA)	Existing Without Air Tours W/S (mph)	Existing Without All Aircraft L ₅₀ (dBA)	Existing Without All Aircraft L ₉₀ (dBA)	Existing Without All Aircraft W/S (mph)	Natural Ambient L ₅₀ (dBA)	Natural Ambient L ₉₀ (dBA)	Natural Ambient W/S (mph)
1: West Rim Crater	P02	30	40.7	27.2	21.5	5.2	26.8	21.6	0.0	26.8	21.6	0.0	27.7	22.2	0.0
1: West Rim Crater	ST7	13	42.5	28.4	21.9	5.1	24.1	20.5	7.6	24.1	20.5	7.5	23.6	20.2	7.6
2: Haleakalā Crater	P01	29	34.7	24.5	18.6	4.2	22.6	18.5	5.0	22.6	18.5	5.0	22.5	18.6	5.0
2: Haleakalā Crater	ST5	14	43.7	24.6	19.3	5.5	21.9	19.0	5.4	21.8	18.8	5.4	21.8	19.0	5.4
2: Haleakalā Crater	ST6	15	34.7	23.5	19.2	5.0	21.4	18.9	5.4	21.4	18.9	5.4	21.4	18.9	5.4
3: Kaupo Gap	ST4	15	35.7	22.5	18.8	6.5	22.7	19.1	8.9	22.7	19.1	8.9	22.6	19.0	8.8
4: Kipahulu Coastal	P03	31	53.2	43.5	38.2	1.5	45.3	42.1	0.8	45.3	42.1	0.8	45.3	42.1	0.8
4: Kipahulu Coastal	ST8*	2	53.2	43.5	38.2	1.5	45.3	42.1	0.8	45.3	42.1	0.8	45.3	42.1	0.8
4: Kipahulu Coastal	ST10†	1	48.1	46.1	44.7	9.1	45.3	42.1	0.8	45.3	42.1	0.8	45.3	42.1	0.8
5: Upper Kipahulu Valley	ST9	15	49.7	34.9	30.0	0.4	30.7	28.1	0.5	30.7	28.1	0.5	30.7	28.1	0.5

* A limited amount of data was collected at this site (2 days); however, due to possible equipment issues, data collected at this site was suspect and, thus, not used in the analyses. As such, the data from Site P03 were used in the ambient mapping as best available.

† Due to equipment issues, no observer logging was performed at Site ST10. As such, the Existing Ambient sound levels could be determined; however, the remaining ambient sound levels could not be readily determined - the data from Site P03 were used in the ambient mapping as best available.

Table 2. Summary of acoustic observer log data. *

Acoustic Zone	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
1: West Rim Crater	P02	Shrubland	Natural	Short Hike	5369	546	0	2109	2714	10.2%	10.2%
1: West Rim Crater	ST7	Bare Rock/Sand/Clay	Developed	Overlook	2421	60	11	665	1685	2.5%	2.9%
2: Haleakalā Crater	P01	Shrubland	Natural	Backcountry	3763	1134	0	154	2475	30.1%	30.1%
2: Haleakalā Crater	ST5	Shrubland	Natural	Backcountry	3348	1066	97	186	1999	31.8%	34.7%
2: Haleakalā Crater	ST6	Bare Rock/Sand/Clay	Natural	Backcountry	3590	2350	0	43	1197	65.5%	65.5%
3: Kaupo Gap	ST4	Shrubland	Natural	Backcountry	2560	116	0	397	2047	4.5%	4.5%
4: Kipahulu Coastal	P03	Evergreen Forest	Natural/Cultural	Short Hike	6101	975	0	409	4717	16.0%	16.0%
4: Kipahulu Coastal	ST8	Evergreen Forest	Natural/Cultural	Overlook	7179	368	0	2586	4225	5.1%	5.1%
4: Kipahulu Coastal	ST10	Bare Rock/Sand/Clay	Natural/Cultural	Overlook	No Observer Logging	No Observer Logging	No Observer Logging	No Observer Logging	No Observer Logging	No Observer Logging	No Observer Logging
5: Upper Kipahulu Valley	ST9	Evergreen Forest	Natural	Wilderness	3095	861	0	8	2226	27.8%	27.8%

* 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, a few sites have only limited observer logging and no logging at one site.

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

	Acoustic Zone	Site ID	Noise-Free Periods	Air Tour Aircraft Events	Other Aircraft Events
Number Periods/Events:	1: West Rim Crater	P02	88	13	8
Mean Time (minutes):	1: West Rim Crater	P02	0:01:09	0:00:42	0:01:23
Minimum Time (minutes):	1: West Rim Crater	P02	0:00:02	0:00:06	0:00:24
Maximum Time (minutes):	1: West Rim Crater	P02	0:12:28	0:02:07	0:02:45
Total Time (minutes):	1: West Rim Crater	P02	1:40:26	0:09:08	0:11:00
Number Periods/Events:	1: West Rim Crater	ST7	35	2	1
Mean Time (minutes):	1: West Rim Crater	ST7	0:01:43	0:01:17	0:01:01
Minimum Time (minutes):	1: West Rim Crater	ST7	0:00:05	0:01:13	0:01:01
Maximum Time (minutes):	1: West Rim Crater	ST7	0:05:54	0:01:21	0:01:01
Total Time (minutes):	1: West Rim Crater	ST7	1:00:04	0:02:34	0:01:01
Number Periods/Events:	2: Haleakalā Crater	P01	224	57	0
Mean Time (minutes):	2: Haleakalā Crater	P01	0:00:36	0:01:06	0:00:00
Minimum Time (minutes):	2: Haleakalā Crater	P01	0:00:05	0:00:08	0:00:00
Maximum Time (minutes):	2: Haleakalā Crater	P01	0:03:15	0:08:03	0:00:00
Total Time (minutes):	2: Haleakalā Crater	P01	2:16:15	1:02:42	0:00:00
Number Periods/Events:	2: Haleakalā Crater	ST5	66	13	1
Mean Time (minutes):	2: Haleakalā Crater	ST5	0:00:36	0:01:33	0:01:43
Minimum Time (minutes):	2: Haleakalā Crater	ST5	0:00:05	0:00:06	0:01:43
Maximum Time (minutes):	2: Haleakalā Crater	ST5	0:02:28	0:04:42	0:01:43
Total Time (minutes):	2: Haleakalā Crater	ST5	0:39:48	0:20:09	0:01:43
Number Periods/Events:	2: Haleakalā Crater	ST6	35	32	0
Mean Time (minutes):	2: Haleakalā Crater	ST6	0:00:35	0:01:14	0:00:00
Minimum Time (minutes):	2: Haleakalā Crater	ST6	0:00:05	0:00:08	0:00:00
Maximum Time (minutes):	2: Haleakalā Crater	ST6	0:02:30	0:04:14	0:00:00
Total Time (minutes):	2: Haleakalā Crater	ST6	0:20:11	0:39:44	0:00:00
Number Periods/Events:	3: Kaupo Gap	ST4	24	12	0
Mean Time (minutes):	3: Kaupo Gap	ST4	0:02:45	0:01:11	0:00:00
Minimum Time (minutes):	3: Kaupo Gap	ST4	0:00:18	0:00:15	0:00:00
Maximum Time (minutes):	3: Kaupo Gap	ST4	0:13:04	0:05:52	0:00:00
Total Time (minutes):	3: Kaupo Gap	ST4	1:05:54	0:14:07	0:00:00
Number Periods/Events:	4: Kipahulu Coastal	P03	88	19	0
Mean Time (minutes):	4: Kipahulu Coastal	P03	0:01:28	0:01:11	0:00:00
Minimum Time (minutes):	4: Kipahulu Coastal	P03	0:00:06	0:00:38	0:00:00
Maximum Time (minutes):	4: Kipahulu Coastal	P03	0:07:38	0:02:01	0:00:00
Total Time (minutes):	4: Kipahulu Coastal	P03	2:08:20	0:22:30	0:00:00
Number Periods/Events:	4: Kipahulu Coastal	ST8	46	8	0
Mean Time (minutes):	4: Kipahulu Coastal	ST8	0:01:32	0:00:46	0:00:00
Minimum Time (minutes):	4: Kipahulu Coastal	ST8	0:00:05	0:00:24	0:00:00
Maximum Time (minutes):	4: Kipahulu Coastal	ST8	0:07:30	0:01:17	0:00:00

	Acoustic Zone	Site ID	Noise-Free Periods	Air Tour Aircraft Events	Other Aircraft Events
Total Time (minutes):	4: Kipahulu Coastal	ST8	1:10:28	0:06:08	0:00:00
	4: Kipahulu Coastal	ST10	(No observer logging)	(No observer logging)	(No observer logging)
Number Periods/Events:	5: Upper Kipahulu Valley	ST9	11	10	0
Mean Time (minutes):	5: Upper Kipahulu Valley	ST9	0:03:22	0:01:26	0:00:00
Minimum Time (minutes):	5: Upper Kipahulu Valley	ST9	0:00:14	0:00:23	0:00:00
Maximum Time (minutes):	5: Upper Kipahulu Valley	ST9	0:09:29	0:03:11	0:00:00
Total Time (minutes):	5: Upper Kipahulu Valley	ST9	0:37:06	0:14:21	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 INM or AEDT model to compute various noise-related descriptors and generate the sound-level contours that will be used in assessment of potential noise impacts due to air tour operations.

For Haleakalā, there were three localized noise sources: Waimoku Falls in the Kipahulu coastal area, and two primary, and relatively busy, roads: Haleakalā Highway, and Highway 31. For Waimoku Falls, ambient data were collected near the Falls for an entire 8-hour day and an estimated drop-off rate, reflecting a continuous decrease in sound level as a function of increasing distance from a point source, was used. The two highways were modeled using the

Federal Highway Administration's Traffic Noise Model[®] (TNM). Figure 5 presents the resultant roadway ambient map.

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.

Metric	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
L_{50}	Map 2: Measured + Roadway	Map 4: Measured + Roadway	Map 6: Measured + Roadway	Map 8: Measured
L_{90}	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 L_{50} and L_{90} 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 analyses:

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

Figure 6 and Figure 7 present the two ambient maps, respectively. Section 7 presents all nine maps.

* 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.

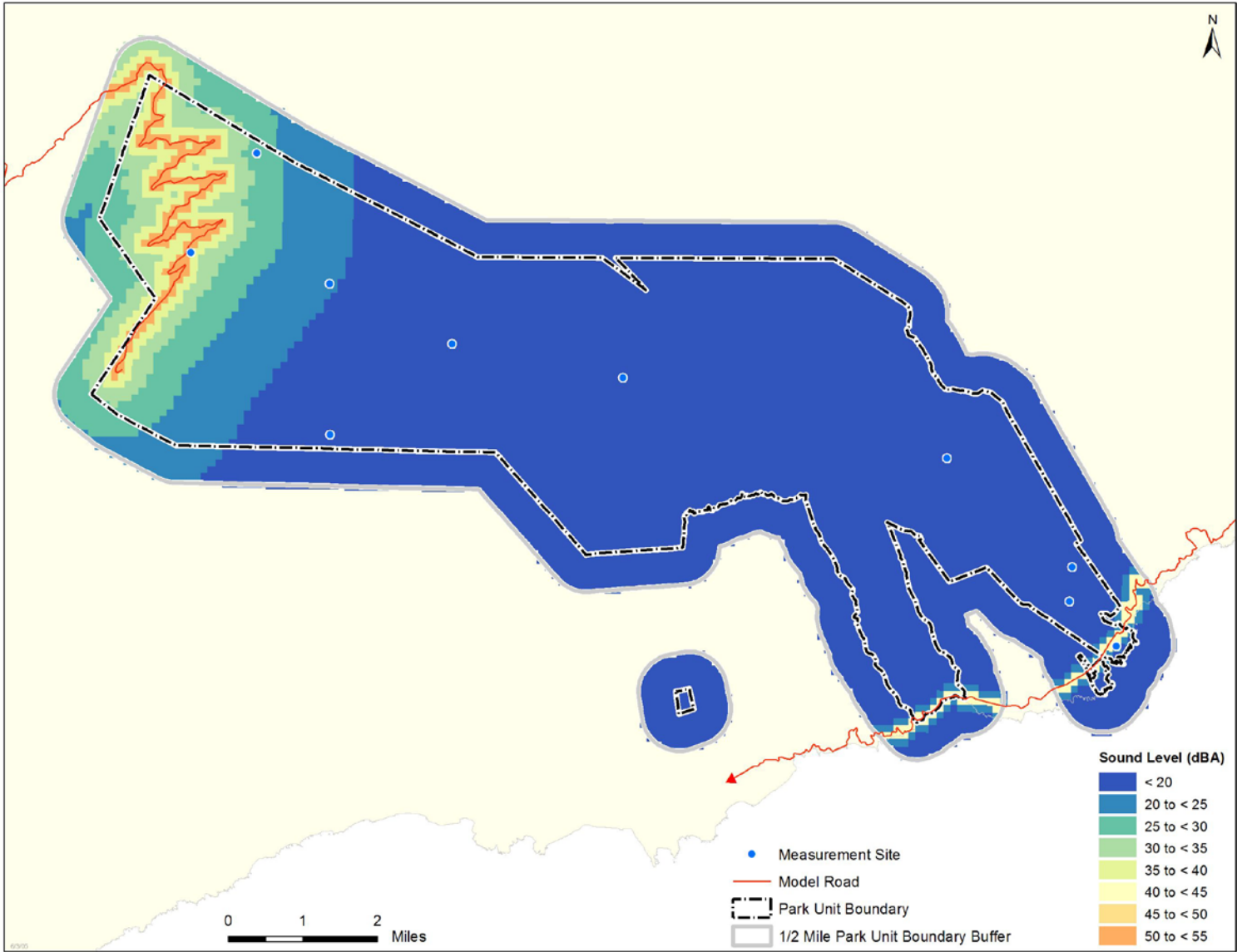


Figure 5. Roadway ambient map.

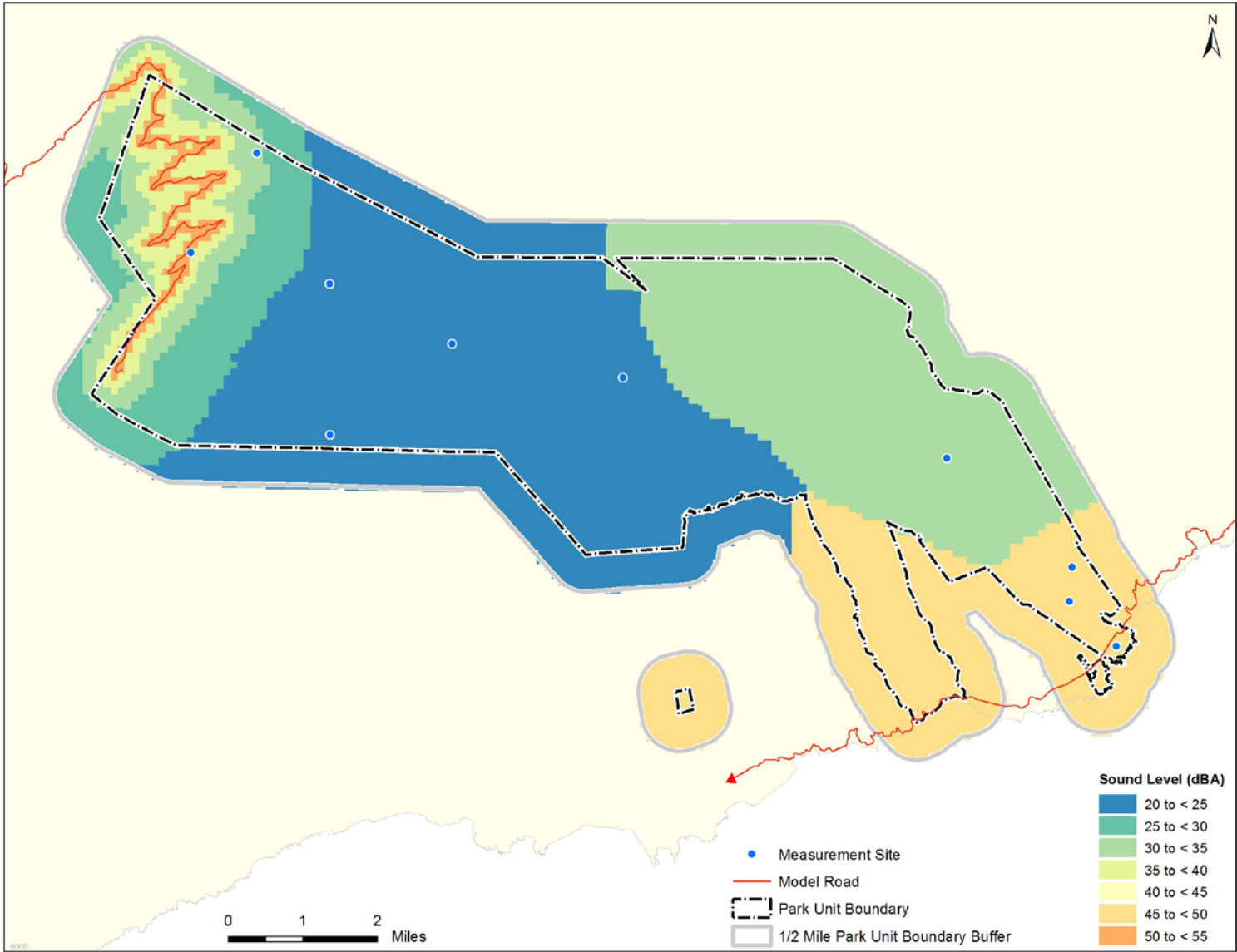


Figure 6. Baseline composite ambient map – Existing Ambient Without Air Tours: L₅₀.

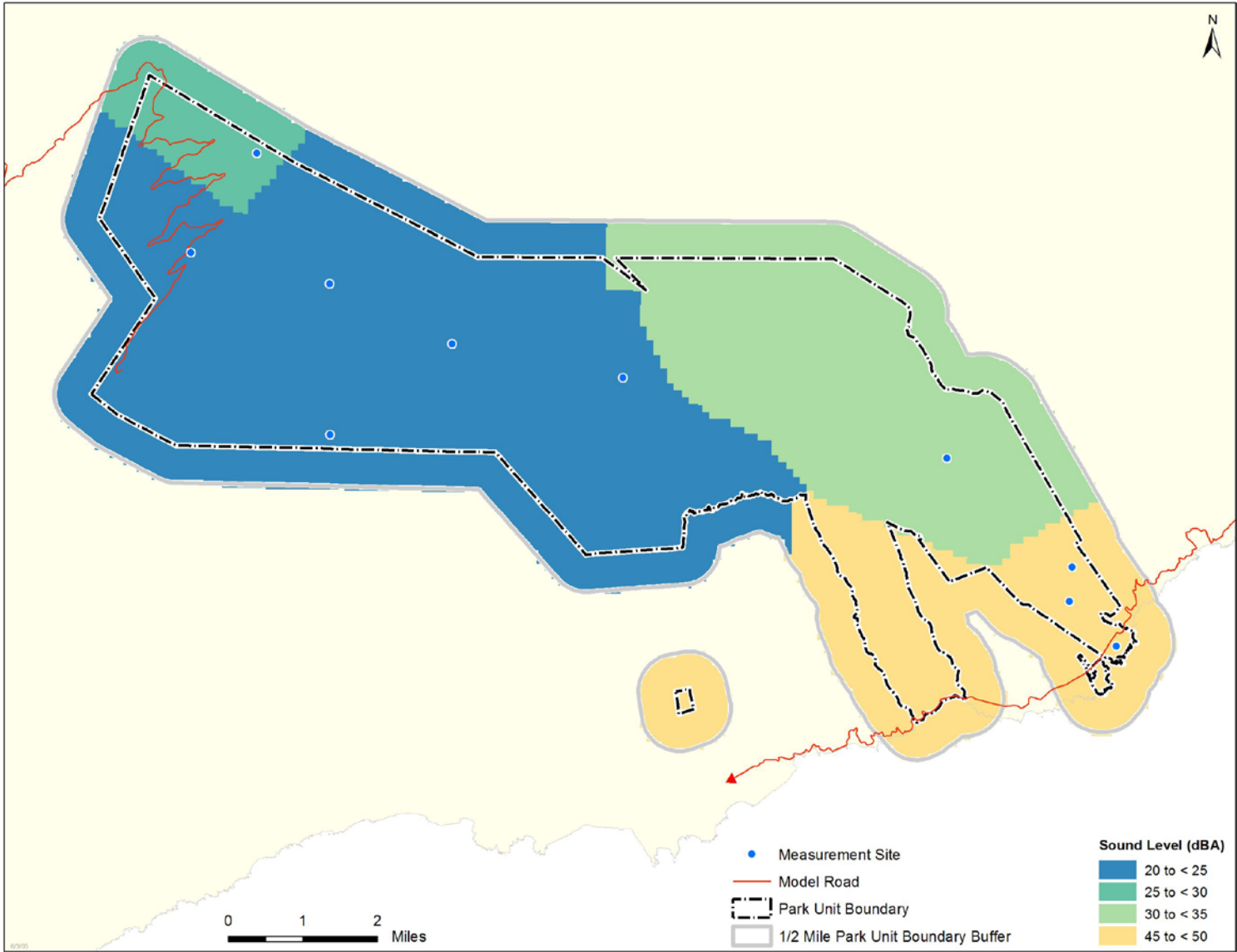


Figure 7. Baseline composite ambient map – Natural Ambient: L₅₀.

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.

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.

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).

CALDERA - A large crater formed by volcanic explosion or by collapse of a volcanic cone.

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 $20 \mu\text{Pa}$, the threshold of human hearing. $L_{\text{Aeq}T}$ is related to L_{AE} by the following equation:

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

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

The L_{Aeq} for a specific time interval, T_1 (expressed in seconds), can be normalized to a longer time interval, T_2 , via the following equation:

$$L_{\text{Aeq}T_2} = L_{\text{Aeq}T_1} - 10\text{Lg}(T_2/T_1) \quad (\text{dB})$$

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

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

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

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

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

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

L_{AE} (see Sound Exposure Level)

L_{Aeq} (see Equivalent Sound Level)

L_{ASmx} (see Maximum Sound Level)

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

L_x - A statistical descriptor describing the sound level exceeded “x” percent of a specific time period, e.g., 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 INM and AEDT, expressed as a function of: (1) engine power, usually the corrected net thrust per engine; and (2) source-to-receptor distance.

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

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

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.

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 8).

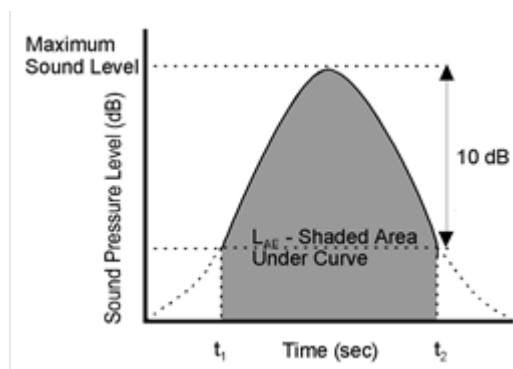


Figure 8. Graphical representation of L_{AE} .

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

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

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), as amended, 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 the period February 27 through May 27, 2003, in Haleakalā National Park.

Haleakalā is located on the island of Maui. A close-in view of the big island is shown in Figure 9. The park was established in 1961 and designated an International Biosphere Reserve in 1980. Of its 30,183 acres, 24,719 acres are designated wilderness.

A more detailed description of the park can be found in Section 2 of this document.



Figure 9. Location of Haleakalā.

1.2 Objectives

The primary objective of this study is to quantify the baseline ambient sound levels within Haleakalā to establish a foundation from which potential noise impacts can be assessed. In total, 165 days of acoustical and meteorological data were measured at ten sites throughout the park. Ambient sound level data collected in this study will be used for the primary purposes of:

- Establishing baseline ambient sound levels (both overall and frequency based) in key areas within Haleakalā;
- Establishing the different sound sources contributing to the baseline levels in key areas within Haleakalā;
- Modeling sound levels in other similar areas within Haleakalā 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 Haleakalā.

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.^{*,2}

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

In addition, an ancillary objective is to further refine an FAA- and NPS-accepted site selection and data collection protocol for use in any future ATMPs or 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, NPS Natural Sounds and Night Skies Division, Haleakalā park personnel, and Flight Standards District Office (FSDO) representatives.

1.3 Report Organization

The presentation of this document, entitled “Haleakalā National Park: Baseline Ambient Sound Levels 2003,” begins with an executive summary and glossary. Section 1 presents an introduction and the objectives of this document. Section 2 overviews the process of measurement site selection with a brief description of the preliminary sites chosen. Section 3 discusses instrumentation. Section 4 presents the measurement procedures employed in the field. Section 5 discusses data reduction. Section 6 discusses 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 presents comparisons between measured, aircraft, sound level data and computer-predicted sound level data. Appendix E discusses the acoustic zone analysis. All related references are presented at the end of this document.

Page left blank intentionally.

2. SITE SELECTION

Haleakalā is located on the island of Maui. The park was established in 1961 and designated an International Biosphere Reserve in 1980. Of its 30,183 acres, 24,719 acres are designated wilderness.¹³ The acoustical environment within the park changes rapidly and dramatically with altitude - from sea level to 10,000 feet over a distance of 35 miles; and from rainforest at sea level to subalpine desert in the crater. Human activity varies substantially from the highly visited two-mile-high summit at the Haleakalā Crater, its vast volcanic valley, and the park's southern waterfalls to the many remote backcountry areas.¹⁴ In 2003, approximately 1.5 million people visited the park.¹⁵ Figure 10 provides a general overview of the areas within Haleakalā.

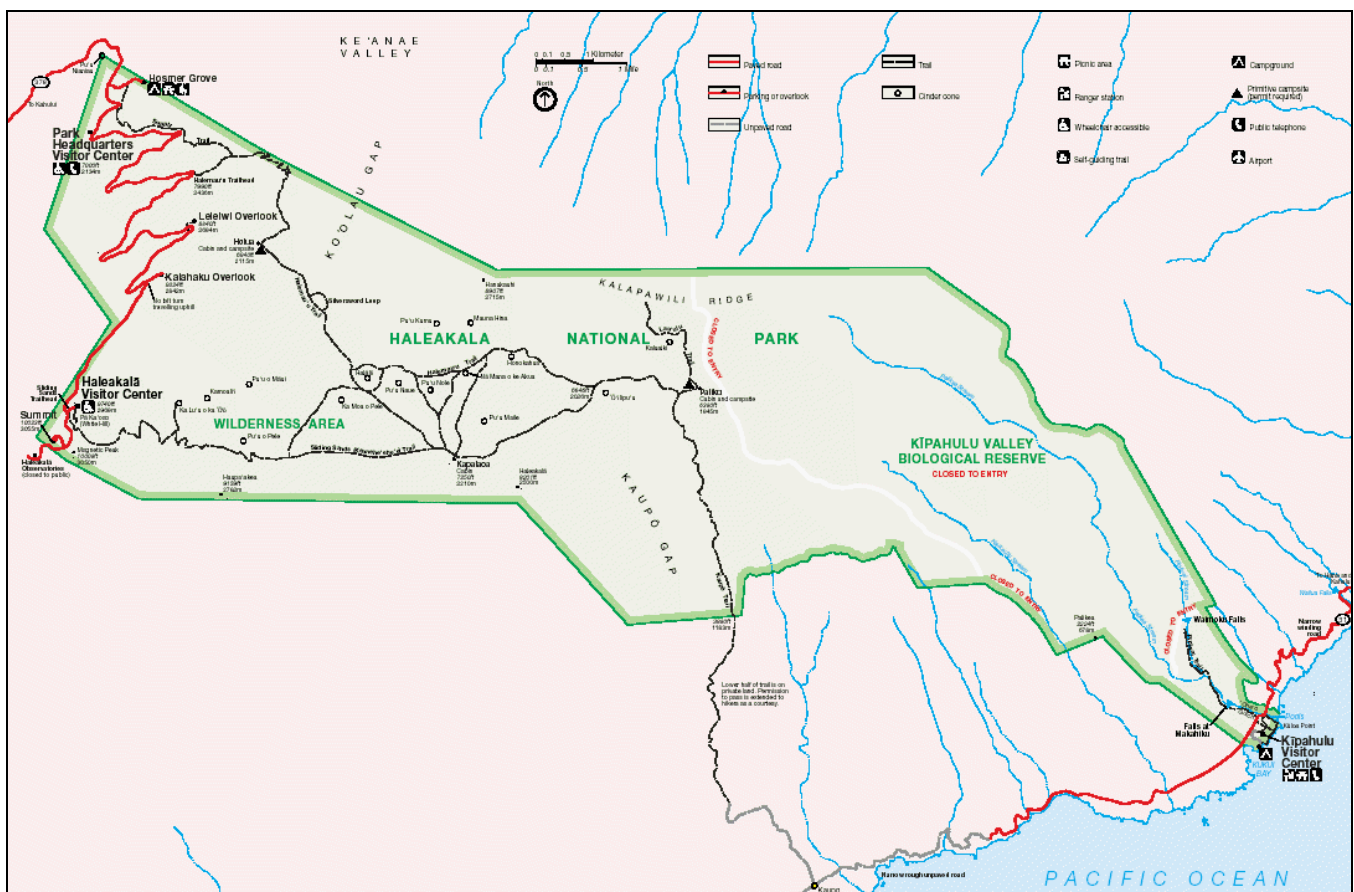


Figure 10. Overview map of Haleakalā.¹⁴

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.^{16,17,18,19}
- *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 were used to determine the acoustic zones in Haleakalā (see Section 2.6), and 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 and 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

Haleakalā, rising from the sea to a 10,000 foot summit, and exposed to both the windward moist tradewinds and leeward drying air, exhibits a wide range of vegetative types - from the tropical rain forest in the Kipahulu Research Reserve to the rock, dry surfaces at the summit to the alpine subalpine shrublands of Kaupo Gap.²⁰ Figure 11 provides an overview of the general land cover

in Haleakalā. Measurement sites were selected to encompass as many of these vegetative types as possible.

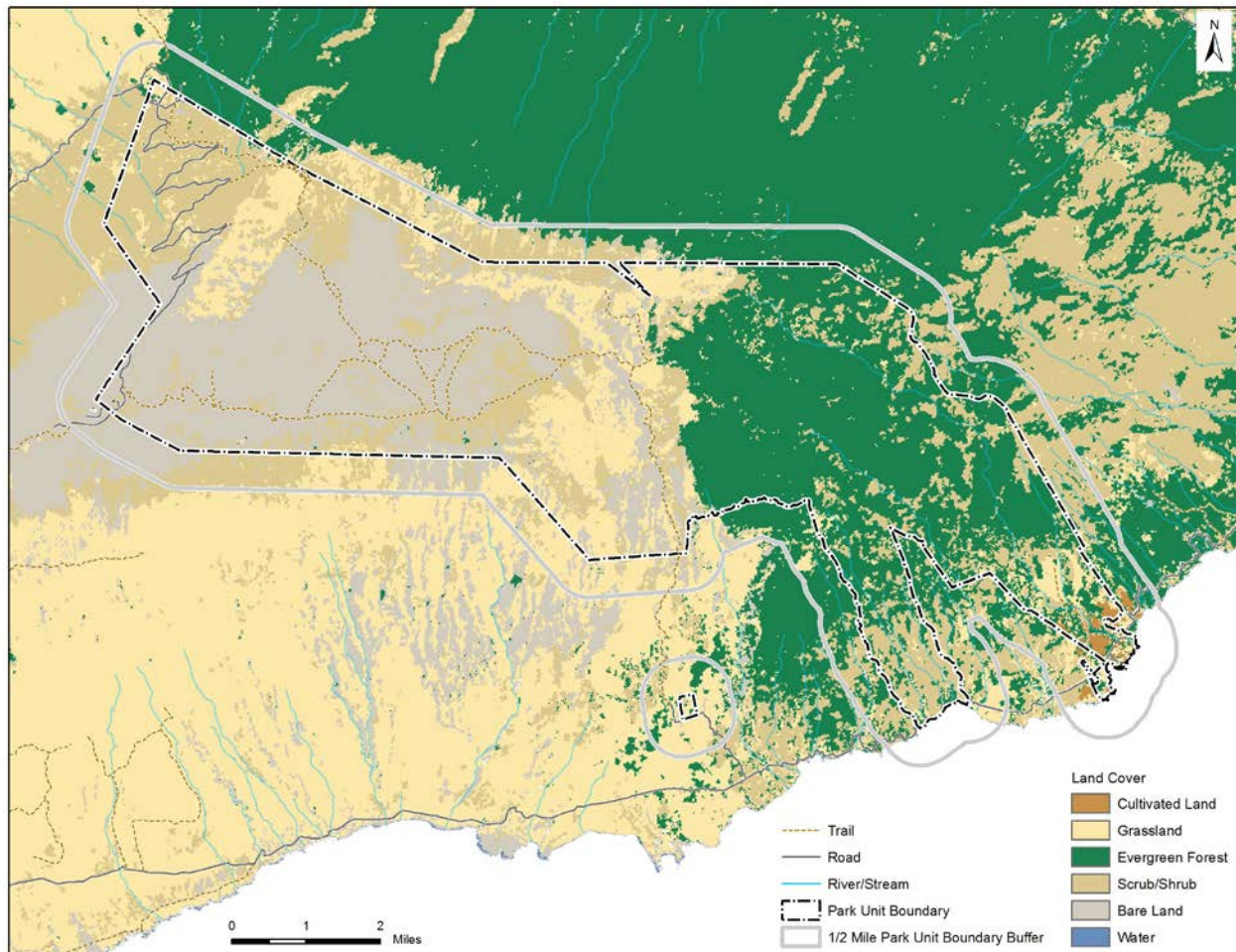


Figure 11. Land cover in Haleakalā.

2.3 Climate Conditions

The contrast in elevation within Haleakalā, from sea level to 10,000 ft, has resulted in a wide range of weather conditions (temperature, humidity, precipitation, wind speed, wind direction, etc.), all of which can greatly affect ambient sound levels.²⁰ For example, higher elevation areas typically exhibit higher wind speeds and contain less vegetative cover resulting in higher ambient sound levels. The effects of wind are particularly important where sound is propagating over distances greater than a few hundred feet.

The crater rim area, located at the higher elevations, is subject to greater seasonal variations, with periods of cold winds and even snow occurring from December to February. The Kipahulu Valley and coastal sections of the park are subject to the moderating influence of the ocean and has a mild and even climate throughout most of the year. Precipitation varies greatly throughout the park according to elevation and exposure. Maximum rainfall occurs at moderate elevations of about 3,000 to 5,000 feet, where the moisture-laden trade winds are pushed up and cooled. Less precipitation occurs at the higher elevations. The greatest precipitation is in the winter months. Fog is a common occurrence; and on many days, it is heavy along some portion of the crater and crater rim, obscuring views for many hours at a time.

Table 5 provides the monthly climate summary (averaged from 1949 through December 2004) recorded by a meteorological station located in the park.

Table 5. Monthly climate summary for Haleakalā. Error! Bookmark not defined.

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (mph)	10.9	11.5	12.1	13.4	12.9	15.4	15.3	14.6	13.3	12.9	11.9	11.8
Prevailing Direction	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Average Max Temp (F)	59.9	59.1	59.4	60.5	62.6	65.7	65.6	66.1	64.9	64.3	62.9	60.8
Average Min Temp (F)	42.1	41.5	41.9	42.7	44.2	46.7	47.5	47.6	46.4	46.1	45.5	43.4
Average Total Precipitation (in)	8.54	6.8	7.1	4.8	2.2	1.2	2.3	2.7	1.9	2.8	5.7	7.1
Average Total Snow Fall (in)	0	0	0	0	0	0	0	0	0	0	0	0

2.4 Park Resources/Management Zones

The NPS' Haleakalā General Management Plan (GMP) identifies different zones by which park areas are designated for different management purposes and the protection of different park resources. Four zones are used as the framework for the manner and intensity of visitor use, as well as management of resources.^{20,21}

- *Natural Zone (28,150 acres):* This zone takes in nearly all of the lands within Haleakalā. It encompasses all of the park lands in the upper Kipahulu Valley, nearly all of the park lands within the crater, most of the West Crater Rim lands, park lands in the lower Kipahulu Valley above the 800-foot contour, the strip of land along the Kipahulu coast, and lands within the `Ohe`o Gulch.

- *Cultural Zone (400 acres)*: This zone encompasses the Kipahulu coastal area up into the lower Kipahulu Valley to about the 800-ft contour. Much of it is essentially a cultural landscape with multiple periods of significance. In addition, due to the numerous and significant Hawaiian archeological sites it contains, Haleakalā crater was placed on the National Register of Historic Places in 1974 as the Crater Historic District. Therefore, though zoned Natural, the crater is also managed as a Cultural Zone.
- *Park Development Zone (60 acres)*: This zone includes Park Headquarters, Visitor Centers and their surrounding areas, campgrounds, Pu`u Nianiau areas, water catchment area, Haleakalā Crater Road, overlooks and their adjacent parking areas, Pu`u `Ula`ula areas, wilderness cabins, and base yard areas.
- *Special Use Zone (8,005 acres)*: Certain lands within the above zones require a special management emphasis. These include lands located in the upper Kipahulu Valley set aside to be managed for strict protection because of the unusual fragility and uniqueness of the biotic resources found here, as well as the ecological significance. Also included are the lands being proposed for the growing of traditional Hawaiian crops.

Figure 12 was provided to the Volpe Center as noise-sensitive areas in Haleakalā, including visitor resources, residential areas, historic districts, and wildlife habitats.²² Sections 2.4.1 through 2.4.3 discuss these areas in more detail.

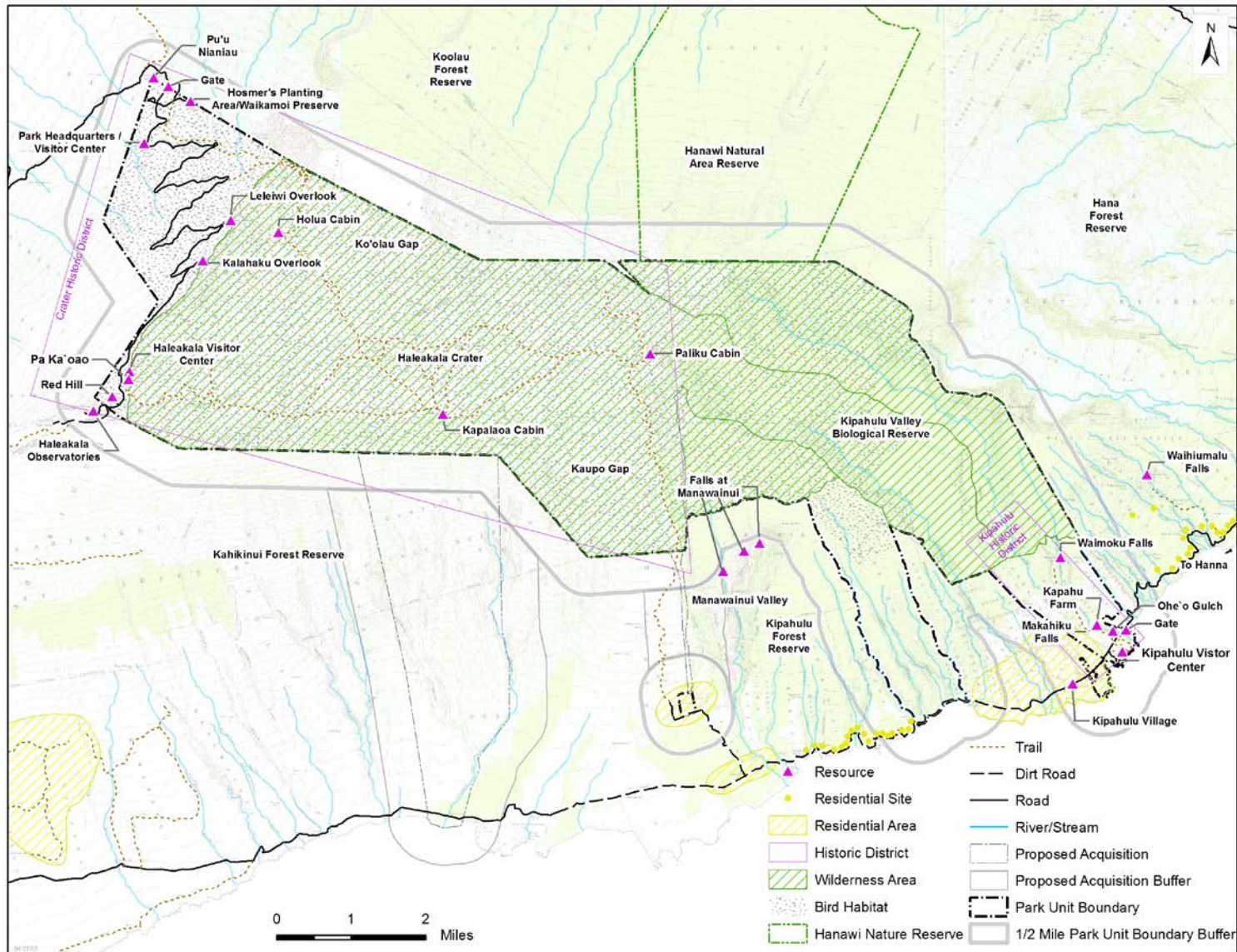


Figure 12. Noise-sensitive areas in Haleakalā.

2.4.1 Visitor Use Areas

Park use at Haleakalā is year-round and 90-percent day use. In 2003, the total recreational visits were approximately 1.5 million, with an average of 122,000 per month.¹⁵ Visitors contribute a wide variety of sounds, from hikers talking and walking, to tour buses and other vehicular noises, to air tours, etc. Sites were chosen to cover different levels of visitor-use:

- *Overlook Sites (high visitor-use):* 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 (e.g., Haleakalā summit and Kalahaku overlook).
- *Short-Hike Sites (medium visitor-use):* Any frontcountry location in a study area subject to moderate to substantial human activity, or destinations generally reached within one hour of hiking (e.g., Pipiwai Trail to Waimoku Falls).
- *Backcountry Sites (low visitor-use):* Any location in a study area subject to minimal human activity, such as designated wilderness areas or restricted, hiking and camping areas - these destinations are generally located 1 hour or more from frontcountry locations (e.g., areas within the crater).

2.4.2 Wildlife Resource Areas

Wildlife activity can directly affect the daily and seasonal characteristics of the Natural Ambient (e.g., the Hawaiian Nene goose nests in the winter, breeds during spring and summer, and fledges their chicks by early fall). The native fauna within Haleakalā contains several important endangered wildlife species – the endangered Hawaiian dark-rumped petrel bird (UAU), Hawaiian goose (NENE), and Hawaiian hoary bat reside in the crater rim area; various species of the Hawaiian Honeycreeper bird live in areas of the Kipahulu Valley; and 60 species of insects and a few aquatic creatures are present in the lower streams of Kipahulu. Because of their importance, sites were chosen within these “noise sensitive” areas.

2.4.3 Cultural and Historic Resource Areas

All areas of the park contain significant cultural or historical sites with the possible exception of the mid and upper Kipahulu Valley. Research in the crater and surrounding areas has found abundant archeological evidence of prehistoric and historic use of the areas by Hawai`ians and other groups. It is important that the solemnity of these areas be preserved and maintained for historical enjoyment and present day native activities. Therefore, to determine the potential impact of visitor intrusions, site selection should include these areas. There are primarily two cultural/historical districts in Haleakalā: Crater District and Kipahulu District. These two districts contain the majority of current historic structures in Haleakalā and include the wilderness cabin areas, bridges, and trails.²⁰

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 Haleakalā NPS, and local air tour operators established Special Federal Aviation Regulation (SFAR) 71 Procedures Manual.²³ SFAR 71 prescribes visual flight rules for fixed-wing airplane and helicopter air tour flights conducted in the State of Hawai`i. In addition, it is unlawful for fixed-wing aircraft or helicopters flying under visual flight rules, to fly at an altitude below 9,500 ft above mean sea level over the surface of any of the following areas in Haleakalā: Haleakalā Crater, cabins, the Scientific Research Reserve in upper Kipahulu Valley, Halemau`u Trail, Kaupo Gap, or any designated visitor overlook. As such, the flight corridors used for commercial air tours are well defined in accordance with an established Letter of Agreement between the Haleakalā and the Hawai`i Air Tour Association in Maui.²⁴ Under this Agreement, no flights over Haleakalā are allowed except for crossing Waimoku Falls in the Kipahulu area (see Figure 13). This exception minimizes the noise that would be generated along the heavily visited Kipahulu District coastline.

