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Glacier National Park: Baseline Ambient Sound Levels 2004



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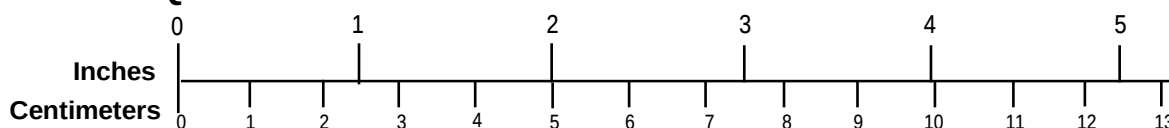
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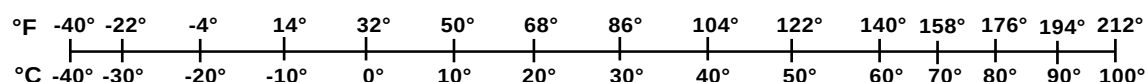
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EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA), with the cooperation of the National Park Service (NPS) and assistance of the U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) is developing Air Tour Management Plans (ATMP) or Voluntary Agreements (VA) for all national parks with commercial air tours, with the exception of the Grand Canyon National Park (GCNP), tribal lands within or abutting the GCNP, air tour operations flying over or near the Lake Mead National Recreation Area solely as a transportation route to conduct an air tour over GCNP, Rocky Mountain National Park, exempt parks (50 or fewer annual tours), and national park units located in Alaska.

An important area of technical support is the determination of representative baseline ambient sound levels for the study parks. The baseline ambient data will be used to establish a foundation from which potential noise impacts can be assessed. Ambient sound level data collected in this study will be used for the primary purposes of:

- Establishing baseline ambient sound levels (both overall and frequency based) in key areas within a park;
- Establishing the different sound sources contributing to the baseline levels in key areas within a park;
- Modeling sound levels in other similar areas within a park for which resource constraints (or other issues) do not allow for direct measurements;
- Building a library of baseline ambient sound levels (both overall and frequency based), which may potentially be used in future ATMPs / 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) ("Findings and Recommendations on Tools for Modeling Aircraft Noise in National Parks"), as the best-

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

[†] Note: The land cover data provided in this figure was obtained from the U.S. Geological Survey (USGS) and does not reflect those areas decimated by forest fires in 2003. Additionally, although a portion of Glacier lies in Canada, any ATMP or VA development will only pertain to areas within the United States.

practice modeling methodology currently available for evaluating aircraft noise in national parks.^{1,2}

This document summarizes the noise measurement study undertaken to provide data for the baseline ambient noise environment in Glacier National Park (Glacier). As shown in Figure 1, Glacier is located in Montana.



Figure 1. Location of Glacier National Park.

The Volpe Center conducted baseline ambient sound level measurements during August 2004, where approximately two weeks of acoustical and meteorological data were measured at eight sites throughout the park. The primary goal of the site selection process was to identify the minimum number of field-measurement sites, which would allow for characterization of the baseline ambient sound levels throughout the entire park. This was accomplished by identifying acoustically representative regions for which data could be collected and stratified, i.e., “acoustic zones.” These data could then be applied to other regions in the park possessing similar attributes, which will affect acoustics, such as land cover, wind conditions, and wildlife habitats.

Because the vegetative land cover within a park is one of the key attributes affecting the acoustics as land cover directly affects how sounds propagate from a source to a receiver, Geographic Information System (GIS) data for land cover were used in the development of the initial acoustic zones. For Glacier, the major land cover types in Glacier are bare rock/sand/clay and evergreen/ conifer forest, which cover 95 percent of the park (see Figure 2).

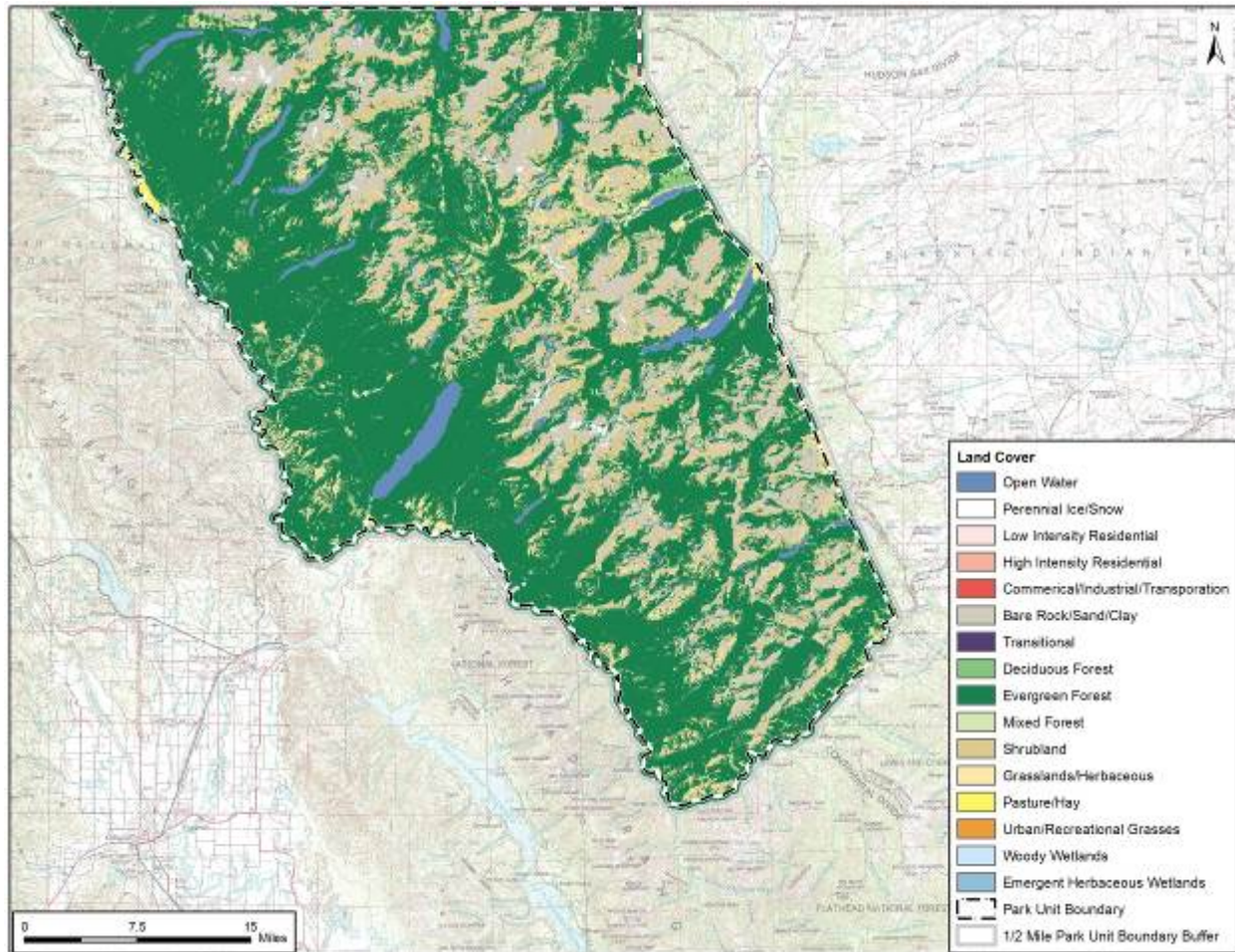


Figure 2. National Land Cover Database (NLCD) land cover types for Glacier.*

The initial acoustic zones were discussed during a 1-day meeting held on August 5, 2004 between the FAA, the NPS, the Volpe Center, and Glacier NPS personnel. Based on Glacier NPS expertise with the soundscape of areas within the park, the following final acoustic zones were agreed upon:

- Alpine/Subalpine (Zone 1 – approximately 13 percent of the park) – includes the NLCD

* Note: The land cover data provided in this figure was obtained from the U.S. Geological Survey (USGS) and does not reflect those areas decimated by forest fires in 2003. Additionally, although a portion of Glacier lies in Canada, any ATMP or VA development will only pertain to areas within the United States.