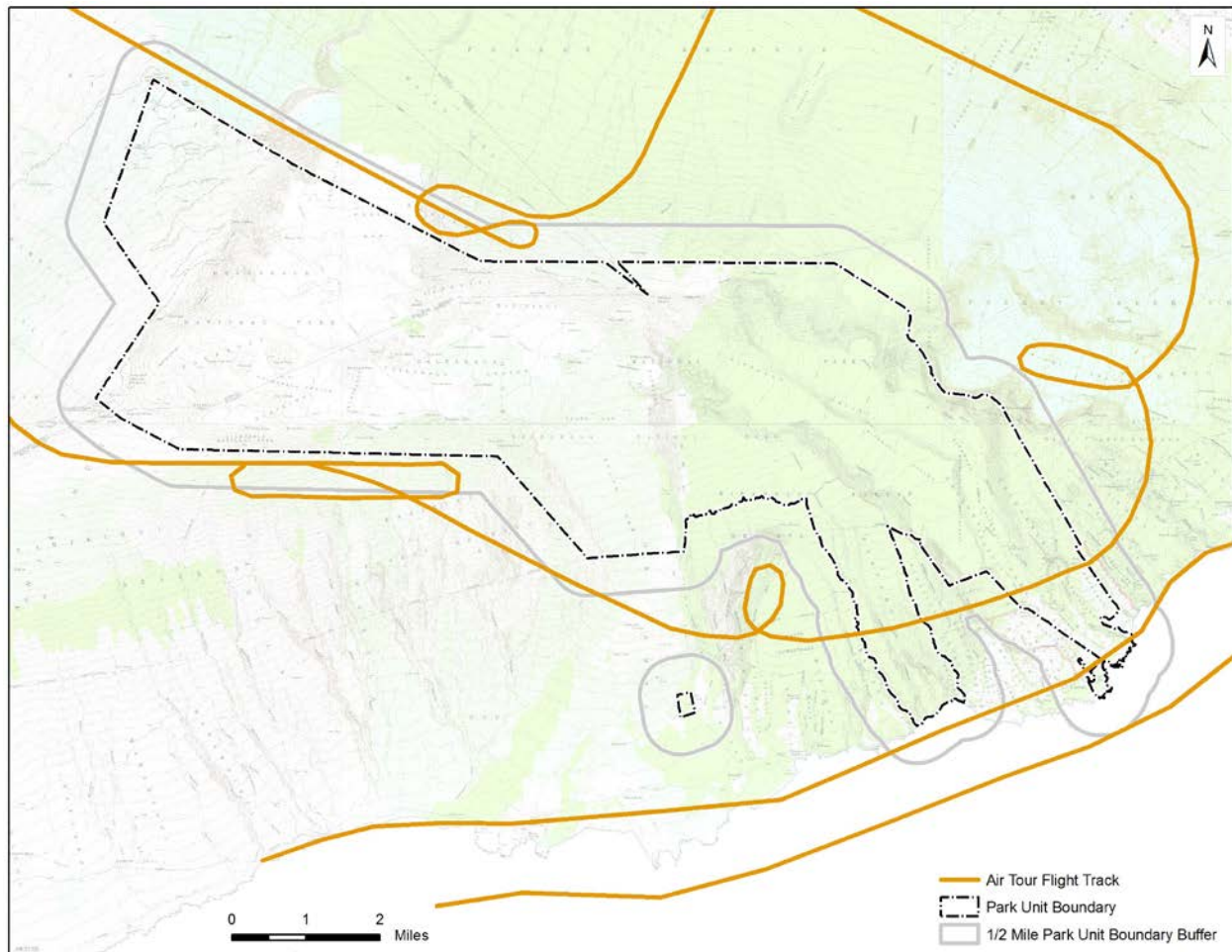


Figure 13. Air tour routes in the vicinity of Haleakalā.

2.6 Haleakalā Acoustic Zones

Using the above site selection considerations, multiple teleconferences took place over the course of several months to discuss the park’s unique acoustic environs, or “acoustic zones,” within which measurement sites would be selected between the FAA, the NPS, the Volpe Center, and Haleakalā NPS personnel. As stated earlier, it is anticipated that the use of acoustic zones as representative units, within which data can be collected and grouped (by vegetation, management zone, etc.) may be extrapolated to similar areas in Haleakalā.

The land cover in Haleakalā is approximately 25 percent bare rock/sand/clay, 30 percent evergreen forest, 27 percent shrubland, and 18 percent grassland, resulting in four, primary acoustic zones. The four zones were then further subdivided based on other factors. These

factors affect the acoustics and how NPS manages different areas within the park. The resultant agreed-upon five acoustic zones were as follows (see Figure 14):

- *West Rim Crater (Zone 1)*: This zone starts at the northern park entrance and follows Haleakalā Highway up to the Haleakalā summit and visitor center. It starts from approximately 6,700 up to 10,000 ft (2,043 to 3,049 m) elevation at the summit. The zone contains not only the park headquarters and a visitor center, but also experiences the heaviest visitor traffic with several popular overlook locations. It is an area of largely rock or low grass or scrub vegetation and characterized by strong winds. The dominant sounds are strong winds, vehicle noise, and bicyclists.
- *Haleakalā Crater (Zone 2)*: This zone comprises the large central core of the park and its prime resources. The crater area is a volcanic landscape, open with very little vegetation, and is very quiet, having very few local sources of noise, ranging from approximately 6,600 to 9,700 ft (2,012 to 2,957 m) elevation. Sounds within the crater include strong winds, hikers, and bird vocalizations. Air tour aircraft can be heard within this zone.
- *Kaupo Gap (Zone 3)*: This zone is an area of low grass and scrub vegetation with some bare rock from approximately 3,700 to 7,000 ft (1,128 to 2,134 m) elevation. The Kaupo Gap Trail is one of the park's three primary access/exit routes. The dominant sounds are strong winds with very few hikers.
- *Kipahulu Coastal (Zone 4)*: This zone encompasses the Kipahulu coastal area from the `Ohe`o Gulch up into the lower Kipahulu Valley extending from sea level to 3,700 ft (0 to 1,128 m) elevation. It is a complex zone of forest, shrublands, grasslands, and bare rock, and contains many cultural resources. It lies in and above the trade wind inversion, where wind speeds are generally lower than along the coast. Bird vocalizations in forested areas are prominent.
- *Upper Kipahulu Valley (Zone 5)*: The 8,000 acre valley cradles one of the most diverse native and intact rain forest ecosystems remaining in Hawai`i and ranges from 488 to 2,317 ft (1,005 to 1,341 m) elevation. It contains the Haleakalā Scientific Research Reserve and can only be reached by helicopter. Because visitors are not allowed in this area, only natural sounds can be heard, such as rain on the tree fern canopy and insects, with localized occurrences of bird vocalizations.

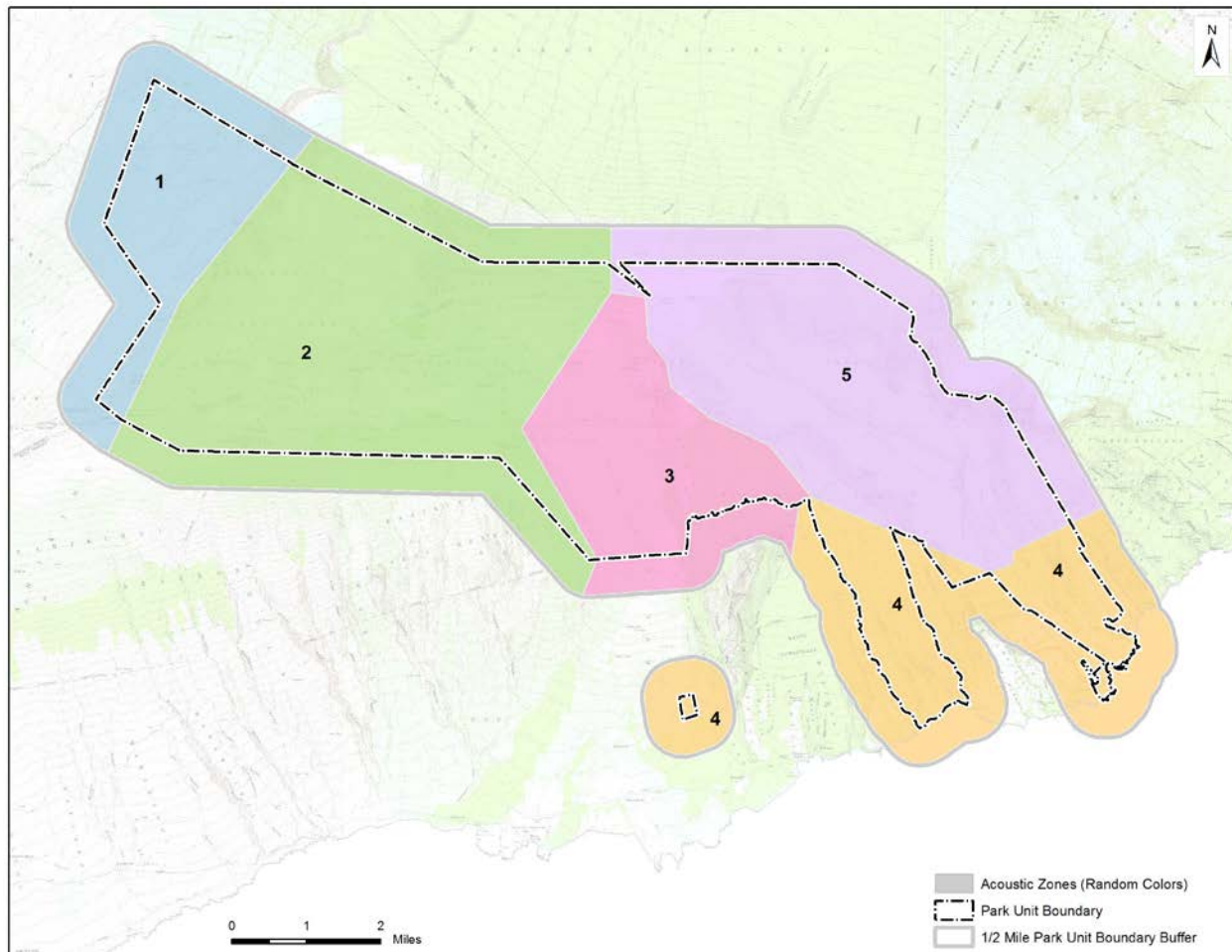


Figure 14. Acoustic zones for Haleakalā.

2.7 Logistics/Access

To validate the use of acoustic zones, it was agreed in teleconferences with NPS that data would be collected at multiple sites within some zones and later analyzed to determine if the data collected at one site within a particular zone is statistically similar to data collected at a different site within the same zone. This effort continues the work that began in Hawai'i Volcanoes National Park with the goal of identifying the minimum number of field-measurement sites, which would allow for characterization of the baseline ambient sound levels throughout the entire park.²⁵

2.7.1 Access

In identifying potential measurement site locations within each zone, the final, overarching consideration was site accessibility. As important as a given site is to satisfy

any of the technical criteria discussed in previous sections, if it is inaccessible, measurements cannot be conducted. There are only three entry points into Haleakalā: the northwest Park Headquarters/Visitor Center entrance, Kaupo Gap Trail, and the southeast Kipahulu Visitor Center entrance. Access to the West Crater area requires driving up a winding road from Park Headquarters to the crater rim. Most visitor-use areas are accessible only by hiking or horseback. For those sites that were in the crater or in the Scientific Research Reserve, Haleakalā NPS provided personnel and/or transportation assistance (e.g., helicopter transport). The access considerations associated with each measurement site are discussed in Appendix A.

2.7.2 Duration of Measurements

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

In discussions with Haleakalā NPS personnel, because there is little climatic seasonal variation in Hawaiʻi as compared with other U.S. national parks, a minimum of one week of continuous, 24-hour measurements at each site was recommended, with up to two weeks being preferred. In discussions with Haleakalā NPS personnel, because there is little climatic seasonal variation in Hawaiʻi as compared with other U.S. national parks, a minimum of one week of continuous, 24-hour measurements at each site was recommended, with up to two weeks being preferred. To validate this recommendation and provide guidance for adequate measurement duration for use in future parks, it was

agreed that: (1) several sites would include data collection on a long-term basis, i.e., longer than 2 weeks up to the entire measurement study duration of approximately two months (“permanent” sites, designated with the letter “P”); and (2) the remaining sites would include data collection on a short-term basis, i.e., one to two weeks (“mobile” sites, designated with the letters “ST”). For example, Sites P01 and ST4 indicate a permanent system and a mobile system, respectively. With regard to Agreement (1), this effort continues the work that began in Hawaiʻi Volcanoes National Park to assess the needed measurement duration of future park ambient studies.

As discussed in greater detail in Section 6.3, the FAA and NPS have jointly agreed that selecting a sample size, which limited measurement uncertainty to 3 decibels, was desirable. Based on the Haleakalā and Hawaiʻi Volcanoes analyses, as well as a joint review of acoustic literature and other recent long-term NPS ambient studies in Bryce Canyon National Park and Arches National Park, the 3-dB variability was achieved between 10, 25, and 40 days, depending on individual site variables/characteristics. As a result, the FAA and NPS have agreed upon a minimum 25-day measurement period for all future acoustic monitoring. An exception to the 25-day requirement would be for measurements in close proximity to localized sound sources, which generally don’t vary substantially in level, such as waterfalls, river rapids, train tracks, and busy visitor centers. The measurement period for such situations will be situation dependent, but generally, for visitor centers and travel corridors, a 10-day measurement period will be adequate.

Figure 15 and Table 6 below summarize the final measurement sites selected. Appendix A contains individual descriptions and photographs of each measurement site location.

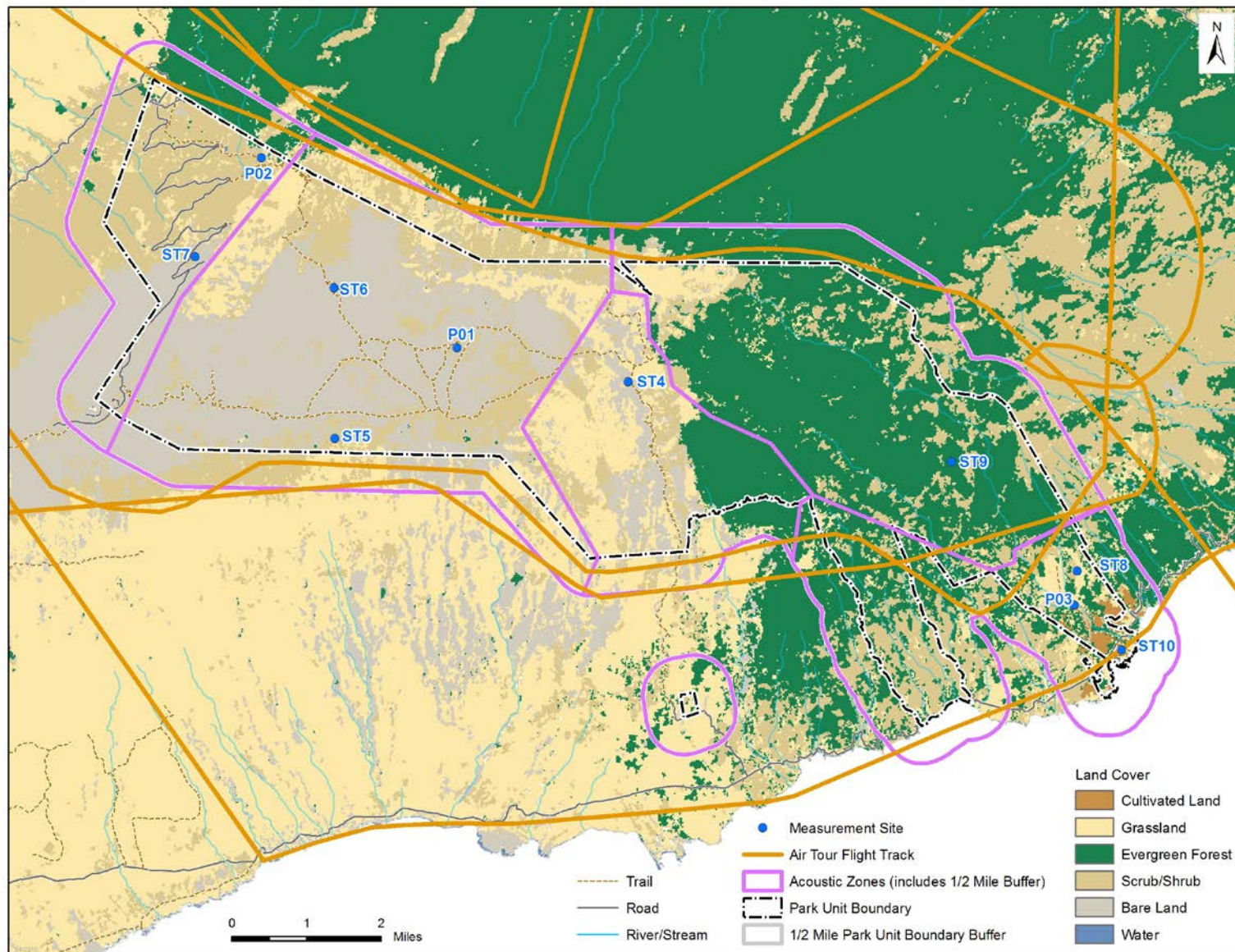


Figure 15. Final measurement sites for Haleakalā.

Table 6. Summary of measurement sites selected for Haleakalā.

Acoustic Zone	Site #	Site Name	Vegetation/ Land Cover	Lat/Lon (decimal degrees)	Approx. Elevation	Site Type	Site Category	Management Zone	Potential Sound Sources
1: West Rim Crater	P02	Supply Trail	Shrubland	20.7572 / 156.2226	7703	Permanent	Short Hike	Developed/Cultural/ Historical	Aircraft Vehicles Hikers Birds Wind
1: West Rim Crater	ST7	Kalahaku Overlook	Bare Rock/Sand/Clay	20.7378 / 156.2362	9111	Mobile	Overlook	Developed/Cultural/ Historical	Aircraft Vehicles Hikers Wind
2: Haleakalā Crater	P01	Namana o ke Akua	Shrubland	20.7194 / 156.1813	7379	Permanent	Backcountry	Natural/Cultural/ Historical	Aircraft Hikers Birds, Horses Wind
2: Haleakalā Crater	ST5	The Notch	Shrubland	20.7024 / 156.2073	8051	Mobile	Backcountry	Natural/Cultural/ Historical	Aircraft Wind
2: Haleakalā Crater	ST6	Silversword Loop	Bare Rock/Sand/Clay	20.7336 / 156.2175	7178	Mobile	Backcountry	Natural/Cultural/ Historical	Aircraft Hikers Birds, Horses Wind
3 Kaupo Gap	ST4	Paliku Kaupo Gap	Shrubland	20.7134 / 156.1467	6322	Mobile	Backcountry	Natural	Hikers Birds Wind
4: Kipahulu Coastal	P03	Waimoku Falls/Mango Tree	Evergreen Forest	20.6620 / 156.0598	518	Permanent	Short Hike	Natural/Cultural/ Historical	Aircraft Hikers Birds Wind
4: Kipahulu Coastal	ST8	Waimoku Falls	Evergreen Forest	20.6765 / 156.0538	1322	Mobile	Overlook	Natural/Cultural/ Historical	Aircraft Hikers Birds Wind Water
4: Kipahulu Coastal	ST10	Oheo Coastal	Bare Rock/Sand/Clay	20.6978 / 156.0797	92	Mobile	Overlook	Natural/Cultural/ Historical	Aircraft Vehicles Hikers Birds Wind
5: Upper Kipahulu Valley	ST9	Kipahulu Scientific Reserve	Evergreen Forest	20.6978 / 156.0797	3100	Mobile	Wilderness	Natural	Birds Wind

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 three types of specialized low-level ambient measurement systems used for this study:

- NoiseLogger™ Continuous Monitoring System (Section 3.1);
- NoiseLogger Plus™ Continuous Monitoring System (Section 3.2); and
- Volpe Low-Amplitude Recording Equipment (VoLARE) System (Section 3.3).

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.²⁶ Eight NoiseLogger™ systems were used in collecting data in this study.

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 16 illustrates the basic components of the 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 prepolarized, 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.

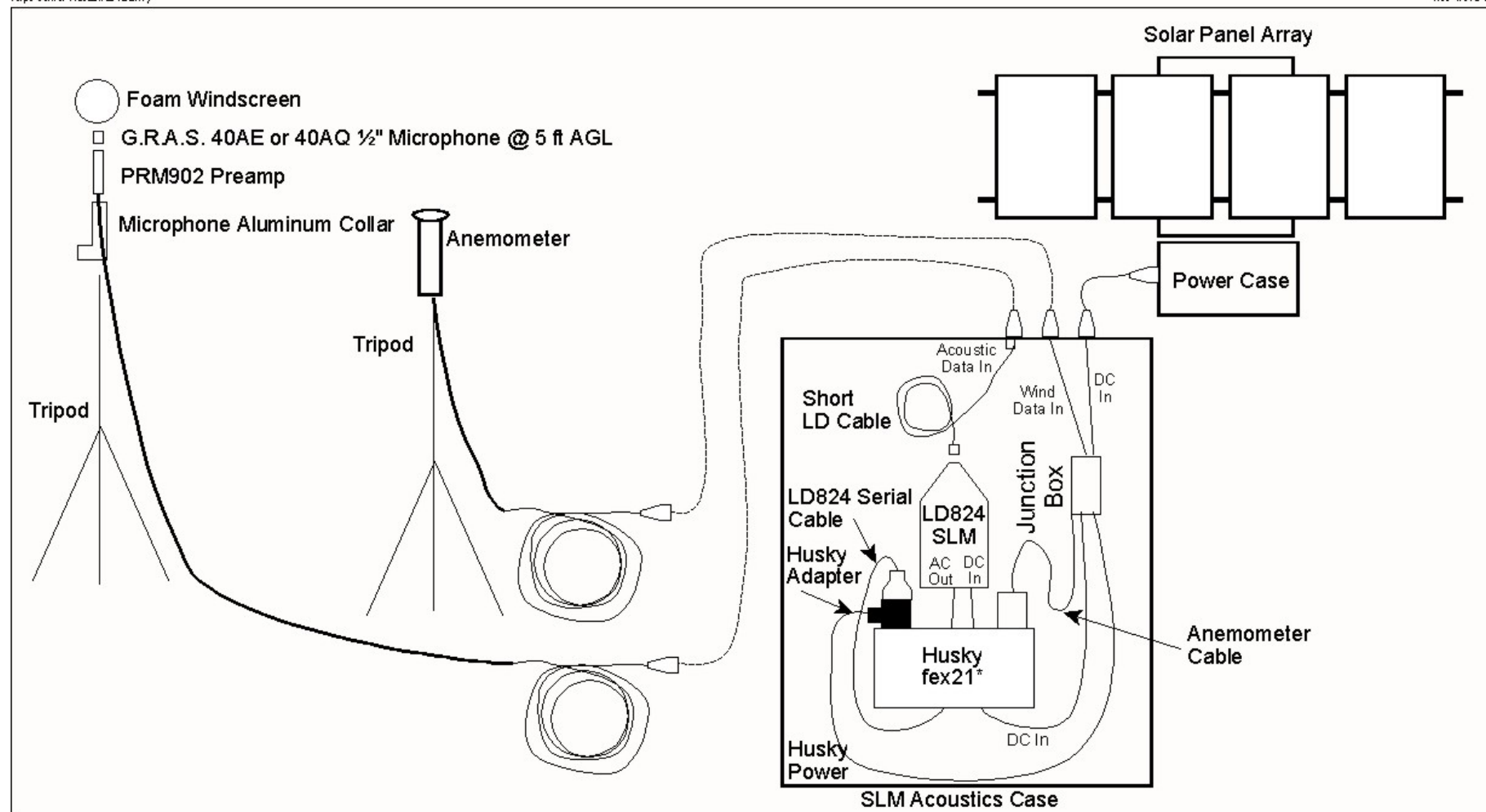
3.2 NoiseLogger Plus™ Continuous Monitoring System

This is similar to the NoiseLogger™ system, but with the capability to record live audio samples using a Fujitsu™ Lifebook P1110 computer, which effectively replaced the Husky™ Fex-21 H/PC. The NoiseLogger Plus™ system is powered by two solar panel arrays or four marine batteries. Figure 17 illustrates the basic components to the system. This system can record sounds on both a periodic basis, e.g., a 5-second recording every five minutes, and on a threshold basis, e.g., a recording is triggered when a sound level exceeds a user-defined threshold. Appendix B contains a more detailed description of these systems.²⁷ One NoiseLogger Plus™ system were used in collecting data in this study.*

* This system was placed at Site P01 for the following reasons: (1) it was a permanent site; (2) it was located under the current air tour routes; and (3) it was expected to record a diversity of natural, visitor, and mechanical sounds.

Volpe Center Acoustics Facility

Rev 4/9/04

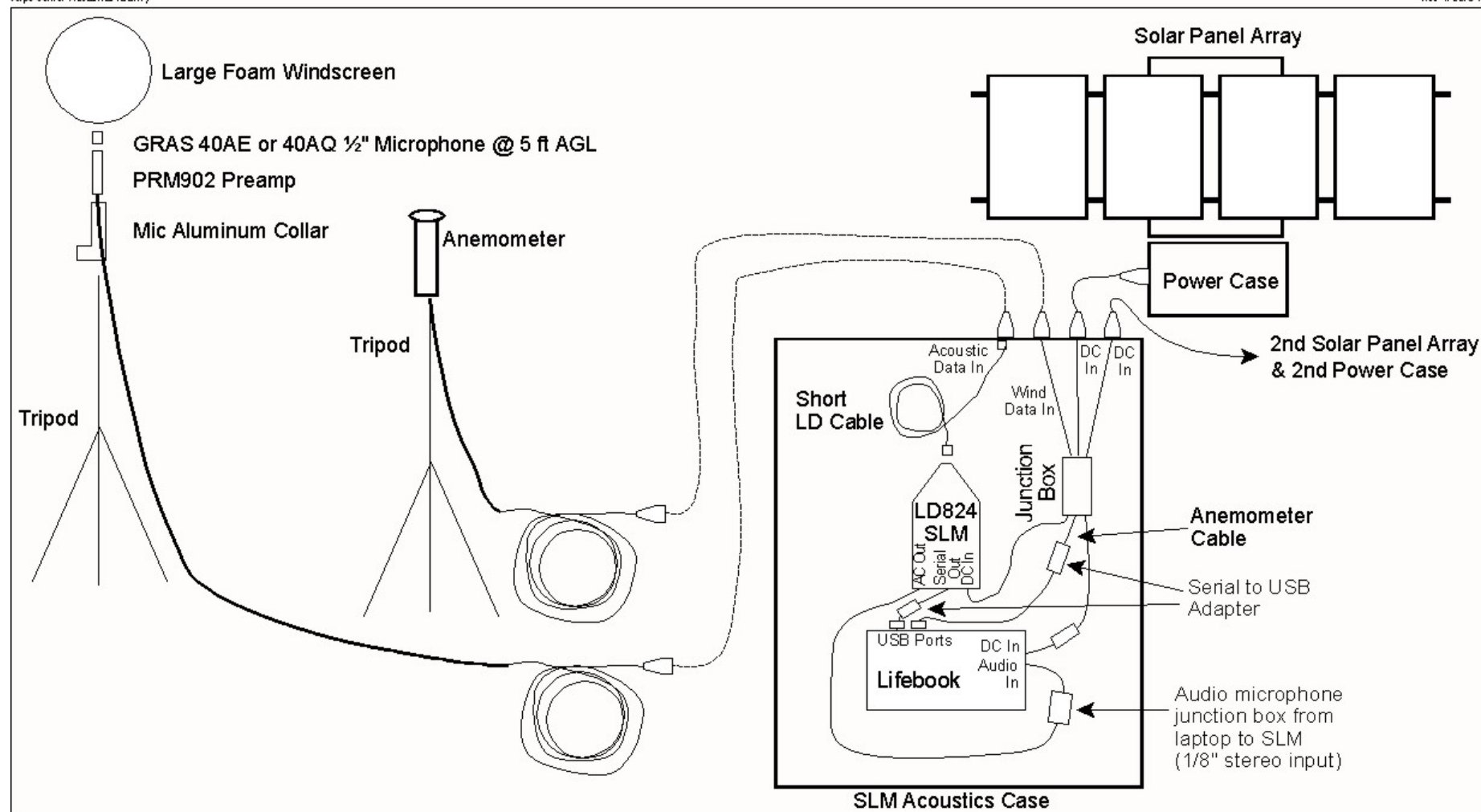


CL:FAA/AT&P/Equipment/Instrumentation_NoiseLogger.wpg

Figure 16. NoiseLogger™ continuous monitoring system.

Volpe Center Acoustics Facility

Rev 4/28/04



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

Figure 17. NoiseLogger Plus™ continuous monitoring system.

3.3 Volpe Low-Amplitude Recording Equipment (VoLARE) System

This is a specialized “turn-key” system, developed by the Volpe Center for low-level ambient noise measurements. It facilitates direct recording or on-site one-third octave-band analysis of measured low-level ambient sound level data. More detailed discussion on this system can be found in Reference 17. Figure 18 illustrates its basic components. VoLARE has been extensively tested and successfully used in previous FAA and NPS studies.^{16,17,18}

3.3.1 Microphone System

The microphones used in most conventional acoustic systems, including the NoiseLogger™ and NoiseLogger Plus™ systems, are capable of measuring sound levels down to about 15 to 20 dBA. For measuring sound level data near the threshold of human hearing (approximately 0 dBA), which is common in some of the remote areas within national parks, the microphone is the limiting component in a conventional measurement system. The Brüel & Kjær™ (B&K) Model 4179 microphone is a highly sensitive, 1-inch condenser microphone specially designed for very low-level sound measurements and capable of measuring down to the threshold of human hearing.* Additionally, the B&K Model 2660 preamplifier and Model 2804 power supply were employed in this system. As per manufacturer’s specifications, the Model 2804 power supply was modified for use with the Model 4179 and 2660.

The VoLARE system utilizes a tripod-mounted, two-stage windscreen, which is documented extensively in Reference 17, consists of a 20-in (51 cm) diameter, fabric-covered, outer stage, and a conventional, B&K Model UA0207 3.5-in (9 cm) diameter, foam windscreen making up the inner stage.

3.3.2 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

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

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.

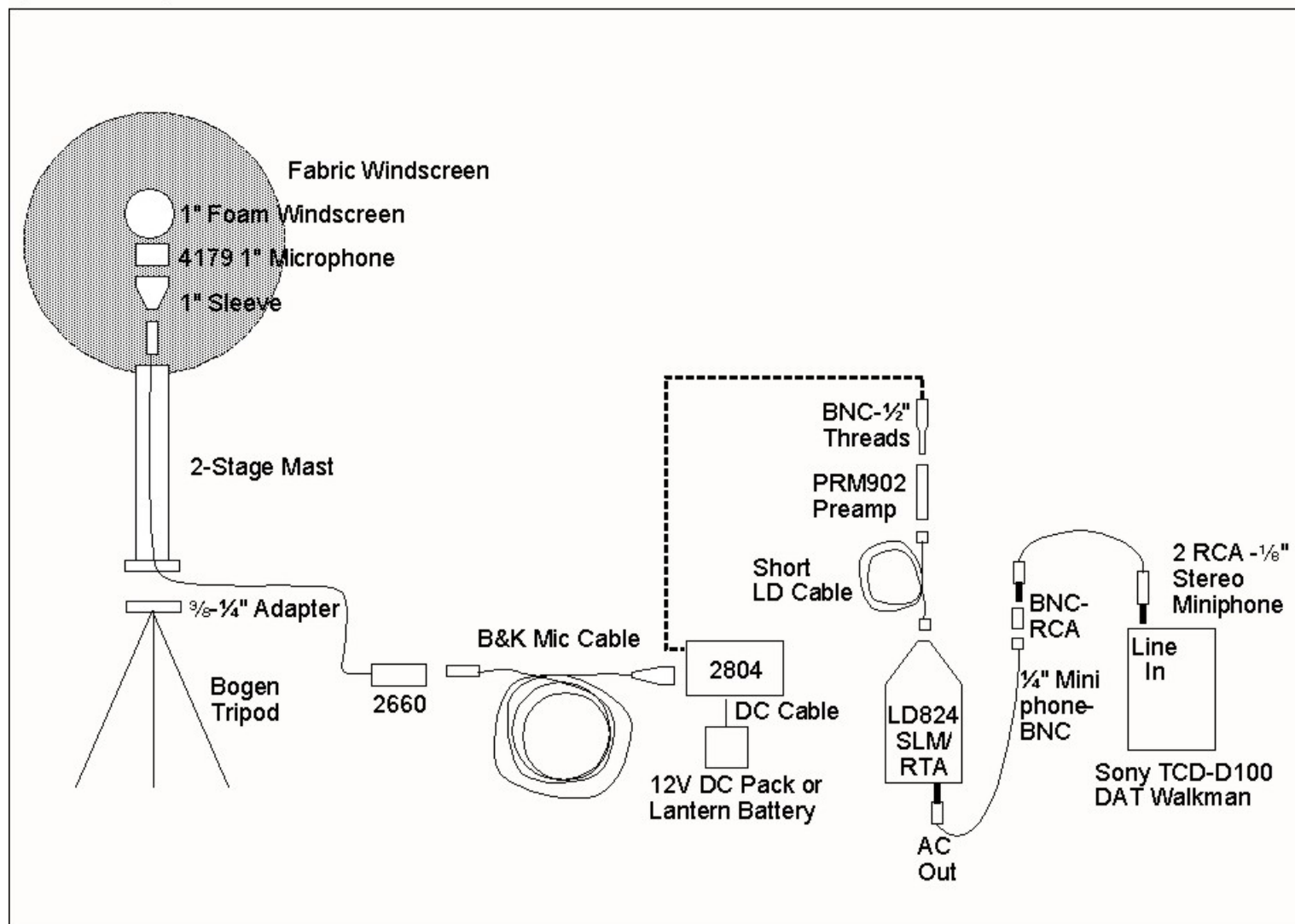
To successfully utilize the 824 SLM for measurements down to the threshold of human hearing, it was necessary to bypass the unit's built-in firmware parameters, which limit the minimum levels that can be measured and stored (about 20 dBA). To circumvent this limitation, an offset calibration technique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

3.3.3 Digital Audio Tape (DAT) Recorder

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

Volpe Center Acoustics Facility

Rev 4/6/04



CL: FAA/AT&P/Equipment/Instrumentation/VOLARE.mpg

Figure 18. Volpe Low-Amplitude Recording Equipment (VoLARE) system.

3.4 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.

3.5 Aircraft Photo-scaling System

The Volpe Center's photo-scaling system,²⁸ developed in accordance with the SAE Aerospace Information Report (AIR) 902,⁹ enables the determination of the minimum distance from an observer at the measurement site to an object - in this case, air tour aircraft.* The system uses:

1. Canon Model D60 digital camera to record an image of the object;
2. Canon "RAW image converter2" software to convert the raw image files to JPEG format;
3. Adobe Photoshop® to convert the image to its pixel equivalent; and
4. Fotoscale (a Volpe-developed program) to convert the pixel dimensions to slant range distance from the observer to the object.

Detailed logs, including camera settings site, data, time, aircraft type, aircraft model, operator, tail number, and direction (when identifiable), were kept for later correlation with the recorded

* As a backup to the photo-scale system, a Bushnell Laser Range Finder, Yardage Pro Model 800 was brought to all sites, but not used. This was because most observed aircraft were more than 800 yd. away, the instrument's maximum distance capability.

images. Slant range data can be used to correlate aircraft altitude with computer-modeled sound level data. As stated in Section 1, computer modeling, utilizing the FAA's model, will be used to compute aircraft sound levels in areas within Haleakalā for which resource constraints (or other issues) did not allow for direct measurements. Slant range data was used to correlate actual data with computer-predicted data during the modeling task (see also Section 5.4).

3.6 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.

4. FIELD MEASUREMENT PROCEDURES

This section presents the field measurement procedures utilized in the study. Two 2-person teams (one Volpe team and one NPS team) performed the initial deployment from February 27 through March 8, 2003, of the NoiseLogger™ and NoiseLogger Plus™ systems. During this time frame, data collection, using the VoLARE system at each site, also took place. At the end of this initial deployment period, the Volpe team departed. From then on, NPS personnel continued downloading data every two weeks, and were responsible for maintaining and relocating the NoiseLogger™ and NoiseLogger Plus™ systems to subsequent site locations throughout the remainder of the measurement period, March 9 through May 27, 2003. Sections 4.1 through 4.5 present a step-by-step description of the field measurement procedure, including deployment and dismantling.

4.1 NoiseLogger™ and NoiseLogger Plus™ System Deployment

Figures 21 and 22 show the NoiseLogger™ and NoiseLogger Plus™ systems as deployed in the field at Sites ST7 and P03, respectively. 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. Note: For the NoiseLogger Plus™ system, two solar panel arrays were deployed.
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. Note: For the NoiseLogger Plus™ system, CompactFlash™ cards were not necessary as this system utilized the Fujitsu laptop computer and measured data were stored in its internal hard drive (see also Section 3.2).
8. The NoiseLogger™ program was retrieved from the CompactFlash™ card, then invoked. Note: Because CompactFlash™ cards were not necessary for the NoiseLogger Plus™ system, the NoiseLogger Plus™ program, stored in its internal hard drive, was invoked from the computer desktop.
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., ST7 for Site ST7), and the site’s name (e.g., Kalahaku Overlook) 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 7 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 7. Summary of NoiseLogger™ and NoiseLogger Plus™ system equipment information.

System #	System Type	LD824 Serial #	Microphone Type and Serial #	Preamplifier Serial #	Anemometer Type and Serial #	Windscreen #	Used at Site
1	NoiseLogger™	A0842R	40AQ #20729	1243	FT702 #2080-77	1	
2	NoiseLogger™	A0843S	40AQ #25837	1276	FT702 #2080-56	2	
3	NoiseLogger™ Plus	A0844T	40AQ #19879	1268	FT702 #2080-88	3	P03
4	NoiseLogger™ Plus	A0845U	40AQ #19905	1282	FT702 #2080-68	4	
5	NoiseLogger™	A1148R	40AE #24020	1643	Gill WindObserver #000528	5	ST6, ST7
6	NoiseLogger™	A1149S	40AE #24021	1647	FT702 #2080-87	6	P01
7	NoiseLogger™	A1150K	40AE #24038	1678	Gill WindObserver #000524	7	
8*	NoiseLogger™	A1150K	40AQ #19909	2133	Gill WindObserver #000524	7	ST4, ST5
9	NoiseLogger™	A1151L	40AE #24017	1650	FT702 #2080-58	8	
10	NoiseLogger™	A1155P	40AE #24040	1630	Gill WindObserver #000525	9	ST8, ST9
11	NoiseLogger™	A1156Q	40AE #24034	1634	FT702 #2080-86	10	P02

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

- 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 8 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 8. 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. For the NoiseLogger Plus™ system, digital audio recording settings were also selected:
- Sampling Rate*: Set to 20 kHz to collect most audible sounds. Equal to twice the highest frequency that is recorded by the wave file;
 - Sound Quality*: Set to 16 Bits to collect the widest range of sounds. This determines the dynamic range of the sound that is recorded by the wave file;
 - Periodic Wave Collection*: Box was “checked” to enable automatic wave file collection, then the option to record a 30-second wave file every 30 minutes was selected;
 - Event Triggered*: Box was “checked” to enable automatic wave file collection when certain threshold parameters (see Item e) are met in order to try and capture certain noise events;
 - Threshold*: Typically set to 50 dBA for quiet sites, and 60 dBA for other sites. This was the sound level that must be exceeded in order for an event-triggered, automatic wave file to begin collection;
 - Trigger Arming Duration*: Set to 5 seconds. This was equal to the number of seconds that either the broadband or tonal triggering conditions must be met in order for wave file collection to begin (e.g., if events were selected with a threshold of 55 dBA and an arming duration of 5 seconds, then the sound level must have been equal to or greater than 55 dBA for 5 seconds for a wave file to begin collection). This helped to avoid collection of impulsive bird chirping events;
 - Trigger Reset Duration*: Set to 10 seconds. In order to avoid constant wave file collection, this was equal to the number of seconds that the threshold triggering condition must NOT be met in order for another wave file to be collected (e.g., if events were selected with a threshold of 55 dBA, a reset duration of 10 seconds, then after a wave file was collected, it was necessary for the sound level to be below 55 dBA for 10 seconds in a row before another wave file could be collected);
 - Number of Wave Files Per Day*: Set to 200. This was the total number of event wave files (Note: Periodic wave files were not counted) that could be collected in each day. This quantity was set to avoid collecting too many wave files within a short period of time and expending all of the laptop’s internal hard drive space.
11. 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.

12. Sections 4.2 and 4.3 next present the step-by-step description of the deployment of the VoLARE system and the field data collection procedure, respectively.

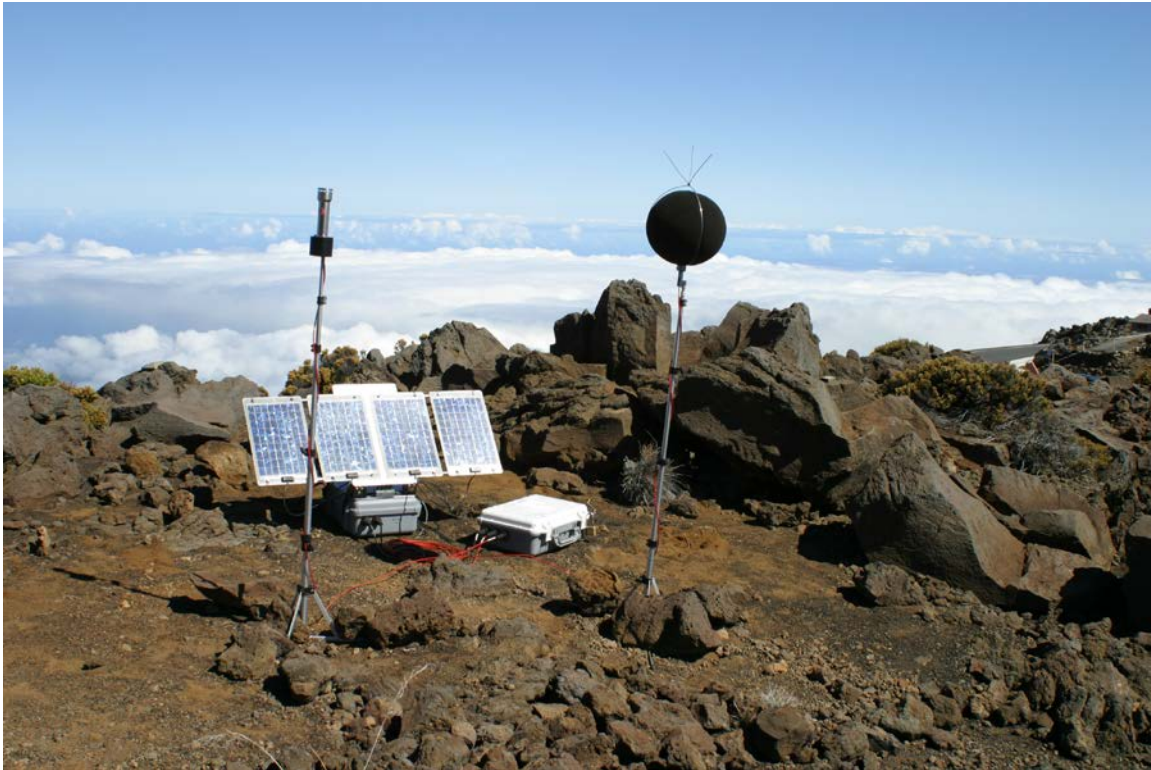


Figure 19. NoiseLogger™ system deployment; Site ST7.



Figure 20. NoiseLogger Plus™ system deployment; Site P03.

4.2 VoLARE System Deployment

Figure 21 and Figure 22 show the microphone and recording instrumentation of the VoLARE system as deployed in the field at Site ST9. Following is a step-by-step description of the VoLARE system setup, which took place at measurements sites from February 27 through March 8, 2003:

1. The microphone, preamplifier, and windscreen were attached to a tripod. The tripod was adjusted to locate the microphone diaphragm at a height of 5 ft (1.5 m) directly above the local ground surface, oriented vertically (microphone grid facing the sky).
2. The SLM, DAT, and acoustic data recording instrumentation were positioned in full view of the microphone location, but at a distance approximately 50 to 100 ft (15-30 m) away from it, to avoid noise intrusions by the acoustic observers.
3. A total of 100 ft (30 m) of cable was connected between the instrumentation at the microphone system and the recording system; and all instrumentation was then powered up.
4. The next step was to establish that the internal clocks of all pertinent instrumentation (namely the SLM, DAT, meteorological system and palmtop) were set to the time of the nearby

NoiseLogger™ or NoiseLogger Plus™ system.