Perennial Ice/Snow and Bare Rock/Sand/Clay land cover categories;

- Deciduous Forest (Zone 2 – approximately 2 percent of the park) – includes the NLCD Deciduous Forest land cover category;
- Coniferous Forest (Zone 3 – approximately 62 percent of the park) – includes the NLCD Evergreen and Mixed Forest land cover categories;
- Herbaceous (Zone 4 – approximately 20 percent of the park) – includes the NLCD Grasslands, Herbaceous, Shrubland, and Pasture land cover categories; and
- Water (Zone 5 – approximately 3 percent of the park) – includes the NLCD Open Water land cover category.

Figure 3 displays the locations of the final acoustic zones and measurement sites selected (see also additional discussion in Section 2).

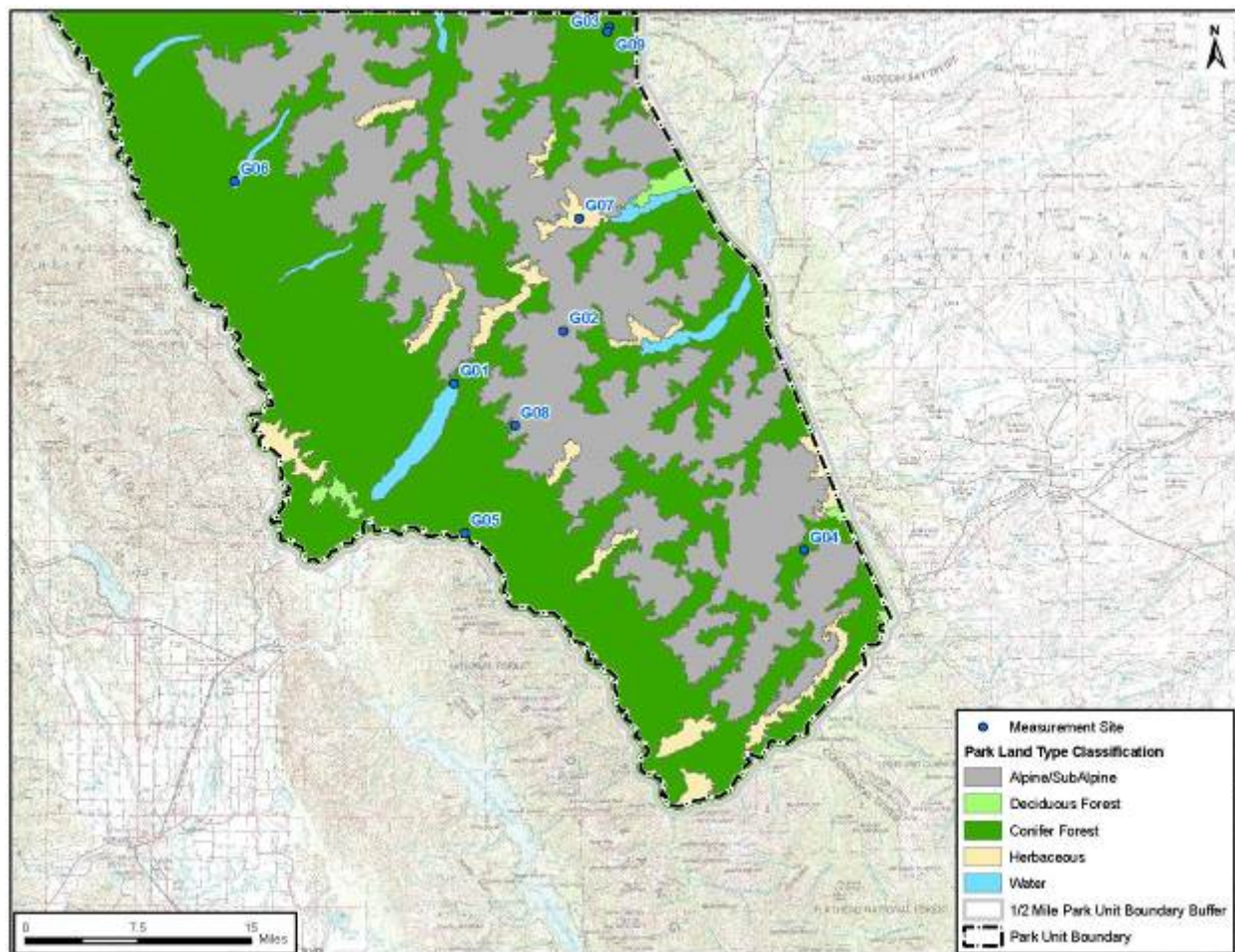


Figure 3. Final acoustic zones and measurement sites for Glacier.

Figure 4 provides a timeline of the data collection for each site. Note: Sites within the same acoustic zones are shown in like colors.

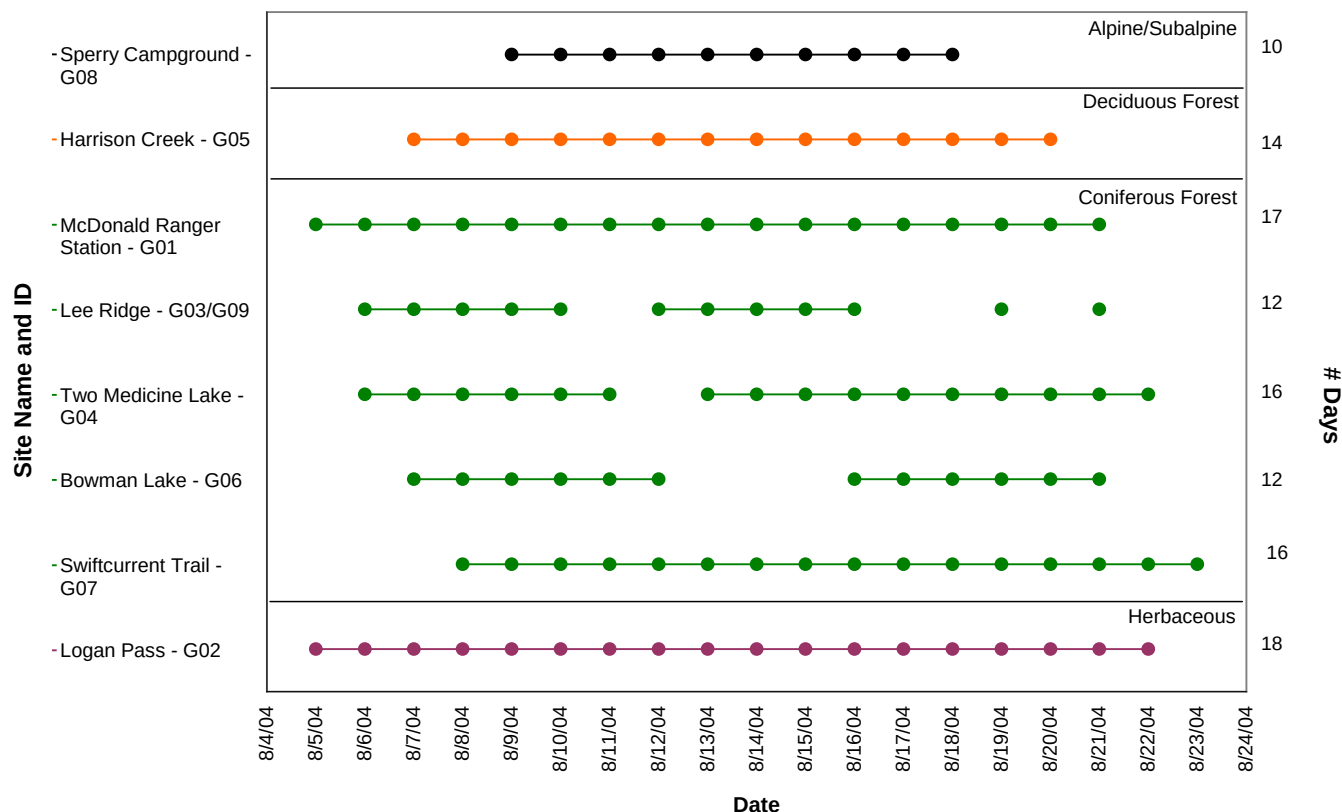


Figure 4. Baseline ambient data collection timeline for each site.