5. With all electrical components of the acoustic measurement system connected and given adequate time to warm up (typically 10 to 15 minutes), a preliminary sound level calibration of the system was performed. The purpose of the preliminary calibration was to ensure that all equipment was operating properly. A frequency-response calibration of the entire electrical system, absent of the microphone was then performed with the pink noise generator.
6. The electronic noise floor of the entire electrical system absent of the microphone was established, using a non-transductive (i.e., mechanically passive) capacitive load.
7. After re-installation of the microphone and given adequate time to stabilize, a pre-measurement sound level calibration of the system was performed.
8. The two-stage windscreen was then deployed and the preamplifier cable secured to a leg of the tripod, to prevent possible vibration. All other cables were “dressed” to allow for easy visual inspection, and to prevent disturbance by site activity.
9. Section 4.3 next presents the step-by-step description of the field data collection procedure.



Figure 21. VoLARE microphone system deployment; Site ST9.



Figure 22. VoLARE recording system deployment; Site ST9.

4.3 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 9.

2. The second field observer periodically checked the equipment and took photographs of any visible aircraft for later determination of slant range. Detailed logs, including site, data, time, aircraft type, aircraft model, operator, tail number, and direction (when identifiable), were kept for later correlation with the recorded images. Note: Slant range data collection occurred only during the initial systems deployment, and not during remaining measurement period, when NPS personnel performed all site visits, acoustic observer logging, and system maintenance/relocation.
 3. At the end of the site visit, all data were downloaded and transferred onto a central computer. For NoiseLogger™ systems, data were downloaded by removing the CompactFlash™ card from the Husky™ H/PC. For NoiseLogger Plus™ systems, data were downloaded by moving the data onto a portable, external hard drive. Copies of the data were then placed on DVD and sent to the Volpe Center for periodic review, quality control (QC) checks, processing, and analysis, approximately once every two weeks during the measurement study. For the VoLARE system, data were downloaded by removing the DAT tape from the recorder and using Larson Davis software to transfer data from the LD824 sound level meter to a laptop.
 4. A post-measurement sound level calibration of the VoLARE's acoustical system was performed and any drift from the initial calibration was documented. The internal clocks of the SLM and DAT were compared with the master clock and any time drift was documented.
 5. All VoLARE instrumentation was powered down, disconnected, and stored.
 6. If the site was designated as a "permanent" site, the NoiseLogger™ system was recalibrated and ambient sound level data collection then re-initiated.
 7. If the site was designated as a "mobile" site, then the NoiseLogger™ system was dismantled and moved to the next location.
 - a. A post-measurement sound level calibration of the acoustical system was performed and any drift from the initial calibration was documented.
 - b. All instrumentation was powered down and the entire system was disconnected and stored.
-

Table 9. 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.

5. DATA REDUCTION AND PROCESSING

Figure 23 presents a diagram of the data reduction process. Essentially, there were three types of data: (1) acoustical; (2) meteorological; and (3) other, e.g., slant range photographs. The acoustical and meteorological data were used by the Volpe Center as input to its data processing program, entitled NLcrunch (see Section 5.4). 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.

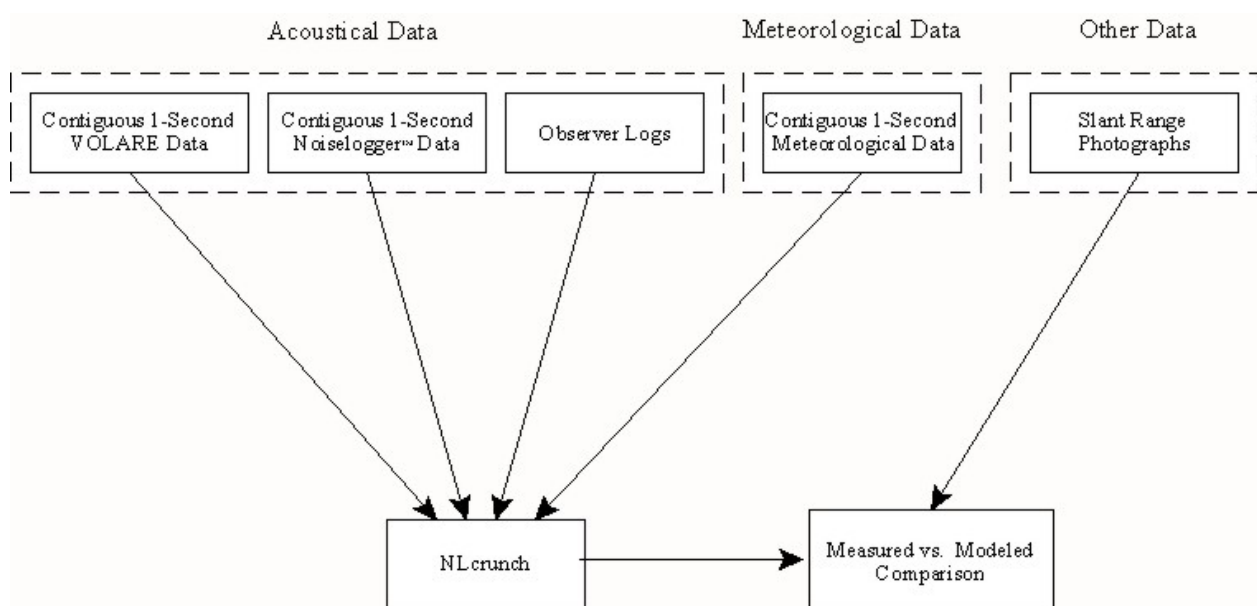


Figure 23. Flow diagram of data reduction process.

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 approximately once every two weeks during the measurement study.

5.1 Raw NoiseLogger™ and NoiseLogger Plus™ 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., “SP01” represents Site P01), “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).

In addition to the binary files, the NoiseLogger Plus™ system also recorded live audio samples. These files were used for later repeated playback whenever there was a question on the noise source of the sound levels from the binary files.

5.2 Raw VoLARE Acoustic Data Reduction

No editing was required for the VoLARE acoustic data. The filename format of the raw, binary files was as follows:

“MMDDYYxx.slmdl”

where “MM” is the two-digit representation for the month, “DD” is the two-digit representation for the day of the month, “YY” is the two-digit representation for the year, and “xxx” is a unique three-character character ID representing the site (e.g., “P01” represents Site P01). The “.slmdl” extension identifies these files as binary formatted Larson Davis (LD) Model 824 sound level meter (SLM) files. It should be noted that the LD 824 was used for VoLARE measurements at all Haleakalā sites except Sites 1A and 1B, where a LD Model 820 SLM was used. The filename format of the raw, binary LD 820 files was “MMDDYYxx.bin.” A filename size of 8 characters, not including the filename extension, is a limitation set by the LD820 utility software and, as such, was the convention used for all VoLARE acoustic files for consistency.

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

5.3 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.

5.4 Slant Range Data Reduction

The filename format of the raw, digital-photograph files was as follows:

“CRW_XXX..CRW”

where “CRW” identifies these files as raw Canon camera digital photograph files, and “xxx” is a sequential three-digit number assigned to the file by Canon’s internal counter.

The digital photograph files were reviewed using Canon’s “RAW image converter2” software to convert the raw files to a format that the image processing software can use (such as Joint Photographic Experts Group, or JPG, format), and compared with the detailed logs, which the field observer kept, noting site, data, time, aircraft type, aircraft model, operator, tail number, and direction of flight (when identifiable). No editing was required for the slant range photos. All photos were individually reviewed to determine if they were properly taken, i.e., the image must represent a perpendicular side or frontal view of the aircraft. If the aircraft was shown at an angle other than perpendicular, that photo is discarded. Remaining “good” photos were then processed using a Volpe-developed program, Fotoscal,²⁸ which computes the slant range distance of the aircraft to the camera, based on a triangular comparison of the length of the aircraft in pixels in the photograph with the actual length of the aircraft as documented by the manufacturer.

As stated in Section 1, computer modeling will be used to compute aircraft sound levels in areas within Haleakalā for which resource constraints (or other issues) did not allow for direct measurements. Slant range data was used to correlate actual data with computer-predicted data during the modeling task. Appendix D provides the results of these correlations.

5.5 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 5.5.1), and then several adjustments (Section 5.5.2) to the acoustic data prior to detailed data reduction and analysis.

5.5.1 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™ or NoiseLogger Plus™ 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);^{25,*}

* 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.

- 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-band frequency 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.

5.5.2 Data Adjustments

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

- Gain adjustments were applied to VoLARE acoustic data (Note: No gain adjustments were required for NoiseLogger™ or NoiseLogger Plus™ data). As mentioned previously in Section 3.3.2, to successfully utilize the VoLARE system down to the threshold of human hearing, an offset calibration technique was employed.
- Calibration adjustments were applied. These adjustments accounted for calibration drift as determined by measuring a calibration signal at the start and end of each data collection period.
- Microphone frequency response adjustments were applied. These adjustments accounted for frequency response biases of the microphone and were provided by a microphone calibration facility. Appendix C presents these adjustments in detail.
- Windscreen frequency response adjustments were applied. These adjustments accounted for frequency response biases of the windscreen. Appendix C presents these adjustments in detail.

- Noise floor adjustments were applied to NoiseLogger™ and NoiseLogger Plus™ 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™ and NoiseLogger Plus™ 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.²⁵

5.5.3 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 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.

* 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

6. DATA ANALYSIS

In support of this study, 165 days of acoustic and wind data were measured at ten sites from February 27 through May 27, 2003. Figure 24 below shows the specific periods of time that data were collected at each site.

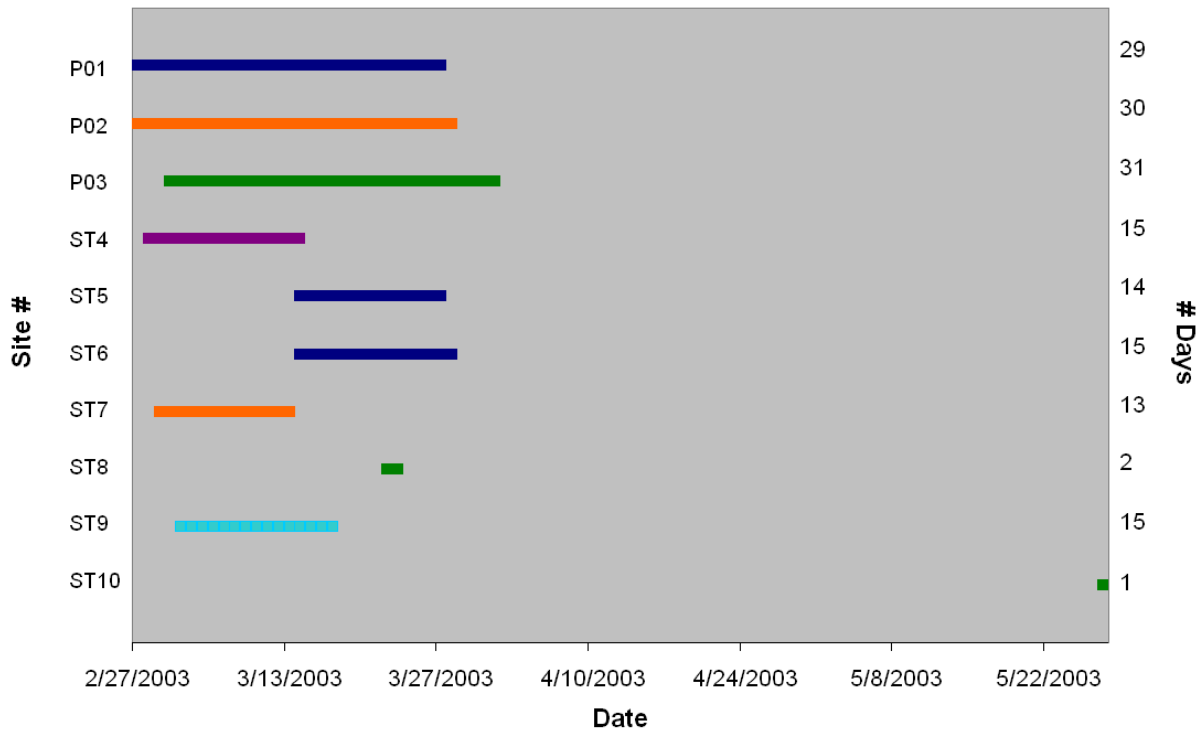


Figure 24. Baseline ambient data collection timeline for each site.

As stated in Section 1.1, the primary objective of this study was to quantify the baseline ambient sound levels within Haleakalā 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)²⁹. 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 Haleakalā ambient maps. 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)* – Determine the feasibility of the use of “acoustic zones” to allow for the transferability of baseline ambient data within large, homogeneous regions of Haleakalā and possibly between similar regions in other parks.
- *Measurement Duration (Section 6.3)* – Determine the potential errors associated with shorter versus longer duration data sets with the goal of potentially minimize data collection/analysis costs in future parks.
- *Development of Ambient Maps (Section 6.4)* – 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

* Note: As discussed in Section 5.5.3, 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

[†] It is likely that there will be substantial season-to-season variability for many parks. However, in discussions with Haleakalā NPS personnel, because there is little climatic seasonal variation in Hawai‘i as compared with other U.S. national parks, it was agreed that seasonal measurements would not be required in Haleakalā.

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. Table 10 through Table 12 present the results for all ten 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 5.5, 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.

As summarized in Table 13, 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.

* 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 10. 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
P01	26.7	25.1	23.1	24.2	28.3	45.4	34.1	30.4	37.2	34.4	34.7	34.1	35.2	34.3	34.1	34.1	37.0	32.6	32.1	31.8	32.5	29.0	31.1	29.0
P02	36.7	35.7	35.7	36.7	36.3	41.4	40.2	46.0	42.1	44.2	38.0	38.8	38.7	37.3	36.6	37.3	38.8	37.1	37.1	37.8	39.2	38.0	35.7	36.4
P03	51.7	53.2	52.0	52.3	49.8	47.1	55.8	50.4	51.2	50.7	55.0	54.9	54.7	53.2	52.0	52.2	53.4	51.0	50.1	49.9	54.6	56.0	50.6	51.5
ST4	20.9	21.5	20.8	21.9	22.4	43.6	40.5	34.0	36.0	30.1	35.6	31.6	31.7	34.0	34.2	40.0	34.4	30.5	30.4	22.2	21.0	23.1	21.2	21.7
ST5	28.5	26.8	28.2	26.0	28.9	27.0	27.9	42.4	44.4	45.6	43.5	43.0	45.3	44.3	43.5	45.1	42.3	39.5	33.2	32.7	34.0	32.0	30.5	30.0
ST6	25.3	24.3	29.1	26.0	31.2	26.5	26.3	28.9	32.3	34.0	36.0	33.4	35.5	36.4	36.9	36.3	36.5	34.3	27.3	26.9	25.1	25.8	26.0	24.5
ST7	45.4	45.6	45.3	42.6	44.0	45.2	41.5	40.8	37.8	38.7	44.3	41.9	44.7	43.4	42.8	42.2	43.4	42.8	43.8	43.9	44.5	46.3	45.9	45.8
ST8†	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	68.9	71.9	63.5	63.5	63.5	63.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ST9	50.7	49.5	49.1	48.3	46.8	46.0	46.4	46.6	43.1	52.6	43.4	43.2	41.5	40.1	55.5	40.8	55.8	42.7	42.2	45.6	49.3	49.3	49.7	48.7
ST10	47.8	47.9	47.3	47.1	47.4	47.4	46.4	47.7	47.3	47.1	47.5	48.7	49.2	46.4	46.2	47.5	52.1	47.8	47.8	47.3	48.5	48.0	47.2	47.1

Table 11. 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
P01	21.0	20.1	19.3	20.1	19.8	20.4	21.0	21.4	24.6	26.1	27.5	27.6	28.0	27.4	26.1	24.9	23.9	23.1	22.4	22.5	23.1	21.7	21.6	22.0
P02	28.5	27.4	27.7	27.7	27.6	28.4	28.7	29.1	28.9	28.4	28.8	28.1	27.9	26.7	27.0	26.7	26.8	27.0	26.6	26.7	26.2	26.7	27.4	28.5
P03	50.0	50.4	50.0	49.2	46.5	41.9	45.0	42.2	42.4	43.2	44.7	45.5	46.9	45.8	45.0	43.5	42.9	41.8	41.9	43.4	45.6	47.7	48.0	49.3
ST4	18.3	18.6	18.3	18.4	18.6	19.3	24.8	21.7	23.8	22.9	23.8	23.0	23.6	23.0	21.9	21.9	21.7	20.3	19.3	18.4	18.2	18.2	18.4	18.4
ST5	23.7	22.0	21.9	22.2	24.0	21.4	23.7	22.5	24.8	25.6	24.2	26.0	29.0	26.6	26.8	25.8	23.9	22.8	23.5	29.1	32.0	29.8	26.7	25.7
ST6	21.2	20.8	21.5	20.5	21.2	20.7	20.7	21.2	24.2	25.3	27.2	26.8	27.1	25.6	25.8	25.4	23.4	21.5	19.7	20.8	20.9	21.2	21.2	21.0
ST7	29.6	28.5	29.8	29.1	29.9	31.1	31.1	30.9	29.0	28.8	30.3	32.1	31.1	30.0	29.1	29.3	29.9	29.3	28.9	29.2	28.1	28.8	28.5	31.1
ST8*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	69.2	70.9	63.2	63.4	63.3	63.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ST9	49.2	48.8	48.5	47.8	46.3	41.5	39.0	34.1	34.2	34.6	34.6	34.7	34.3	34.4	34.1	34.0	33.8	37.8	39.4	43.6	47.6	48.2	48.6	48.4
ST10	47.5	47.1	46.8	46.5	46.4	46.4	45.8	45.8	45.8	45.9	45.8	46.1	46.4	46.0	45.7	46.2	47.5	47.0	47.0	47.2	47.5	47.6	46.8	46.9

* 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 (2 days); however, due to possible equipment issues, data collected at this site was suspect and, thus, not used in the analyses.

Table 12. 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
P01	18.8	18.4	18.1	18.4	18.4	18.5	19.2	19.1	20.2	20.8	21.8	22.1	22.1	21.8	21.4	20.4	20.4	20.0	19.5	19.4	20.3	19.7	19.8	19.8
P02	24.6	24.0	23.9	24.4	24.4	25.2	25.1	25.4	24.9	24.7	24.8	24.6	24.5	23.6	23.5	23.5	23.3	23.4	23.2	23.4	23.0	23.5	24.2	24.4
P03	49.0	49.2	49.1	47.8	44.1	40.5	41.2	40.8	40.4	40.9	41.8	42.1	43.0	42.6	42.2	41.1	40.7	40.1	40.4	40.7	43.4	46.0	46.8	48.2
ST4	17.9	18.0	17.9	18.0	18.1	18.4	20.4	19.6	20.3	20.6	21.5	21.0	21.2	20.7	20.2	19.6	19.3	18.8	18.2	18.0	17.9	17.9	18.0	18.0
ST5	20.5	19.7	19.1	19.9	20.6	19.8	21.2	19.7	20.6	20.5	20.6	21.4	22.9	22.1	22.7	21.8	21.4	21.1	21.5	21.9	28.1	24.8	22.0	21.7
ST6	19.8	19.7	19.5	19.5	19.7	19.5	19.4	19.6	20.6	21.1	22.0	21.7	21.9	21.2	21.1	21.1	20.4	19.3	19.1	19.5	20.0	19.9	19.9	19.7
ST7	25.5	24.9	25.3	24.3	25.2	26.3	26.2	25.9	25.2	24.5	25.8	27.0	26.4	25.6	25.1	25.2	25.3	24.9	24.8	25.0	25.0	25.5	24.9	25.7
ST8†	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	67.2	69.6	63.0	63.2	63.2	63.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ST9	47.8	47.6	47.5	46.8	44.7	36.2	32.5	31.2	30.9	31.2	31.4	32.1	31.8	32.2	31.9	31.4	30.6	34.1	36.5	40.0	46.2	47.0	47.2	47.4
ST10	46.4	46.1	45.6	45.5	45.2	45.1	44.5	44.5	44.7	44.6	44.4	44.9	45.2	44.7	44.6	44.9	46.1	45.8	46.0	45.8	46.4	46.5	45.7	45.8

Table 13. 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)
P01	35.1	21.6	18.0	34.7	24.5	18.6	35.5	19.7	17.9	0.4	-2.9	-0.6	-0.4	1.9	0.1
P02	39.4	26.9	20.5	40.7	27.2	21.5	37.6	26.6	20.0	-1.3	-0.3	-1.0	1.8	0.3	0.5
P03	52.7	45.7	38.5	53.2	43.5	38.2	52.2	47.9	39.3	-0.5	2.2	0.3	0.5	-2.2	-0.8
ST4	34.6	19.3	17.7	35.7	22.5	18.8	33.3	18.0	17.6	-1.1	-3.2	-1.1	1.3	1.3	0.1
ST5	42.0	24.7	19.0	43.7	24.6	19.3	30.7	24.9	18.6	-1.7	0.1	-0.3	11.3	-0.2	0.4
ST6	32.2	21.3	19.0	34.7	23.5	19.2	27.0	20.2	18.8	-2.5	-2.2	-0.2	5.2	1.1	0.2
ST7	43.7	27.8	21.2	42.5	28.4	21.9	44.9	27.1	19.9	1.2	-0.6	-0.7	-1.2	0.7	1.3
ST8*	66.6	63.4	63.1	66.6	63.4	63.1	NA	NA	NA	N/A	N/A	N/A	N/A	N/A	N/A
ST9	49.1	42.3	31.1	49.7	34.9	30.0	48.4	47.7	40.4	-0.6	7.4	1.1	0.7	-5.4	-9.3
ST10	48.0	46.3	44.8	48.1	46.1	44.7	47.5	46.9	45.6	-0.1	0.2	0.1	0.5	-0.6	-0.8
									Average	-0.7	0.1	-0.3	2.2	-0.3	-0.9

* 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 (2 days); however, due to possible equipment issues, data collected at this site was suspect and, thus, not used in the analyses.

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 scientifically justified 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 E discusses the analysis methodology in greater detail). In addition, human activity has been found to play a significant role in the acoustic characteristics of some park locations and, in some cases, overrides the land cover/ecological factors. This effort continues the work that began in Hawai'i Volcanoes National Park to examine the use of acoustic zones for future park ambient studies.²⁵ Figure 25 displays the acoustic zones and measurement sites for Haleakalā as discussed in Section 2.6.

The following comparisons were performed to statistically assess ambient data collected at a pair of sites within Haleakalā 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. 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.

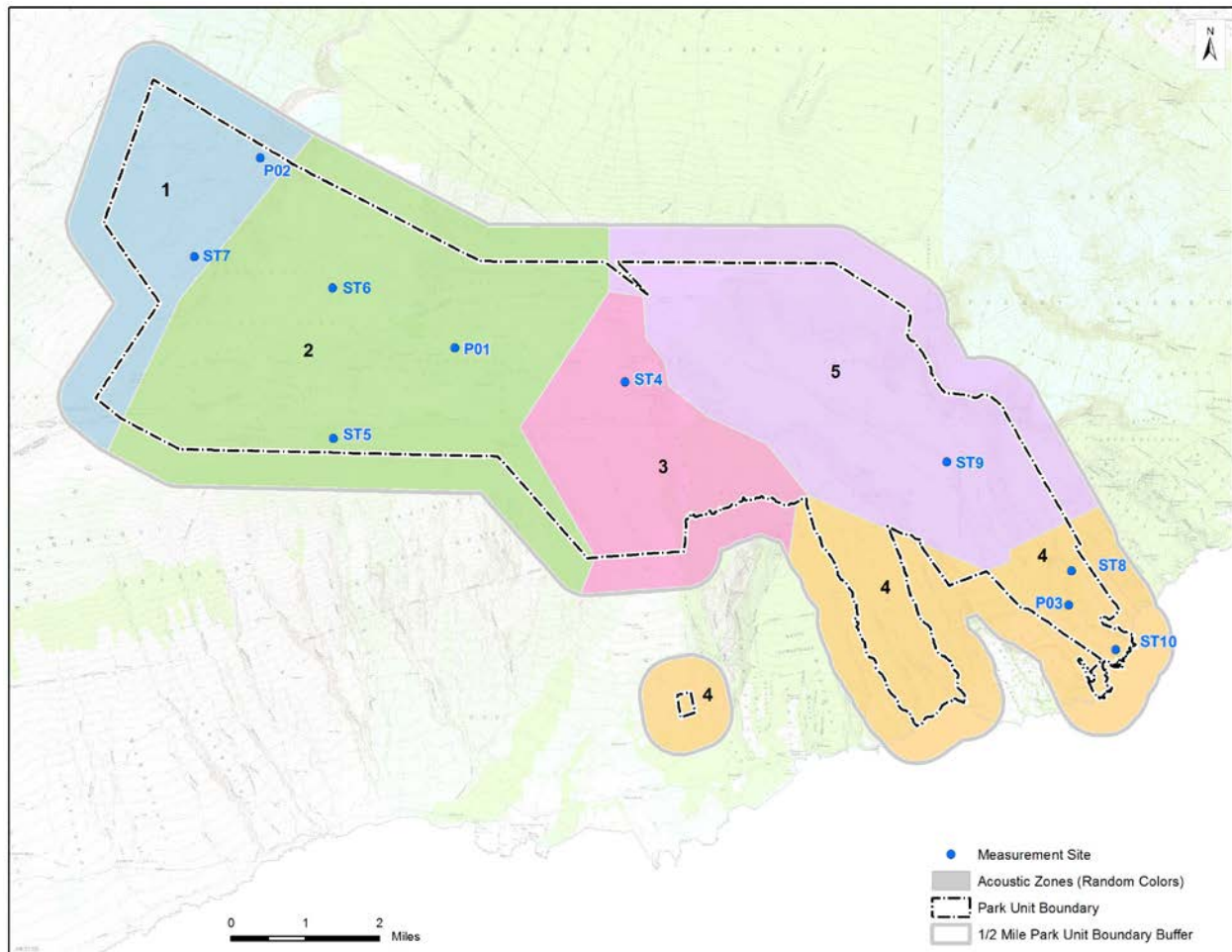


Figure 25. Acoustic zones and measurement sites for Haleakalā.

Figure 26 presents the results of comparing ambient data collected at pairs of sites within Haleakalā, located in the same acoustic zone. From this analysis, there is statistical evidence to support the transferability of ambient data hypothesis. Specifically, the sites on the West Rim in Acoustic Zone 1 (P02 and ST7) were found to be strongly similar; and sites in Haleakalā Crater in Acoustic Zone 2 (P01, ST5, and ST6) showed similarity as well.

Acoustic Zone	Site ID	P01	P02	P03	ST4	ST5	ST6	ST7	ST9
Haleakala Crater	P01		SS	F	S	S	S	SS	S
West Rim Crater	P02			F	F	SS	S	SS	F
Kipahulu Coastal	P03				F	F	F	F	F
Kaupo Gap	ST4					S	S	F	S
Haleakala Crater	ST5						SS	SS	S
Haleakala Crater	ST6							S	F
West Rim Crater	ST7								S
Upper Kipahulu Valley	ST9								

Figure 26. Data transferability within acoustic zones.

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 acoustic zone.

Note 3: Sites ST8 and ST10 were not included in this analysis due to insufficient data.

Figure 27 presents the results of comparing ambient data collected at pairs of sites within Haleakalā, located in the same land cover class/subclass (per National Land Cover Database, or NLCD, as discussed in Appendix E). From this analysis, data similarities can be seen for shrubland (P01, P02, and ST4) and bare rock/sand/clay sites (ST6 and ST7), which support the transferability of ambient data hypothesis, i.e., generalizing data measured with these types of land cover to other similar areas in the park. Interestingly, data similarities did not occur for the forested areas and, in this case, the role of human interaction is evident. The rain forest sites (P03 and ST9) are similar in land cover and wildlife; however, Site P03 experiences heavy visitor and air tour use, which is likely the cause of the dissimilarity.

NLCD Land Cover Classification	Site ID	P01	P02	P03	ST4	ST5	ST6	ST7	ST9
51 Shrubland	P01		SS	F	S	S	S	SS	S
51 Shrubland	P02			F	F	SS	S	SS	F
42 Evergreen Forest	P03				F	F	F	F	F
51 Shrubland	ST4					S	S	F	S
51 Shrubland	ST5						SS	SS	S
31 Bare Rock/Sand/Clay	ST6							S	F
31 Bare Rock/Sand/Clay	ST7								S
42 Evergreen Forest	ST9								

Figure 27. 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.

Note 3: Sites ST8 and ST10 were not included in this analysis due to insufficient data.

Figure 28 presents the results of comparing ambient data collected at pairs of sites within Haleakalā with similar levels of estimated visitor activity (see Section 2.5.1). These sites were

grouped according to visitor-use, primarily foot traffic. Note: Because there was only one high visitor-use site (ST7), conclusions could not be drawn with other high visitor-use sites. The moderate or medium use sites (P02 and P03) did not show similarity, while the low use sites showed large 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 human mechanical noise, i.e., aircraft and vehicular traffic. The low visitor-use sites were similar due to their similar natural-eco characteristics, not the amount of foot traffic. While the medium-use sites showed dissimilarity because the high level of air tour aircraft at P03, which was not present at P02.

Visitor-Use	Site ID	P01	P02	P03	ST4	ST5	ST6	ST7	ST9
Backcountry	P01		SS	F	S	S	S	SS	S
Short Hike	P02			F	F	SS	S	SS	F
Short Hike	P03				F	F	F	F	F
Backcountry	ST4					S	S	F	S
Backcountry	ST5						SS	SS	S
Backcountry	ST6							S	F
Overlook	ST7								S
Wilderness	ST9								

Figure 28. 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.

Note 3: Sites ST8 and ST10 were not included in this analysis due to insufficient data.

In conclusion, the results of the acoustic zone analysis can be summarized as follows:

- Sites with low or medium human activity (hikers, vehicular traffic, aircraft activity) showed acoustic similarity when the land cover and ecological conditions were similar; and
- Sites with high human activity, particularly aircraft activity, showed similarity that seemed to be independent of land cover and ecological conditions.

6.3 Measurement Duration

As discussed earlier in Section 2.7.2, measurement duration is a very difficult technical issue on which to reach consensus. Because many parks experience not only daily, but also seasonal, variability, the choice of how long to measure must balance technical considerations and available resources. It is simply not practical to measure at sites for many months, or over the

course of several years. However, measurements at a particular site should not only be of sufficient duration to ensure statistical confidence in the data, but also be reasonable in light of practical and other resource considerations.

To continue the work that began in Hawaiʻi Volcanoes National Park²⁵ to assess the needed measurement duration for future park ambient studies, the Haleakalā data (29-31 days of data collected at three long-term sites) were examined to test the magnitude of data variability as a function sample size (measurement duration). The assessment presented herein includes determining the potential errors associated with shorter versus longer duration data sets. The data measured in this study and in the previous Hawaiʻi Volcanoes study provide a scientific basis to optimize future data collection durations and, thus, potentially minimize data collection/analysis costs in future parks. The assessment presented herein includes determining the potential errors associated with shorter versus longer duration data sets.

Figure 29 plots the average minimum and maximum differences in L_{50} and sound levels associated with various sample sizes, from 4 to 21 days (the orange and magenta lines, respectively) when compared to the overall L_{50} sound level for the entire measurement duration **for the three long-term measurement sites**. For example, the maximum L_{50} for a 4-day sample size represents the maximum L_{50} that would be obtained should the measurement team had visited and performed data collection at a permanent site for *any* 4 days within the full measurement period. As can be seen, the maximum and minimum L_{50} values can be many decibels different than the overall L_{50} . That indicates that a 4-day sample could result in a substantial overstatement/ understatement of the L_{50} . This “error” steadily decreases with increasing sample size and begins to approach reasonable (within about 5 dB) levels of uncertainty between about 10- and 14-day sample period. Also, at about this sample size, the rate of change in the variability begins to level out, i.e., longer sample periods increase the confidence in the measured data to a much lesser degree. As shown, the greater the sample size, the more the data converges with the overall level presenting a more accurate characterization of the ambient at that site. Figure 30 plots the results of this analysis performed using L_{90} sound levels.

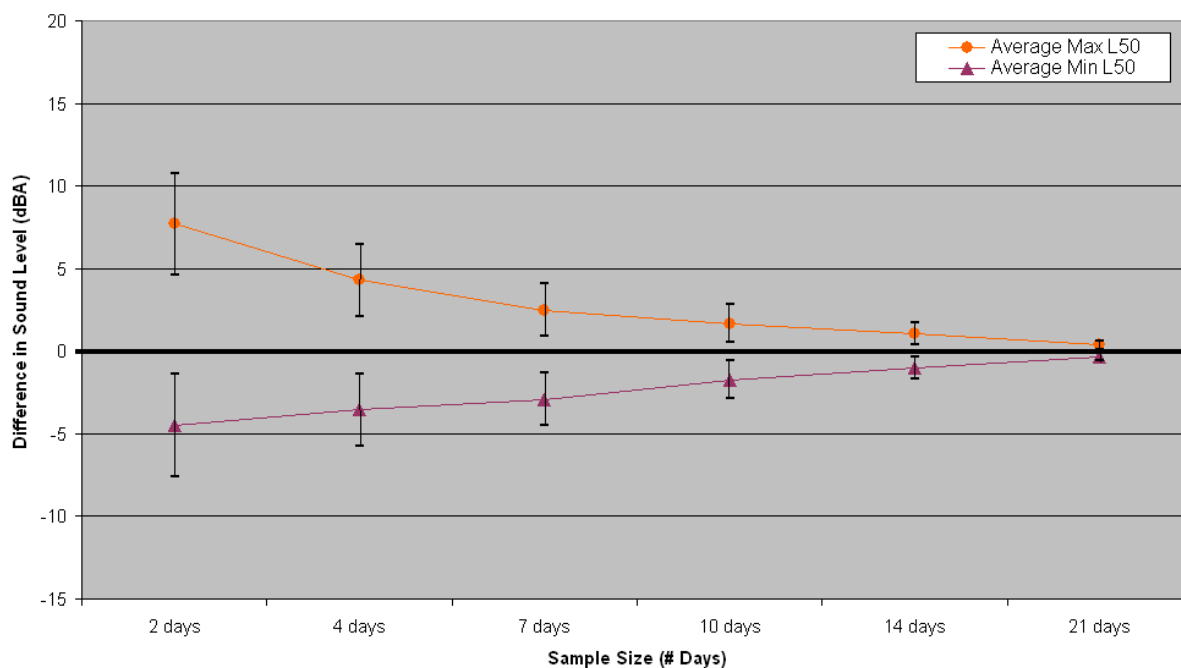


Figure 29. Summary of L₅₀ results for all permanent measurement sites.

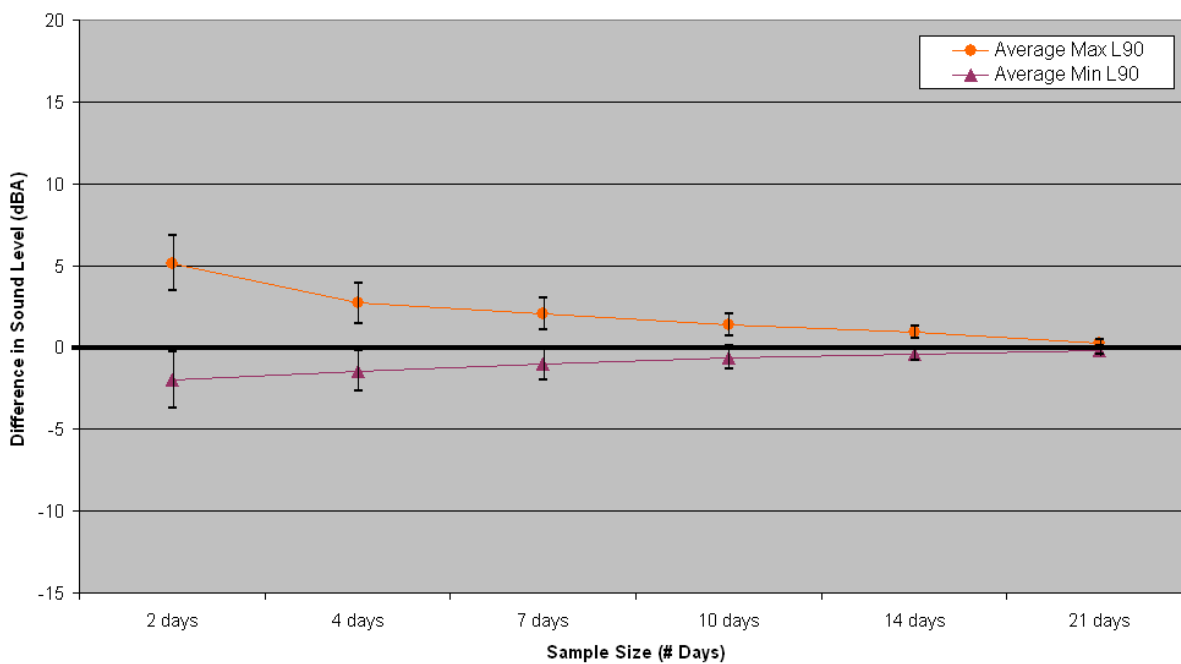


Figure 30. Summary of L₉₀ results for all permanent measurement sites.

The FAA and NPS have jointly agreed that selecting a sample size, which limited measurement uncertainty to 3 decibels, was desirable. Based on this and the Hawai'i Volcanoes analyses,²⁵ as well as a joint review of acoustic literature and other recent long-term NPS ambient studies in Bryce Canyon National Park and Arches National Park,³⁰ the 3-dB variability was achieved between 10, 25, and 40 days, depending on individual site variables/characteristics. As a result, the FAA and NPS have agreed upon a minimum 25-day measurement period for all future acoustic monitoring.

An exception to the 25-day requirement would be for measurements in close proximity to localized sound sources, which don't vary substantially in level, such as waterfalls, river rapids, train tracks, busy visitor centers, and roads. As discussed in Section 2.1, for the purpose of characterizing these sound sources, acoustic data should be measured at a minimum of two distinct distances from the source, so as to characterize a reference level and the rate at which sound level decreases with increasing distance from the source. For roadways, traffic sounds may be modeled using the Federal Highway Administration's Traffic Noise Model® (TNM).³¹ Note: To support TNM modeling, the following input data are required: traffic volume, traffic speed, vehicle mix, and ground surface characteristics, e.g., grass, water, rock, etc. Section 6.4.2 discusses the localized sound sources for Haleakalā.

6.4 Development of Ambient Maps

Over the past decade, several definitions of ambient noise have been adopted by different organizations depending on their application.^{7,16,17,32} 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.^{33,34} 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 31):

- *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.

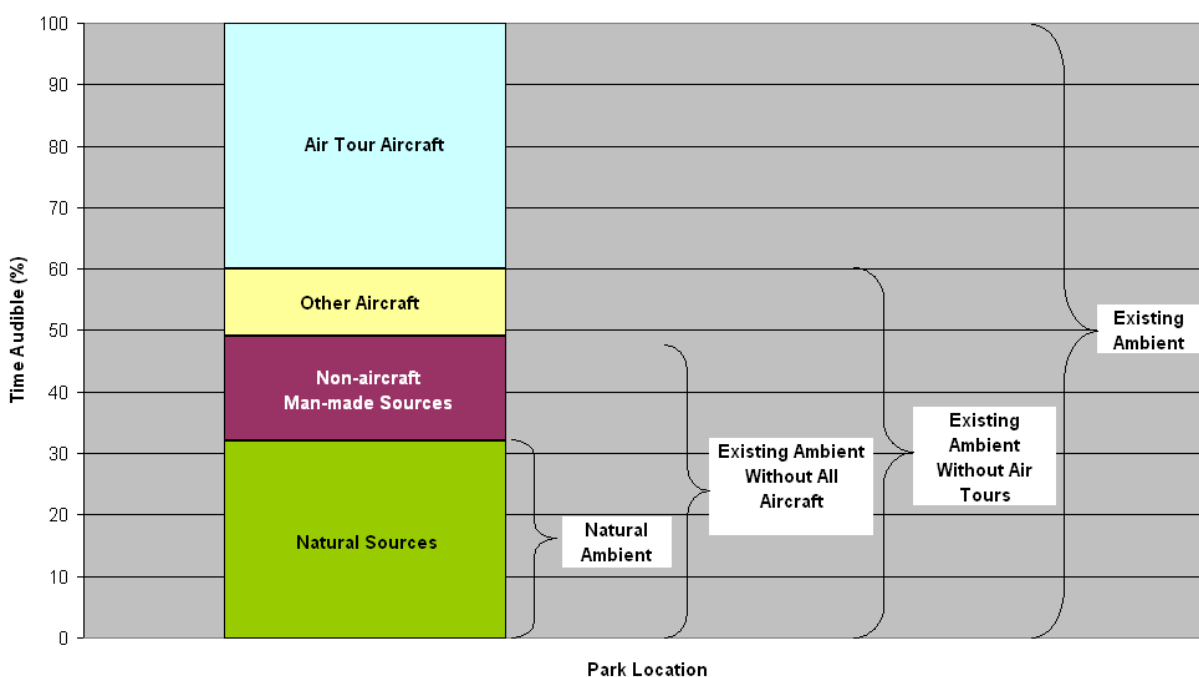


Figure 31. Graphical depiction of ambient definitions.

Nine ambient sound level values were initially computed for every measurement site as listed in Table 14. Note: The L_{Aeq} metric was computed for the Existing Ambient only.

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

Table 14. 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

6.4.1 Computation of 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,³⁵ a methodology was developed to utilize short-term VoLARE 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 NoiseLogger™ data. The objectives of the methodology were:

- To obtain a percentile statistical value from VoLARE 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 VoLARE would only be used to determine the statistical index; and
- To obtain a spectral shape from VoLARE, 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 VoLARE 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 VoLARE 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 all the VoLARE 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 computer 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 6.4.2). The ambient maps, along with aircraft source and schedule data, provide the input parameters utilized by the INM or AEDT 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.

6.4.2 Other Considerations

In addition to the measured ambient sound levels, the contributing effect of localized noise sources, such as waterfalls, river rapids, train tracks, and roads, should be considered in the development of the ambient maps. For Haleakalā, there were three localized noise sources: Waimoku Falls in the Kipahulu coastal area, and two primary, and relatively busy, roads: Haleakalā Highway, and Highway 31. For Waimoku Falls, ambient data were collected near the Falls for an entire 8-hour day and an estimated drop-off rate, reflecting a continuous decrease in sound level as a function of increasing distance from a point source, was used. The two roads were modeled using the Federal Highway Administration's Traffic Noise Model[®] (TNM).³¹ 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 Haleakalā 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. Note: No truck data were available. As such, it is assumed that any trucks entering the parks do not travel beyond Park Headquarters; and any traveling in the Kipahulu area is minimal, if any.

Table 15. TNM traffic volume input.

Vehicle Type	Haleakalā Highway: Annual Volume	Haleakalā Highway: Hourly Volume	Highway 31: Annual Volume	Highway 31: Hourly Volume
Autos	126,153	29	166,933	38
Buses	84,118	19	2,690	1
Heavy Trucks	0	0	0	0

- *Traffic Speeds* – According to Haleakalā NPS personnel, the posted speed limit ranges from 15 to 25 mph (24.1 to 40.2 kph) on Haleakalā Highway, and 10 to 35 mph (16.1 to 56.3 kph) on Highway 31. A conservatively high average speed of 20 mph (32.2 kph) was used for both roads.
- *Ground Impedance* – Because much of the land cover in vicinity of the roads was rocky, a moderately hard acoustical ground impedance was assumed using an effective flow resistivity of 1000 cgs/rayls.

6.4.3 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 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 Haleakalā, 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 (two roads in Haleakalā were

^{*} 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.

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 6.4).
- 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 6.4.2.
- Compute a combined “measured” and “roadway” ambient (and spectra), as appropriate, at each grid point (see Table 16). The resultant ambient maps are presented in Section 7.

Table 16. 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 6.4, 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 (Section 7.1), and the final, ambient, sound level maps developed in support of this study.

Table 17 contains a summary of the ambient, sound level data measured at each Haleakalā 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 6.4. 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 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

* 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 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.

- **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 32 through Figure 35 present the data in Table 17 graphically for each ambient type. Figure 36 and Figure 37 present the data graphically for each metric.