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 20 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.

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/VA analyses will be based on daytime ambient data. For Glacier, only data measured during the time period of 7 am to 7 pm were used. This time period reflects typical operating hours for air tour operators conducting air tours in Glacier according to Flight Standards District Office personnel.

In general, 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.

Using the data in the acoustic observer logs to group the individual, one-second, sound level values, four different types of ambient for each of the three above metrics can be computed from the data. The four primary types of “ambient” used in this document are defined as follows (see Figure 5):

- *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.

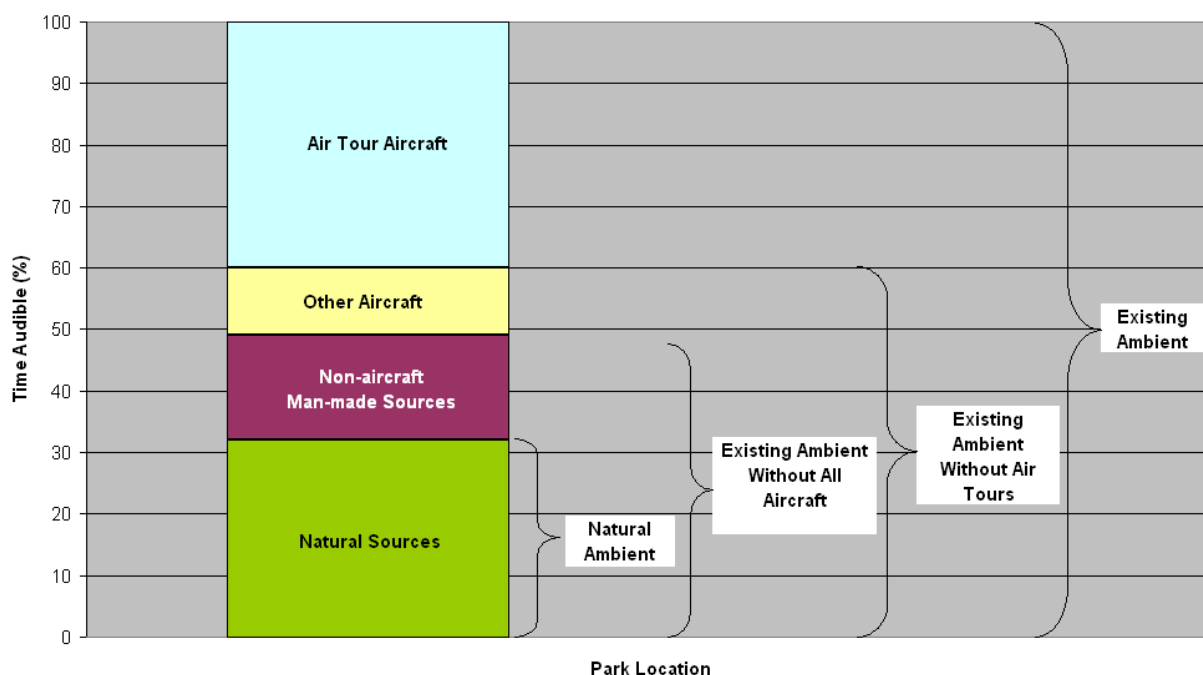


Figure 5. Graphical depiction of ambient definitions.

Table 1 contains a summary of the ambient, sound level data measured at each measurement site.

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

The table is arranged by acoustic zone, followed by measurement site number. The first four columns in the table are arranged as follows:

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

The remaining columns define the ambient sound levels computed, as described in Section 6.3.1.*

- For the Existing Ambient, the following metrics are computed:
 - *L_{Aeq}*: The equivalent, A-weighted sound level (in decibels). Presented is the energy-averaged value determined from daytime sound levels (7 am to 7 pm), taking into account the data from all days of measurements;
 - *L₅₀*: The *L₅₀* sound level (in decibels) determined by the sound level exceeded 50 percent of the daytime hours (7 am to 7 pm), taking into account the data from all days of measurements; and
 - *L₉₀*: The *L₉₀* sound level (in decibels) determined by the sound level exceeded 90 percent of the daytime hours (7 am to 7 pm), taking into account the data from all days of measurements.
- For the Existing Ambient Without Air Tours, the Existing Ambient Without All Aircraft, and Natural Ambient:
 - *L₅₀*

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

- *Acoustic Zone*: The acoustic zone in which the measurement site was located;

* 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 Glacier, only data measured during the time period of 7 am to 7 pm were used. This time period reflects typical operating hours for air tour operators conducting air tours in Glacier according to Flight Standards District Office personnel.

- *Site Name*: The name of the site;
- *Site ID*: The unique three-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;
- *Level of Visitor-Use*: A designator indicating expected visitor use (with “high” indicating sites such as overlooks, “moderate” indicating short hikes, and “low” indicating minimal or no visitor use such as in the wilderness/backcountry) in the measurement site area;
- *Total Duration (hh:mm:ss)*: The duration of all acoustic observer logging performed at the measurement site.

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

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

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

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

The columns in the table are arranged as follows:

- *Acoustic Zone*: The acoustic zone in which the measurement site was located;
- *Site ID*: The unique three-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 (e.g., general aviation, commercial jet, and military) sounds were audible; and
- *Human*: Periods of time during which human noise sources (visitor- and mechanical-related) were audible.

Table 1. Summary of measured ambient sound level data.

Acoustic Zone	Site Name	Site ID	Total # Days	Existing Ambient, All Data: L _{Aeq} (dBA)	Existing Ambient, All Data: L ₅₀ (dBA)	Existing Ambient, All Data: L ₉₀ (dBA)	Existing Ambient, 7am to 7pm: L _{Aeq} (dBA)	Existing Ambient, 7am to 7pm: L ₅₀ (dBA)	Existing Ambient, 7am to 7pm: L ₉₀ (dBA)	Existing Ambient Without Air Tours, 7am to 7pm: L ₅₀ (dBA)	Existing Ambient Without All Aircraft: L ₅₀ (dBA)	Natural Ambient : L ₅₀ (dBA)
1 Alpine/Subalpine	Sperry Campground	G08	10	36.3	34.2	32.3	36.3	34.1	32.2	34.0	34.0	34.0
2 Deciduous Forest	Harrison Creek	G05	14	42.9	31.3	24.1	41.6	32.9	26.5	32.6	32.6	25.7
3 Coniferous Forest	McDonald Ranger Station	G01	17	36.7	28.8	24.9	37.4	29.3	24.8	28.9	28.9	23.4
3 Coniferous Forest	Lee Ridge	G03/G09*	12	37.6	25.9	21.1	38.7	29.7	22.7	29.3	28.9	23.2
3 Coniferous Forest	Two Medicine Lake	G04	16	39.6	27.1	20.7	38.3	28.4	22.1	28.4	28.2	23.8
3 Coniferous Forest	Bowman Lake	G06	12	39.8	20.5	12.7	35.6	21.0	16.1	20.9	20.7	19.4
3 Coniferous Forest	Swiftcurrent Trail	G07	16	37.1	33.7	28.1	36.7	31.1	27.1	30.9	30.8	30.5
4 Herbaceous	Logan Pass	G02	18	35.2	31.9	28.6	36.1	30.5	27.9	30.3	30.3	29.6

* Due to access issues, site G03 was moved to another nearby clearing (site G09). Because of their proximity, however, the data for both sites were combined and treated as a single site.

Table 2. Summary of acoustic observer log data.