Table 18 presents the associated spectral data for the two ambient maps agreed upon for use in analyses: Existing Ambient Without Air Tours (L_{50}) and Natural Ambient (L_{50}). ***Note: For comparison purposes, Table 19 contains a summary of the ambient, sound level data for the entire measurement period, where daytime and nighttime hours were included.***

Table 20 and Figure 38 contain a summary of the acoustic observer data logged at each Haleakalā measurement site. As discussed in Section 6.4.1, this data was used to determine short-term distributions of ambient data from the VoLARE measurement data as a function of acoustic state, and apply these short-term distributions to the long-term NoiseLogger™ 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 21 summarize 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 39 through Figure 48 present the roadway ambient map and the resultant, nine, baseline ambient maps, respectively, as above in Table 17.

Table 17. Summary of measured, daytime (6 am to 6 pm), ambient sound level data.

Acoustic Zone	Site ID	Total # Days	Existing L _{Aeq} (dBA)	Existing L ₅₀ (dBA)	Existing L ₉₀ (dBA)	Existing W/S (mph)	Existing Without Air Tours L ₅₀ (dBA)	Existing Without Air Tours L ₉₀ (dBA)	Existing Without Air Tours W/S (mph)	Existing Without All Aircraft L ₅₀ (dBA)	Existing Without All Aircraft L ₉₀ (dBA)	Existing Without All Aircraft W/S (mph)	Natural Ambient L ₅₀ (dBA)	Natural Ambient L ₉₀ (dBA)	Natural Ambient W/S (mph)
1: West Rim Crater	P02	30	40.7	27.2	21.5	5.2	26.8	21.6	0.0	26.8	21.6	0.0	27.7	22.2	0.0
1: West Rim Crater	ST7	13	42.5	28.4	21.9	5.1	24.1	20.5	7.6	24.1	20.5	7.5	23.6	20.2	7.6
2: Haleakalā Crater	P01	29	34.7	24.5	18.6	4.2	22.6	18.5	5.0	22.6	18.5	5.0	22.5	18.6	5.0
2: Haleakalā Crater	ST5	14	43.7	24.6	19.3	5.5	21.9	19.0	5.4	21.8	18.8	5.4	21.8	19.0	5.4
2: Haleakalā Crater	ST6	15	34.7	23.5	19.2	5.0	21.4	18.9	5.4	21.4	18.9	5.4	21.4	18.9	5.4
3: Kaupo Gap	ST4	15	35.7	22.5	18.8	6.5	22.7	19.1	8.9	22.7	19.1	8.9	22.6	19.0	8.8
4: Kipahulu Coastal	P03	31	53.2	43.5	38.2	1.5	45.3	42.1	0.8	45.3	42.1	0.8	45.3	42.1	0.8
4: Kipahulu Coastal	ST8*	2	53.2	43.5	38.2	1.5	45.3	42.1	0.8	45.3	42.1	0.8	45.3	42.1	0.8
4: Kipahulu Coastal	ST10†	1	48.1	46.1	44.7	9.1	45.3	42.1	0.8	45.3	42.1	0.8	45.3	42.1	0.8
5: Upper Kipahulu Valley	ST9	15	49.7	34.9	30.0	0.4	30.7	28.1	0.5	30.7	28.1	0.5	30.7	28.1	0.5

* A limited amount of data was collected at this site (2 days); however, due to possible equipment issues, data collected at this site was suspect and, thus, not used in the analyses. As such, the data from Site P03 were used in the ambient mapping as best available.

† Due to equipment issues, no observer logging was performed at Site ST10. As such, the Existing Ambient sound levels could be determined; however, the remaining ambient sound levels could not be readily determined - the data from Site P03 were used in the ambient mapping as best available.

Table 18 Summary of measured, daytime (6 am to 6 pm), ambient sound level spectral data.*

Frequency (Hz)	Existing No Tours P01	Existing No Tours P02	Existing No Tours P03	Existing No Tours ST4	Existing No Tours ST5	Existing No Tours ST6	Existing No Tours ST7	Existing No Tours ST8 [†]	Existing No Tours ST9	Existing No Tours ST10 [‡]	Natural P01	Natural P02	Natural P03	Natural ST4	Natural ST5	Natural ST6	Natural ST7	Natural ST8 [†]	Natural ST9	Natural ST10 [‡]
12.5	30.8	43.7	37.5	37.2	34.5	40.0	40.1	37.5	23.8	37.5	31.1	44.8	37.5	37.0	34.5	40.0	40.1	37.5	23.8	37.5
16	29.5	41.3	35.5	33.8	33.1	36.3	38.1	35.5	24.4	35.5	29.7	42.3	35.5	33.8	33.1	36.3	37.9	35.5	24.4	35.5
20	31.0	38.9	35.3	30.4	32.5	35.6	38.8	35.3	25.8	35.3	30.9	39.9	35.3	30.4	32.4	35.7	38.2	35.3	25.8	35.3
25	27.8	36.5	34.7	26.6	31.0	30.8	37.1	34.7	25.2	34.7	27.8	37.7	34.7	26.4	30.8	31.0	36.1	34.7	25.2	34.7
31	25.9	33.7	33.5	23.2	29.6	28.5	36.4	33.5	22.6	33.5	25.9	34.8	33.5	23.2	29.5	28.5	35.6	33.5	22.6	33.5
40	27.1	32.5	32.9	21.6	29.1	29.0	36.7	32.9	22.8	32.9	27.0	33.5	32.9	21.6	29.0	29.1	36.0	32.9	22.8	32.9
50	25.7	31.1	32.5	20.2	28.5	27.4	36.1	32.5	22.2	32.5	25.6	32.0	32.5	20.2	28.4	27.4	35.4	32.5	22.2	32.5
63	26.0	30.8	30.3	19.4	27.4	27.4	35.2	30.3	22.0	30.3	25.9	31.5	30.3	19.4	27.4	27.5	34.7	30.3	22.0	30.3
80	23.8	31.0	28.9	19.8	26.1	26.5	34.5	28.9	21.2	28.9	23.8	32.2	29.1	19.8	26.0	26.3	34.2	29.1	21.2	29.1
100	23.0	29.1	29.3	19.2	24.0	24.6	31.9	29.3	20.0	29.3	23.0	30.2	29.3	19.2	23.9	24.6	31.8	29.3	20.0	29.3
125	21.3	28.4	31.3	19.4	22.1	23.4	29.7	31.3	19.6	31.3	21.3	29.4	31.5	19.4	22.0	23.4	29.3	31.5	19.6	31.5
160	19.1	25.0	32.7	17.4	20.9	22.0	26.6	32.7	18.8	32.7	19.0	25.9	32.9	17.6	20.8	22.1	26.2	32.9	18.8	32.9
200	16.9	21.9	33.1	15.2	19.2	21.8	21.6	33.1	18.8	33.1	16.8	23.1	33.1	15.4	19.0	21.9	21.0	33.1	18.8	33.1
250	15.4	19.9	33.9	14.6	16.6	22.1	18.6	33.9	19.4	33.9	15.3	20.8	34.1	14.6	16.4	22.4	18.3	34.1	19.4	34.1
315	14.0	18.5	34.9	14.0	14.8	19.3	16.8	34.9	18.8	34.9	13.9	19.4	34.9	14.0	14.7	19.6	16.5	34.9	18.8	34.9
400	12.9	18.2	35.5	14.0	14.2	12.8	14.6	35.5	19.2	35.5	12.8	19.0	35.5	14.0	14.1	12.8	14.3	35.5	19.2	35.5
500	12.6	18.5	35.3	14.6	13.2	9.3	12.9	35.3	20.2	35.3	12.6	19.4	35.3	14.4	13.2	9.3	12.4	35.3	20.2	35.3
630	12.8	18.7	35.1	14.6	12.6	6.7	12.1	35.1	20.0	35.1	12.8	19.6	35.3	14.6	12.6	6.7	11.6	35.3	20.0	35.3
800	14.1	19.0	35.3	15.2	11.5	4.2	13.2	35.3	20.4	35.3	14.2	19.9	35.3	15.2	11.6	4.2	12.8	35.3	20.4	35.3
1000	14.3	18.7	35.3	15.2	10.8	1.7	12.8	35.3	20.4	35.3	14.4	19.7	35.5	15.0	10.9	1.7	12.2	35.5	20.4	35.5
1250	13.0	15.1	34.3	13.2	9.6	1.2	9.8	34.3	19.4	34.3	13.1	16.2	34.5	13.0	9.6	1.2	9.1	34.5	19.4	34.5
1600	10.4	11.6	34.3	11.4	7.7	1.0	7.3	34.3	18.6	34.3	10.5	12.9	34.3	11.2	7.8	1.0	6.3	34.3	18.6	34.3
2000	6.4	8.1	34.1	9.0	5.8	1.1	4.1	34.1	18.4	34.1	6.4	9.6	34.1	8.6	5.8	1.1	3.0	34.1	18.4	34.1
2500	4.0	4.6	33.9	6.4	5.7	1.9	0.8	33.9	18.2	33.9	4.0	6.0	33.9	6.2	5.7	1.9	-0.2	33.9	18.2	33.9
3150	2.9	2.9	33.3	3.8	5.7	2.5	-2.0	33.3	18.2	33.3	2.9	4.1	33.1	3.6	5.7	2.5	-3.2	33.1	18.2	33.1
4000	2.1	2.1	31.9	1.4	4.8	2.9	-5.1	31.9	19.8	31.9	2.1	3.0	32.1	1.2	4.8	2.9	-6.1	32.1	19.8	32.1
5000	1.5	0.0	30.1	-1.0	4.6	3.4	-7.7	30.1	17.2	30.1	1.6	0.9	30.1	-1.2	4.6	3.4	-8.3	30.1	17.2	30.1
6300	1.2	-0.9	27.3	-2.6	4.3	4.2	-9.5	27.3	1.6	27.3	1.3	-0.7	27.3	-2.8	4.3	4.2	-9.7	27.3	1.6	27.3
8000	1.6	-2.4	21.7	-3.2	4.9	4.5	-8.7	21.7	-1.8	21.7	1.6	-1.7	21.7	-3.4	4.9	4.5	-8.8	21.7	-1.8	21.7
10000	2.0	-3.9	17.1	-4.2	5.7	5.5	-8.7	17.1	-2.4	17.1	2.0	-3.2	17.1	-4.2	5.7	5.5	-8.6	17.1	-2.4	17.1
12500	2.4	-4.6	11.1	-4.8	4.7	6.2	-6.3	11.1	-6.6	11.1	2.4	-4.9	11.1	-5.0	4.7	6.2	-6.6	11.1	-6.6	11.1
16000	1.5	-6.6	1.5	-7.2	5.7	5.1	-7.6	1.5	-7.4	1.5	1.5	-6.7	1.5	-7.2	5.7	5.1	-7.7	1.5	-7.4	1.5
20000	0.9	-8.2	-0.3	-8.8	3.4	1.3	-8.9	-0.3	-6.4	-0.3	0.9	-8.2	-0.3	-8.8	3.6	1.2	-8.8	-0.3	-6.4	-0.3

* As discussed in Section 5.4.3, 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.

[†] As discussed previously, due to possible equipment issues, data from Site P03 were used as best available.

[‡] As discussed previously, because no observer logging was performed at Site ST10, data from Site P03 were used as best available.

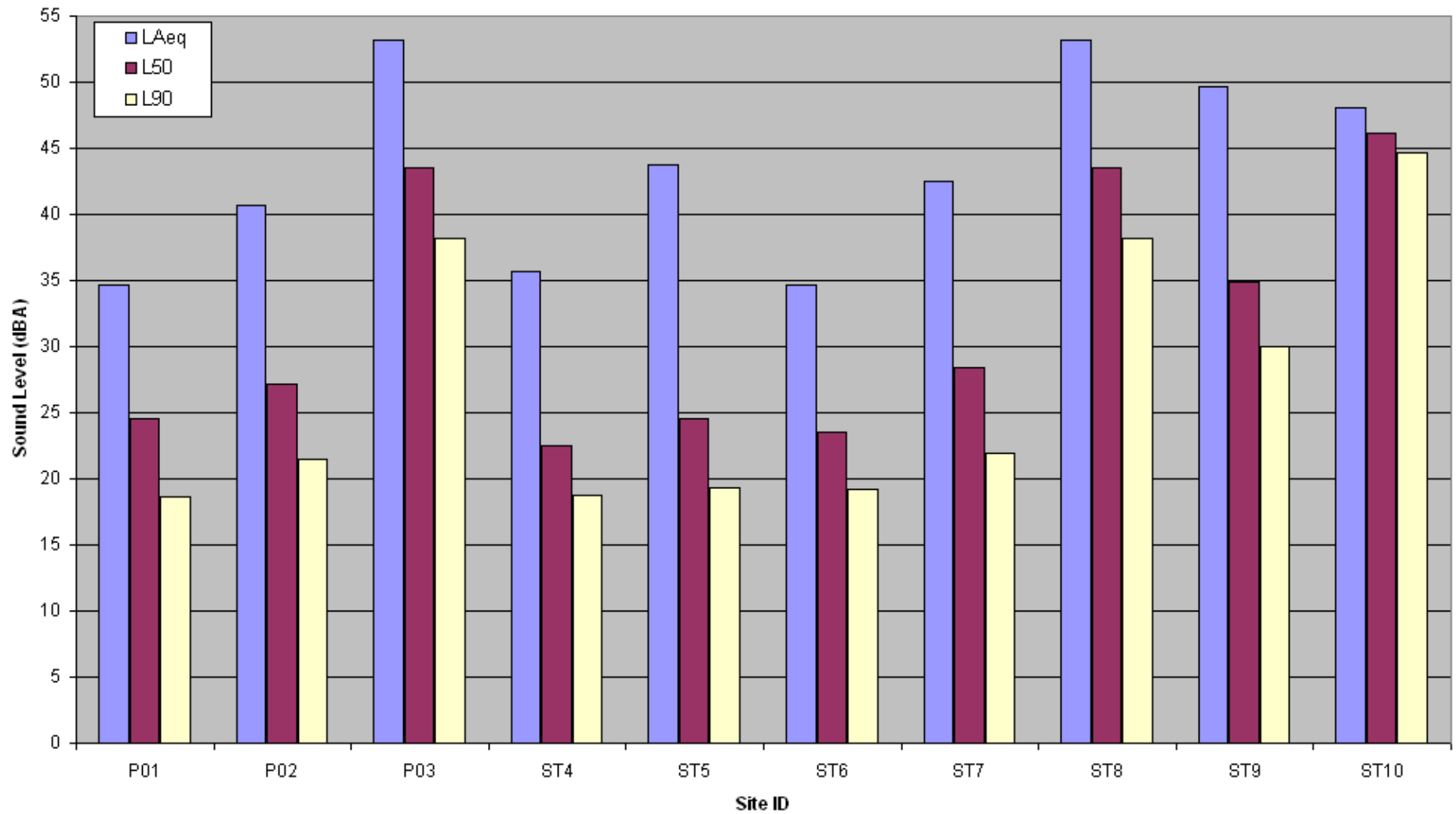


Figure 32. Summary of measured ambient sound level data – Existing Ambient (L_{Aeq}, L₅₀, L₉₀).

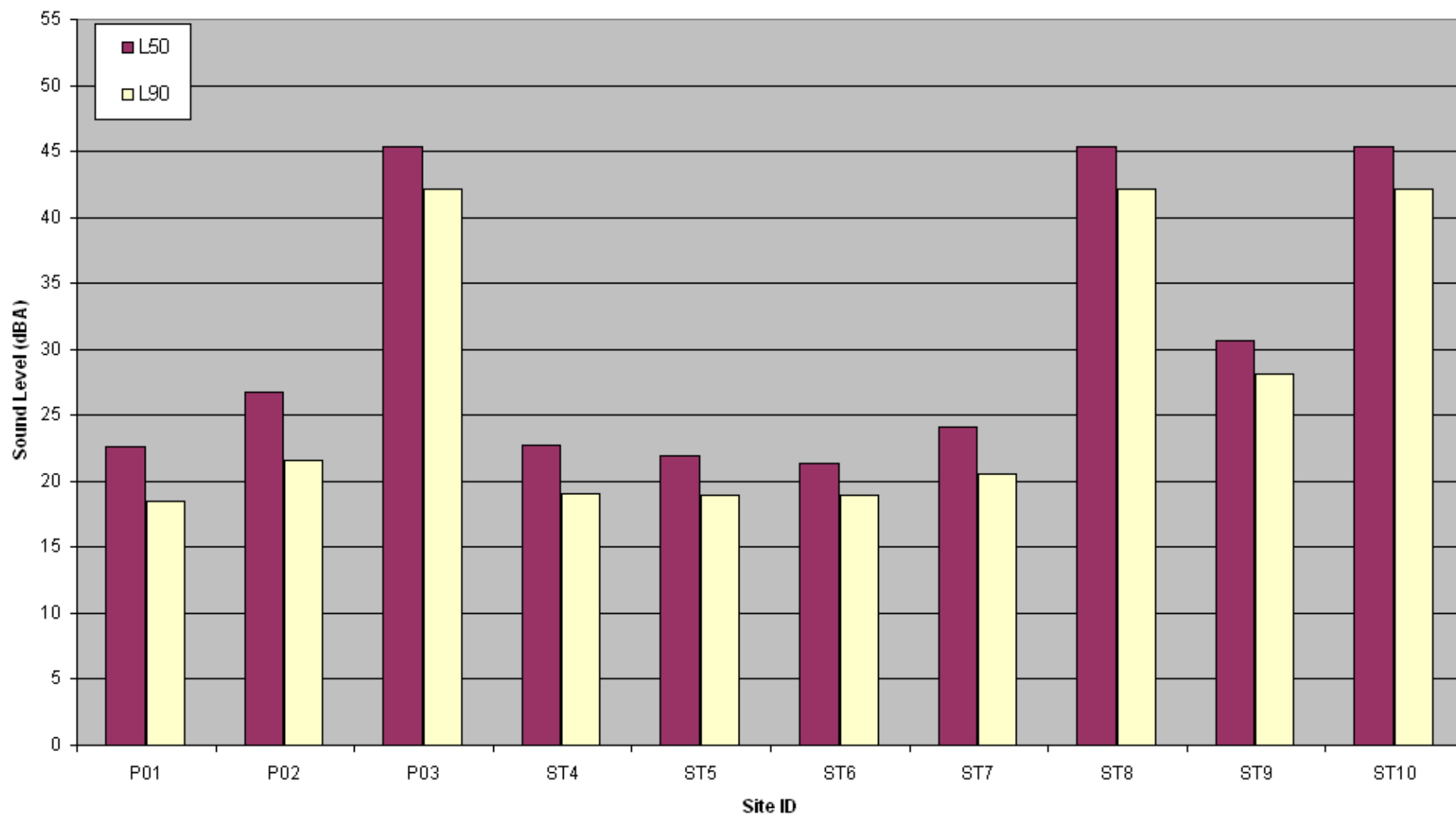


Figure 33. Summary of measured ambient sound level data – Existing Ambient Without Air Tours (L₅₀, L₉₀).

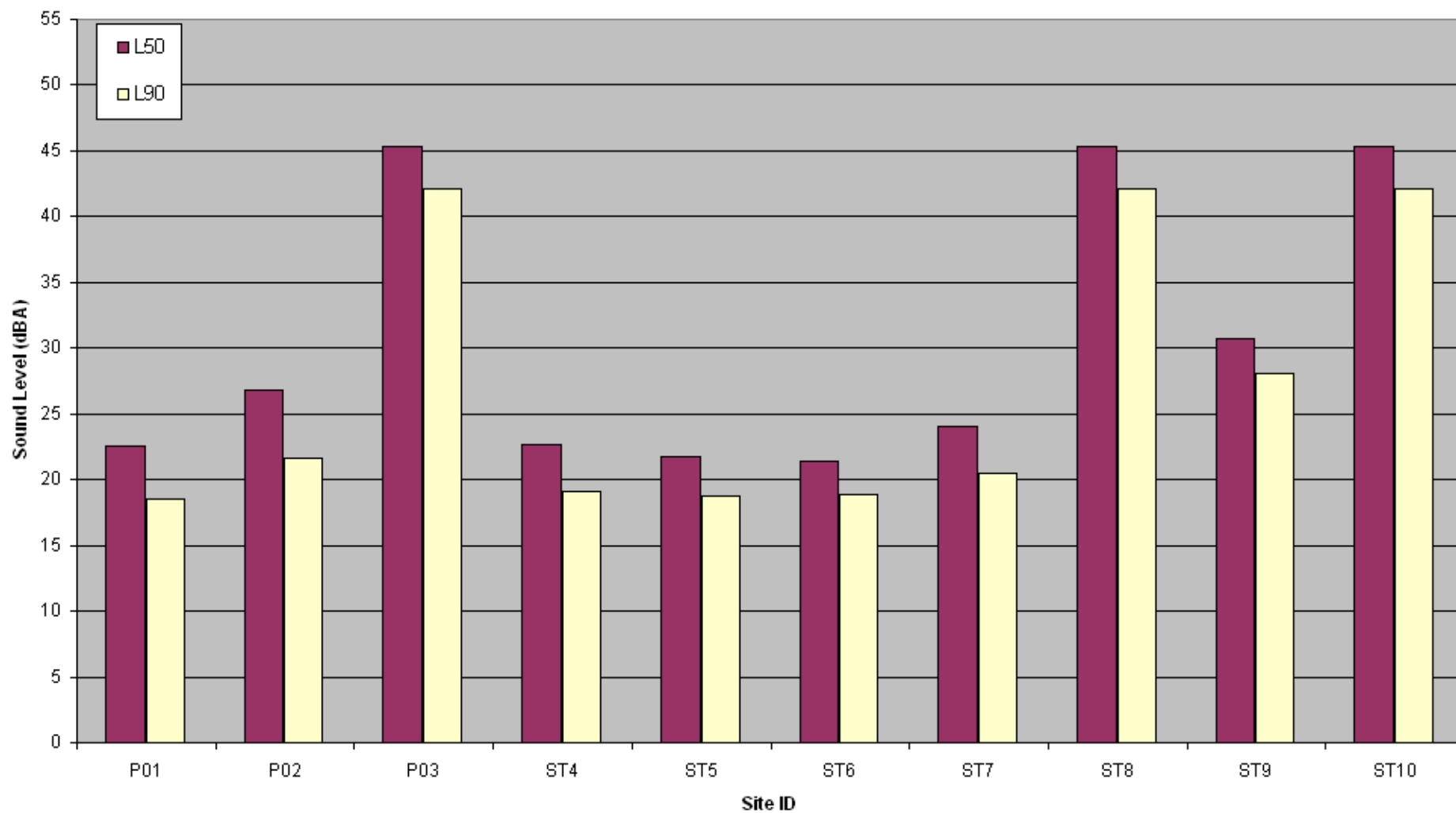


Figure 34. Summary of measured ambient sound level data – Existing Ambient Without All Aircraft (L₅₀, L₉₀).

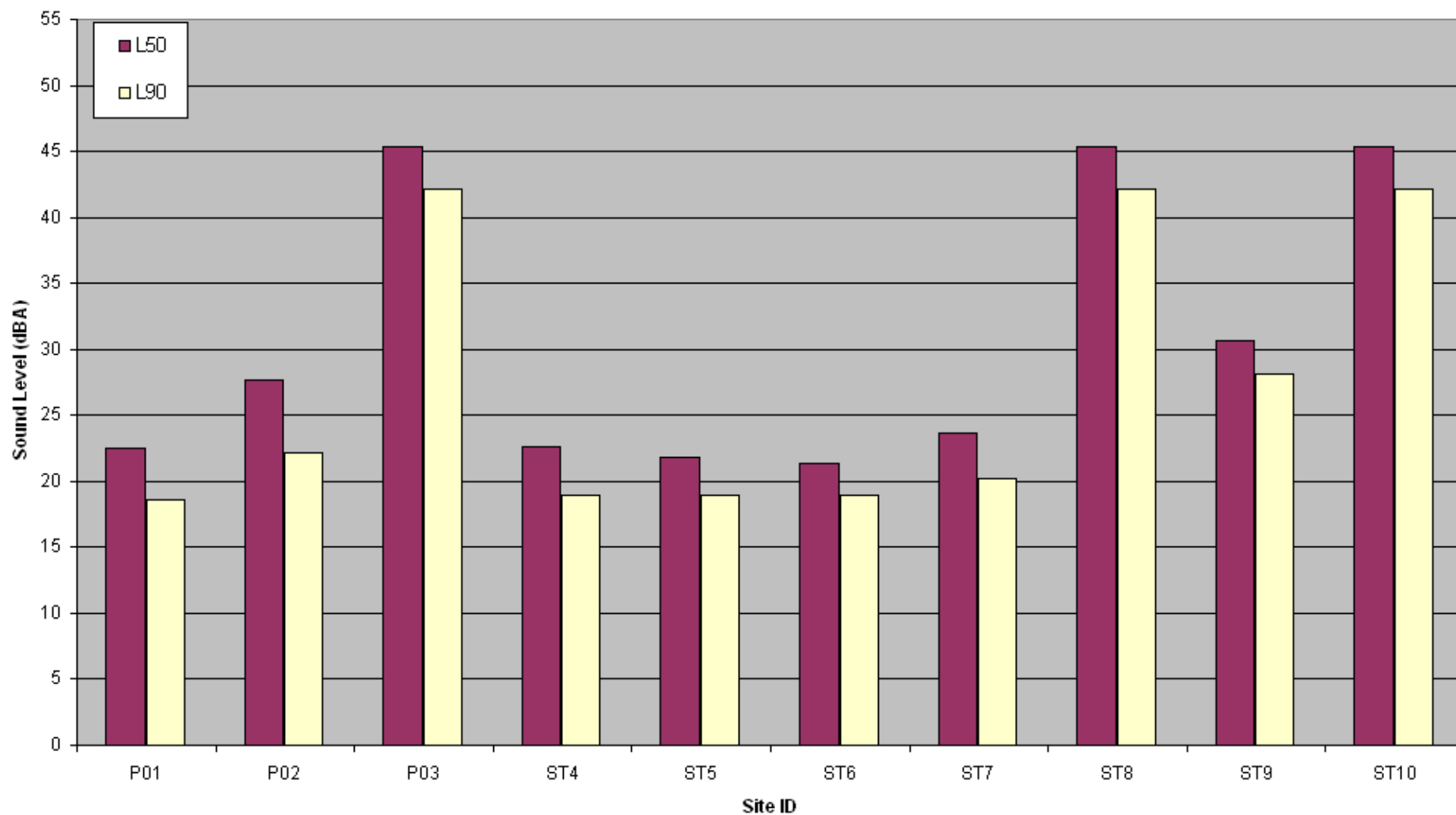


Figure 35. Summary of measured ambient sound level data – Natural Ambient (L₅₀, L₉₀).

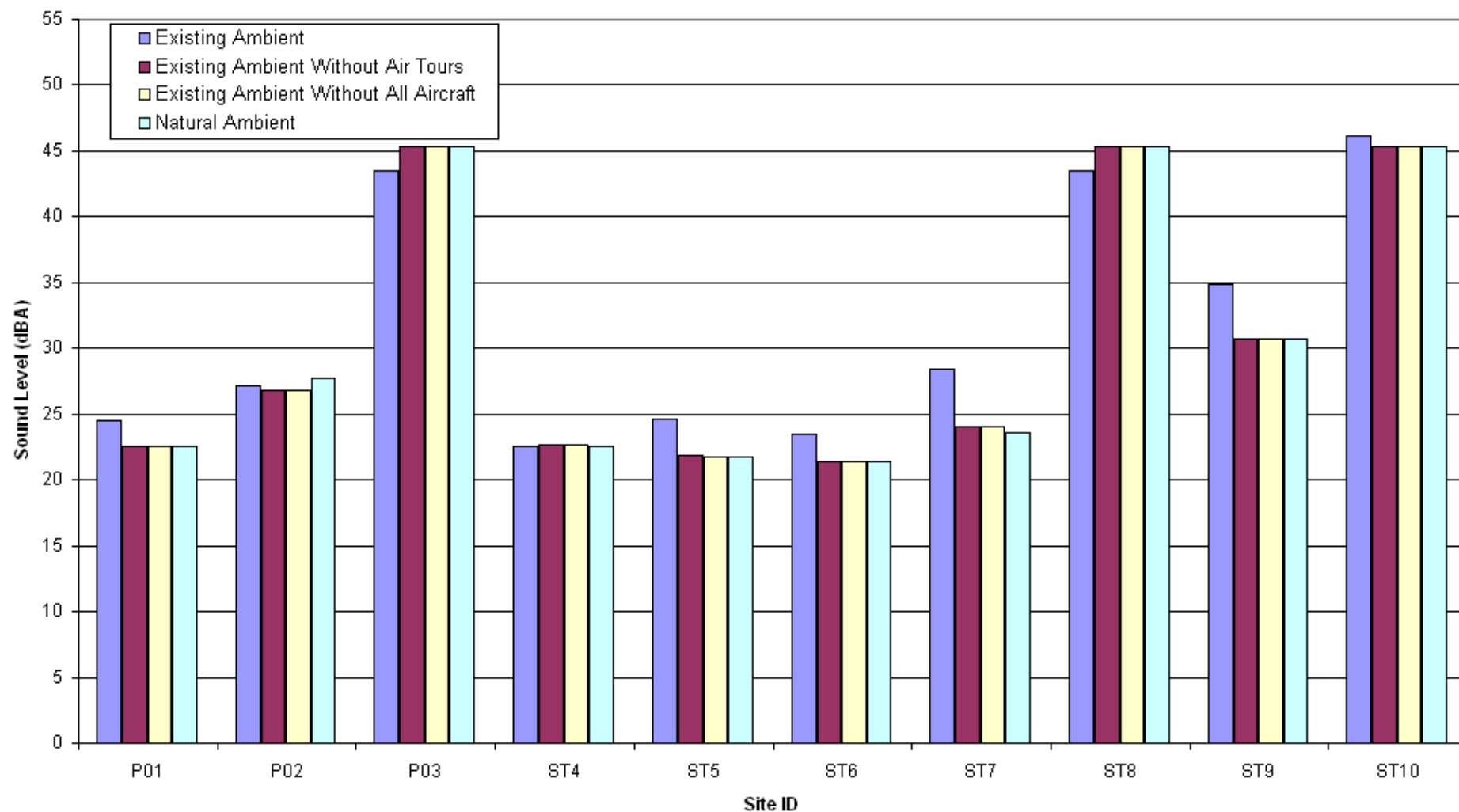


Figure 36. Summary of measured ambient sound level data – L₅₀.

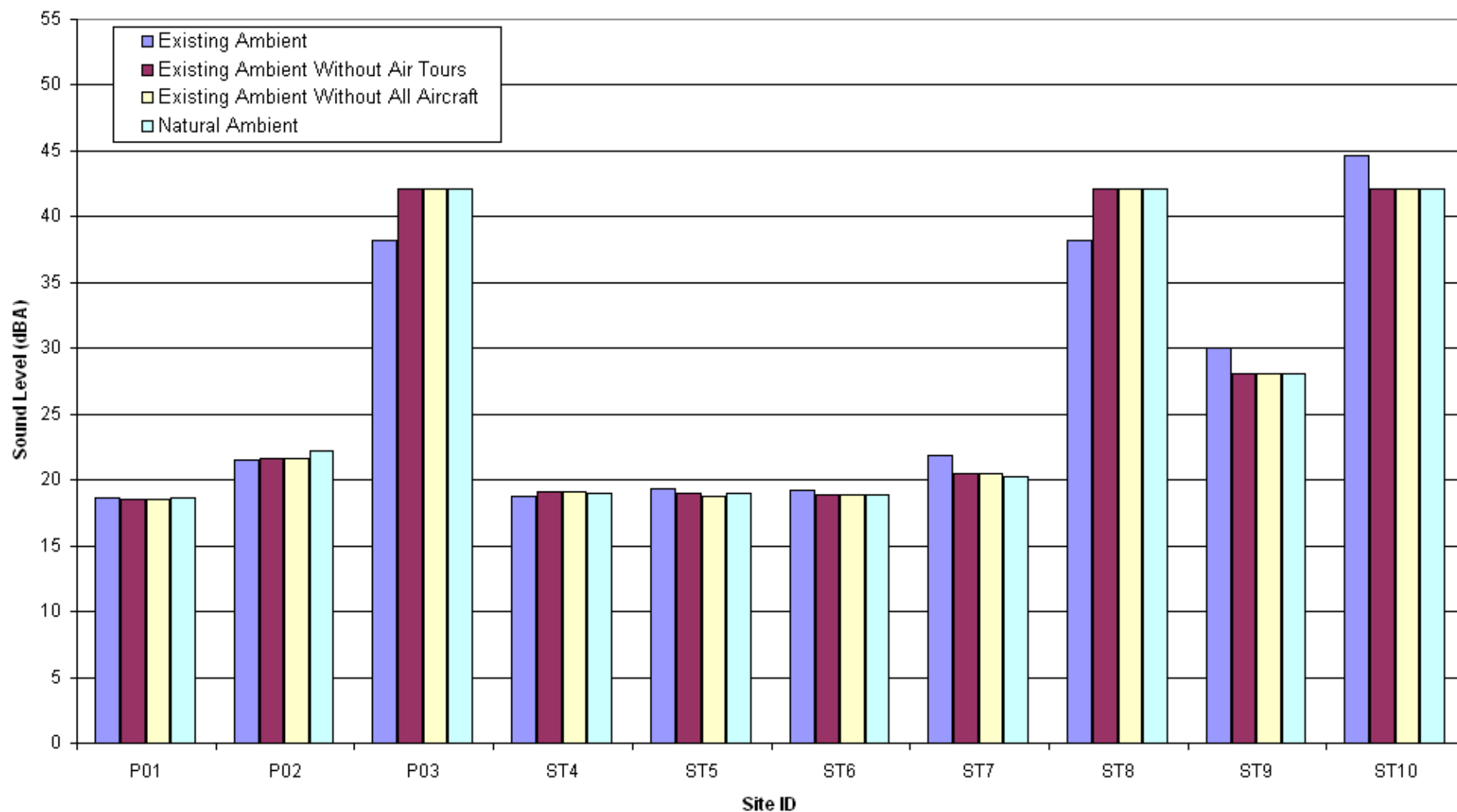


Figure 37. Summary of measured ambient sound level data – L₉₀.

Table 19. Summary of measured ambient sound level data (daytime and nighttime hours included).

Acoustic Zone	Site ID	Total # Days	Existing L _{Aeq} (dBA)	Existing L ₅₀ (dBA)	Existing L ₉₀ (dBA)	Existing W/S (mph)	Existing Without Air Tours L ₅₀ (dBA)	Existing Without Air Tours L ₉₀ (dBA)	Existing Without Air Tours W/S (mph)	Existing Without All Aircraft L ₅₀ (dBA)	Existing Without All Aircraft L ₉₀ (dBA)	Existing Without All Aircraft W/S (mph)	Natural Ambient L ₅₀ (dBA)	Natural Ambient L ₉₀ (dBA)	Natural Ambient W/S (mph)
1: West Rim Crater	P02	30	39.4	26.9	20.5	5.4	26.5	20.6	0.0	26.5	20.6	0.0	27.4	21.2	0.0
1: West Rim Crater	ST7	13	43.7	27.8	21.2	5.4	23.5	19.5	7.6	23.5	19.5	7.5	23.1	19.1	7.6
2: Haleakalā Crater	P01	29	35.1	21.6	18.0	3.7	20.2	18.0	5.0	20.2	18.0	5.0	20.1	18.1	5.0
2: Haleakalā Crater	ST5	14	42.0	24.7	19.0	5.7	21.7	18.7	5.4	21.6	18.6	5.4	21.6	18.7	5.4
2: Haleakalā Crater	ST6	15	32.2	21.3	19.0	4.3	20.1	18.8	5.4	20.1	18.8	5.4	20.1	18.8	5.4
3: Kaupo Gap	ST4	15	34.6	19.3	17.7	6.4	19.5	17.8	8.9	19.5	17.8	8.9	19.4	17.8	8.8
4: Kipahulu Coastal	P03	31	52.7	45.7	38.5	1.4	47.9	43.8	0.8	47.9	43.8	0.8	47.9	43.8	0.8
4: Kipahulu Coastal	ST8*	2	52.7	45.7	38.5	1.4	47.9	43.8	0.8	47.9	43.8	0.8	47.9	43.8	0.8
4: Kipahulu Coastal	ST10†	1	48.0	46.3	44.8	9.2	47.9	43.8	0.8	47.9	43.8	0.8	47.9	43.8	0.8
5: Upper Kipahulu Valley	ST9	15	49.1	42.3	31.1	0.3	32.1	28.6	0.5	32.1	28.6	0.5	32.1	28.6	0.5

* A limited amount of data was collected at this site (2 days); however, due to possible equipment issues, data collected at this site was suspect and, thus, not used in the analyses. As such, the data from Site P03 were used as best available.

† Due to equipment issues, no observer logging was performed at Site ST10. As such, the Existing Ambient sound levels could be determined; however, the remaining ambient sound levels could not be readily determined - the data from Site P03 were used as best available.

Table 20. Summary of acoustic observer log data*

Acoustic Zone	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
1: West Rim Crater	P02	Shrubland	Natural	Short Hike	5369	546	0	2109	2714	10.2%	10.2%
1: West Rim Crater	ST7	Bare Rock/Sand/Clay	Developed	Overlook	2421	60	11	665	1685	2.5%	2.9%
2: Haleakalā Crater	P01	Shrubland	Natural	Backcountry	3763	1134	0	154	2475	30.1%	30.1%
2: Haleakalā Crater	ST5	Shrubland	Natural	Backcountry	3348	1066	97	186	1999	31.8%	34.7%
2: Haleakalā Crater	ST6	Bare Rock/Sand/Clay	Natural	Backcountry	3590	2350	0	43	1197	65.5%	65.5%
3: Kaupo Gap	ST4	Shrubland	Natural	Backcountry	2560	116	0	397	2047	4.5%	4.5%
4: Kipahulu Coastal	P03	Evergreen Forest	Natural/Cultural	Short Hike	6101	975	0	409	4717	16.0%	16.0%
4: Kipahulu Coastal	ST8	Evergreen Forest	Natural/Cultural	Overlook	7179	368	0	2586	4225	5.1%	5.1%
4: Kipahulu Coastal	ST10	Bare Rock/Sand/Clay	Natural/Cultural	Overlook	No Observer Logging	No Observer Logging	No Observer Logging	No Observer Logging	No Observer Logging	No Observer Logging	No Observer Logging
5: Upper Kipahulu Valley	ST9	Evergreen Forest	Natural	Wilderness	3095	861	0	8	2226	27.8%	27.8%

* 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, a few sites have only limited observer logging and no logging at one site.

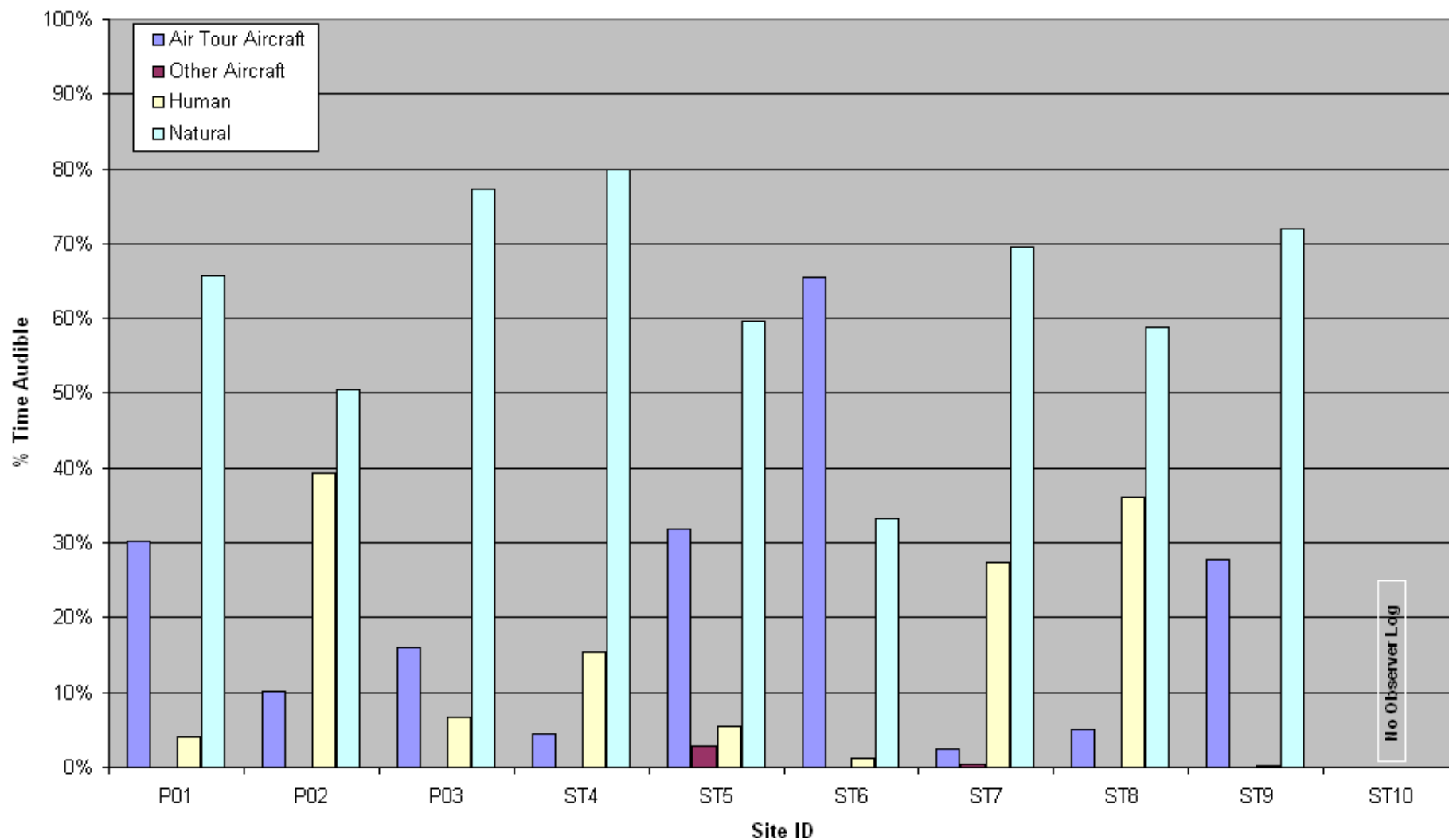


Figure 38. Summary of acoustic observer log data.

Table 21. Summary of acoustic observer log data: number of events per hour and noise-free interval.

	Acoustic Zone	Site ID	Noise-Free Periods	Air Tour Aircraft Events	Other Aircraft Events
Number Periods/Events:	1: West Rim Crater	P02	88	13	8
Mean Time (minutes):	1: West Rim Crater	P02	0:01:09	0:00:42	0:01:23
Minimum Time (minutes):	1: West Rim Crater	P02	0:00:02	0:00:06	0:00:24
Maximum Time (minutes):	1: West Rim Crater	P02	0:12:28	0:02:07	0:02:45
Total Time (minutes):	1: West Rim Crater	P02	1:40:26	0:09:08	0:11:00
Number Periods/Events:	1: West Rim Crater	ST7	35	2	1
Mean Time (minutes):	1: West Rim Crater	ST7	0:01:43	0:01:17	0:01:01
Minimum Time (minutes):	1: West Rim Crater	ST7	0:00:05	0:01:13	0:01:01
Maximum Time (minutes):	1: West Rim Crater	ST7	0:05:54	0:01:21	0:01:01
Total Time (minutes):	1: West Rim Crater	ST7	1:00:04	0:02:34	0:01:01
Number Periods/Events:	2: Haleakalā Crater	P01	224	57	0
Mean Time (minutes):	2: Haleakalā Crater	P01	0:00:36	0:01:06	0:00:00
Minimum Time (minutes):	2: Haleakalā Crater	P01	0:00:05	0:00:08	0:00:00
Maximum Time (minutes):	2: Haleakalā Crater	P01	0:03:15	0:08:03	0:00:00
Total Time (minutes):	2: Haleakalā Crater	P01	2:16:15	1:02:42	0:00:00
Number Periods/Events:	2: Haleakalā Crater	ST5	66	13	1
Mean Time (minutes):	2: Haleakalā Crater	ST5	0:00:36	0:01:33	0:01:43
Minimum Time (minutes):	2: Haleakalā Crater	ST5	0:00:05	0:00:06	0:01:43
Maximum Time (minutes):	2: Haleakalā Crater	ST5	0:02:28	0:04:42	0:01:43
Total Time (minutes):	2: Haleakalā Crater	ST5	0:39:48	0:20:09	0:01:43
Number Periods/Events:	2: Haleakalā Crater	ST6	35	32	0
Mean Time (minutes):	2: Haleakalā Crater	ST6	0:00:35	0:01:14	0:00:00
Minimum Time (minutes):	2: Haleakalā Crater	ST6	0:00:05	0:00:08	0:00:00
Maximum Time (minutes):	2: Haleakalā Crater	ST6	0:02:30	0:04:14	0:00:00
Total Time (minutes):	2: Haleakalā Crater	ST6	0:20:11	0:39:44	0:00:00
Number Periods/Events:	3: Kaupo Gap	ST4	24	12	0
Mean Time (minutes):	3: Kaupo Gap	ST4	0:02:45	0:01:11	0:00:00
Minimum Time (minutes):	3: Kaupo Gap	ST4	0:00:18	0:00:15	0:00:00
Maximum Time (minutes):	3: Kaupo Gap	ST4	0:13:04	0:05:52	0:00:00
Total Time (minutes):	3: Kaupo Gap	ST4	1:05:54	0:14:07	0:00:00
Number Periods/Events:	4: Kipahulu Coastal	P03	88	19	0
Mean Time (minutes):	4: Kipahulu Coastal	P03	0:01:28	0:01:11	0:00:00
Minimum Time (minutes):	4: Kipahulu Coastal	P03	0:00:06	0:00:38	0:00:00
Maximum Time (minutes):	4: Kipahulu Coastal	P03	0:07:38	0:02:01	0:00:00
Total Time (minutes):	4: Kipahulu Coastal	P03	2:08:20	0:22:30	0:00:00
Number Periods/Events:	4: Kipahulu Coastal	ST8	46	8	0
Mean Time (minutes):	4: Kipahulu Coastal	ST8	0:01:32	0:00:46	0:00:00
Minimum Time (minutes):	4: Kipahulu Coastal	ST8	0:00:05	0:00:24	0:00:00
Maximum Time (minutes):	4: Kipahulu Coastal	ST8	0:07:30	0:01:17	0:00:00

	Acoustic Zone	Site ID	Noise-Free Periods	Air Tour Aircraft Events	Other Aircraft Events
Total Time (minutes):	4: Kipahulu Coastal	ST8	1:10:28	0:06:08	0:00:00
	4: Kipahulu Coastal	ST10	(No observer logging)	(No observer logging)	(No observer logging)
Number Periods/Events:	5: Upper Kipahulu Valley	ST9	11	10	0
Mean Time (minutes):	5: Upper Kipahulu Valley	ST9	0:03:22	0:01:26	0:00:00
Minimum Time (minutes):	5: Upper Kipahulu Valley	ST9	0:00:14	0:00:23	0:00:00
Maximum Time (minutes):	5: Upper Kipahulu Valley	ST9	0:09:29	0:03:11	0:00:00
Total Time (minutes):	5: Upper Kipahulu Valley	ST9	0:37:06	0:14:21	0:00:00

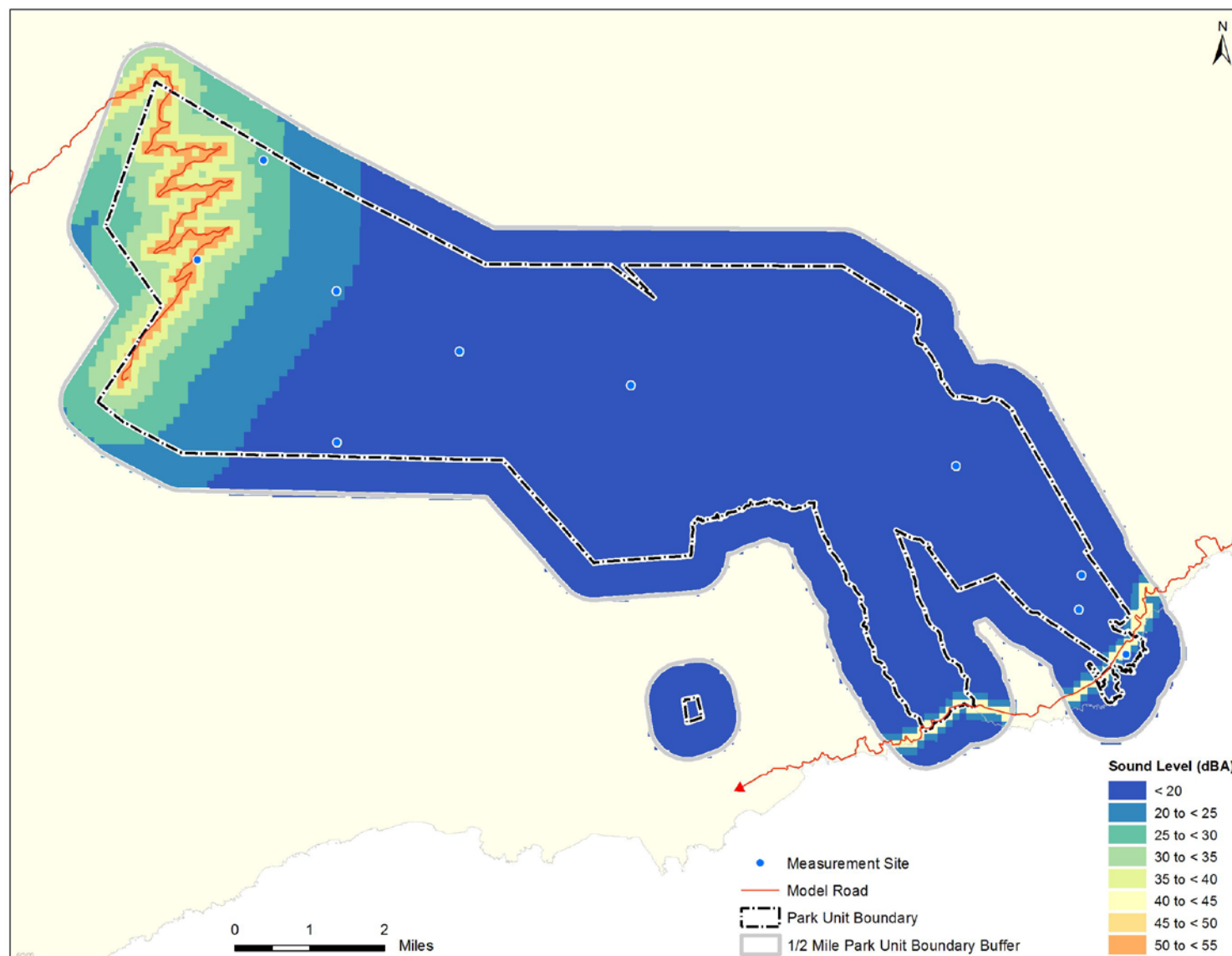


Figure 39. Roadway ambient map.

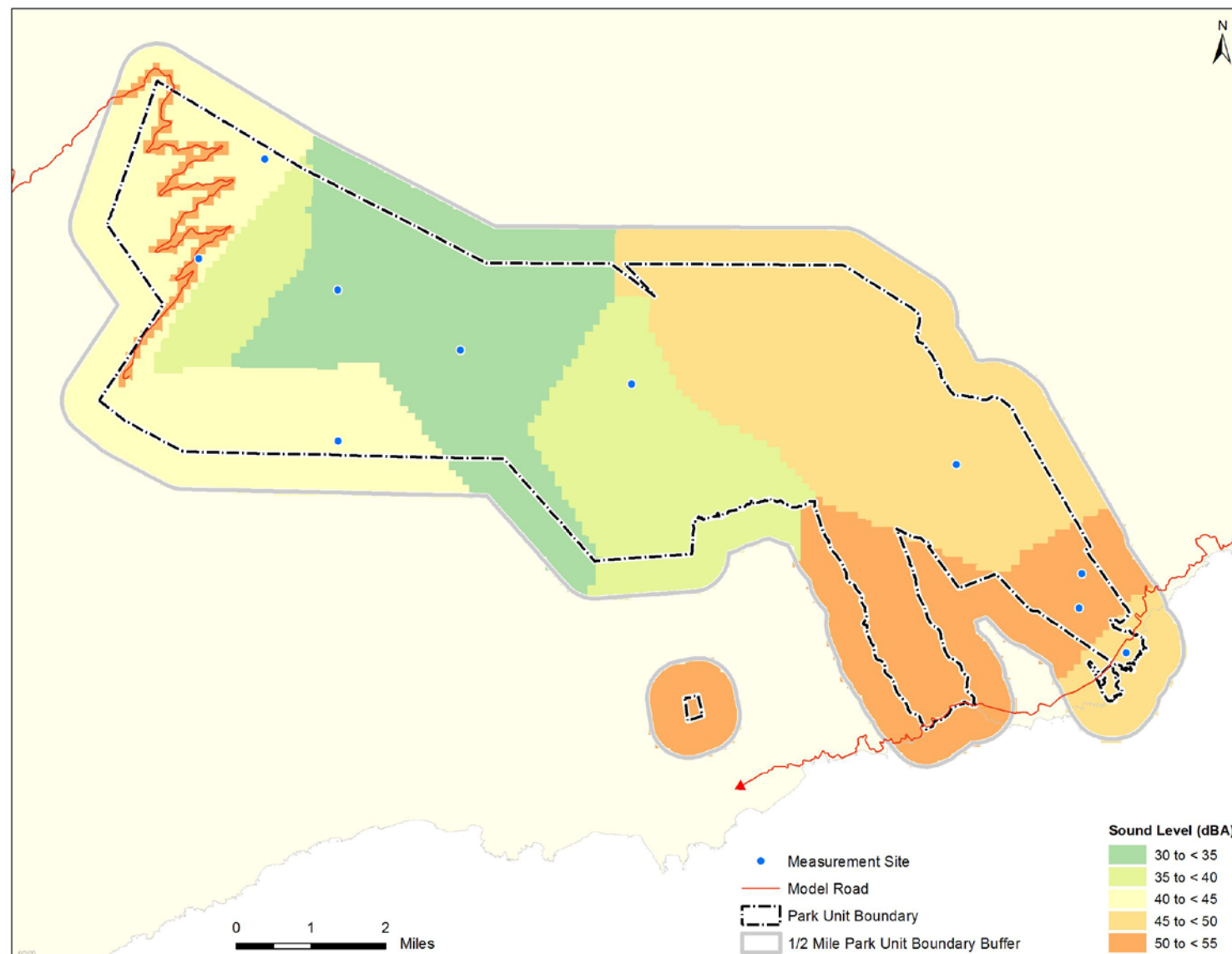


Figure 40. Baseline ambient map – Existing Ambient: L_{Aeq} .

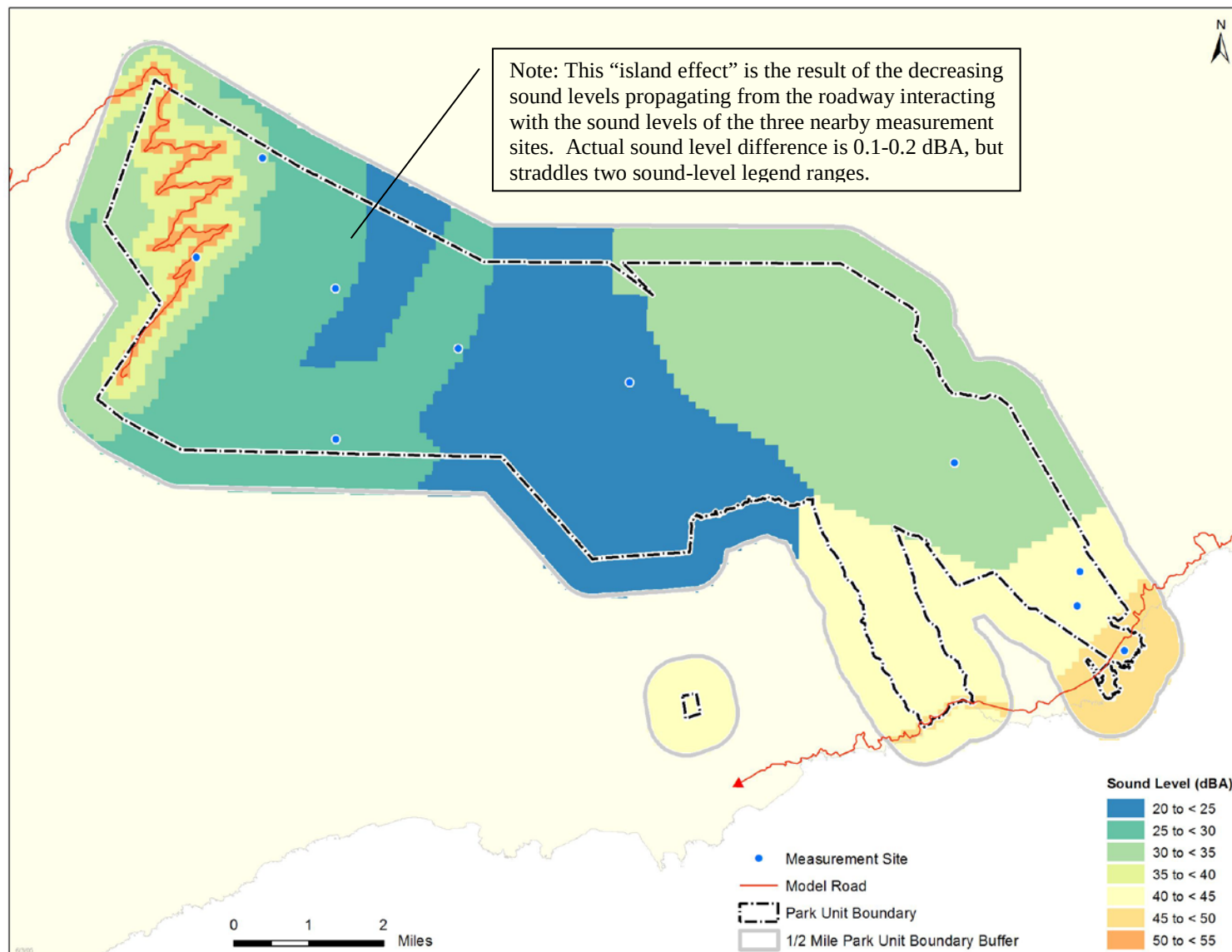


Figure 41. Baseline ambient map – Existing Ambient: L_{50} .

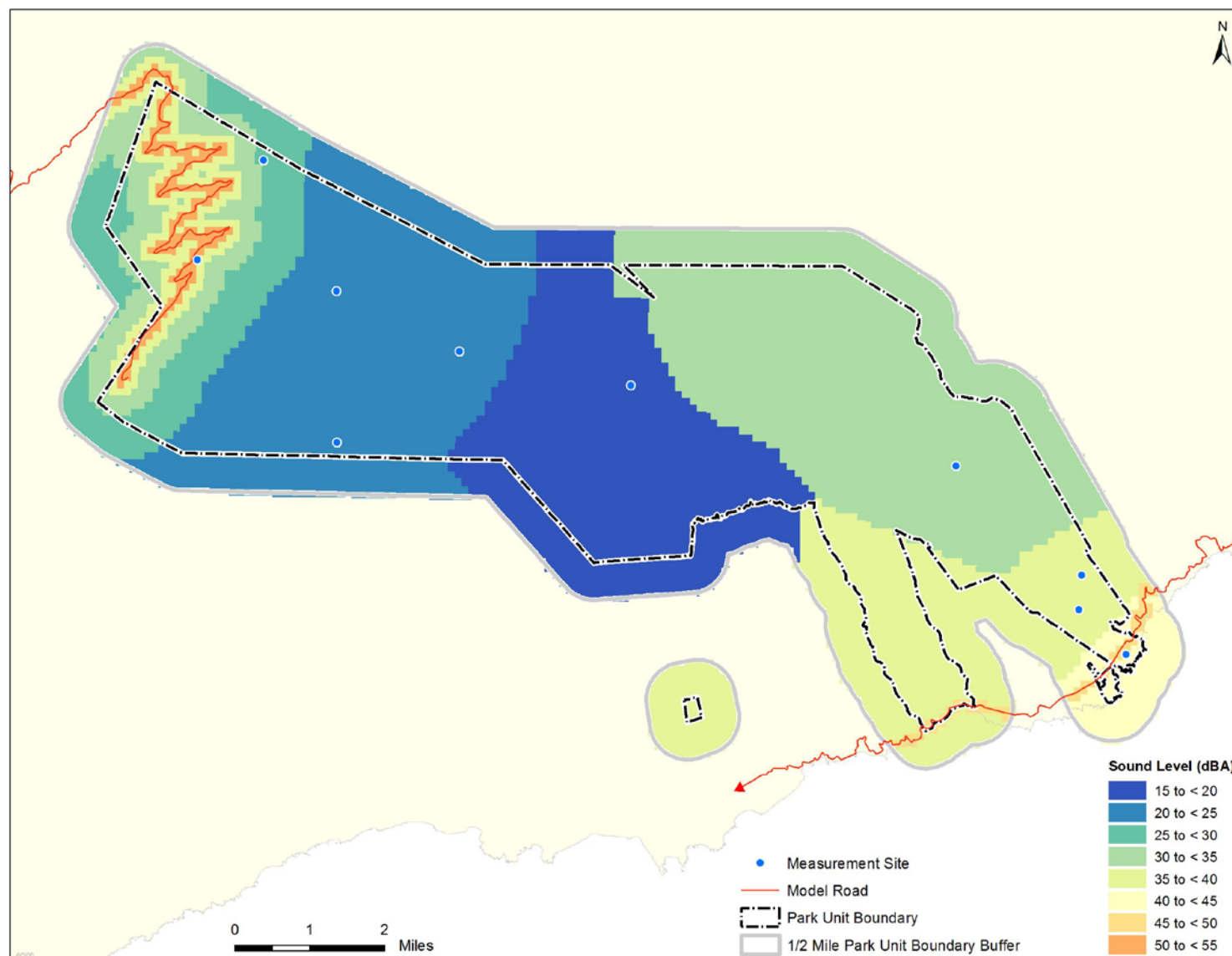


Figure 42. Baseline ambient map – Existing Ambient: L_{90} .

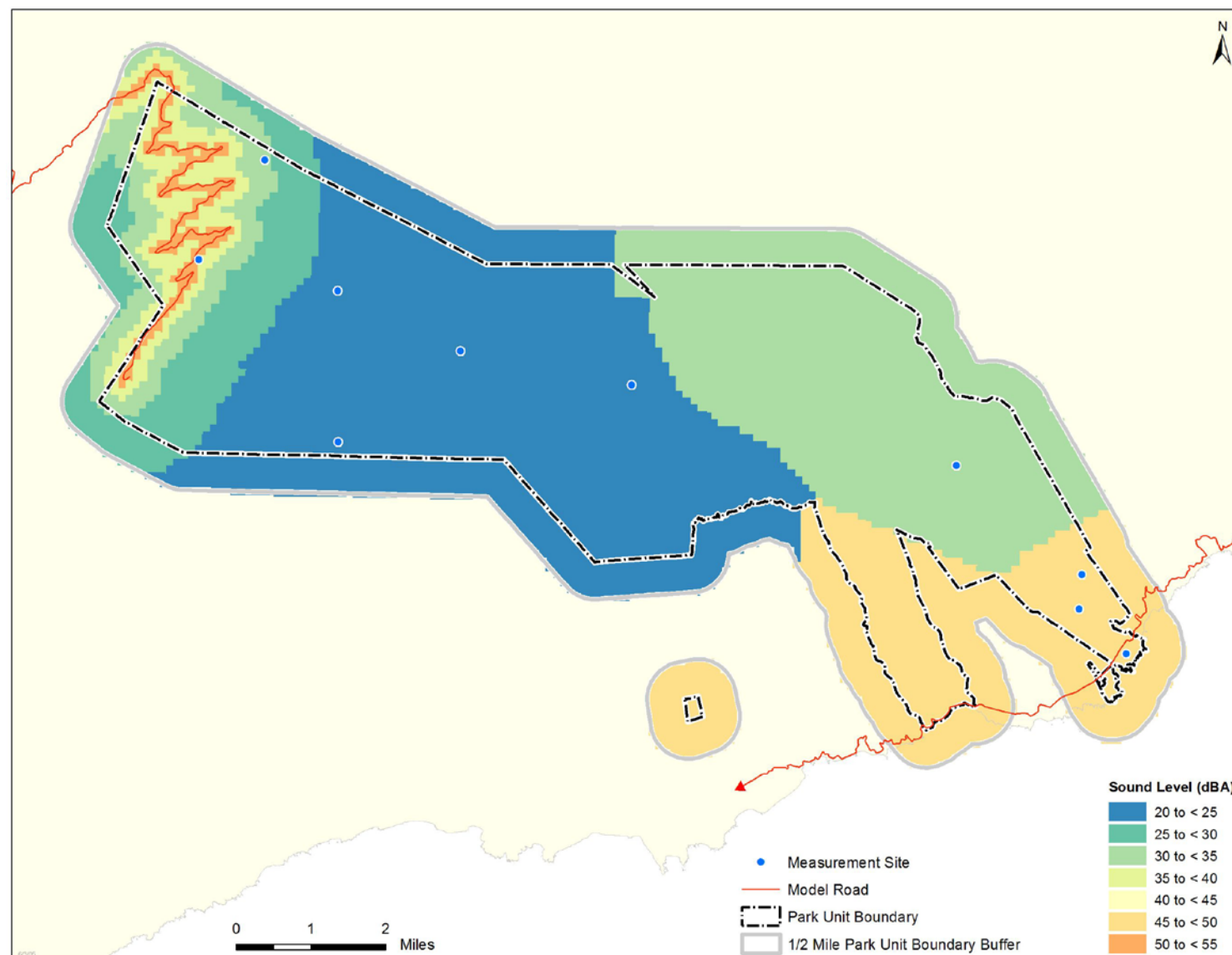


Figure 43. Baseline ambient map – Existing Ambient Without Air Tours: L₅₀.

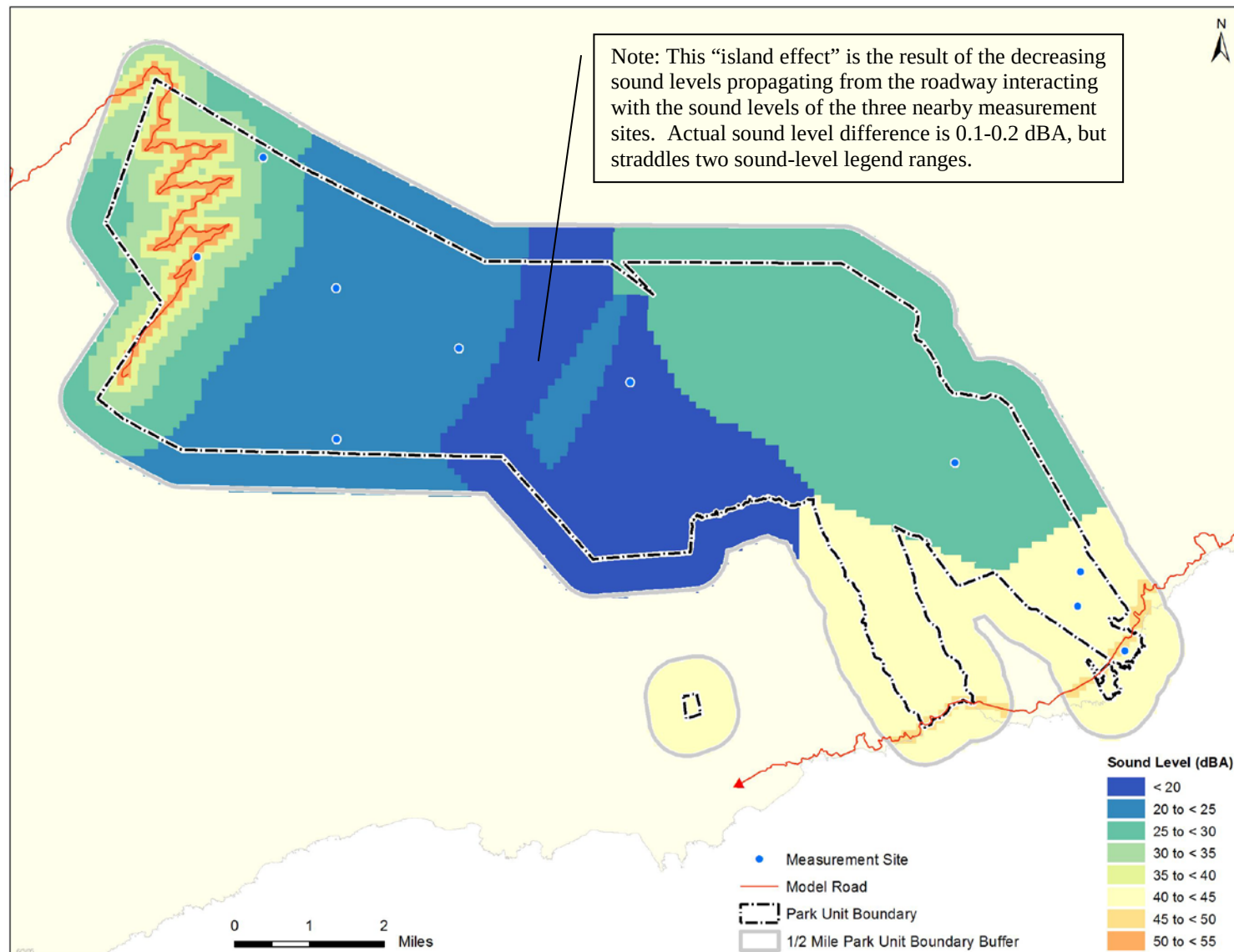


Figure 44. Baseline ambient map – Existing Ambient Without Air Tours: L_{90} .

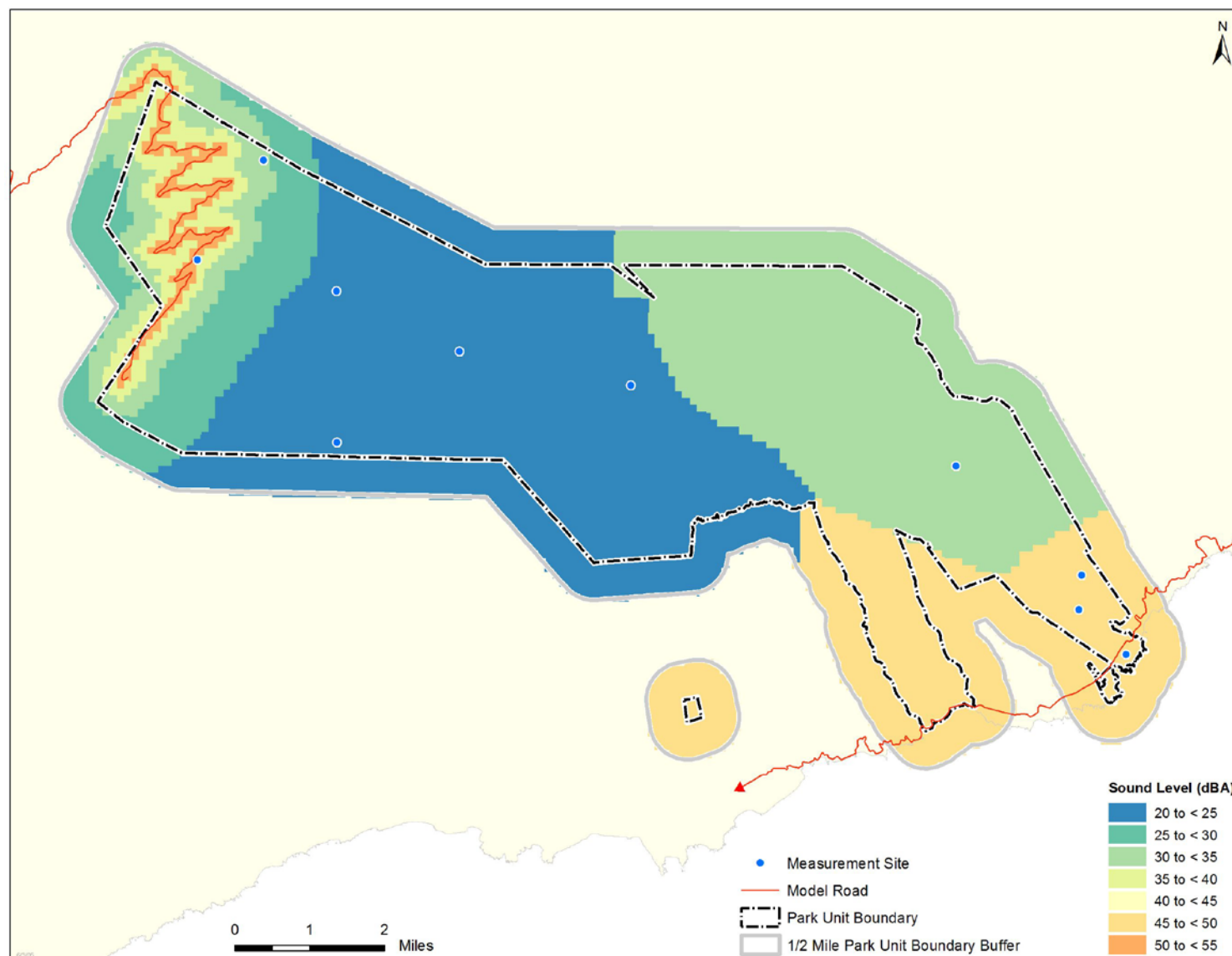


Figure 45. Baseline ambient map – Existing Ambient Without All Aircraft: L_{50} .

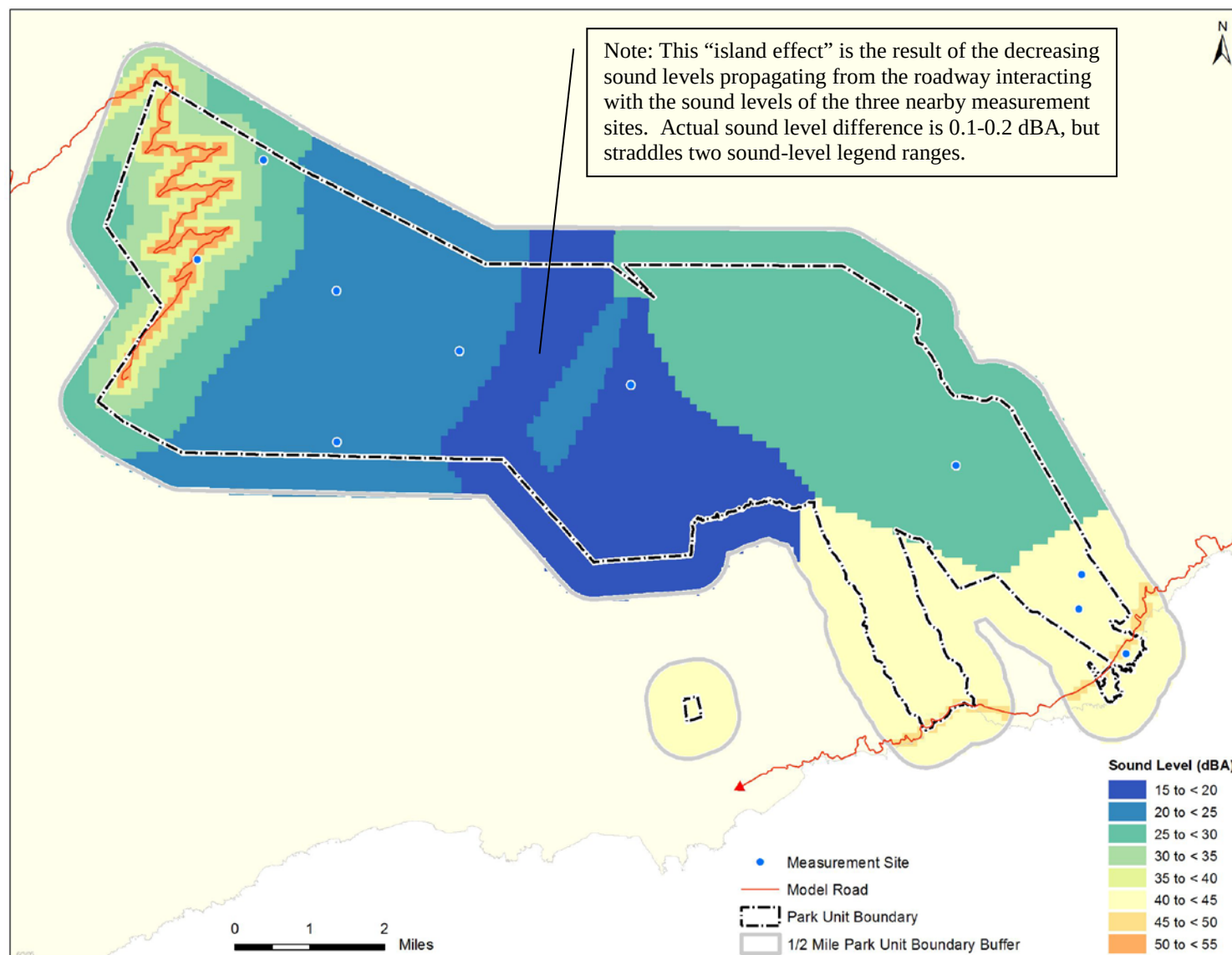


Figure 46. Baseline ambient map – Existing Ambient Without All Aircraft: L_{90} .

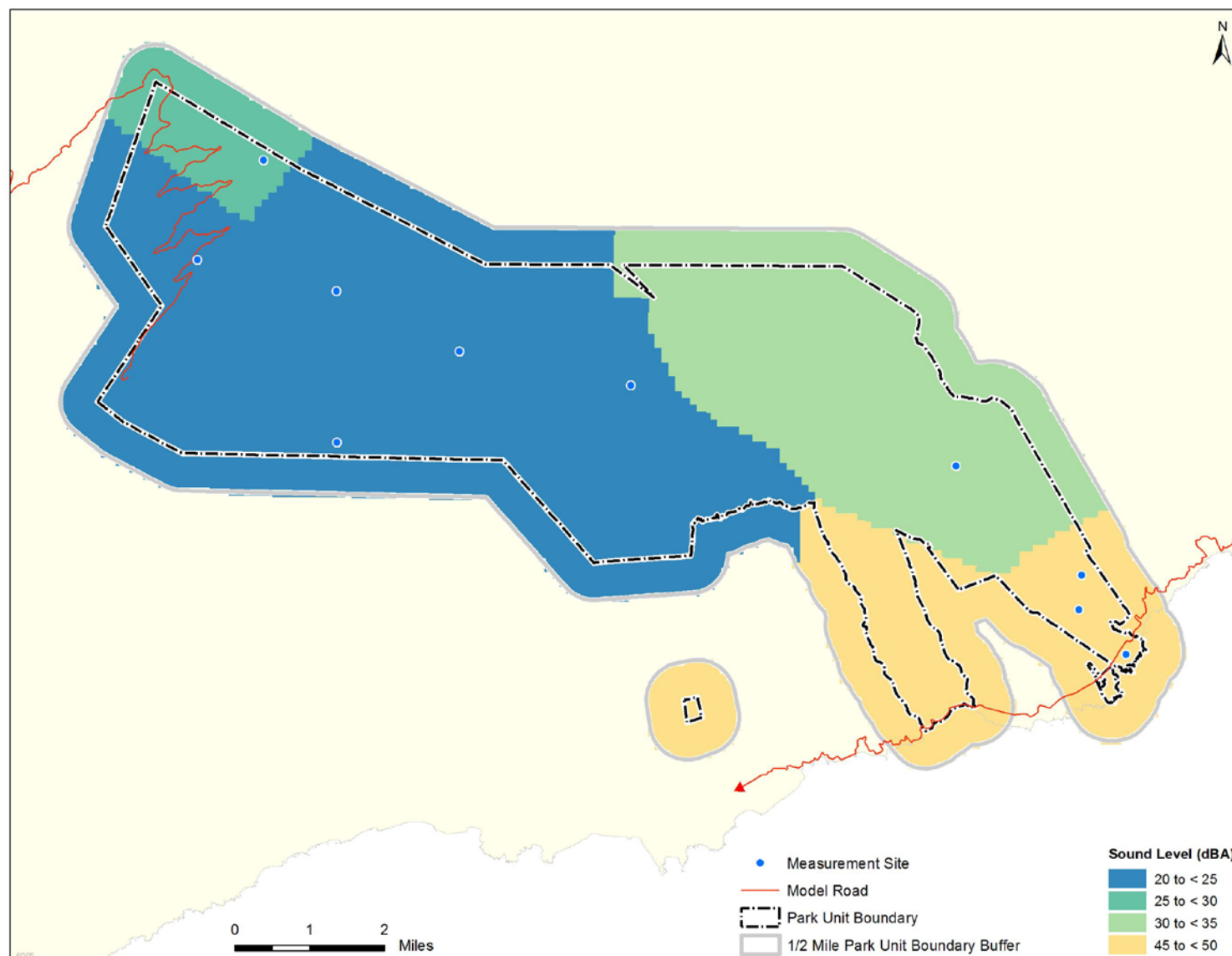


Figure 47. Baseline ambient map – Natural Ambient: L₅₀.

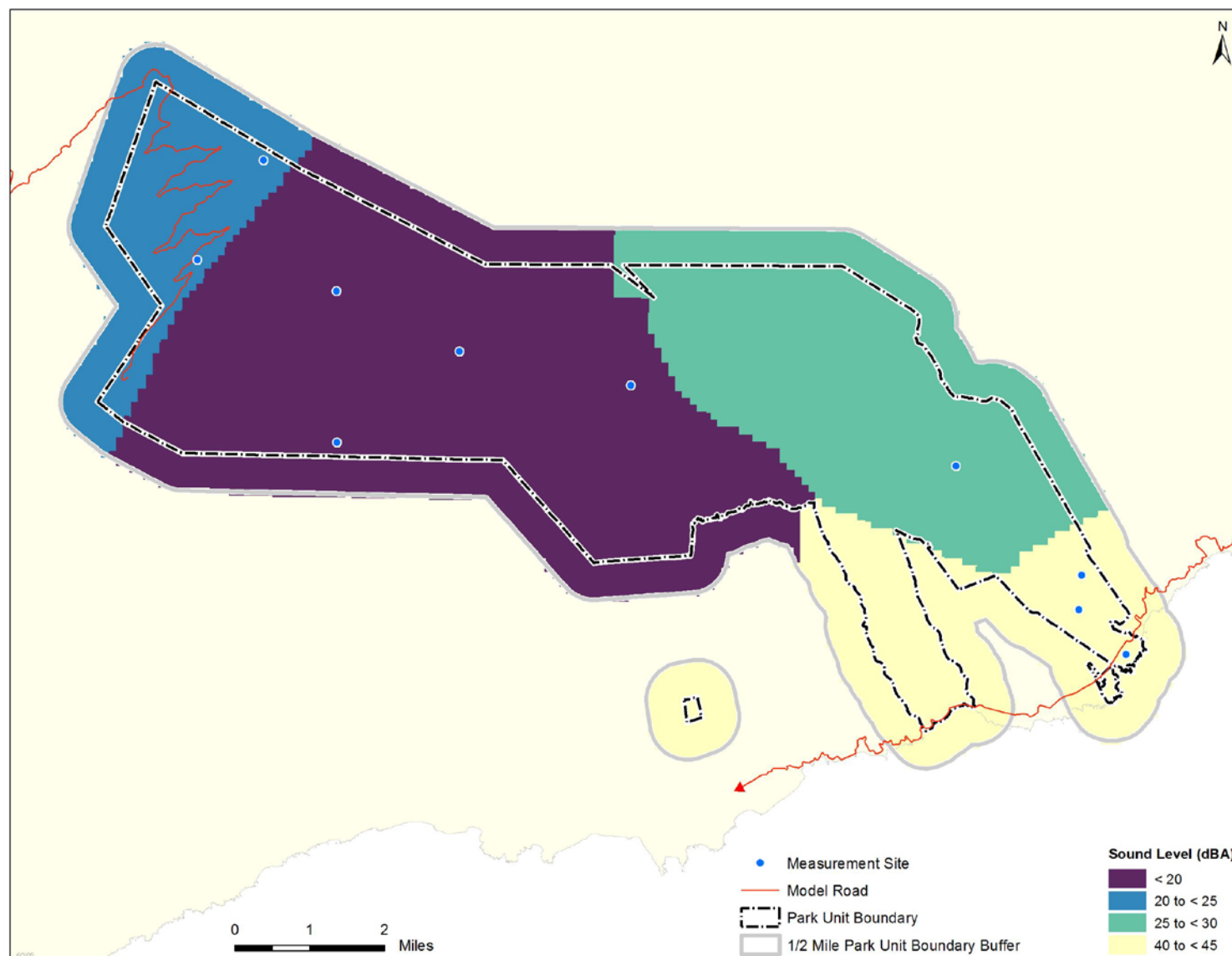


Figure 48. Baseline ambient map – Natural Ambient: L₉₀.

Page left blank intentionally.

APPENDIX A. MEASUREMENT SITE DETAILS

All Haleakalā measurement sites are shown in Figure 49 and described here in detail.

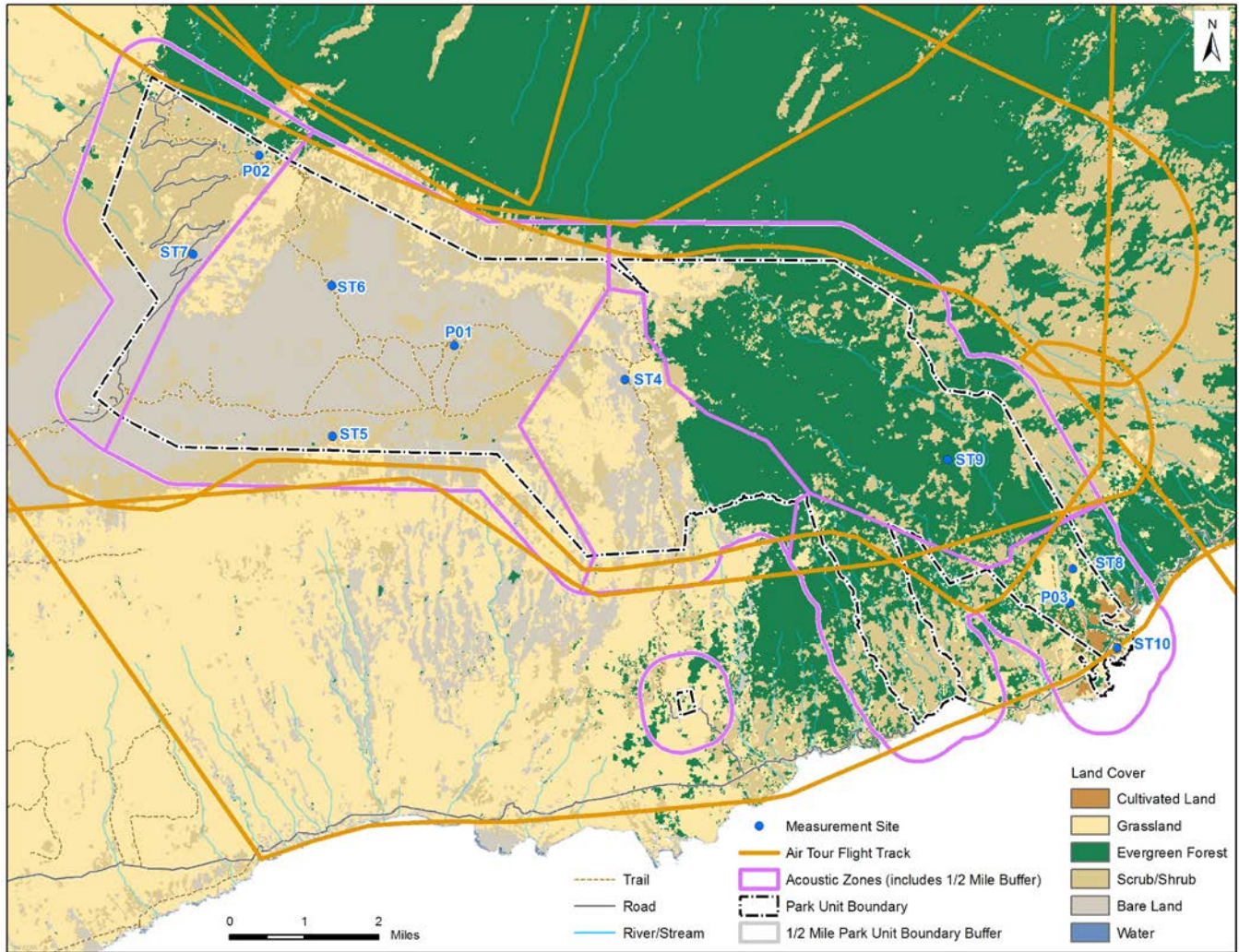


Figure 49. Final measurement sites for Haleakalā.