Acoustic Zone	Site Name	Site ID	Land Cover*	General Management Plan Zone (Geographical Area)	Level of Visitor-Use	Total Duration (hh:mm:ss)	% Time Audible: Air Tour Aircraft	% Time Audible: Other Aircraft	% Time Audible: Human	% Time Audible: Natural
1 Alpine/Subalpine	Sperry Campground	G08	42 Evergreen Forest	Backcountry (Going-to-the-Sun Road)	Low	4:36:35	3%	0%	3%	93%
2 Deciduous Forest	Harrison Creek	G05	42 Evergreen Forest	Backcountry (Middle Fork)	Low	5:10:17	4%	1%	80%	15%
3 Coniferous Forest	McDonald Ranger Station	G01	42 Evergreen Forest	Visitor Service (Going-to-the-Sun Road)	High	5:01:01	5%	1%	87%	7%
3 Coniferous Forest	Lee Ridge	G03/G09 [†]	42 Evergreen Forest	Backcountry (Goat Haunt-Belly River)	Low	2:46:30	3%	3%	63%	32%
3 Coniferous Forest	Two Medicine Lake	G04	42 Evergreen Forest	Day Use (Two Medicine)	Moderate	3:45:11	0%	1%	54%	44%
3 Coniferous Forest	Bowman Lake	G06	42 Evergreen Forest	Backcountry (North Fork)	Moderate	5:19:26	1%	3%	8%	88%
3 Coniferous Forest	Swiftcurrent Trail	G07	42 Evergreen Forest	Day Use (Many Glacier)	Moderate	2:32:58	2%	2%	7%	89%
4 Herbaceous	Logan Pass	G02	71 Grasslands/Herbaceous	Day Use (Going-to-the-Sun Road)	High	5:01:21	5%	0%	20%	75%

* Land cover is shown in accordance with the National Land Cover Data 21-class land cover classification scheme (see also Appendix E).

[†] Due to access issues, site G03 was moved to another nearby clearing (site G09). Because of their proximity, however, the data for both sites were combined and treated as a single site.

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

Metric	Acoustic Zone	Site ID	Noise-Free Periods (Natural Events)	Air Tour Aircraft Events	Other Aircraft Events	Human Events
Number Periods/Events:	1 Alpine/ Subalpine	G08	130	8	2	21
Mean Time (hh:mm:ss):	1 Alpine/ Subalpine	G08	0:01:59	0:01:11	0:00:27	0:00:22
Minimum Time (hh:mm:ss):	1 Alpine/ Subalpine	G08	0:00:03	0:00:44	0:00:26	0:00:06
Maximum Time (hh:mm:ss):	1 Alpine/ Subalpine	G08	0:22:46	0:01:43	0:00:28	0:01:53
Total Time (hh:mm:ss):	1 Alpine/ Subalpine	G08	4:18:24	0:09:29	0:00:54	0:07:48
Number Periods/Events:	2 Deciduous Forest	G05	79	8	2	90
Mean Time (hh:mm:ss):	2 Deciduous Forest	G05	0:00:37	0:01:54	0:01:23	0:02:45
Minimum Time (hh:mm:ss):	2 Deciduous Forest	G05	0:00:08	0:00:08	0:00:27	0:00:08
Maximum Time (hh:mm:ss):	2 Deciduous Forest	G05	0:05:33	0:03:23	0:02:18	0:35:31
Total Time (hh:mm:ss):	2 Deciduous Forest	G05	0:48:01	0:11:22	0:02:45	4:08:09
Number Periods/Events:	3 Coniferous Forest	G01	78	12	2	286
Mean Time (hh:mm:ss):	3 Coniferous Forest	G01	0:00:16	0:00:57	0:01:01	0:00:55
Minimum Time (hh:mm:ss):	3 Coniferous Forest	G01	0:00:05	0:00:10	0:00:55	0:00:07
Maximum Time (hh:mm:ss):	3 Coniferous Forest	G01	0:01:43	0:02:08	0:01:06	0:07:26
Total Time (hh:mm:ss):	3 Coniferous Forest	G01	0:20:28	0:15:18	0:02:01	4:23:14
Number Periods/Events:	3 Coniferous Forest	G03/G09	102	4	3	150

Metric	Acoustic Zone	Site ID	Noise-Free Periods (Natural Events)	Air Tour Aircraft Events	Other Aircraft Events	Human Events
Mean Time (hh:mm:ss):	3 Coniferous Forest	G03/G09	0:00:31	0:00:42	0:01:31	0:00:42
Minimum Time (hh:mm:ss):	3 Coniferous Forest	G03/G09	0:00:04	0:00:09	0:01:23	0:00:07
Maximum Time (hh:mm:ss):	3 Coniferous Forest	G03/G09	0:03:57	0:02:39	0:01:37	0:12:16
Total Time (hh:mm:ss):	3 Coniferous Forest	G03/G09	0:52:39	0:04:55	0:04:32	1:44:24
Number Periods/Events:	3 Coniferous Forest	G04	199	0	4	217
Mean Time (hh:mm:ss):	3 Coniferous Forest	G04	0:00:30	0:00:00	0:00:50	0:00:34
Minimum Time (hh:mm:ss):	3 Coniferous Forest	G04	0:00:05	0:00:00	0:00:29	0:00:05
Maximum Time (hh:mm:ss):	3 Coniferous Forest	G04	0:08:43	0:00:00	0:01:24	0:08:04
Total Time (hh:mm:ss):	3 Coniferous Forest	G04	1:40:00	0:00:00	0:03:18	2:01:53
Number Periods/Events:	3 Coniferous Forest	G06	258	4	6	60
Mean Time (hh:mm:ss):	3 Coniferous Forest	G06	0:01:06	0:01:05	0:01:08	0:00:26
Minimum Time (hh:mm:ss):	3 Coniferous Forest	G06	0:00:04	0:00:29	0:00:15	0:00:06
Maximum Time (hh:mm:ss):	3 Coniferous Forest	G06	0:27:30	0:01:42	0:02:33	0:01:20
Total Time (hh:mm:ss):	3 Coniferous Forest	G06	4:42:19	0:02:11	0:09:05	0:25:51
Number Periods/Events:	3 Coniferous Forest	G03/G09	102	4	3	150
Mean Time (hh:mm:ss):	3 Coniferous Forest	G03/G09	0:00:31	0:00:42	0:01:31	0:00:42

Metric	Acoustic Zone	Site ID	Noise-Free Periods (Natural Events)	Air Tour Aircraft Events	Other Aircraft Events	Human Events
Minimum Time (hh:mm:ss):	3 Coniferous Forest	G03/G09	0:00:04	0:00:09	0:01:23	0:00:07
Maximum Time (hh:mm:ss):	3 Coniferous Forest	G03/G09	0:03:57	0:02:39	0:01:37	0:12:16
Total Time (hh:mm:ss):	3 Coniferous Forest	G03/G09	0:52:39	0:04:55	0:04:32	1:44:24
Number Periods/Events:	4 Herbaceous	G02	188	8	0	126
Mean Time (hh:mm:ss):	4 Herbaceous	G02	0:01:12	0:02:04	0:00:00	0:00:28
Minimum Time (hh:mm:ss):	4 Herbaceous	G02	0:00:05	0:00:15	0:00:00	0:00:05
Maximum Time (hh:mm:ss):	4 Herbaceous	G02	0:12:45	0:03:06	0:00:00	0:01:30
Total Time (hh:mm:ss):	4 Herbaceous	G02	3:45:42	0:16:29	0:00:00	0:59:10

The measured ambient values presented in Table 1 are assigned to each acoustic zone. Then, because it is not feasible to carry out field data collection efforts in all areas of a park, the contributing effect of localized noise sources, such as waterfalls, river rapids, trains, and vehicles on roads, are typically modeled and combined with the measured sound levels to develop a composite, baseline, ambient “map” of a park. An ambient “map” is essentially a comprehensive grid of ambient sound levels throughout a study area. The composite, baseline, ambient map (along with representative one-third octave-band spectral data) is used as input to the INM to compute various noise-related descriptors and generate the sound-level contours that will be used in the assessment of potential noise impacts due to air tour operations.

In the vicinity of and within Glacier, there were nine localized sound sources (i.e., roadways and railways): Going-to-the-Sun Road, Camas Road, Outside North Fork Road, Inside North Fork Road, Routes 2, 49, 89, and 17, and the Burlington Northern and Santa Fe Railway. Roadway sound sources were modeled using the Federal Highway Administration’s Traffic Noise Model[®] (TNM).^{3,4} Railway sound source was modeled using a railway simulation model developed for the Florida Department of Transportation.⁵

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

- *Existing Ambient Without Source of Interest* – Descriptor 5 from the table above; and
- *Natural Ambient* – Descriptor 11 from the table above.