For each site, the following are included:

- A table providing site description and arranged as follows:
 - o *Site ID*: The unique two-character ID representing the site “number”;
 - o *Site Name*: The name of the site;
 - o *# Measurement Days and Dates*: The total number of days measured and the dates the measurements started and ended, respectively;
 - o *System # and Type*: The numeric identifier and type of the continuous monitoring system

- used at the site (see Table 7 in Section 4.1);
- o *Latitude/Longitude (decimal degrees)*: The latitudinal and longitudinal location of the site in decimal degrees;
 - o *Approximate Elevation (ft)*: The elevation of the site above mean sea level (MSL) in feet;
 - o *Ecological Domain*: The geographic ecosystem unit of the site (see also Appendix E);
 - o *Ecological Division*: The geographic ecosystem subunit of the site (see also Appendix E);
 - o *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 E);
 - o *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 E);
 - o *Management Zone*: The NPS management zone that the site was located in (see also Section 2.5);
 - o *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;
 - o *Site Type*: A designator indicating if the site was a long-term “permanent” site (i.e., data were collected for up to one month), or a short-term, “mobile” site (i.e., data were collected for approximately one to two weeks);
 - o *Site Description*: A short textual description of the site;
 - o *Access Considerations*: A short textual description of any access considerations related to the site; and
 - o *Potential Sound Sources*: Per discussions with the NPS during final site selection (see Section 2.6) and from site visits, the sound sources that may be and were heard at the site.
- 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 5.5, 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 Site P01 – Haleakalā Crater Measurement Site**Table 22. Site P01: description.**

Site ID	P01
Site Name	Namana o ke Akua
# Measurement Days and Dates	29 days - February 27, 2003 to March 27, 2003
System # and Type	6 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.7194 / 156.1813
Approximate Elevation (ft)	7379
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(5) Shrubland
Land Cover Subclass (see Appendix E)	(51) Shrubland
Management Zone (see Section 2.5)	Natural/Cultural/Historical
Site Category (see Section 2.5.1)	Backcountry
Site Type (see Section 2.7.2)	Permanent
Site Description	Shrubland located at about the center of the crater
Access Considerations	Helicopter or 12-mile round trip hike on trail
Potential Sound Sources	Aircraft, Hikers, Birds, Horses, Wind

**Figure 50. Site P01: Description and photograph.**

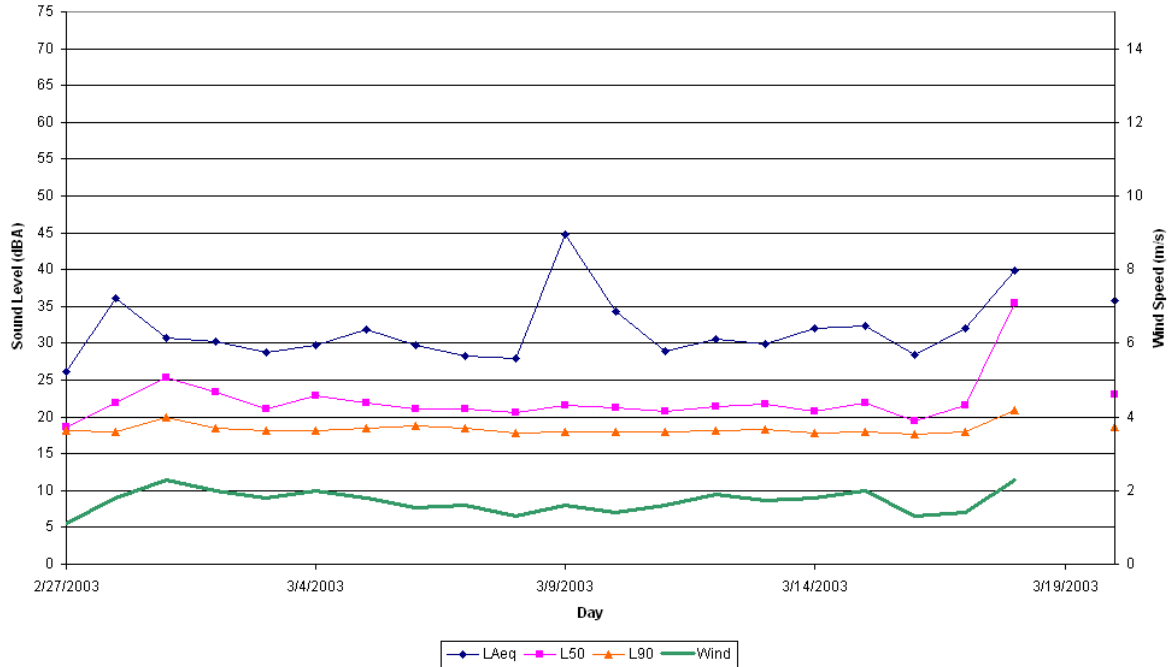


Figure 51. Daily sound levels and wind speeds: Site P01.

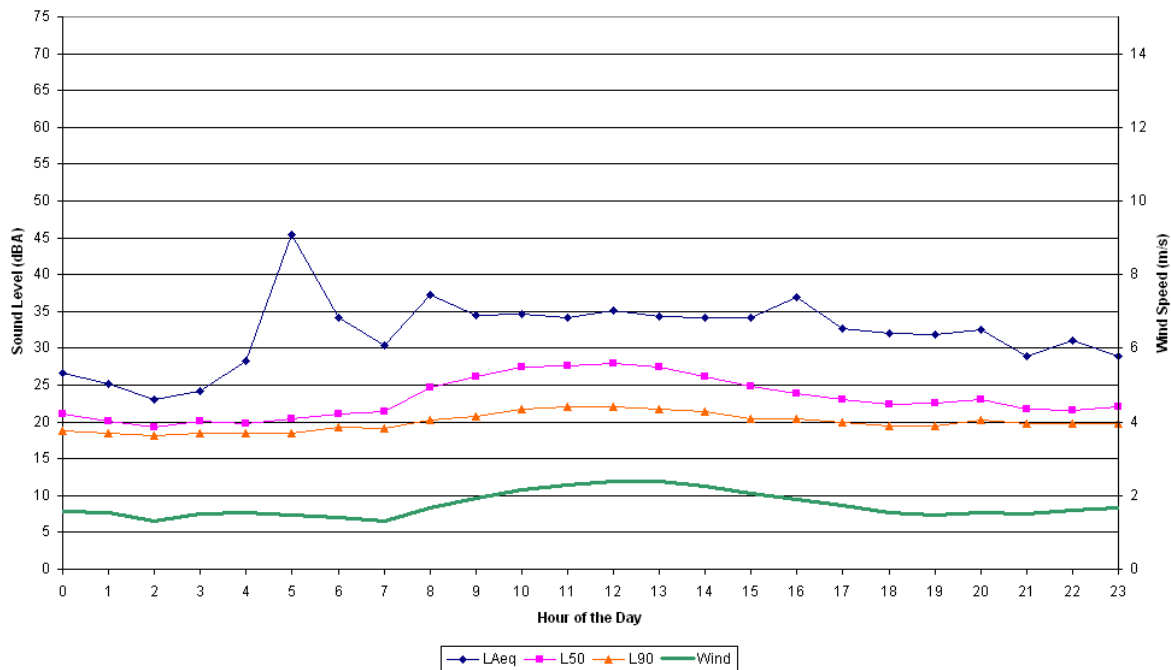


Figure 52. Average hourly sound levels and wind speeds: Site P01.

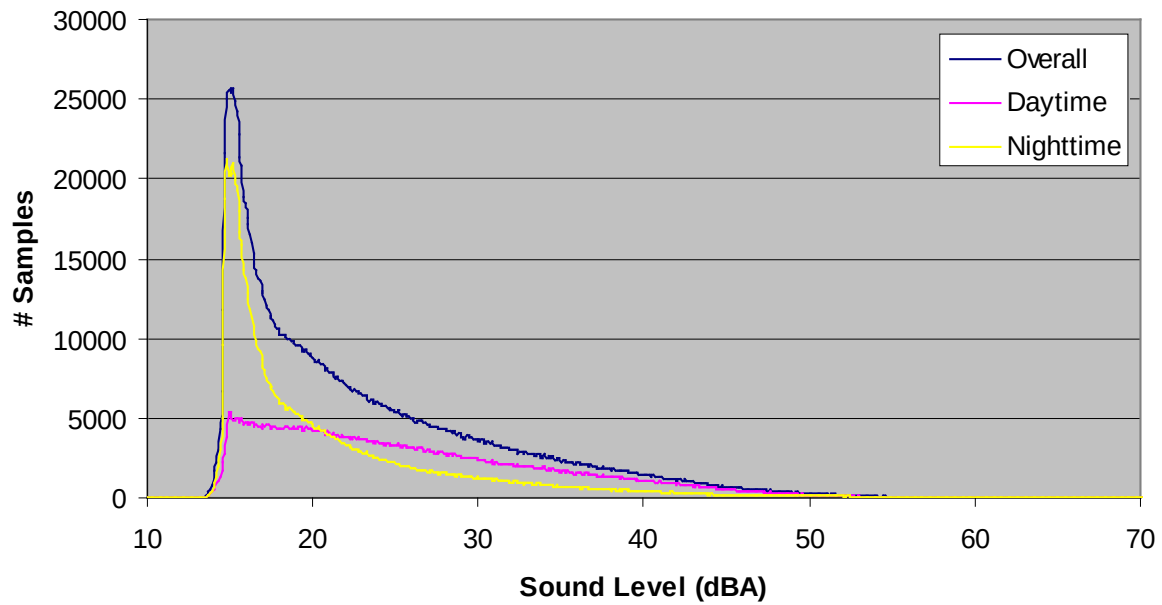


Figure 53. Distribution of data: Site P01.

This site was located near the center of Haleakalā crater. This area is characterized by sounds from wind through the low brush, birds, occasional backcountry hikers and helicopters.

A.2 Site P02 – West Rim Crater Measurement Site**Table 23. Site P02: description.**

Site ID	P02
Site Name	Supply Trail
# Measurement Days and Dates	30 days - February 27, 2003 to March 28, 2003
System # and Type	11 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.7572 / 156.2226
Approximate Elevation (ft)	7703
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(5) Shrubland
Land Cover Subclass (see Appendix E)	(51) Shrubland
Management Zone (see Section 2.5)	Developed/Cultural/Historical
Site Category (see Section 2.5.1)	Short Hike
Site Type (see Section 2.7.2)	Permanent
Site Description	Trail connecting Hosmer Grove Campground to Halemau`u Trail
Access Considerations	2-mile round trip hike on trail
Potential Sound Sources	Aircraft, Vehicles, Hikers, Birds, Wind

**Figure 54. Site P02: Description and photograph.**

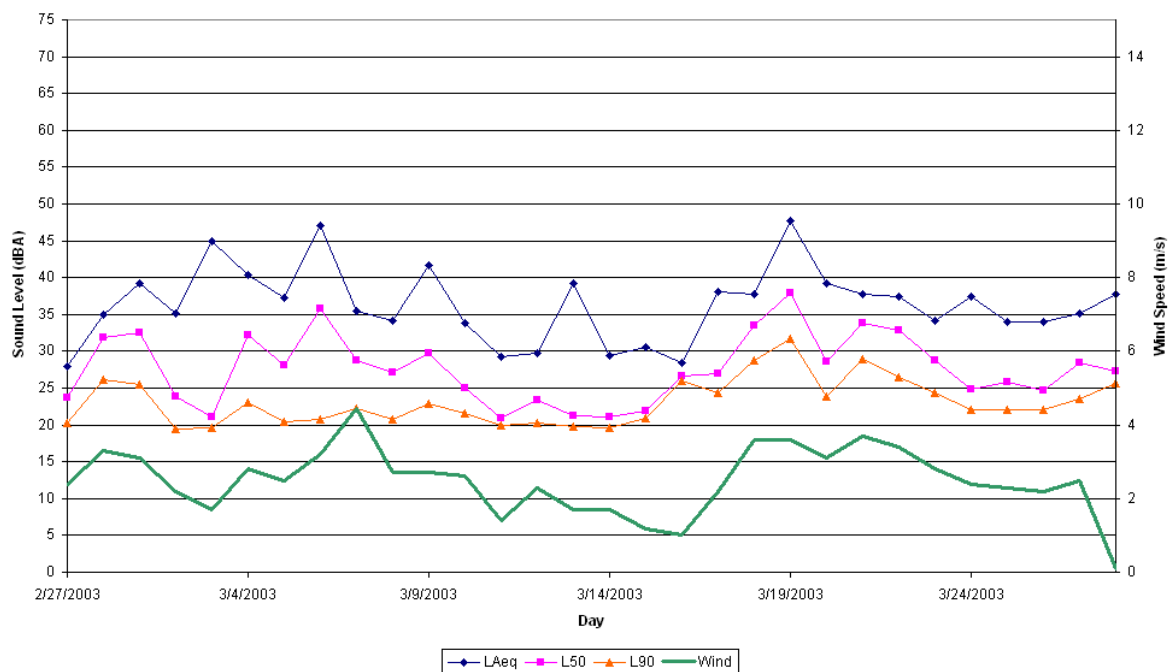


Figure 55. Daily sound levels and wind speeds: Site P02.

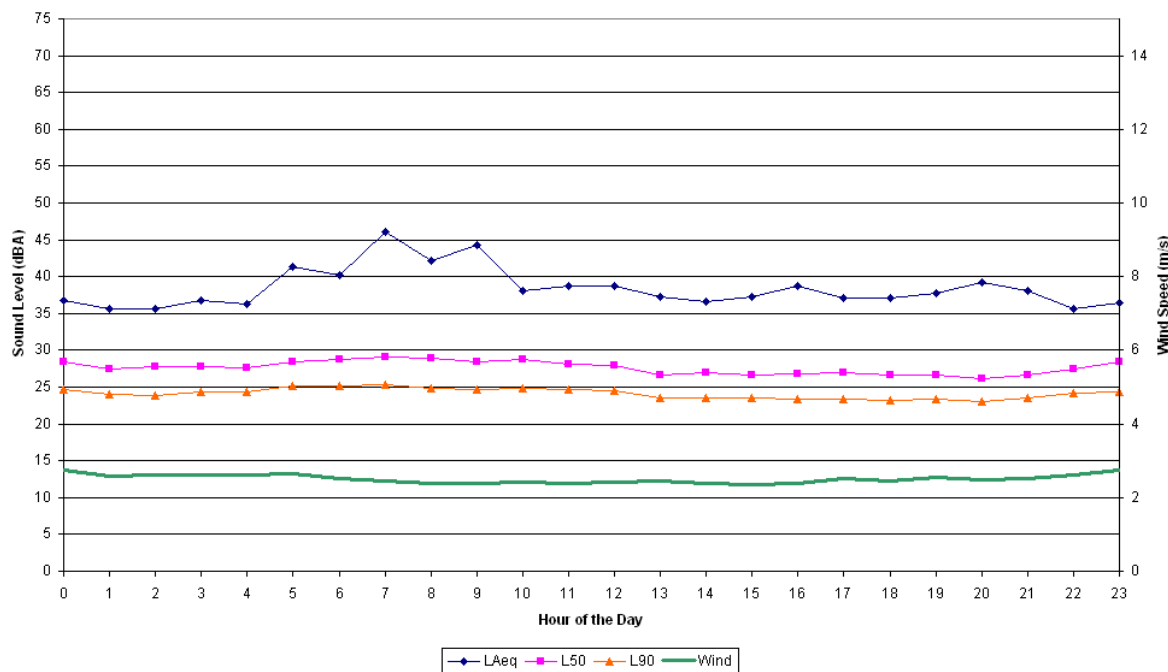


Figure 56. Average hourly sound levels and wind speeds: Site P02.

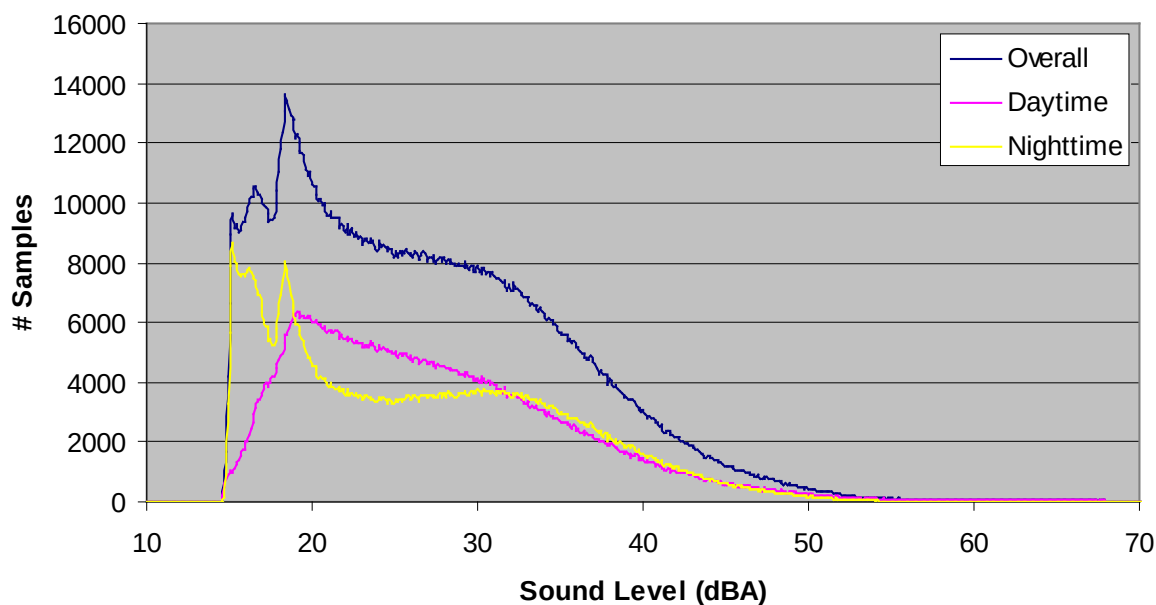


Figure 57. Distribution of data: Site P02.

This site was located off the supply trail near Hosmer Grove. This area is characterized by sounds from wind, birds, day hikers, occasional vehicles, and helicopters operated for both air tours and NPS administrative purposes.

A.3 Site P03 – Kipahulu Coastal Measurement Site**Table 24. Site P03: description.**

Site ID	P03
Site Name	Waimoku Falls/Mango Tree
# Measurement Days and Dates	31 days – March 2, 2003 to April 1, 2003
System # and Type	3 (NoiseLogger™ Plus)
Latitude / Longitude (decimal degrees)	20.6620 / 156.0598
Approximate Elevation (ft)	518
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(4) Forested Upland
Land Cover Subclass (see Appendix E)	(42) Evergreen Forest
Management Zone (see Section 2.5)	Natural/Cultural/Historical
Site Category (see Section 2.5.1)	Short Hike
Site Type (see Section 2.7.2)	Permanent
Site Description	Bamboo forest site located off Pipiwai Trail en route to Waimoku Falls
Access Considerations	3-mile round trip hike on trail
Potential Sound Sources	Aircraft, Hikers, Birds, Insects, Wind, Bamboo

**Figure 58. Site P03: Description and photograph.**

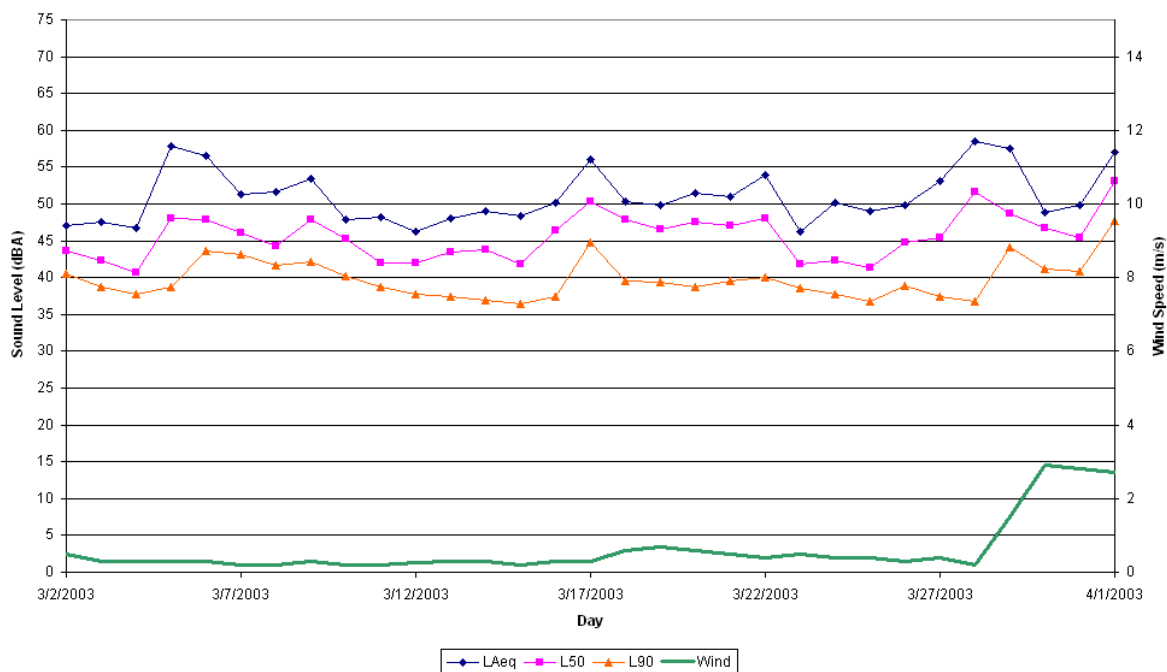


Figure 59. Daily sound levels and wind speeds: Site P03.

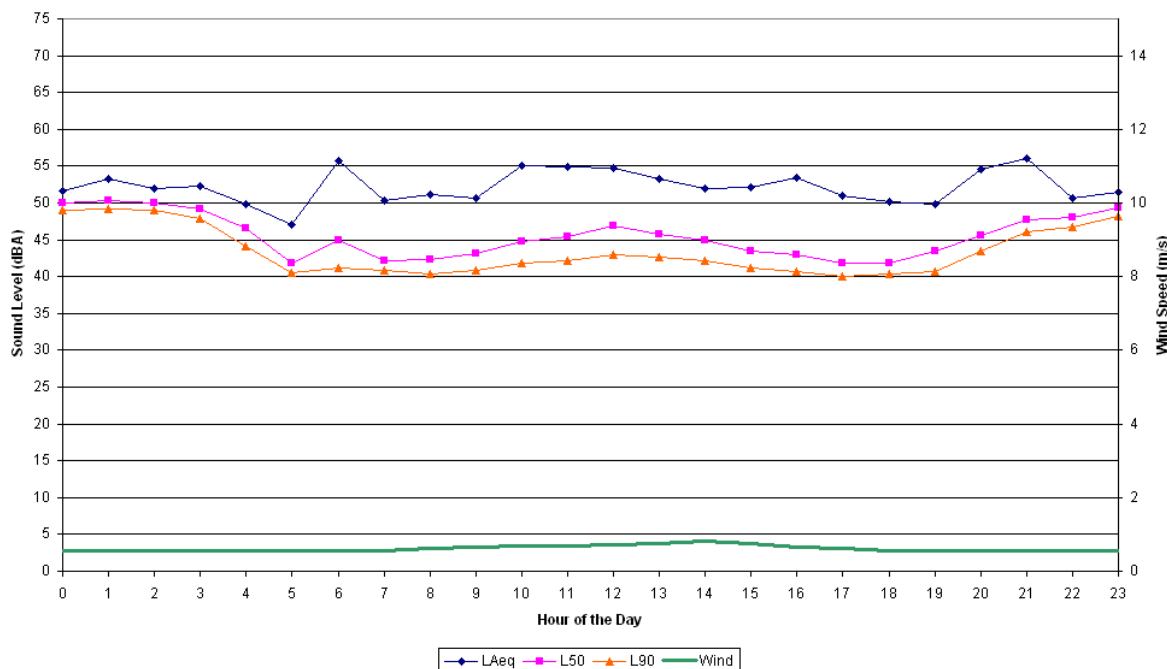


Figure 60. Average hourly sound levels and wind speeds: Site P03.

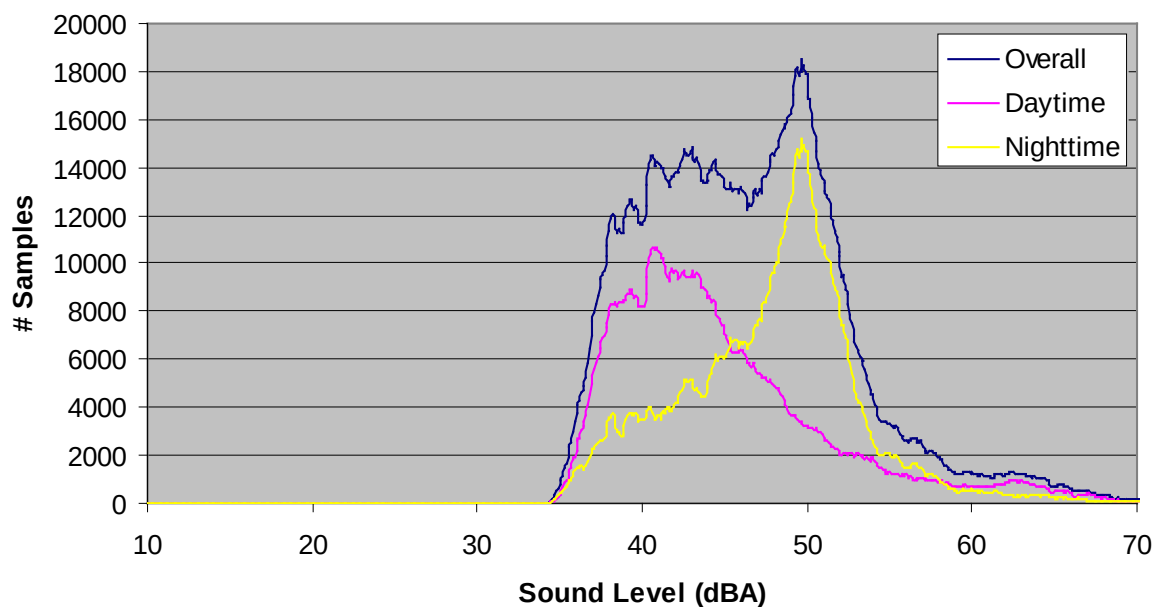


Figure 61. Data distributions: Site P03.

This site was located within the bamboo forest along the heavily used trail en route to Waimoku Falls. This area is characterized by sounds from bamboo, birds, insect, day hikers, and helicopters, as the Waimoku Falls area is the only part of the park that air tours are allowed to cross within park boundaries.

A.4 Site ST4 – Kaupo Gap Measurement Site**Table 25. Site ST4: description.**

Site ID	ST4
Site Name	Paliku Kaupo Gap
# Measurement Days and Dates	15 days – February 28, 2003 to March 14, 2003
System # and Type	7 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.7134 / 156.1467
Approximate Elevation (ft)	6322
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(5) Shrubland
Land Cover Subclass (see Appendix E)	(51) Shrubland
Management Zone (see Section 2.5)	Natural
Site Category (see Section 2.5.1)	Backcountry
Site Type (see Section 2.7.2)	Mobile
Site Description	Dryland forest and shrubland shielded from most air tour noise
Access Considerations	Helicopter or 20-mile round trip hike on trail
Potential Sound Sources	Helicopters (NPS administrative use), Hikers, Birds, Wind

**Figure 62. Site ST4: Description and photograph.**

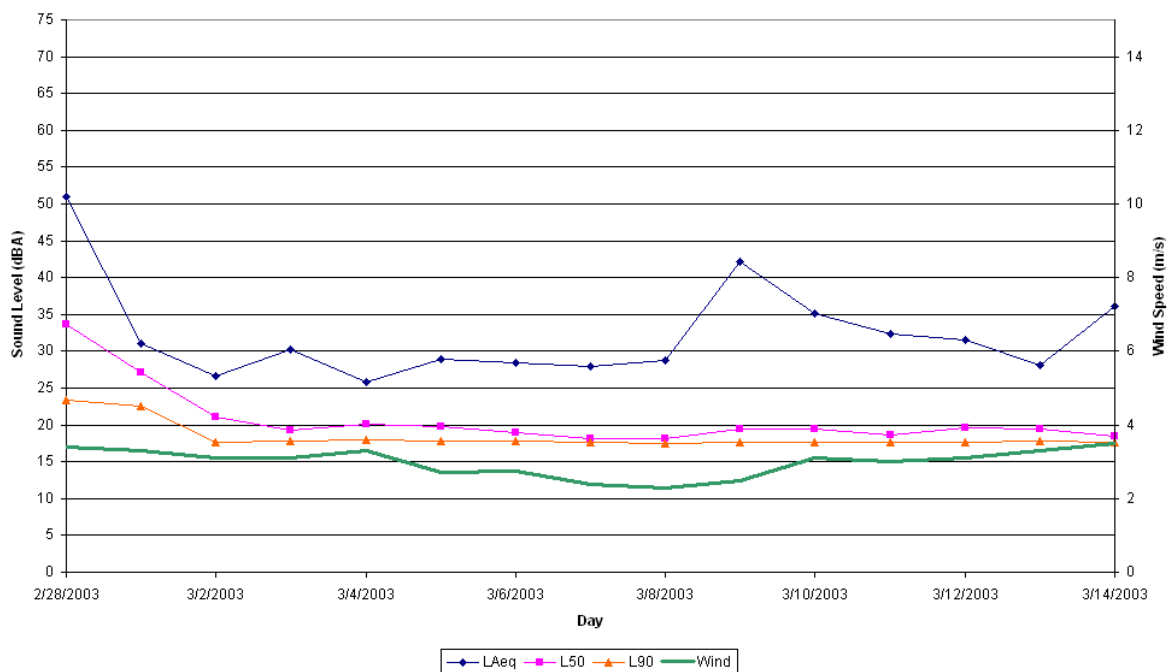


Figure 63. Daily sound levels and wind speeds: Site ST4.*

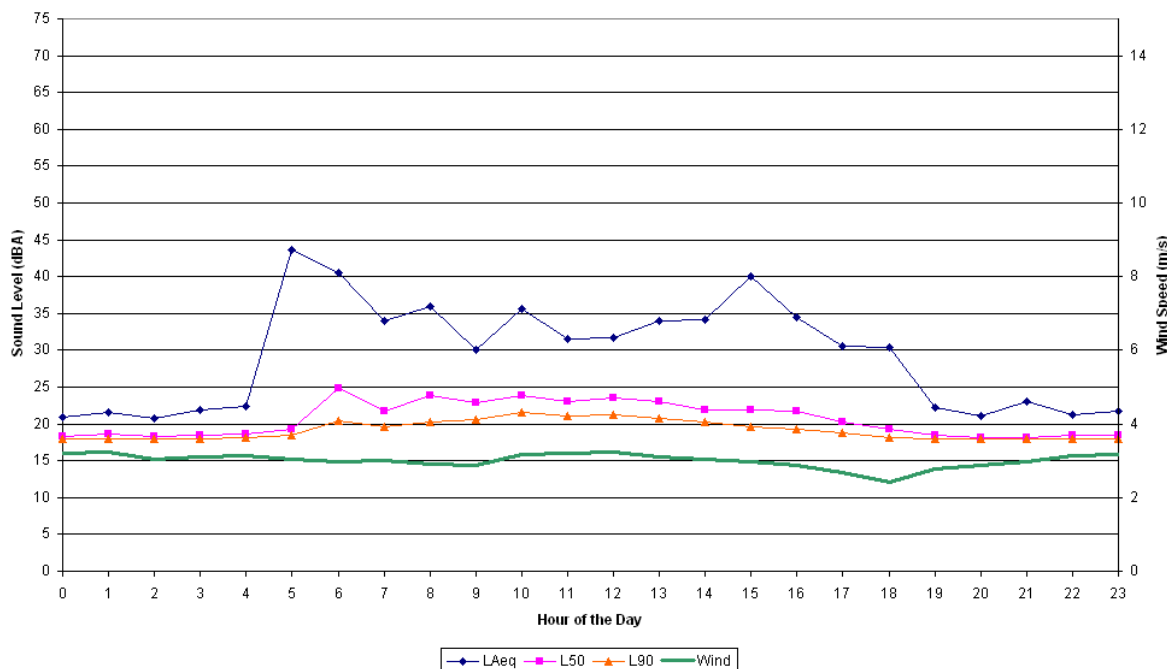


Figure 64. Average hourly sound levels and wind speeds: Site ST4.*

* Note: Closer examination of the spectral data indicate the increases in observed in L_{Aeq} sound levels are due to distant fixed-wing aircraft activity.

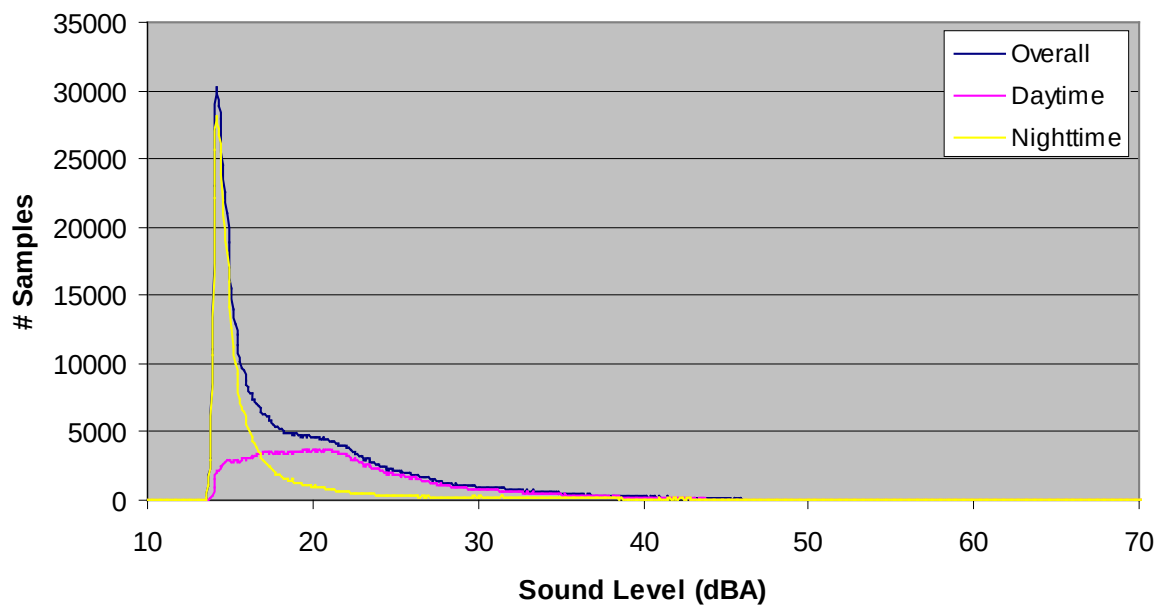
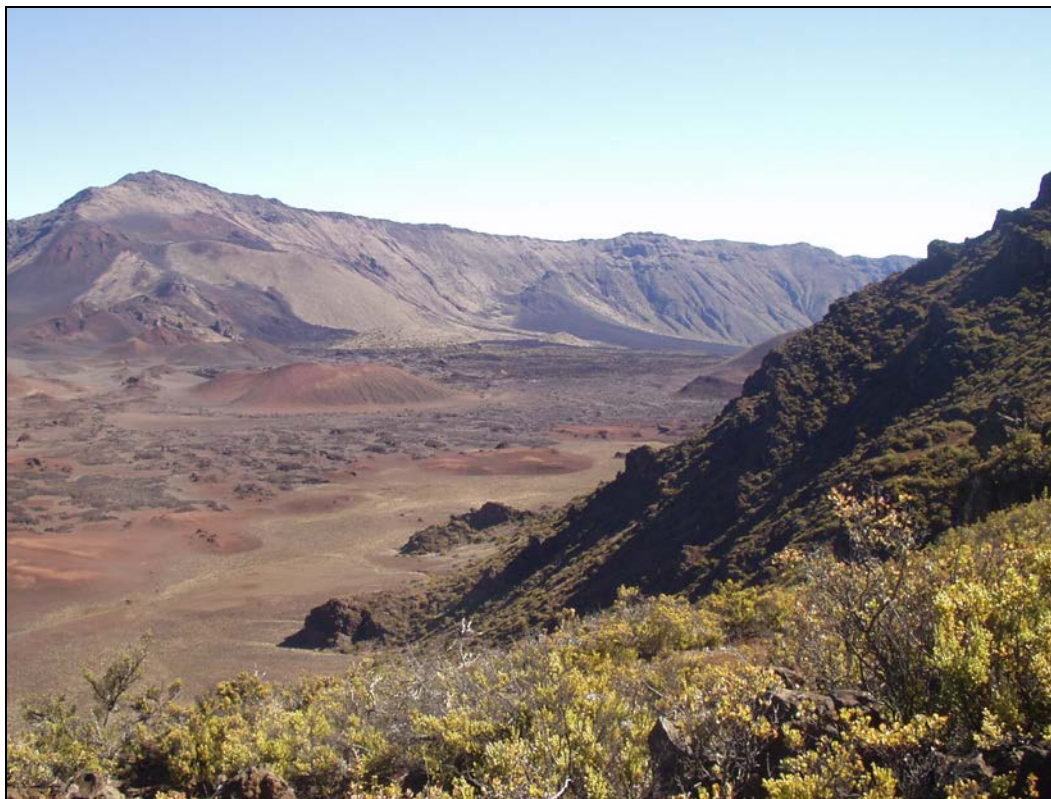


Figure 65. Data distributions: Site ST4.

This site is characterized by high winds, insect and bird vocalizations, and distant aircraft sounds. Very few visitors make the 10-mile hike to this area. The site was generally very quiet at night.

A.5 Site ST5 – Haleakalā Crater Measurement Site**Table 26. Site ST5: description.**

Site ID	ST5
Site Name	The Notch
# Measurement Days and Dates	14 days – March 14, 2003 to March 27, 2003
System # and Type	7 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.7024 / 156.2073
Approximate Elevation (ft)	8051
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(5) Shrubland
Land Cover Subclass (see Appendix E)	(51) Shrubland
Management Zone (see Section 2.5)	Natural/Cultural/Historical
Site Category (see Section 2.5.1)	Backcountry
Site Type (see Section 2.7.2)	Mobile
Site Description	Crater perimeter site where all helicopters on southern tour route turns
Access Considerations	Helicopter
Potential Sound Sources	Aircraft, Hikers, Birds, Horses, Wind

**Figure 66. Site ST5: Description and photograph (Note: System not shown).**

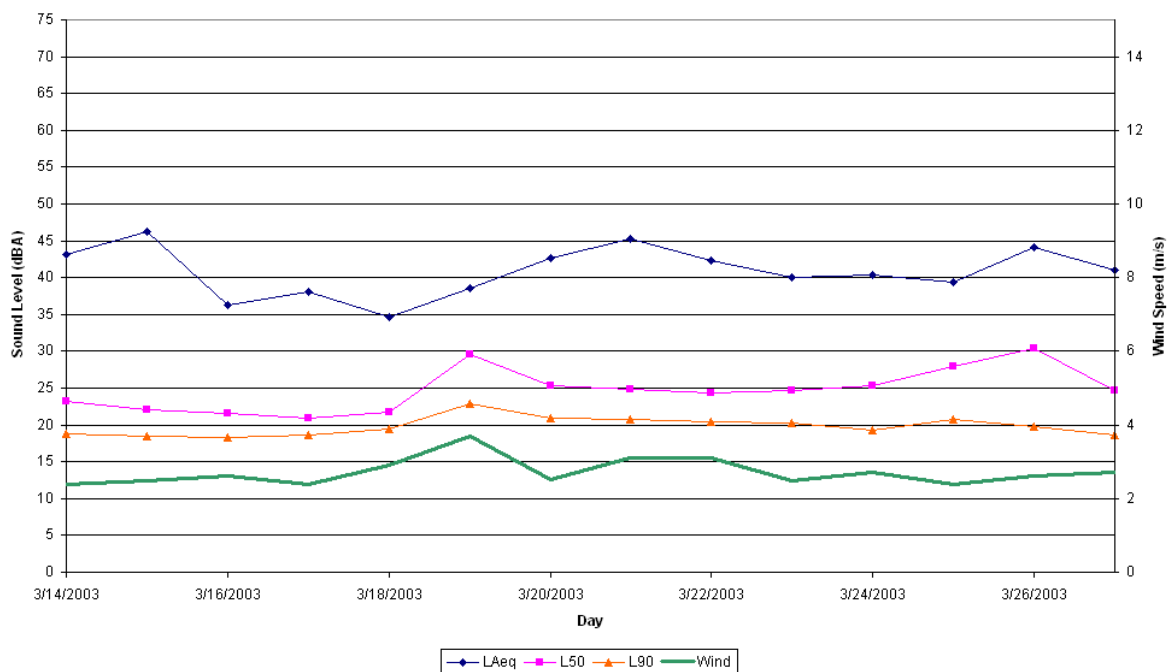


Figure 67. Daily sound levels and wind speeds: Site ST5.

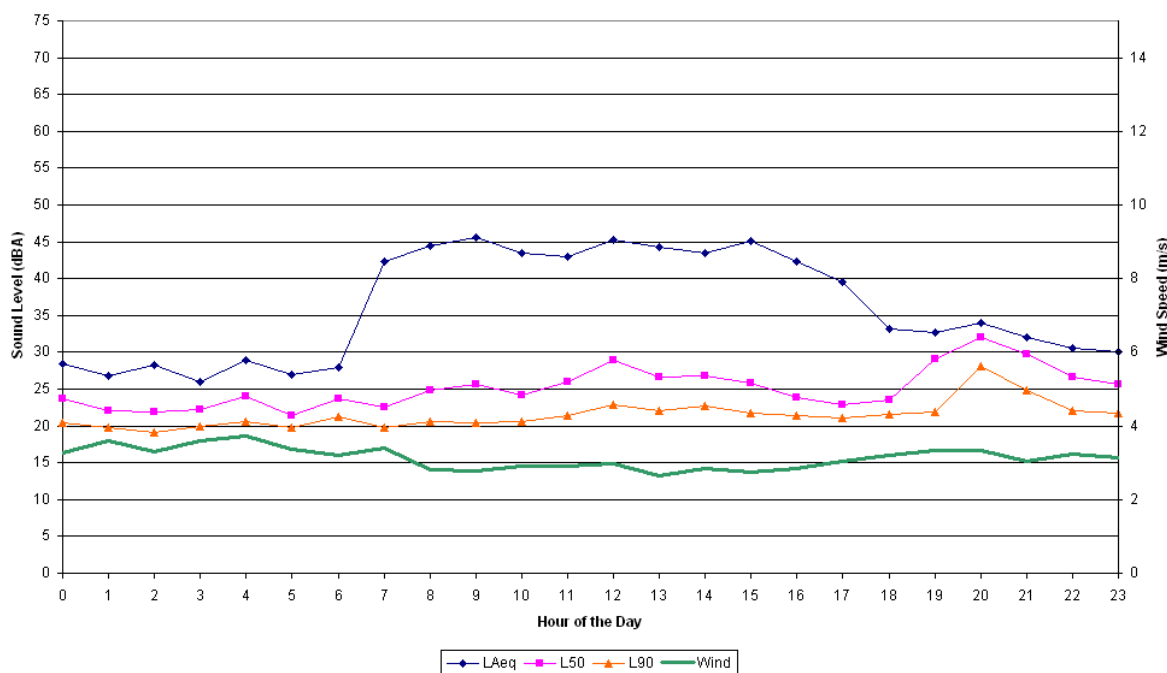


Figure 68. Average hourly sound levels and wind speeds: Site ST5.