Figure 6 and Figure 7 present the two ambient maps, respectively.

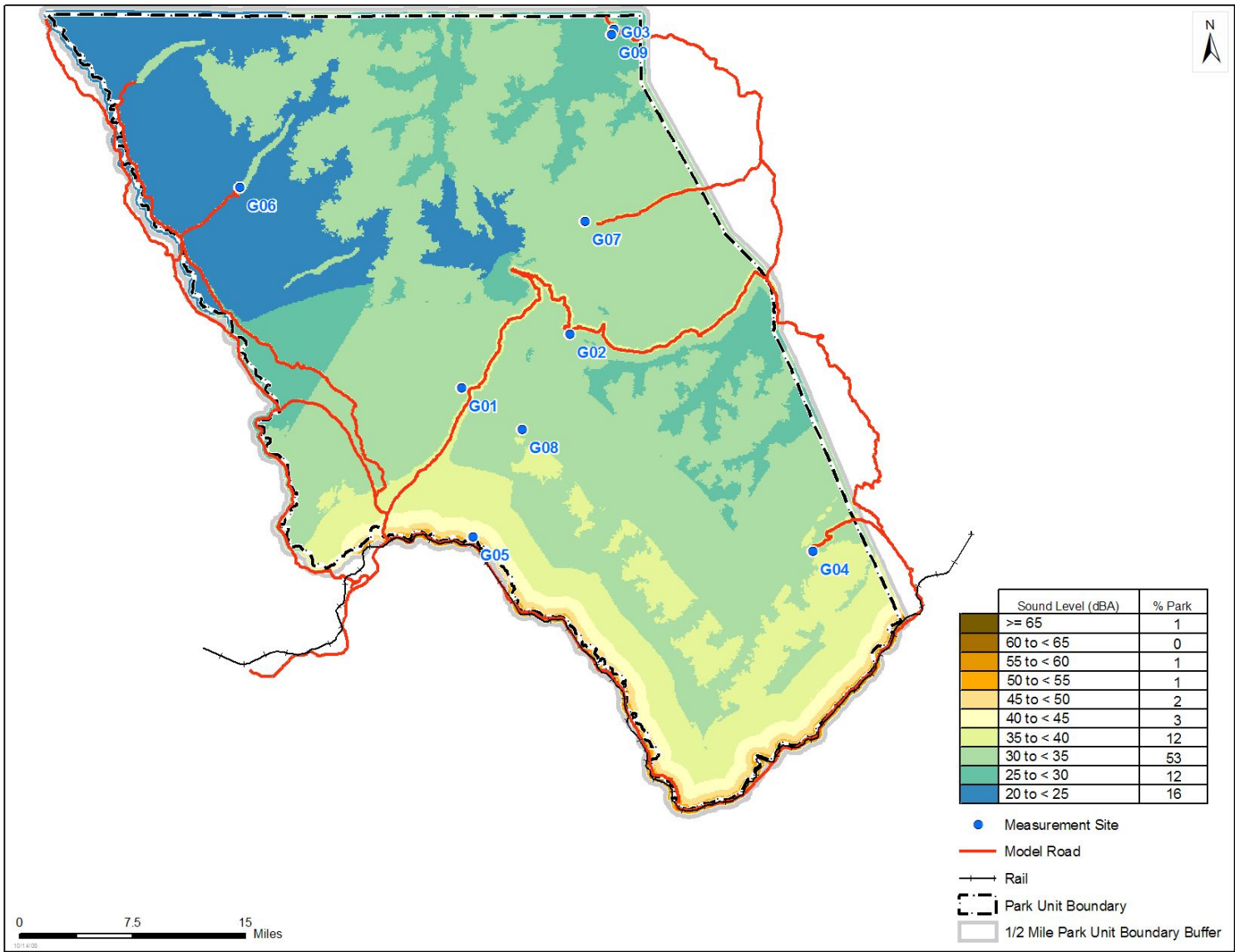


Figure 6. Baseline composite ambient map – Existing Ambient without Air Tours: L₅₀.

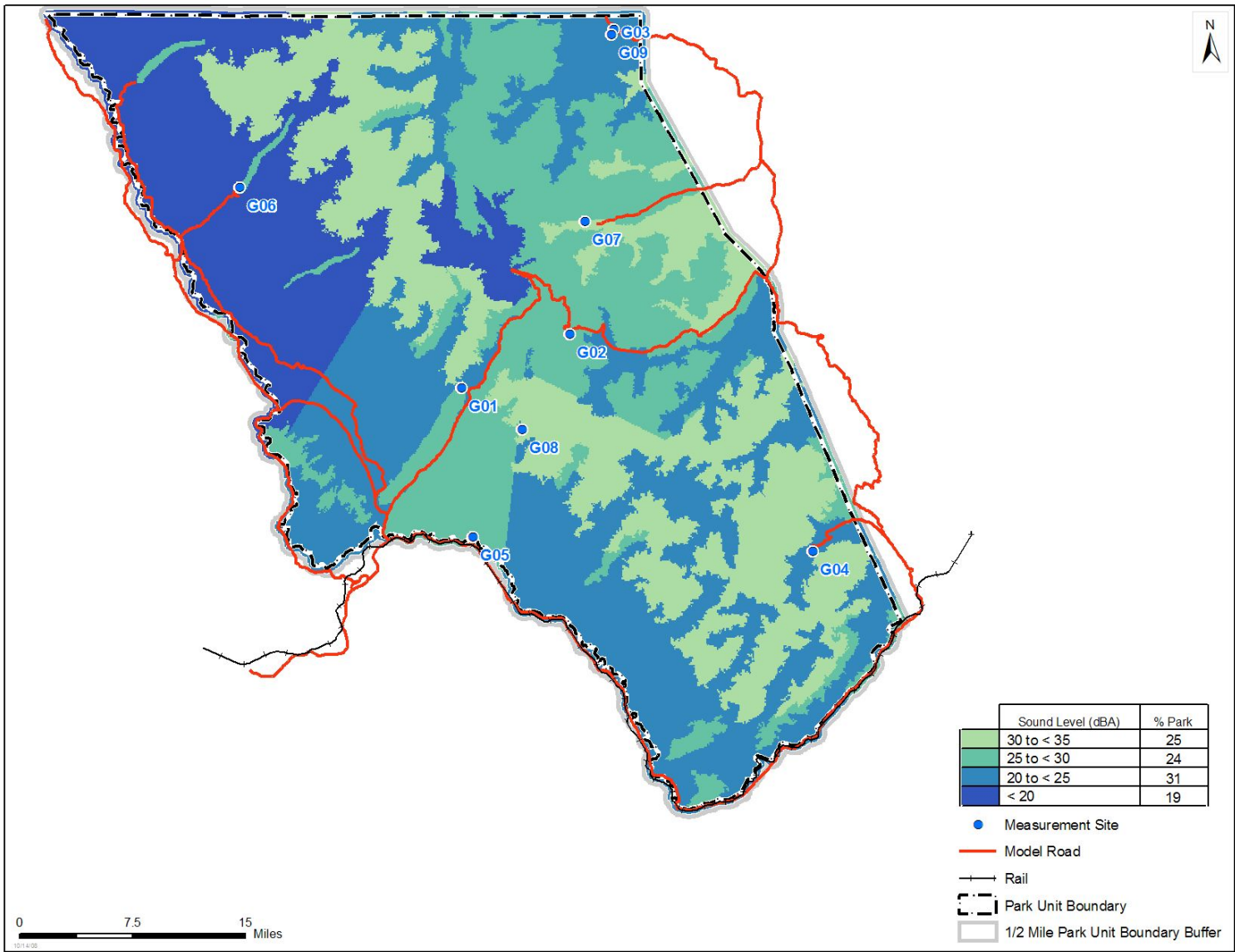


Figure 7. Baseline composite ambient map – Natural Ambient: L₅₀

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.⁶ 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, Research and Special Programs Administration, John A. Volpe National Transportation Systems Center (Volpe Center) is supporting the FAA, Western-Pacific Region (AWP), and working cooperatively with the NPS, Natural Sounds 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 August 2004 in Glacier National Park (Glacier). As shown in Figure 8 Glacier is located in northwestern Montana and was established in 1910. In 1932, it was designated the Waterton-Glacier International Peace Park with Canada, which became a World Heritage Site in 1995. A more detailed description of the Park can be found in Section 2 of this document.

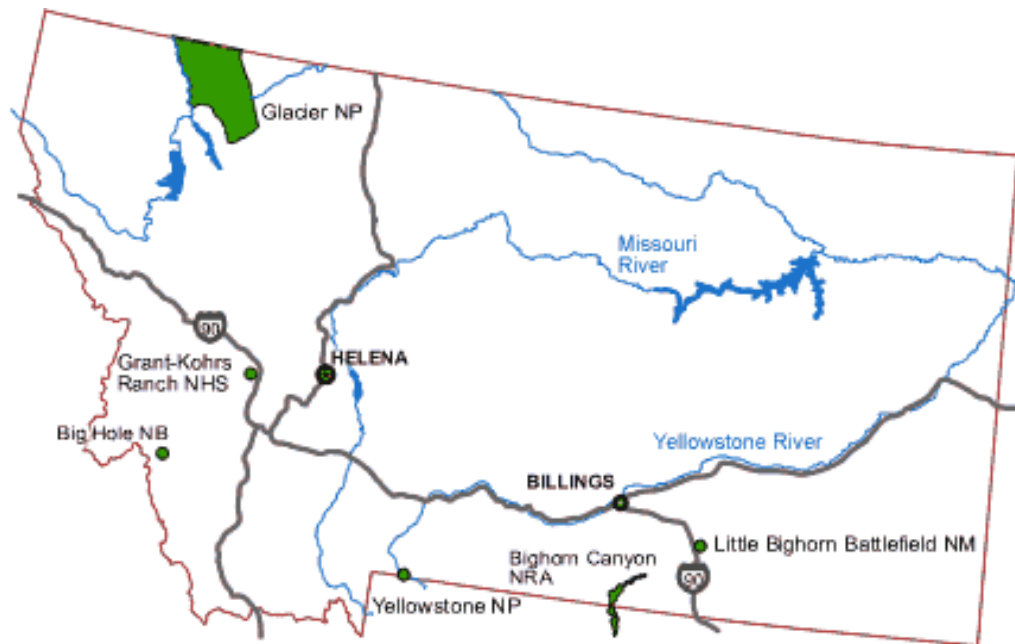


Figure 8. Location of Glacier National Park.

1.2 Objectives

The primary objective of this study is to quantify the baseline ambient sound levels within Glacier to establish a foundation from which potential noise impacts can subsequently be assessed, if necessary. Approximately two weeks of acoustical and meteorological data were measured at nine 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 Glacier;
- Establishing the different sound sources contributing to the baseline levels in key areas within Glacier;
- Modeling sound levels in other similar areas within Glacier 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 future ATMPs or VAs to generalize baseline ambient sound levels within similar types of parks, or park areas to those encountered at Glacier.

The data will be used as input into the FAA's Integrated Noise Model (INM)),⁷ 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) ("Findings and Recommendations on Tools for Modeling Aircraft Noise in National Parks"), as the best-practice modeling methodology currently available for evaluating aircraft noise in national parks, and agreed to by the NPS and FAA.^{1,2}

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,⁸ and discussions with the members of the FAA Western-Pacific Region, NPS Natural Sounds and Night Skies Division, Glacier park personnel, and Flight Standards District Office (FSDO) representatives.

1.3 Report Organization

The presentation of this document, entitled "Glacier National Park: Baseline Ambient Sound Levels 2004," 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 describes the development of instrumentation noise floor adjustments. Appendix E discusses the acoustic zone analysis. All related references are presented at the end of this document.

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

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2. SITE SELECTION

Glacier is located in northwestern Montana, on the Canadian border. The park was established in 1910. In 1932, Glacier and Waterton Lakes National Park, in Canada, were designated Waterton-Glacier International Peace Park, which was recognized as a World Heritage Site in 1995.⁹ The park preserves 1,013,572 acres with over 90 percent proposed wilderness, and contains at least 27 active glaciers.¹⁰ The acoustical environment within the park is varied due to grasslands on lower mountain slopes, forested valleys, areas of alpine vegetation, and rock- and ice-capped peaks rising to nearly 10,500 feet. As it encompasses an area around the Continental Divide, natural and meteorological conditions differ on eastern and western portions of the park. Human activity is primarily concentrated along the Going-to-the-Sun Road, which runs through the center of the park. Over 2 million people visit the park annually.¹¹ Figure 9 provides a general overview of the areas within Glacier.

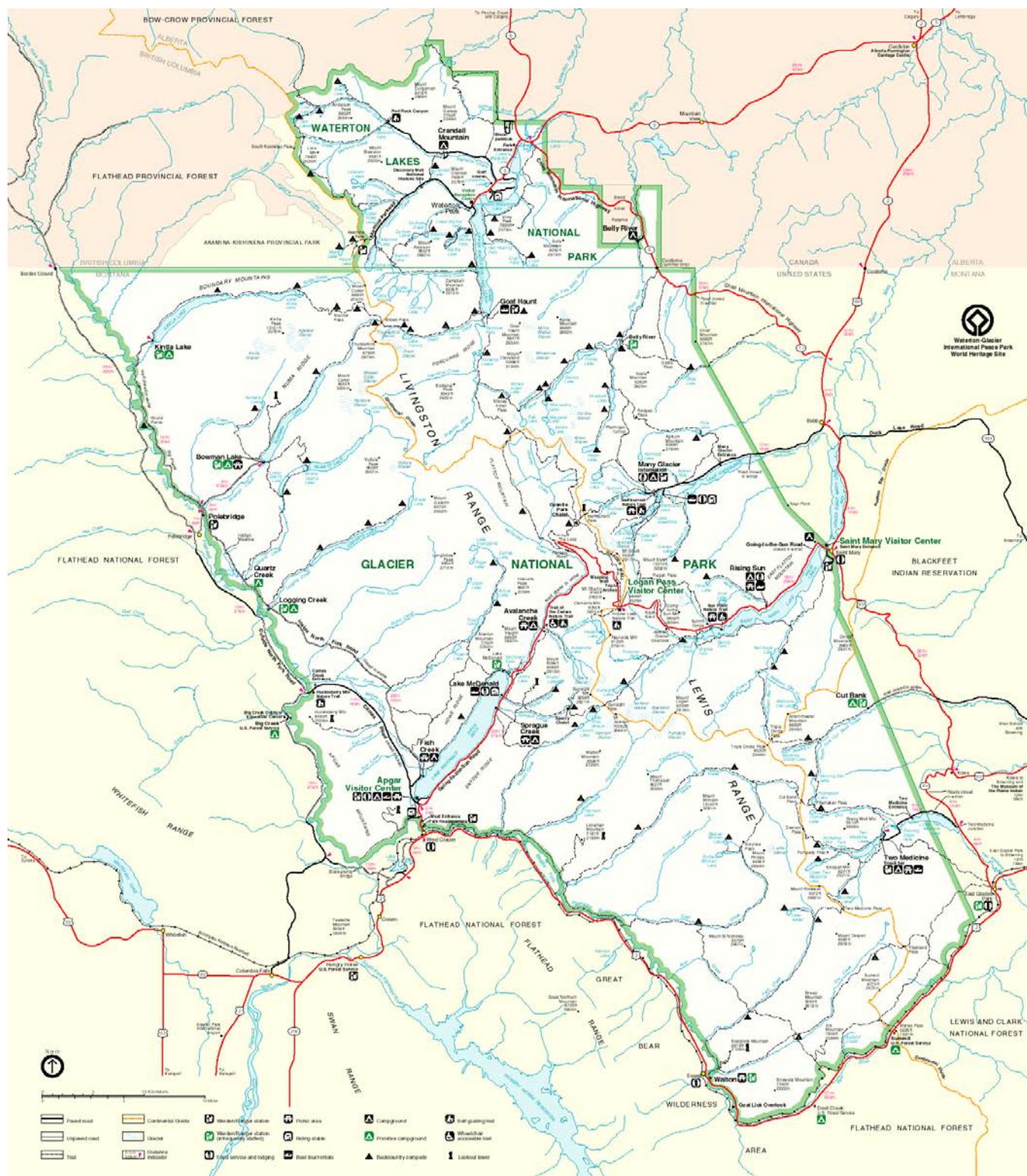


Figure 9. Overview map of Glacier.*

* As shown, a portion of Glacier lies in Canada. Areas within Canada are not within the scope of NPATMA.