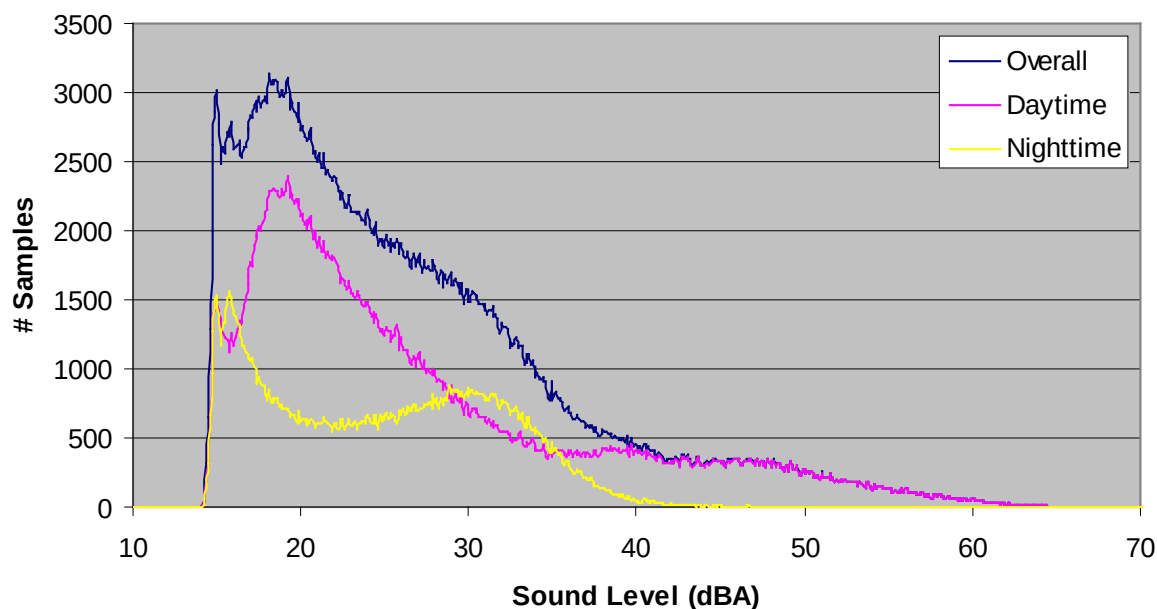
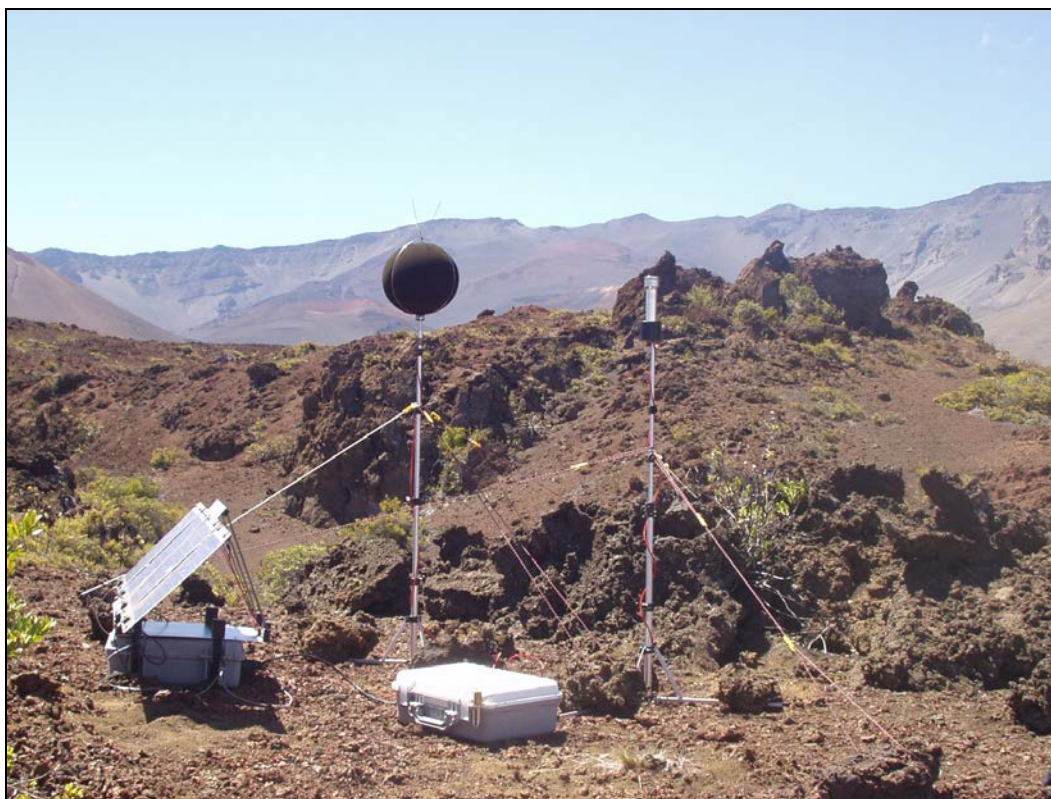


Figure 69. Data distributions: Site ST5.

This site was located on the southern edge of the crater. The majority of air tour operations not only fly past this area, but also perform turning maneuvers to offer their passengers various views of Haleakalā crater. This activity is evident in the increased L_{Aeq} sound levels during daytime hours.

A.6 Site ST6 – Haleakalā Crater Measurement Site**Table 27. Site ST6: description.**

Site ID	ST6
Site Name	Silversword Loop
# Measurement Days and Dates	15 days – March 14, 2003 to March 28, 2003
System # and Type	5 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.7336 / 156.2175
Approximate Elevation (ft)	7178
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(3) Barren
Land Cover Subclass (see Appendix E)	(31) Bare Rock/Sand/Clay
Management Zone (see Section 2.5)	Natural/Cultural/Historical
Site Category (see Section 2.5.1)	Backcountry
Site Type (see Section 2.7.2)	Mobile
Site Description	Cinder cone desert within crater
Access Considerations	Helicopter or 6-mile round trip hike on trail
Potential Sound Sources	Aircraft, Hikers, Birds, Horses, Wind

**Figure 70. Site ST6: Description and photograph.**

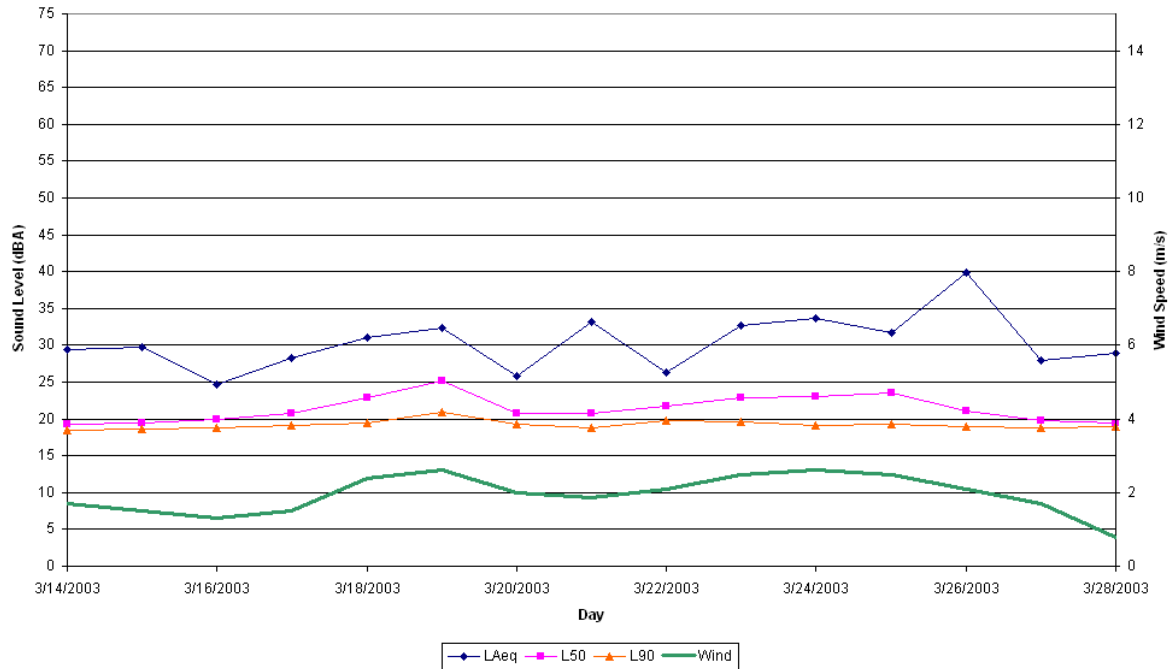


Figure 71. Daily sound levels and wind speeds: Site ST6.

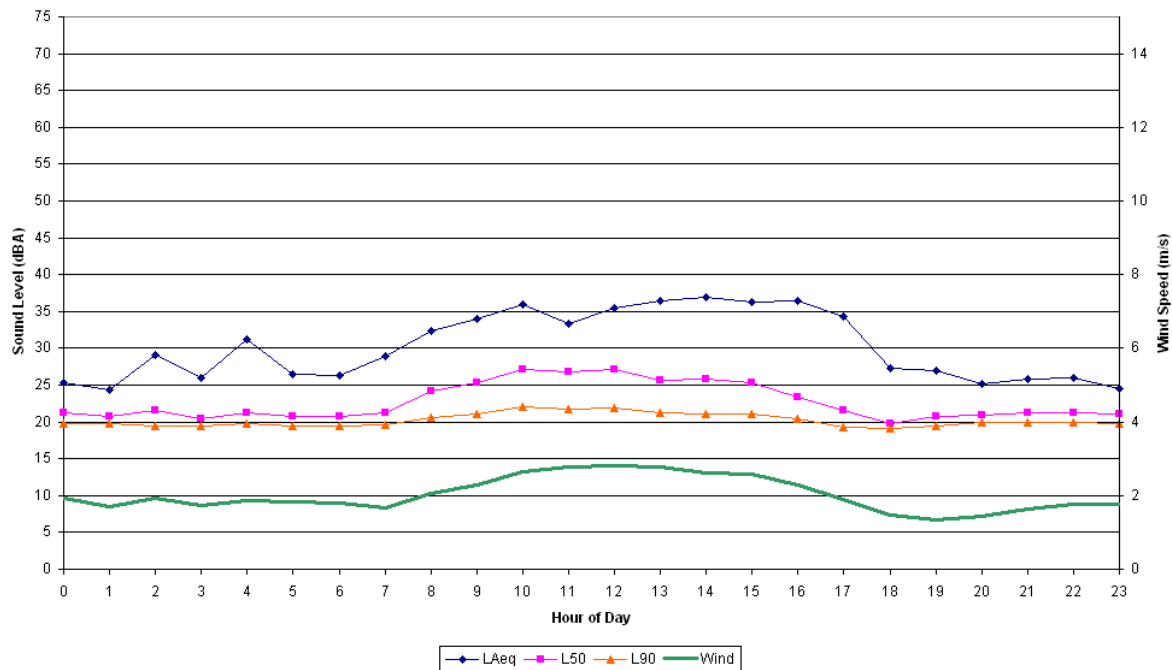


Figure 72. Average hourly sound levels and wind speeds: Site ST6.

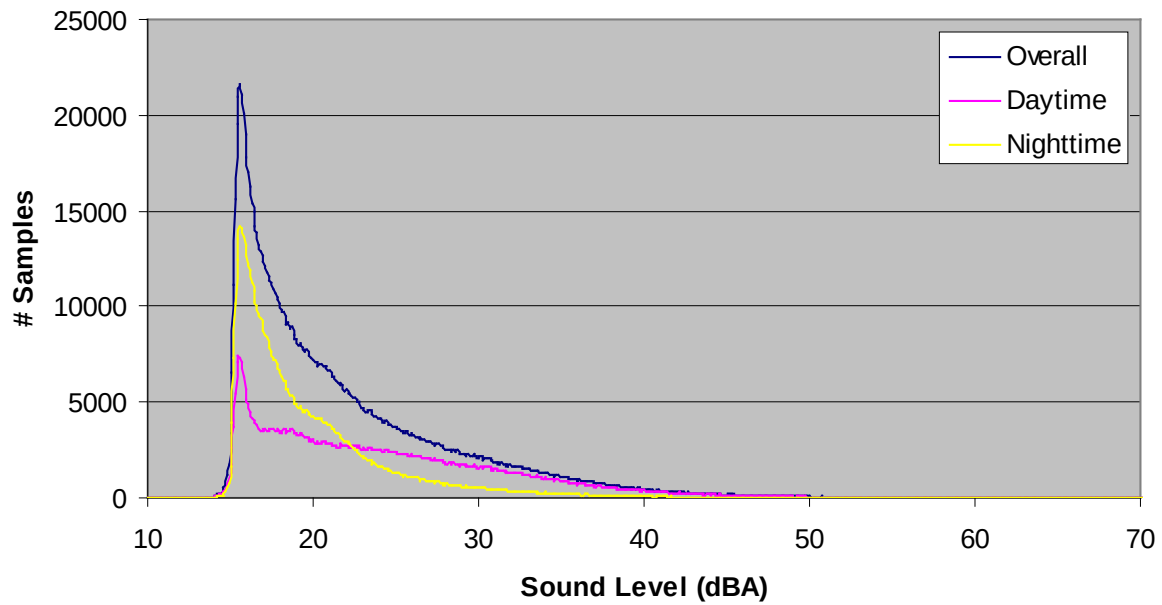


Figure 73. Data distributions: Site ST6.

This site is characterized by high winds, insect and bird vocalizations, occasional backcountry hikers and distant helicopter sounds. The site was generally very quiet at night.

A.7 Site ST7 – West Rim Crater Measurement Site**Table 28. Site ST7: description.**

Site ID	ST7
Site Name	Kalahaku Overlook
# Measurement Days and Dates	13 days – March 1, 2003 to March 13, 2003
System # and Type	5 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.7378 / 156.2362
Approximate Elevation (ft)	9111
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(3) Barren
Land Cover Subclass (see Appendix E)	(31) Bare Rock/Sand/Clay
Management Zone (see Section 2.5)	Developed/Cultural/Historical
Site Category (see Section 2.5.1)	Overlook
Site Type (see Section 2.7.2)	Mobile
Site Description	Rocky dry surface with a nearby parking lot
Access Considerations	Vehicle accessible
Potential Sound Sources	Aircraft, Vehicles, Hikers, Wind

**Figure 74. Site ST7: Description and photograph.**

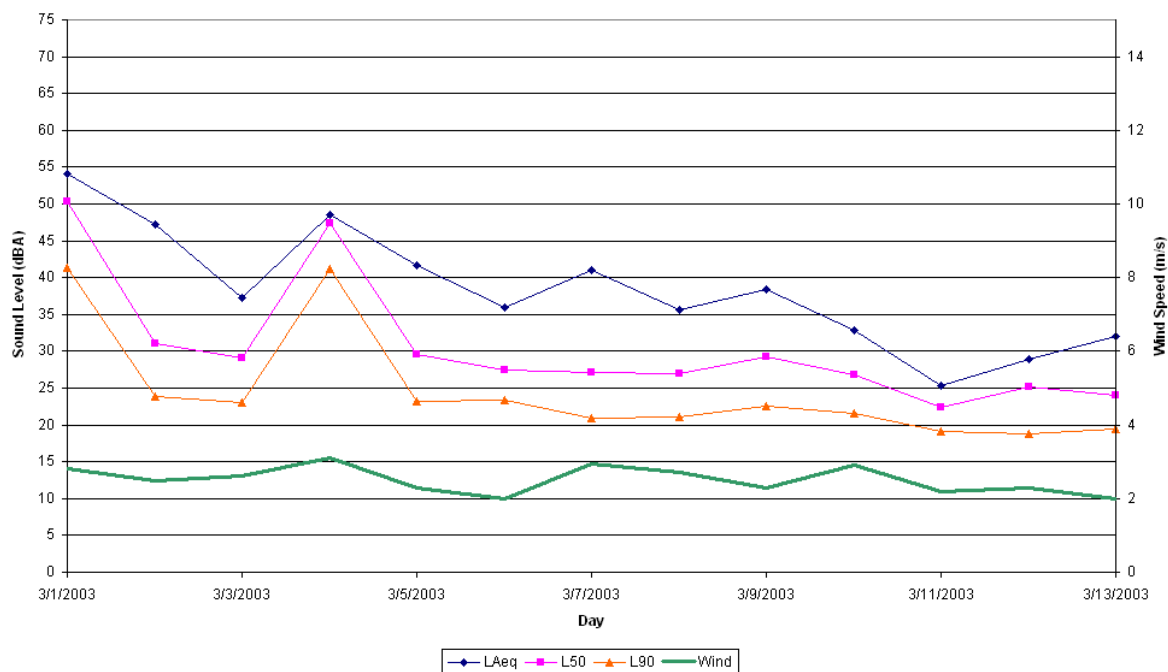


Figure 75. Daily sound levels and wind speeds: Site ST7.

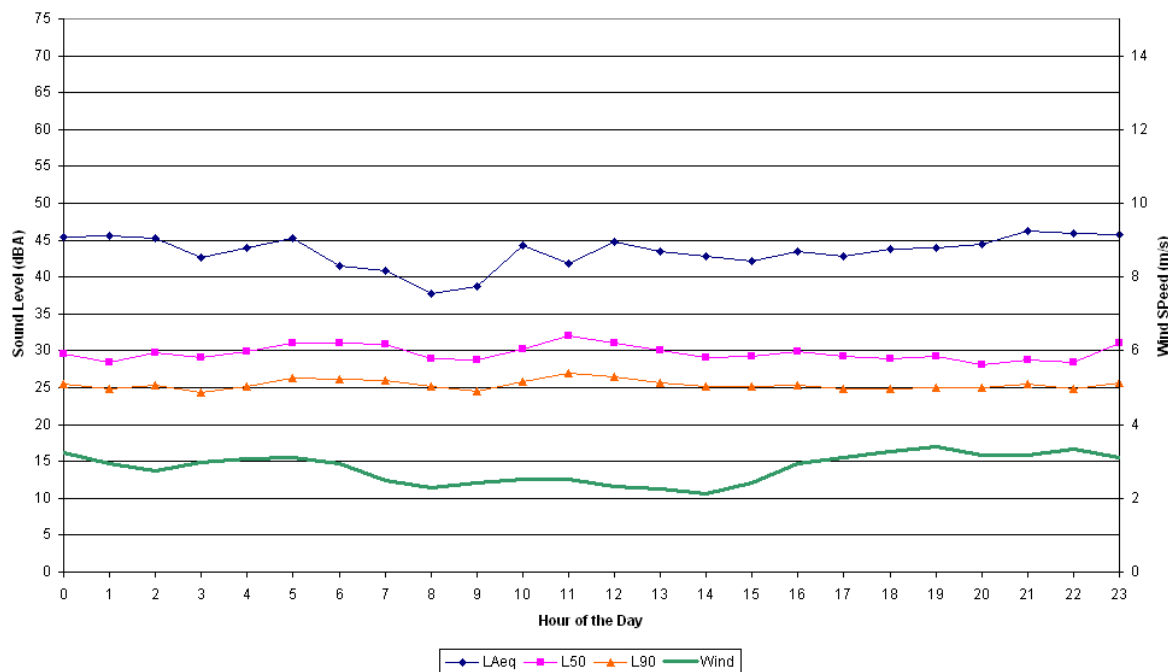


Figure 76. Average hourly sound levels and wind speeds: Site ST7.

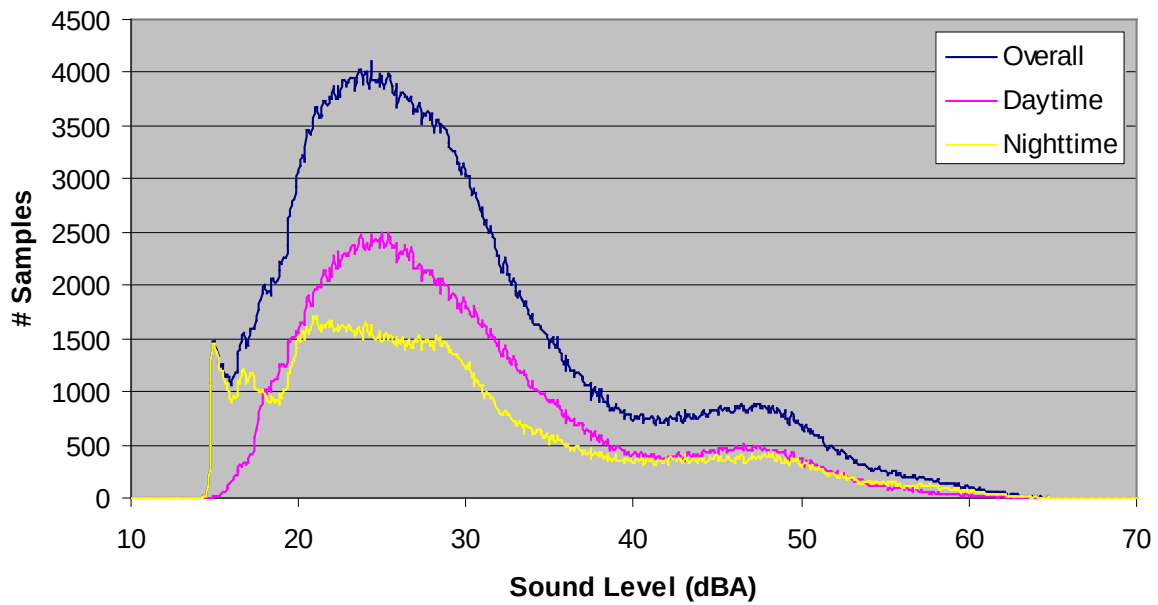


Figure 77. Data distributions: Site ST7.

This site is characterized by very high winds, some aircraft sounds, and frequent vehicular sounds as this was a popular overlook site en route to the summit.

A.8 Site ST8 – Kipahulu Coastal Measurement Site**Table 29. Site ST8: description.**

Site ID	ST8
Site Name	Waimoku Falls
# Measurement Days and Dates	2 days – March 22, 2003 to March 23, 2003
System # and Type	10 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.6765 / 156.0538
Approximate Elevation (ft)	1322
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(4) Forested Upland
Land Cover Subclass (see Appendix E)	(42) Evergreen Forest
Management Zone (see Section 2.5)	Natural/Cultural/Historical
Site Category (see Section 2.5.1)	Overlook
Site Type (see Section 2.7.2)	Mobile
Site Description	Highly-visited waterfalls site located at end of Pipiwai Trail
Access Considerations	4-mile round trip hike on trail
Potential Sound Sources	Aircraft, Hikers, Birds, Wind, Water

**Figure 78. Site ST8: Description and photograph (Note: System not shown).**

This site was located in close proximity to Waimoku Falls. This area is characterized by sound from the waterfall, sounds from many day hikers, and frequent helicopter sounds, as this is the only part of the park that air tours are allowed within park boundaries. A limited amount of data was collected at this site (2 days); however, due to possible equipment issues, data collected at this site was suspect and, thus, not used in the analyses.

A.9 Site ST9 – Upper Kipahulu Valley Measurement Site**Table 30. Site ST9: description.**

Site ID	ST9
Site Name	Kipahulu Scientific Reserve
# Measurement Days and Dates	15 days – March 3, 2003 to March 17, 2003
System # and Type	10 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.6978 / 156.0797
Approximate Elevation (ft)	3100
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(4) Forested Upland
Land Cover Subclass (see Appendix E)	(42) Evergreen Forest
Management Zone (see Section 2.5)	Natural
Site Category (see Section 2.5.1)	Backcountry
Site Type (see Section 2.7.2)	Mobile
Site Description	Remote rainforest site where no park visitors are allowed
Access Considerations	Helicopter only (public not allowed in this area)
Potential Sound Sources	Aircraft, Birds, Insects, Wind

**Figure 79. Site ST9: Description and photograph.**

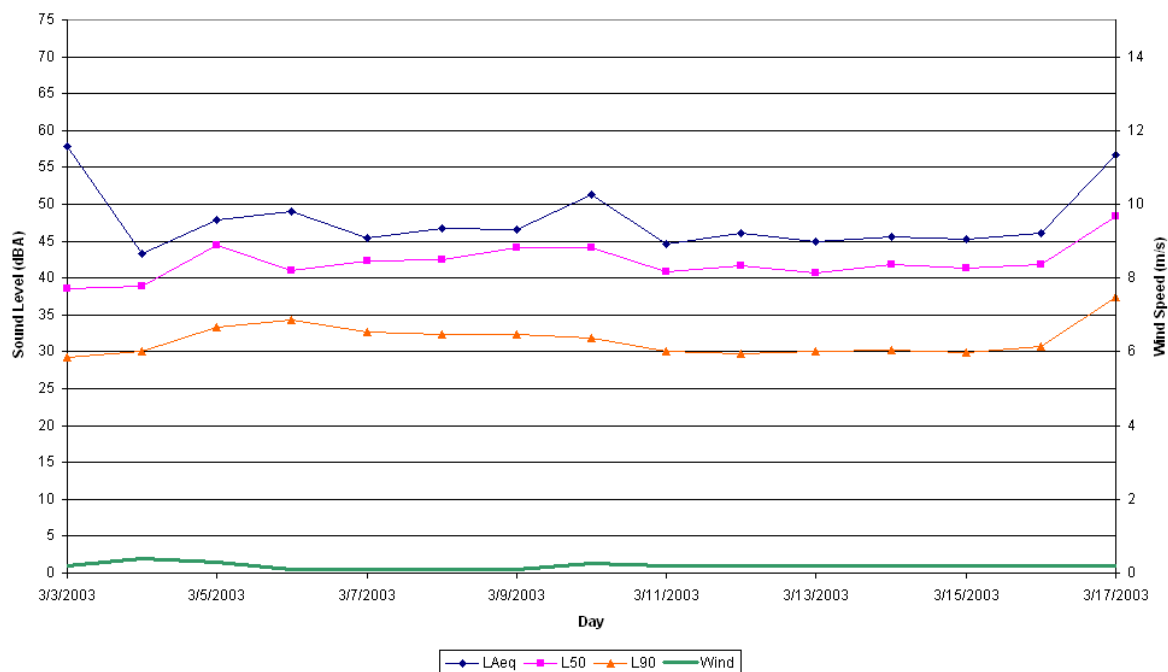


Figure 80. Daily sound levels and wind speeds: Site ST9. *

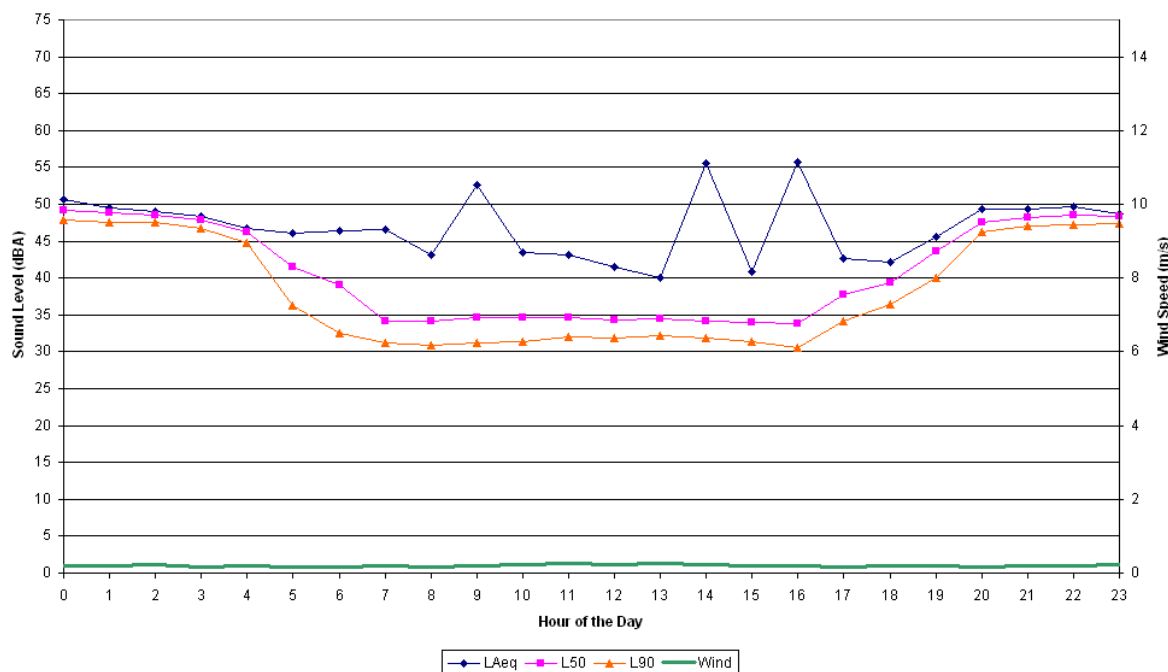


Figure 81. Average hourly sound levels and wind speeds: Site ST9. *

* Note: Closer examination of the spectral data indicate the increases in observed in L_{Aeq} sound levels are due to distant fixed-wing aircraft activity.

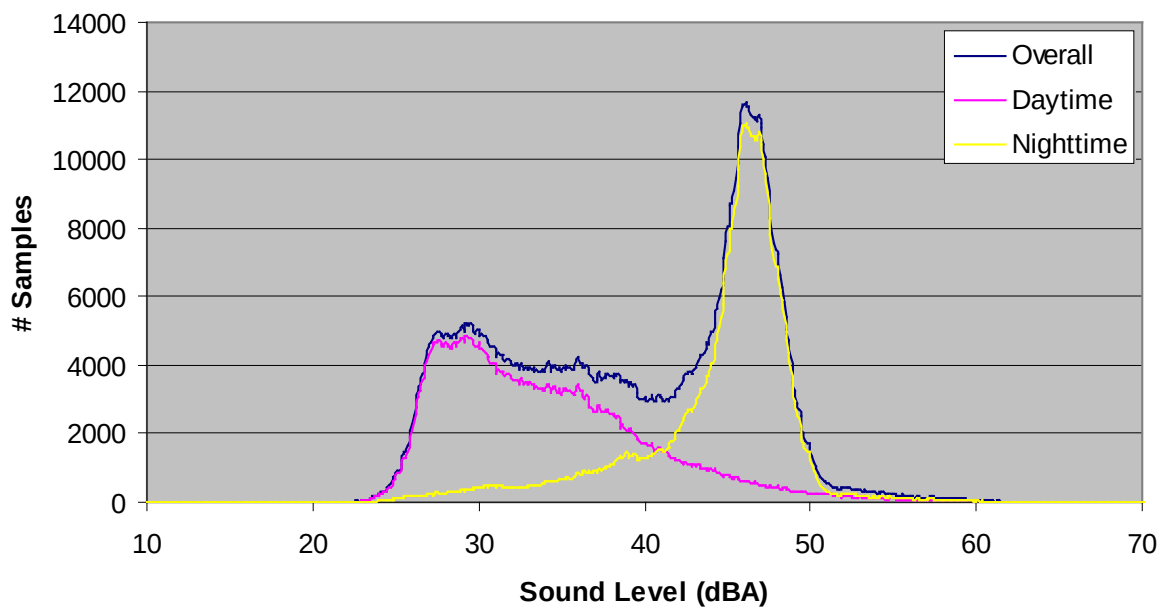


Figure 82. Data distributions: Site ST9.

This site is located deep within the Kipahulu Scientific Research Reserve, where no visitation or air tour overflights are allowed. However, entries in the acoustic observer logs show distant helicopter and fixed-wing aircraft were audible. The area is also dominated by insect and bird vocalizations, and wind noise through the abundant rain forest vegetation.

A.10 Site ST10 – Kipahulu Coastal Measurement Site**Table 31. Site ST10: description.**

Site ID	ST10
Site Name	Oheo Coastal
# Measurement Days and Dates	1 day – May 27, 2003
System # and Type	X (NoiseLogger™)
Latitude / Longitude (decimal degrees)	20.xxxx / 156.xxxx
Approximate Elevation (ft)	92
Ecological Domain (see Appendix E)	(400) Humid Neotropical
Ecological Division (see Appendix E)	(412) Hawaiian Highlands
Land Cover Class (see Appendix E)	(3) Barren
Land Cover Subclass (see Appendix E)	(31) Bare Rock/Sand/Clay
Management Zone (see Section 2.5)	Natural/Cultural/Historical
Site Category (see Section 2.5.1)	Short Hike
Site Type (see Section 2.7.2)	Mobile
Site Description	Rocky terrain with small waterfalls and pools located near coast
Access Considerations	0.5-mile round trip hike on trail
Potential Sound Sources	Aircraft, Hikers, Birds, Insects, Wind, Water

**Figure 83. Site ST10: Description and photograph (Note: System not shown).**

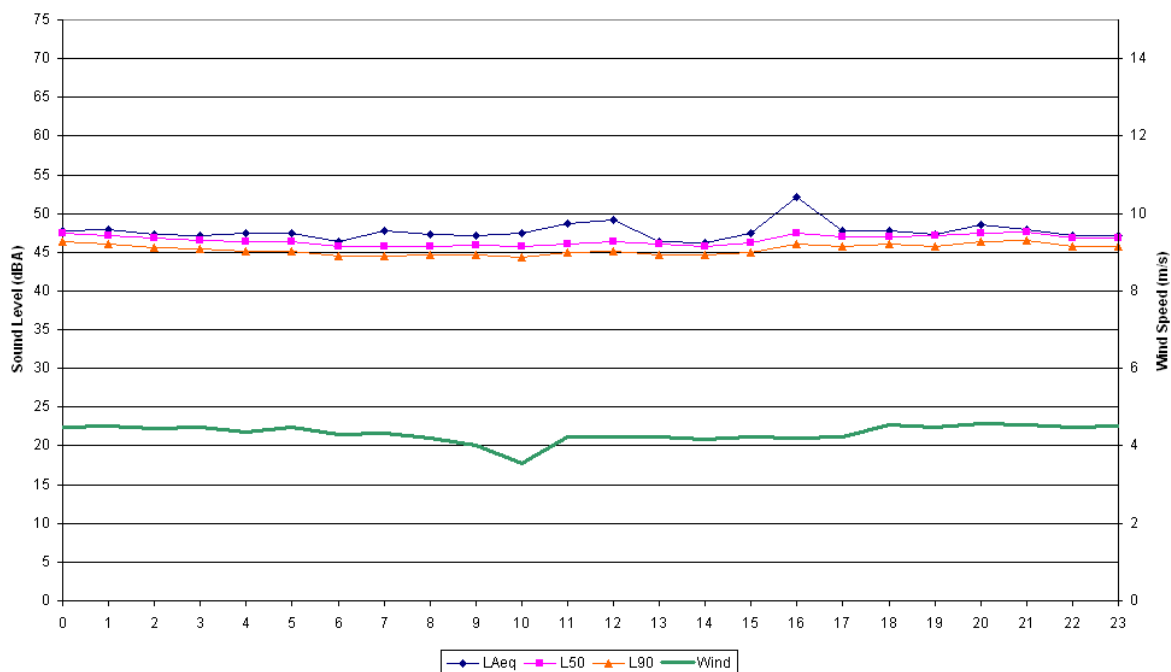


Figure 84. Average hourly sound levels and wind speeds: Site ST10.

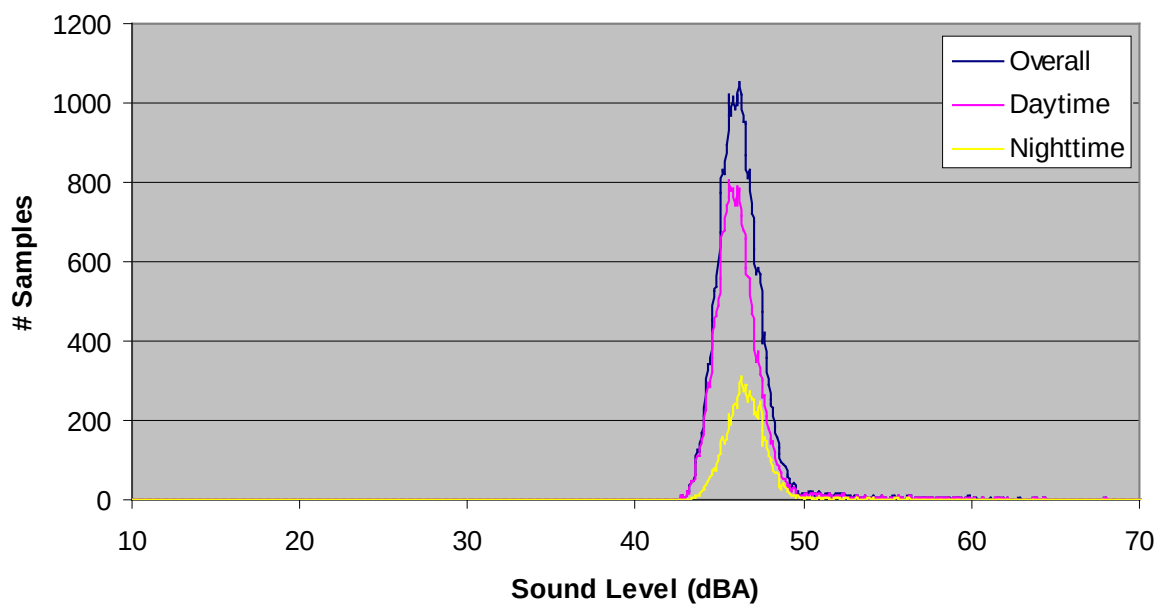


Figure 85. Data distributions: Site ST10.

This site was located near the Kipahulu entrance of the park. A limited amount of data was collected at this site (1 day). The area is characterized by sounds from small waterfalls, day hikers, occasional vehicles, and distant aircraft.

Page left blank intentionally

APPENDIX B. NOISELOGGER™ AND NOISELOGGER PLUS™ CONTINUOUS SYSTEM REFERENCE

This appendix presents the step-by-step procedures for the deployment, setup, and dismantling of the NoiseLogger™ and NoiseLogger Plus™ systems. Sections 3.1 and 3.2 discuss 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 one-third 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 32 and Figure 86 illustrate the basic components of the system.

The NoiseLogger Plus™ system is similar to the NoiseLogger™ system, but modified to also support the capability to record live audio samples. It can record sounds on both a periodic basis, e.g., a 5-second recording every five minutes, and on a threshold basis, e.g., a recording is triggered when a sound level exceeds a user-defined threshold. Table 32 and Figure 87 illustrate the basic components to this system.

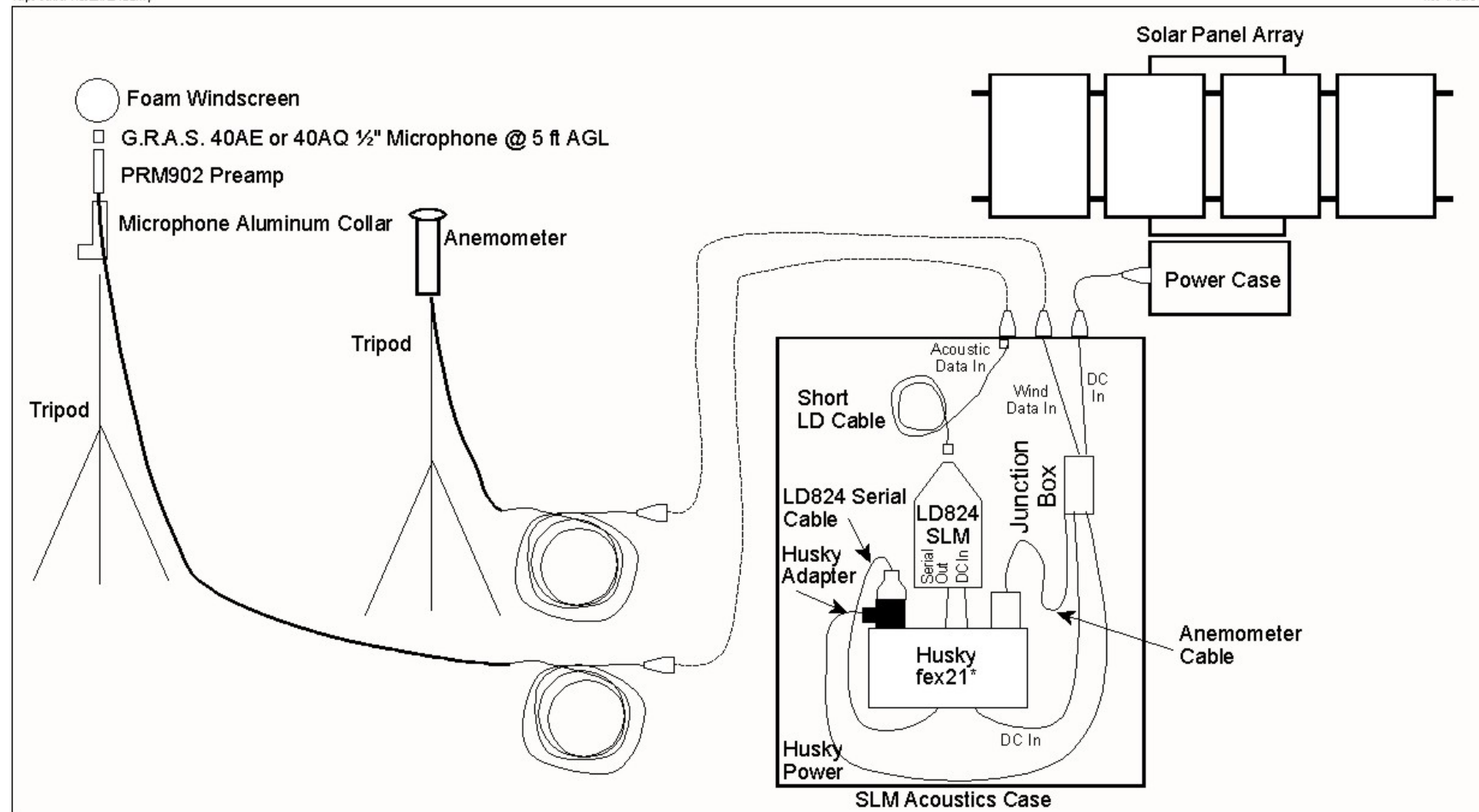
B.2 Instrumentation List

Table 32. NoiseLogger™ and NoiseLogger Plus™ system instrumentation list.

Components	NoiseLogger™ System	NoiseLogger Plus™ System
Microphone System	GRAS 40 AE ½-inch Microphone PRM902 Preamp Microphone Cable with 7-pin Connector Large Foam Windscreen	GRAS 40 AE 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	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	LD824 Sound Level Meter Fujitsu Lifebook P1110 Computer
Power System	217-AH Gell Cells 1 Solar Panel Array	4 17-AH Gell Cells2 Solar Panel Arrays
Ancillary Equipment	Garmin GPS Plus III Unit B&K 4231 Calibrator Microphone Simulator	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.wpg

Figure 86. NoiseLogger™ continuous monitoring system.

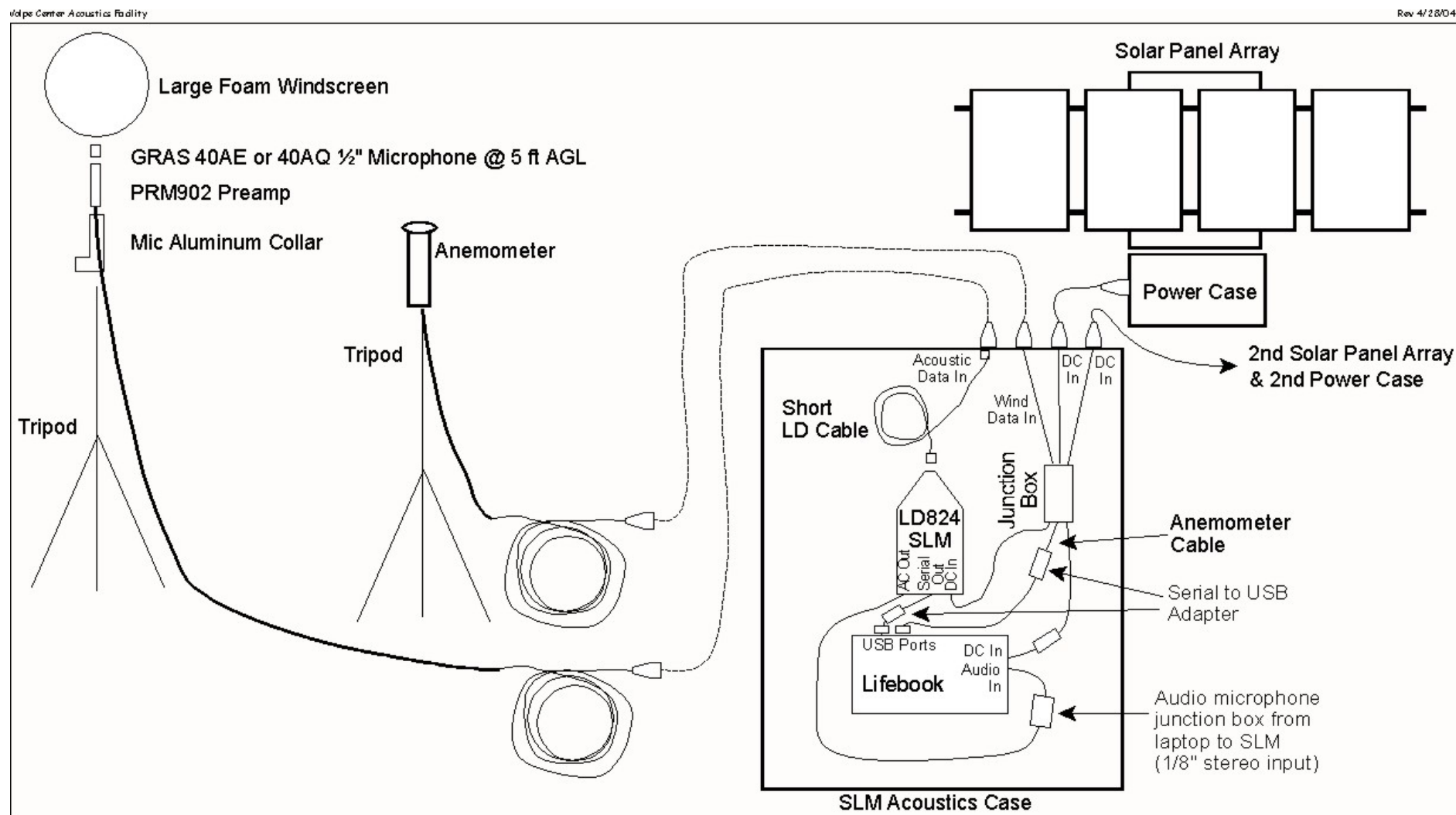


Figure 87. NoiseLogger Plus™ continuous monitoring system.