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.^{12,13,14,15}
- *Climate Conditions (see Section 2.3):* Climate conditions include: temperature, humidity, precipitation, wind speed, wind direction, etc.; all of which can affect ambient sound levels as shown in previously referenced studies. For example, higher elevation areas typically exhibit higher wind speeds resulting in higher ambient sound levels. Climate is also dependent upon daily and seasonal variations, which can affect ambient sound levels. For example, under conditions of a temperature inversion (temperature increasing with increasing height as in winter and at sundown), sound waves may be heard over larger distances; and winds tend to increase later in the day, and, as such, may be expected to contribute to higher ambient noise levels in the afternoon as compared with the morning. In addition, biological activity is also affected by climate and seasonality. Natural biological sounds fluctuate with season and might contribute to lower ambient sound levels in the winter. Finally, visitors contribute to a wide variety of sounds, including hikers talking and walking, tour buses and other vehicular noises, as well as air tours. The influence of weather on visitor-use patterns is also important. For example, moderate climate areas of a park are much more popular for backcountry hiking and camping. Areas with more extreme climates are visited less often, for shorter periods of time and more likely only during the day.

The above primary criteria were used to determine the acoustic zones in Glacier (see Section 2.7), and then combined with the following secondary criteria to determine the final sites selected (see Section 2.8):

- *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 significant impacts, if any, caused by commercial air tours, the consideration of existing air tour routes during site selection is very important. Sites in the vicinity of air tour routes provide the unique opportunity to gather in-situ information during ambient data collection regarding the noise source of interest, i.e., air tour aircraft.
- *Logistics/Access (see Section 2.6):* 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

Glacier's large size and diverse landscape of forests, alpine meadows, and lakes supports a wide range of vegetative types, including Arctic, Great Basin, Great Plains, Rocky Mountain, and Pacific Northwest vegetation.¹⁶ Figure 10 provides an overview of the general land cover in Glacier. The two major land cover types in Glacier (bare rock/sand/clay and evergreen/conifer forest) cover 95 percent of the park. The steep, variable terrain ranging from 3,200 to 10,500 ft

(975 to 3,200 m), exhibits marked contrasts in temperature and precipitation over relatively short distances. Measurement sites were selected to encompass as many of vegetative/topography types as possible.

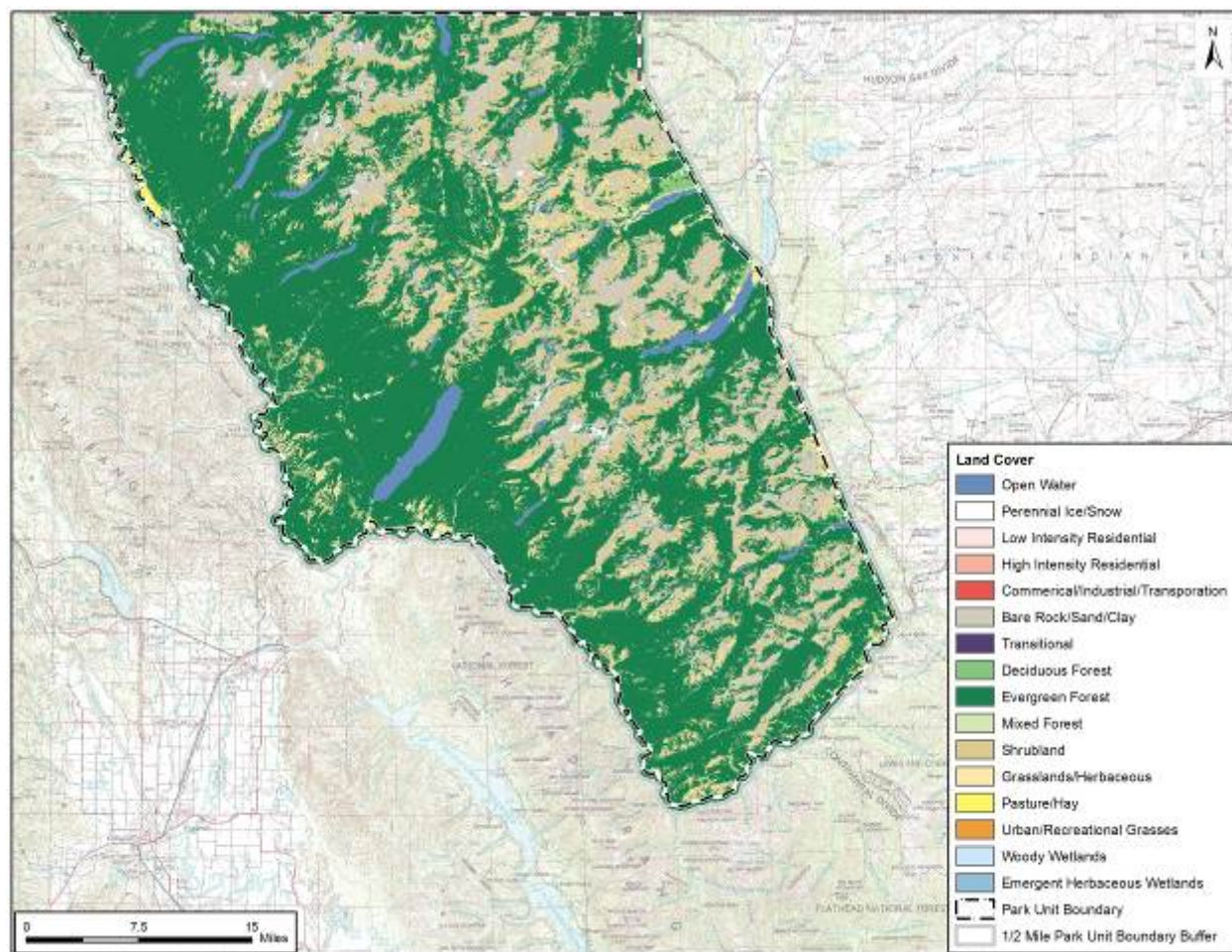


Figure 10. National Land Cover Database (NLCD) land cover types in Glacier.

2.3 Climate Conditions

Summer temperatures in Glacier can range from overnight lows around 20 degrees F, to daytime highs above 90 degrees F, with average daytime temperatures in the 60s and 70s, and average nighttime temperatures in the 40s.¹⁷ Temperatures are generally 10 to 15 degrees cooler above the tree line, and snow can fall at any time. The western valleys receive more rainfall, while strong winds and sunny days prevail on the eastern side of the park. The mountainous terrain and high elevation with peaks reaching nearly 10,500 ft (3200 m) allow for a range of weather

conditions (temperature, humidity, precipitation, wind speed, wind direction, etc.), which greatly affect ambient sound levels. 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.

Table 4 provides the monthly climate summary recorded by meteorological stations nearest the park (Kalispell, MT). It should be noted that it was agreed that data collection would take place during peak visitor season – summer. It is during this season that wildlife activity is more prevalent, visitor activity is increased, and air tours operate.

Table 4. Monthly climate summary for Glacier.