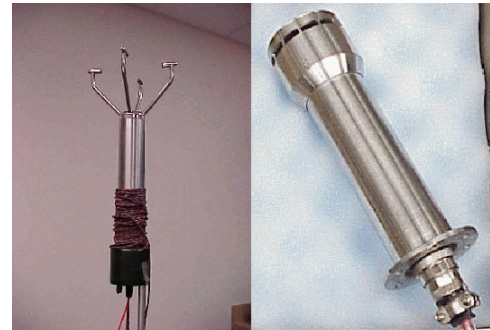
CL:FAA/AT&RP/Equipment/Instrumentation_NoiseLogger.wpg

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 88) 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.



Windobserver II
Anemometer

FT702
Anemometer

Figure 88. 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 88).
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 89.
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 90). 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.

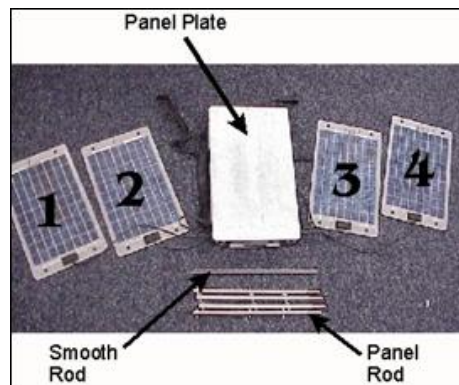


Figure 90. Unpack solar panel
array

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 91).
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.”

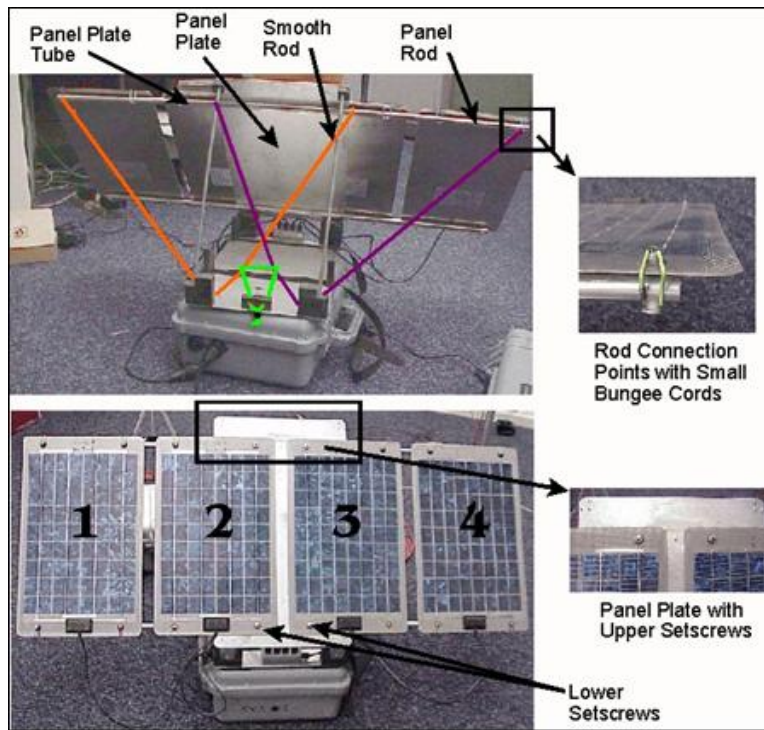


Figure 91. Solar panel array setup.

6. Tighten the “X” pattern by pulling the small string loop at the base of the “X” and raising the tension knob (see Figure 92).
7. Insert the two lower panel rods into the tubes at the bottom of the “panel plate.”



Figure 92. 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.
 18. For the NoiseLogger Plus™ system, a second solar panel array should be setup similarly.

B.3 Operation

B.3.1 NoiseLogger™ Startup

1. See Section B.3.2 for NoiseLogger Plus startup.
2. Open SLM acoustics case. Remove top foam piece.
3. Verify connections as shown in Figure 93, 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.

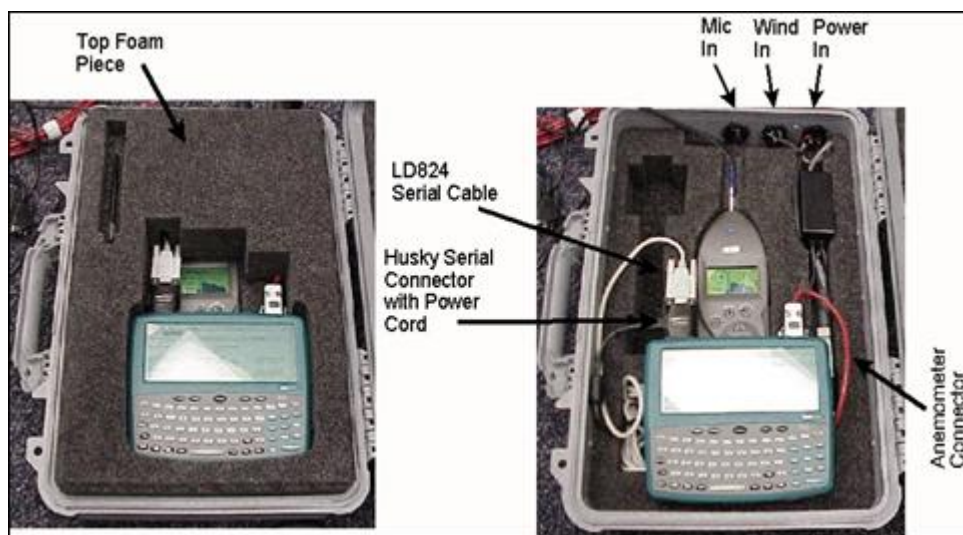


Figure 93. SLM acoustics case.

4. Open the plastic back plate to the Husky™ by squeezing the two clips on the back of the Husky™ and check to ensure a 128-MB CompactFlash™ card (Storage Card) is in one of the two card slots. Restore the back plate.
5. Power up the Husky™ by pressing the red center button below the screen. Note: If the Husky™ hasn't been turned on for a long time, the unit may display several screens to calibrate the touch screen and perform time zone setup on the unit.
6. Power up the LD824 by pressing the lighted green (left-most) button on the front panel Note: The LD824 may power up automatically when the Husky™ is started.
7. Reset/reboot the Husky™ by pressing both the contrast and brightness buttons on either side of the power button.
8. Using the red tip of the stylus, select "My Handheld PC" icon on the desktop.
9. A Windows browser is displayed. Select the "Storage Card" directory to access the 128-MB CompactFlash™ card. Select the "NoiseLogger™ ver 2.1.0.0" folder and then run the NoiseLogger.exe program by double clicking the filename with the stylus.
10. An "About NoiseLogger" dialog is displayed. Select OK.
11. Per the program instructions, enter a unique three-character ID representing the site "number" (e.g., ST7 for Haleakalā Site ST7), and the site's name (e.g., Kalahaku Overlook).
12. Select "Equipment Info" and proceed to the GPS Synchronization (Section B.3.3).

B.3.2 NoiseLogger Plus™ Startup

1. Open SLM acoustics case. Remove top foam piece.
2. Verify Fujitsu™ laptop computer connections as shown in Figure 94, specifically that the USB cable from the LD824 is connected to the left USB com port and the USB cable from the anemometer is connected to the right USB com port. Verify also that the AC In power cable and microphone (for wave file recording) cable are connected.

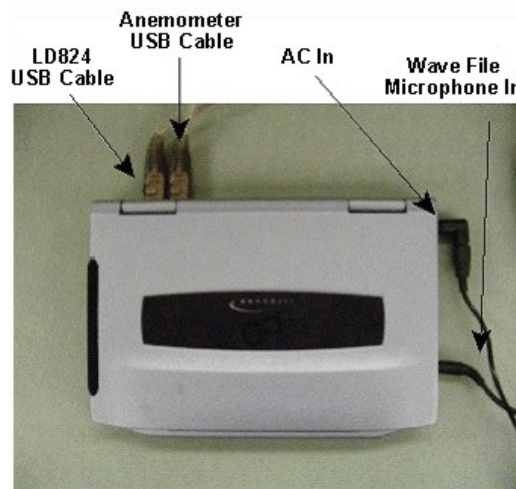


Figure 94. NoiseLogger Plus™ Fujitsu™ computer.

3. Power up the laptop by pressing silver button below the screen.
4. 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 laptop is started.
5. Using the mouse pad, move the mouse to select OK and skip log in.
6. Select the NoiseLogger Plus™ folder and then run the NoiseLogger Plus™ program by double clicking the icon.
7. An “About NoiseLogger” dialog is displayed. Select OK.
8. Per the program instructions, enter a unique three-character ID representing the site “number” (e.g., ST7 for Haleakalā Site ST7), and the site’s name (e.g., Kalahaku Overlook).
9. Select the following digital audio recording settings:
 - a. *Sampling Rate*: Set to 20 kHz to collect most audible sounds. Equal to two times the highest frequency that is recorded by the wave file;
 - b. *Sound Quality*: Set to 16 Bits to collect the widest range of sounds. This

- determines the dynamic range of the sound that is recorded by the wave file;
- c. *Periodic Wave Collection*: Check the box to enable automatic wave file collection, then select the option to record a 30-second wave file every 30 minutes;
 - d. *Event Triggered*: Check the box to enable automatic wave file collection when certain threshold parameters (see Item e) are met in order to try and capture certain noise events;
 - e. *Threshold*: Typically set to 50 dBA for quiet sites, and 60 dBA for other sites. This is the sound level that is needed in order for an event-triggered wave file to begin collection;
 - f. *Trigger Arming Duration*: Set to 5 seconds. This is equal to the number of seconds that either the broadband or tonal triggering conditions must be met in order for wave file collection to begin (e.g., if events are selected with a threshold of 55 dBA and an arming duration of 5 seconds, then the sound level must be equal to or greater than 55 dBA for 5 seconds for a wave file to begin collection). This helps to avoid collection of impulsive bird chirping events;
 - g. *Trigger Reset Duration*: Set to 10 seconds. In order to avoid constant wave file collection, this is equal to the number of seconds that the threshold triggering condition must NOT be met in order for another wave file to be collected (e.g., if events are selected with a threshold of 55 dBA, an reset duration of 10 seconds, then after a wave file is collected, it is necessary of the sound level to be below 55 dBA for 10 seconds in a row before another wave file can be collected);
 - h. *Number of Wave Files Per Day*: Set to 200. This is the total number of event wave files (Note: Periodic wave files are not counted) that can be collected in each day. This is set to avoid collecting too many wave files within a short period of time and expending all of the laptop's internal hard drive space.

10. Select "Equipment Info" and proceed to the GPS Synchronization (Section B.3.3).

B.3.3 GPS Synchronization

1. A GPS unit and cable can be found in the calibration kit.
 - a. *For the NoiseLogger™ system*, 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.
 - b. *For the NoiseLogger Plus™ system*, connect the serial end of the GPS cable to the serial-USB adapter cable connected to the right the laptop's USB com port. If the anemometer cable is already connected to this adapter cable, disconnect the wind sensor cable from the adapter, 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 minuets. 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.3.4.

B.3.4 Equipment Information

1. Verify that the wind sensor (anemometer) cable is connected properly to the computer.
2. Select the type of anemometer being used in the pull-down menu in the "Equipment Info" dialog. Note: This must be performed even if the anemometer is the default type. Select [Continue].
3. If an anemometer error occurs or a com port error message is displayed, check the

- connection, then press [Continue] and select [Equipment Info] again. If the problem persists continue on to the [Calibrate SLM] procedure (Section B.3.4).
4. Enter the sound level meter type and serial number. Refer to the equipment info sheet taped to the inside cover of the case). Note: The info sheet should be checked as some equipment may have been switched out in the field.
 5. Enter the anemometer type and serial number.
 6. Select the desired calibration level. If a level other than 94 or 114 dB is selected, enter the level in the field to the right. Verify that the “Frequency” field shows 1000.
 7. Enter the calibrator type and serial number. A calibrator can be found in the calibration kit.
 8. Select the [Continue] button.
 9. Enter the microphone type and serial number.
 10. Enter the preamp type and serial number.
 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.3.5

B.3.5 Calibration

1. The NoiseLogger™/ NoiseLogger Plus™ program sends commands to the LD824 to control it during calibration and data logging. There is no need to handle the LD824 other than ensuring the preamp cable connection, serial data connection and power connection.
2. Carefully remove the large foam windscreen and apply the calibrator to microphone (see Figure 95). 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.



Figure 95. System calibration.

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 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.3.6 System Integrity Check

1. System integrity is checked prior to the start of data collection to ensure that there is no outside signal influence on the system. This is performed by recording the sound level with a dummy microphone.
2. Carefully remove the large foam windscreen. Carefully replace the microphone on the preamp with a microphone simulator. Place the microphone back in its holder during this exercise for safekeeping.
3. In the “Sound Level Range” (located in the upper right corner of the computer screen)

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

B.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 36 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 33. 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:
 - a. *For the NoiseLogger™ system*, 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.
 - b. *For the NoiseLogger Plus™ system*, connect an external hard drive to the serial com port. Open Windows Explorer by double clicking on the program icon on the screen. Copy all the wave files stored in the laptop's hard drive to the external hard drive. Disconnect the external hard drive. If this is the end of the measurement period for this site, power down the computer by selecting the [Start] button and [Shut Down], and then proceed to Section B.6 for instructions on dismantling the system. If measurements are to continue, erase all the existing wave files from the laptop.
9. Perform calibration (see Section B.3.5).
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:
 - a. *For the NoiseLogger™ system*, 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.
 - b. *For the NoiseLogger Plus™ system*, power down the computer by selecting the [Start] button and [Shut Down].
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 96).
16. Close panel plate over the top of the stack of panels and secure with black straps.



Figure 96. 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.

Page left blank intentionally.

APPENDIX C. INSTRUMENTATION FREQUENCY RESPONSE ADJUSTMENTS

All NoiseLogger™ and NoiseLogger Plus™ 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 34 and Figure 97). 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 7 in Section 4.1).

Table 34. 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

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

Frequency (Hz)	1	2	3	4	5	6	7	8	9	10	11
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

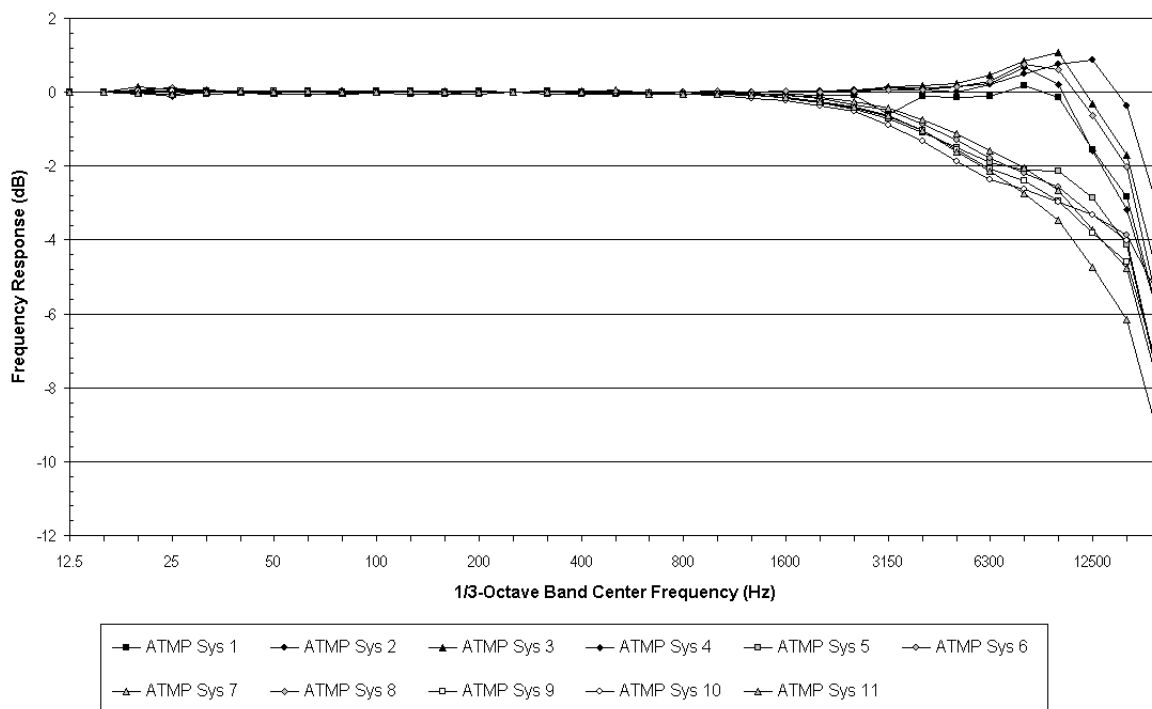


Figure 97. Microphone frequency responses (see Table 7 in Section 4.1).

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 35 and Figure 98.³⁶

Table 35. 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

Frequency (Hz)	1	2	3	4	5	6	7	8	9	10	11
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

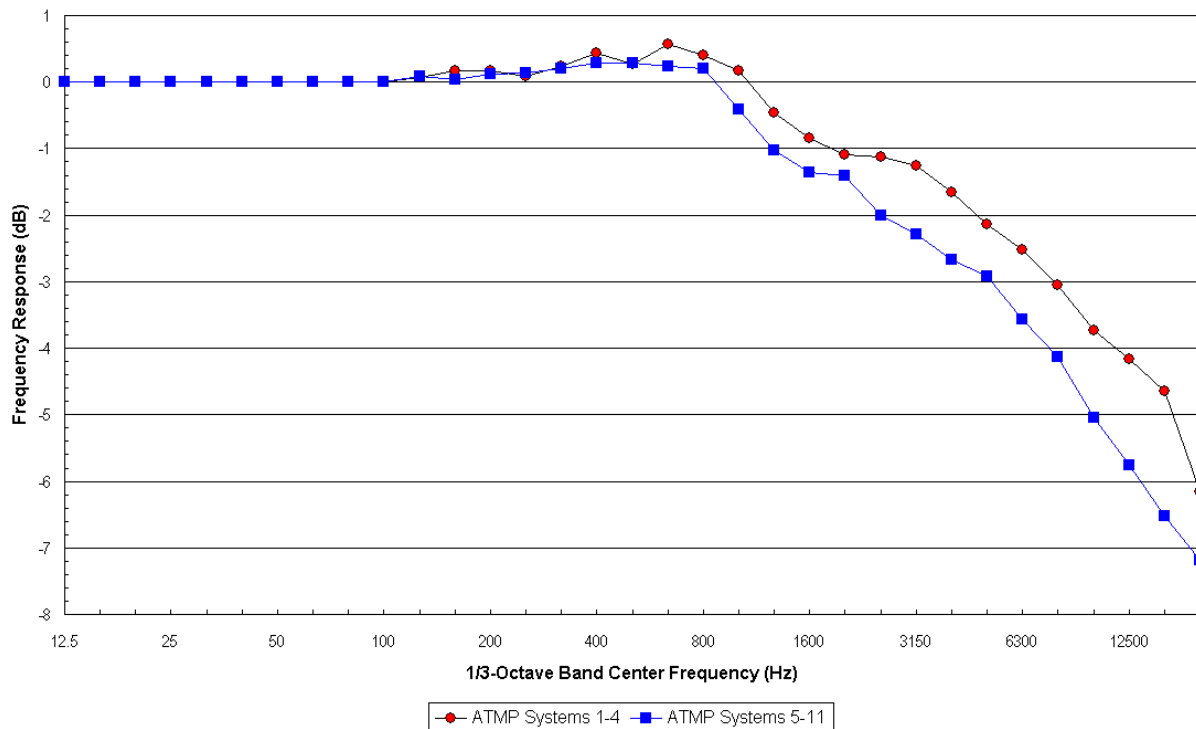


Figure 98. Windscreen frequency responses.

APPENDIX D. SLANT RANGE PHOTO ANALYSIS

Because NPATMA directs the development of ATMPs and 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. As stated in Section 2.1, 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. Computer modeling, utilizing the FAA's Integrated Noise Model (INM) or Aviation Environmental Design Tool (AEDT), will then be used to compute aircraft sound levels in areas within Haleakalā for which resource constraints (or other issues) did not allow for direct measurements. This section discusses the slant range data collected during acoustic observer logging and used to correlate actual data with computer-predicted data during the INM-modeling task.

In Haleakalā, slant range photos were taken at two measurement sites: Site P01 (Namana o ke Akua) in Haleakalā Crater, and Site ST8 (Waimoku Falls) in lower Kipahulu. As discussed in Section 5.4, the digital photograph files were compared with the detailed logs, which the field observer kept, noting site, data, time, aircraft type, aircraft model, operator, tail number, and direction of flight (when identifiable). No editing was required for the slant range photos. All photos were individually reviewed to determine if they were properly taken, i.e., the image must represent a perpendicular side or frontal view of the aircraft. If the aircraft was shown at an angle other than perpendicular, that photo is discarded. Remaining "good" photos were then processed using a Volpe-developed program, Fotoscal,²⁸ which computes the slant range distance of the aircraft to the camera, based on a triangular comparison of the length of the aircraft in pixels in the photograph with the actual length of the aircraft as documented by the manufacturer.

Table 36 provides a summary of the slant range data collected. Using this data as model input into the model, computer-predicted, aircraft sound levels were determined and compared with sound levels measured in the park (see Table 37 and Figure 99). It should be noted that these comparisons do not account for "real world" variability of meteorological conditions, complex terrain, and assumes cruise-operating conditions. They are meant solely as a reasonableness check.

Table 36. Summary of computed slant range data.

Site ID	Photo #	Date and Time	Air Tour Operator	Aircraft	Direction of Flight	Computed Slant Range (ft)
P01	0067	2/28/03 9:02 AM	Sunshine	Aerospatiale AS-350	E->W	13755
P01	0074	2/28/03 9:16 AM	Blue Hawaiian	Aerospatiale AS-350	W->E	13626
P01	0077	2/28/03 9:24 AM	Air Maui	Aerospatiale AS-350	W->E	10583
P01	0078	2/28/03 9:25 AM	Air Maui	Aerospatiale AS-350	E->W	13501
P01	0080	2/28/03 9:27 AM	Blue Hawaiian	Eurocopter EC-130B	W->E	12505
P01	0081	2/28/03 9:28 AM	Blue Hawaiian	Eurocopter EC-130B	E->W	16153
P01	0083	2/28/03 9:33 AM	Sunshine	Aerospatiale AS-350	W->E	13949
P01	0084	2/28/03 9:33 AM	Sunshine	Aerospatiale AS-350	W->E	11580
P01	0307	N/A	Air Maui	Aerospatiale AS-350	N/A	17384
ST8*	0221	3/4/03 10:18 AM	Air Maui	Aerospatiale AS-350	NW->E	2176
ST8*	0222	3/4/03 10:18 AM	Air Maui	Aerospatiale AS-350	NW->E	2196
ST8*	0225	3/4/03 10:43 AM	Blue Hawaiian	Eurocopter EC-130B	NW->E	2917
ST8*	0226	3/4/03 10:44 AM	Blue Hawaiian	Eurocopter EC-130B	NW->E	2646
ST8*	0227	3/4/03 11:31 AM	Blue Hawaiian	Eurocopter EC-130B	NW->E	2299
ST8*	0229	3/4/03 11:31 AM	Blue Hawaiian	Eurocopter EC-130B	NW->E	1985
ST8*	0230	3/4/03 11:31 AM	Blue Hawaiian	Eurocopter EC-130B	NW->E	1820
ST8*	0231	3/4/03 11:31 AM	Blue Hawaiian	Eurocopter EC-130B	NW->E	1780

Table 37. Comparison of measured and predicted aircraft sound levels.

Site ID	Photo #	Air Tour Operator	Aircraft	Computed Slant Range (ft)	Maximum Measured Sound Level (dBA)	Maximum Predicted Sound Level (dBA)
P01	0067	Sunshine	Aerospatiale AS-350	13755	45.0	42.0
P01	0074	Blue Hawaiian	Aerospatiale AS-350	13626	39.0	35.4
P01	0077	Air Maui	Aerospatiale AS-350	10583	35.8	45.5
P01	0078	Air Maui	Aerospatiale AS-350	13501	41.6	42.2
P01	0080	Blue Hawaiian	Eurocopter EC-130B	12505	38.7	36.8
P01	0081	Blue Hawaiian	Eurocopter EC-130B	16153	41.7	32.5
P01	0083	Sunshine	Aerospatiale AS-350	13949	45.0	41.7

Site ID	Photo #	Air Tour Operator	Aircraft	Computed Slant Range (ft)	Maximum Measured Sound Level (dBA)	Maximum Predicted Sound Level (dBA)
P01	0084	Sunshine	Aerospatiale AS-350	11580	45.0	44.3
P01	0307	Air Maui	Aerospatiale AS-350	17384	37.9	38.8
ST8*	0221	Air Maui	Aerospatiale AS-350	2176	66.6	65.3
ST8*	0222	Air Maui	Aerospatiale AS-350	2196	66.6	65.2
ST8*	0225	Blue Hawaiian	Eurocopter EC-130B	2917	67.0	61.7
ST8*	0226	Blue Hawaiian	Eurocopter EC-130B	2646	67.0	62.7
ST8*	0227	Blue Hawaiian	Eurocopter EC-130B	2299	82.0	61.3
ST8*	0229	Blue Hawaiian	Eurocopter EC-130B	1985	70.7	65.8
ST8*	0230	Blue Hawaiian	Eurocopter EC-130B	1820	70.7	66.5
ST8*	0231	Blue Hawaiian	Eurocopter EC-130B	1780	82.0	64.4

Note 1: Sound level measurements were not being conducted at Site ST8 during the time of slant range photo data collection.

Note 2: The Sound Exposure Level (SEL, denoted by the symbol L_{AE}) is essentially the sound level determined by the sum of the sound energy of an event, normalized to 1 second. See also the Terminology Section.

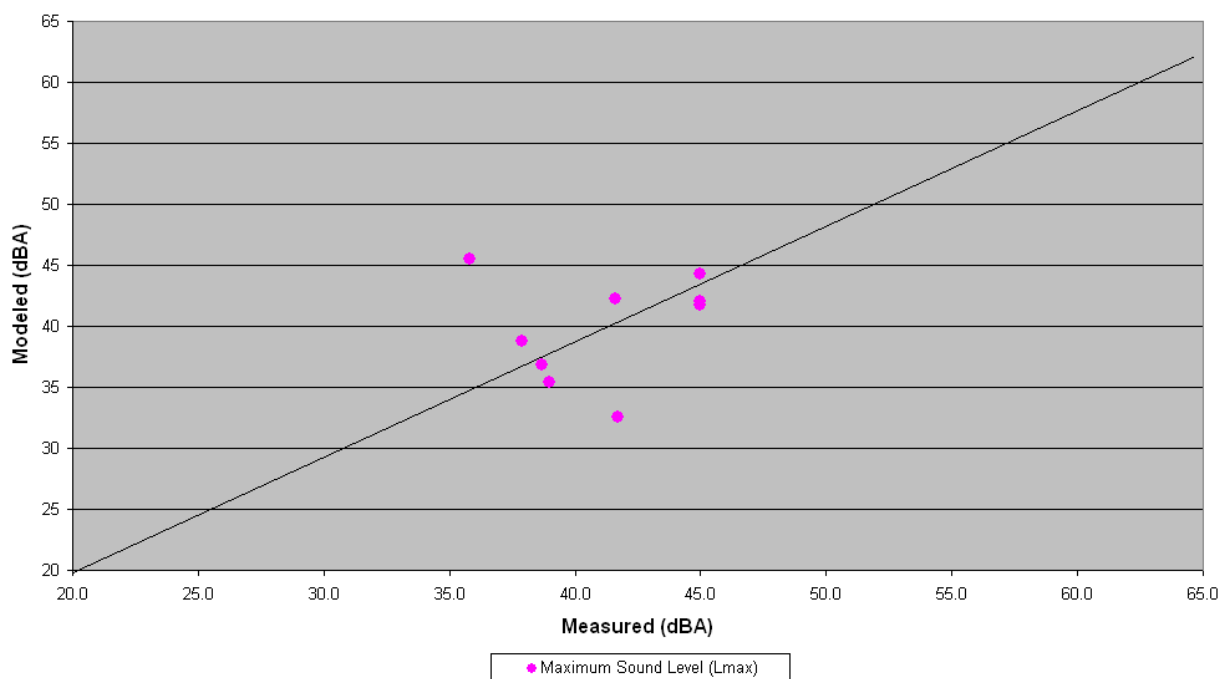


Figure 99. Comparison of measured and predicted aircraft sound levels.

Page left blank intentionally.

APPENDIX E. 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.²⁵

The concept of transferability of data is currently a working hypothesis.³⁷ 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 (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 E.1) and climate/ecological domain (Section E.2) are the two most important technical factors influencing

* The number of initial acoustic zones within a particular park are 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.³⁸

E.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 38).³⁹ Haleakalā' land cover distribution using the NLCD categories is shown in Table 39. 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.
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.

* 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	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 se-ed 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 Haleakalā.

Land Cover Class	Land Cover Subclass	Area (Sq. Mi.)
Water	11 Open Water	0.0
Water	12 Perennial Ice/Snow	0.0
Developed	21 Low Intensity Residential	0.1
Developed	22 High Intensity Residential	0.0

Land Cover Class	Land Cover Subclass	Area (Sq. Mi.)
Developed	23 Commercial/Industrial/Transportation	0.0
Barren	31 Bare Rock/Sand/Clay	17.3
Barren	32 Quarries/Strip Mines/Gravel Pits	0.0
Barren	33 Transitional	0.0
Forested Upland	41 Deciduous Forest	0.0
Forested Upland	42 Evergreen Forest	20.6
Forested Upland	43 Mixed Forest	0.0
Shrubland	51 Shrubland	18.4
Non-Natural Woody	61 Orchards/Vineyards/Other	0.0
Herbaceous Upland Natural/Semi-natural Vegetation	71 Grasslands/Herbaceous	12.4
Herbaceous Planted/Cultivated	81 Pasture/Hay	0.0
Herbaceous Planted/Cultivated	82 Row Crops	0.3
Herbaceous Planted/Cultivated	83 Small Grains	0.0
Herbaceous Planted/Cultivated	84 Fallow	0.0
Herbaceous Planted/Cultivated	85 Urban/Recreational Grasses	0.0
Wetlands	91 Woody Wetlands	0.0
Wetlands	92 Emergent Herbaceous Wetlands	0.0
	Total *	69.1

E.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 Alaska, and adjacent portions of Mexico and Canada. The ecological divisions of North America used in association with NatureServe are shown in Figure 100.⁴⁰ 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.[†]

* 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.

† It should be noted that there is currently no standard vegetation classification system in the NPS. However, several

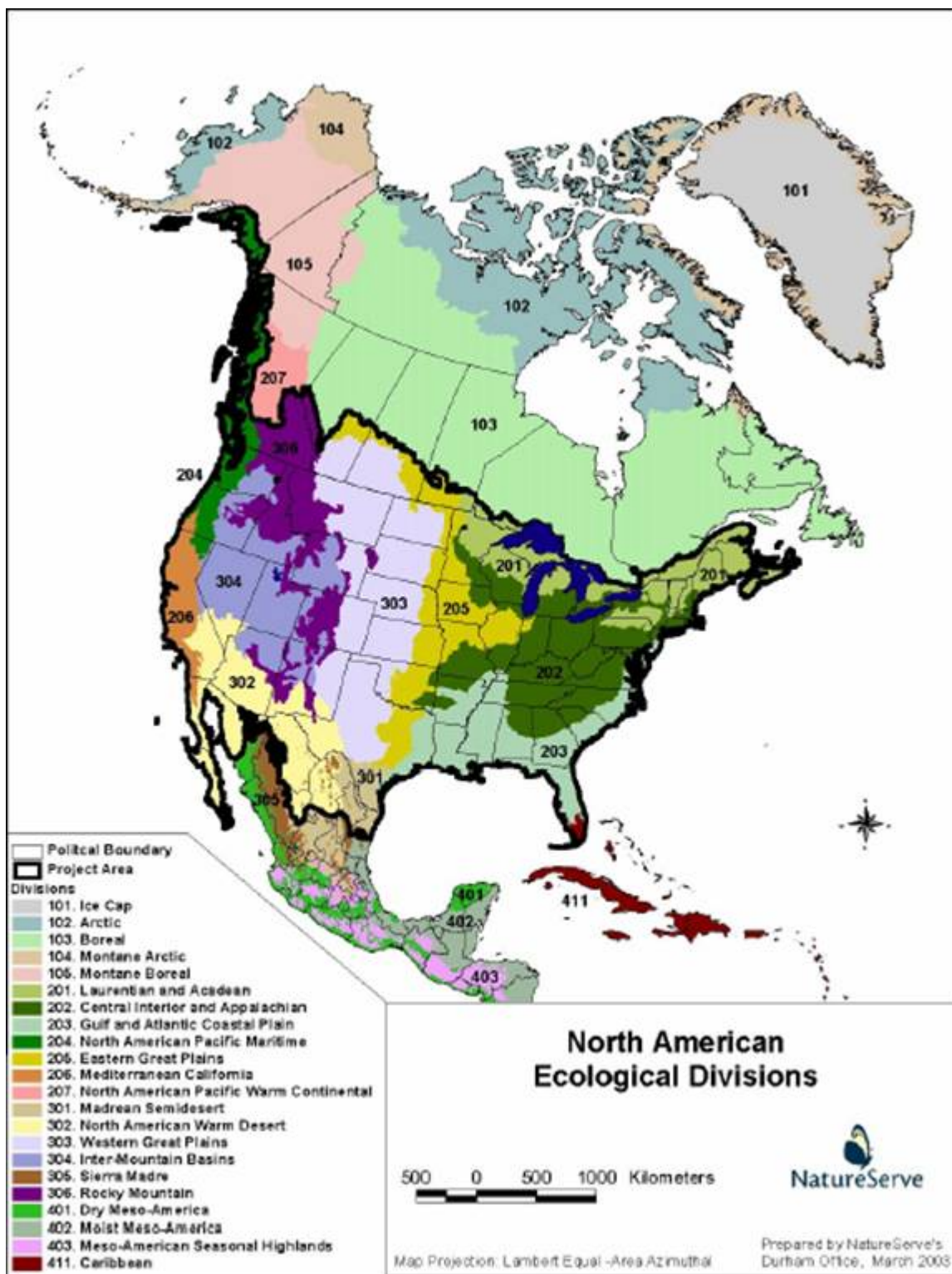


Figure 100. NatureServe ecological divisions of North America.*

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.

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

E.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 E.3.1) and the Kolmogorov-Smirnoff (K-S) Statistic (see Section E.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.

E.3.1 Regression Analysis

Although sound-level data, whose associated wind speed was greater than 5 m/s (see Section 5.5.1), 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 dependent 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.

E.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.⁴¹ 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 Haleakalā 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.

Page left blank intentionally.

REFERENCES

- ¹ FICAN Findings and Recommendations on Tools for Modeling Aircraft Noise in National Parks, Washington, DC: Federal Interagency Committee on Aviation Noise, February 2005.
- ² Fleming, Gregg G., Plotkin, Kenneth J., Roof, Christopher J., Ikelheimer, Bruce J., Senzig, David A., FICAN Assessment of Tools for Modeling Aircraft Noise in the National Parks, Cambridge, MA: John A. Volpe National Transportation Systems Center, Arlington, VA: Wyle Laboratories, Winchester, MA: Senzig Engineering, March 2005.
- ³ “Acoustical Terminology,” American National Standard, ANSI S1.1-1994, New York: American National Standards Institute, 1994.
- ⁴ “Procedures for Outdoor Measurement of Sound Pressure Level,” American National Standard, ANSI Standard S12.18-1994, New York: American National Standards Institute, 1994.
- ⁵ Johnson, D.L., Marsh, A.H., and Harris, C.M. “Acoustical Measurement Instruments,” Handbook of Acoustical Measurements and Noise Control, New York: Columbia University, 1991.
- ⁶ “Specification for Sound Level Meters,” American National Standard, ANSI Standard S1.4-1983 (R 1990), New York: American National Standards Institute, 1990.
- ⁷ Report on Effects of Aircraft Overflights on the National Park System, Washington, DC: National Park Service, July 1995.
- ⁸ “Soundscape Preservation and Noise Management,” Director’s Order #47, Washington, DC: National Park Service, December 2000.
- ⁹ “Determination of Minimum Distance from Ground Observer to Aircraft for Acoustic Tests,” Society of Automotive Engineers, Aerospace Information Report AIR 902,

- Warrendale, Pennsylvania: Society of Automotive Engineers, May 1966.
- ¹⁰ National Parks Air Tour Management Act of 2000. Public Law 106-181, 114 Stat. 61, Title VIII, Section 801, April 2000.
- ¹¹ Boeker, E.R., E. Dinges, B. HE, G. Fleming, G.J. Roof, P.J. Gerbi, A.S. Rapoza, and J.Hemann, Integrated Noise Model (INM) version 7.0 technical manual, Report No. FAA-AEE-08-01 (OMB No. 704-0188), Washington D.C.: Federal Aviation Administration, 2008.
- ¹² Fleming, Gregg G., Roof, Christopher J., and Read, David R., Draft Guidelines for the Measurement and Assessment of Low-Level Ambient Noise, Report No. DTS-34-FA865-LR1. Cambridge, MA: John A. Volpe National Transportation Systems Center, March 1998.
- ¹³ National Park Service. <http://www.nps.gov/hale/index.htm>.
- ¹⁴ Haleakalā National Park: Comprehensive Interpretive Plan - Section 1. Long-Range Interpretive Plan. Official Review Draft. Makawao, HI: Haleakalā National Park, 2001.
- ¹⁵ National Park Service Public Use Statistics Office. <https://irma.nps.gov/Stats/>
- ¹⁶ Fleming, G., Roof, C., Read, D., Burstein, J., Senzig, D., Rapoza, A., Gerbi, P., and Lee, C., Ambient Sound Levels at Four Department of Interior Conservation Units in Support of Homestead Air Base Reuse Supplemental Environmental Impact Statement, Report Nos. DOT-VNTSC-FAA-99-3, FAA-AEE-99-02, Cambridge, MA: John A. Volpe National Transportation Systems Center, June 1999.
- ¹⁷ Fleming, G., Roof, C., Rapoza, A., and Read, D., Development of Noise Dose/Visitor Response Relationships for the National Parks Overflight Rule: Bryce Canyon National Park Study, Report Nos. DOT-VNTSC-FAA-98-6, FAA-AEE-98-01, Cambridge, MA: John A. Volpe National Transportation Systems Center, July 1998.
-

- ¹⁸ Roof, C., Rapoza, A., Fleming, G., and Read, D., Development of Noise Dose/Visitor Response Relationships for the National Parks' Overflight Rule: Bryce Canyon National Park & Grand Canyon National Park Overlook Study, Cambridge, MA: John A. Volpe National Transportation Systems Center, (to be published).
- ¹⁹ Sneddon, Matthew, Silvati, Laura, Pearsons, Karl, and Fidell, Sanford, Measurements and Analyses of the Indigenous Sound Environment of Coniferous Forests Canoga Park, CA: BBN Systems and Technologies, January 1994.
- ²⁰ Department of the Interior: Haleakalā National Park Statement for Management. Maui County, HI: Haleakalā National Park Staff, December 1997.
- ²¹ General Management Plan/Environmental Impact Statement: Haleakalā National Park. Maui County, HI: U.S. Department of the Interior, National Park Service, January 1995.
- ²² Joshi, Amishi, Alternatives Development Report, Cambridge, MA: John A. Volpe National Transportation Systems Center, June 2005.
- ²³ Special Operating Rules for Air Tour Operators in the State of Hawai'i, 14 CFR, Chapter I, Part 91, Special Federal Aviation Regulation 71, October 2003.
- ²⁴ Letter of Agreement between Haleakalā National Park and Hawai'i Air Tour Association (Maui), January 1998.
- ²⁵ Cynthia S.Y. Lee, Gregg G. Fleming, Christopher J. Roof, John M. MacDonald, Christopher J. Scarpone, Andrew R. Malwitz, and Gary Baker, Hawai'i Volcanoes National Park: Baseline Ambient Sound Levels 2003, Report No. DOT-VNTSC-FAA-06-07, Cambridge, MA: John A. Volpe National Transportation Systems Center, September 2016.
- ²⁶ Macdonald, J., Lee, C., and Scarpone, C., NoiseLogger™ System Reference, Cambridge, MA: John A. Volpe National Transportation Systems Center, April 2003.
-

- ²⁷ Macdonald, J., Lee, C., and Scarpone, C., NoiseLogger Plus™ System Reference, Cambridge, MA: John A. Volpe National Transportation Systems Center, April 2003.
- ²⁸ Senzig, David, User's Guide for Volpe Photo-scaling System, Cambridge, MA: John A. Volpe National Transportation Systems Center, January 2003.
- ²⁹ Koopmann, Jonathan, et al., Aviation Environmental Design Tool (AEDT) Technical Manual Version 2b, Report No. DOT-VNTSC-FAA-16-11, Washington, D.C.: Federal Aviation Administration, June 2016.
- ³⁰ NPS report on ambient sound levels in Arches National Park and Bryce Canyon National Park (to be published).
- ³¹ Lau, Michael C., Lee, Cynthia S.Y., Rochat, Judith L., Boeker, Eric R., and Fleming, Gregg G., FHWA Traffic Noise Model® (FHWA TNM®) User's Guide (Version 2.5 Addendum), Report No. FHWA-PD-96-009, Washington, D.C.: Federal Highway Administration, April 2004.
- ³² Anderson, G., et al., Dose-Response Relationships Derived from Data Collected at Grand Canyon, Haleakalā and Hawai'i Volcanoes National Parks, National Parks Service, NPOA Report No. 93-6, Lexington, MA and Madison, WI: Harris Miller & Hanson Inc. and HBRS Inc., October 1993.
- ³³ Plotkin, Kenneth J., Review of Technical Acoustical Issues Regarding Noise Measurements in National Parks, Draft Report WR 01-20, Arlington, VA: Wyle Laboratories, January 2002.
- ³⁴ Fleming, Gregg, Summary of Noise-Related Technical Areas of Agreement, Cambridge, MA: John A. Volpe National Transportation Systems Center Acoustics Facility, November 2003.
- ³⁵ On-going discussions with Skip Ambrose (NPS Natural Sounds and Night Skies
-

- Division).
- ³⁶ Miller, Nicholas P., Ross, Jason C., Horonjeff, Richard D., Anderson, Grant S., Acoustic Data Collected at Hawai'i Volcanoes National Park, HMMH Report No. 295860.341, Burlington, MA: Harris Miller Miller & Hanson Inc., July 2003.
- ³⁷ National Parks Air Tour Management Plan (ATMP) Program Implementation Plan, Cambridge, MA: John A. Volpe National Transportation Systems Center, September 2005.
- ³⁸ Lee, Cynthia and Fleming, Gregg, Proposed FY04 Acoustic Monitoring Plan, Cambridge, MA: John A. Volpe National Transportation Systems Center Acoustics Facility, March 2004.
- ³⁹ Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, N. Van Driel, Completion of the 1990s National Land Cover Data Set for the Conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources, Photogrammetric Engineering and Remote Sensing, 67:650-652, 2001.
- ⁴⁰ Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K., Snow, and J. Teague, Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems, NatureServe, Arlington, Virginia, 2003.
- ⁴¹ Press, W.H., Teukolsky, S.A., Vetterling, W.T., Flannery B.P., Numerical Recipes in Fortran; The Art of Scientific Computing, Cambridge University Press, pg. 617, 1992.