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (mph)	3.9	4.4	5.5	6.6	6.6	5.9	5.4	5.3	4.8	4.2	4.1	3.8
Prevailing Direction	S	S	SSE	SSE	SSE	SSE	SSE	S	S	S	S	S
Average Max Temp (F)	28.8	34.8	41.9	53.0	64.1	71.2	79.5	78.4	66.9	52.7	37.4	30.2
Average Min Temp (F)	15.5	18.6	23.0	29.8	37.1	43.7	47.4	46.3	39.0	31.8	25.0	18.7
Average Total Precipitation (in)	3.5	2.3	1.9	1.8	2.5	3.3	1.7	1.6	2.1	2.4	3.1	3.3
Average Total Snow Fall (in)	38.7	21.8	15.2	3.4	0.5	0.2	0.0	0.0	0.1	1.9	16.9	36.6
Average Snow Depth (in.)	18.0	21.0	18.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	9.0

2.4 Park Resources/Management Zones

The NPS' 1999 Glacier 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:¹⁸

- *Visitor Service Zone*: includes developed areas, paved roads, and campgrounds with potable water and sanitation facilities. Natural resources will be managed to protect visitor health and safety, promote enjoyment of the setting, and mitigate the effects on surrounding areas. Cultural resources will be managed to preserve historic districts, landmarks, and national register properties and the elements that contribute to their designations. Visitors can expect congested conditions.

- *Day Use Zone*: includes selected areas with specific destinations that visitors can reach easily within a day from visitor use zones. Natural resources will be managed to ensure a high degree of resource integrity, though concentrated use of trail corridors and destinations will be expected.
- *Rustic Zone*: includes primitive facilities and campgrounds representative of early western national park development and traditional visitor experiences in them. Modest impacts on natural resources will be tolerated, mostly near campgrounds and facilities. Most facilities in this zone will be fully accessible. Natural quiet will predominate.
- *Backcountry Zone*: Management will focus on protection and (when necessary) restoration of resources and natural processes. The expectations of visitors will be for few encounters with other visitors most of the time. Impacts on natural resources will be confined to trail corridors and designated camping areas. Natural processes will prevail.

2.4.1 Visitor Use Areas

Park use at Glacier is year round, but concentrated in the summer months of July and August. In 2004, the total recreational visits were approximately 2 million, with nearly 600,000 visitors in August.¹¹ 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 three levels of visitor-use:

- *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., Logan Pass).
- *Moderate 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., Swiftcurrent Trail).
- *Low Visitor-Use*: Any location in a study area subject to minimal human activity, such as designated wilderness areas or restricted, hiking and camping backcountry areas - these destinations are generally located 1 hour or more from frontcountry locations (e.g., Lee Ridge).

The Glacier GMP provides for varying visitor use within six geographical areas (as shown in Figure 11). Based on the descriptions of these zones in the GMP, the general level of visitor-use for each area is as follows:

- *Many Glacier* – medium;
- *Goat Haunt-Belly River* – low;
- *Two Medicine* – medium;
- *Middle Fork* – low;
- *North Fork* – low; and
- *Going-to-the-Sun-Road Corridor* – high.

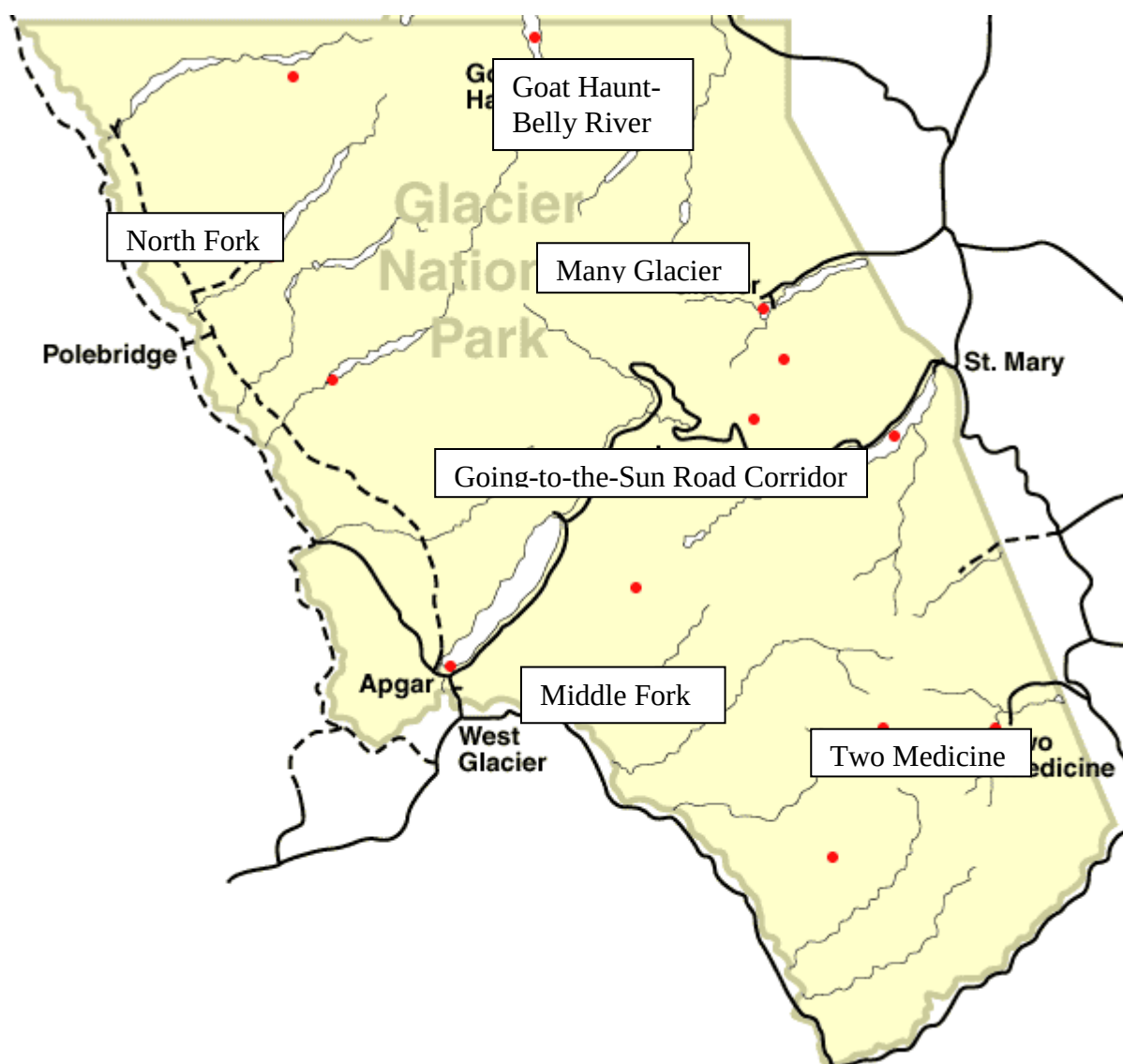


Figure 11. Visitor-Use Areas in Glacier.

2.4.2 Wildlife Resource Areas

Wildlife activity can directly affect the daily and seasonal characteristics of the natural ambient (e.g., nighttime howling from coyotes, daytime birdcalls from loons or meadowlarks). The native fauna within Glacier contains 261 bird, 63 mammal, and 172 native aquatic animal species, including several threatened and endangered wildlife species, such as the bald eagle, gray wolf, Canadian lynx, and grizzly bear. During the summer season, higher elevations provide important habitat for bears, bighorn sheep, and goats. Because of their importance, sites were chosen within these “noise sensitive” areas.

2.4.3 Cultural and Historic Resource Areas

The Blackfeet Indian Reservation borders the park in the east, while the Flathead Indian Reservation is located west and south of the park. There are six National Historic Landmarks in the park, including the Many Glacier Hotel, and the park contains over 350 structures listed on the National Register of Historic Sites. 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.

2.5 Commercial Air Tour Flight Routes

According to the Interim Operating Authority applications received by the FAA, there are currently eight existing commercial air tour operators approved to provide approximately 1,800 tours over Glacier annually. The map shown in Figure 12 which was provided to Volpe by FSDO personnel, illustrates the typical air tour routes over Glacier.

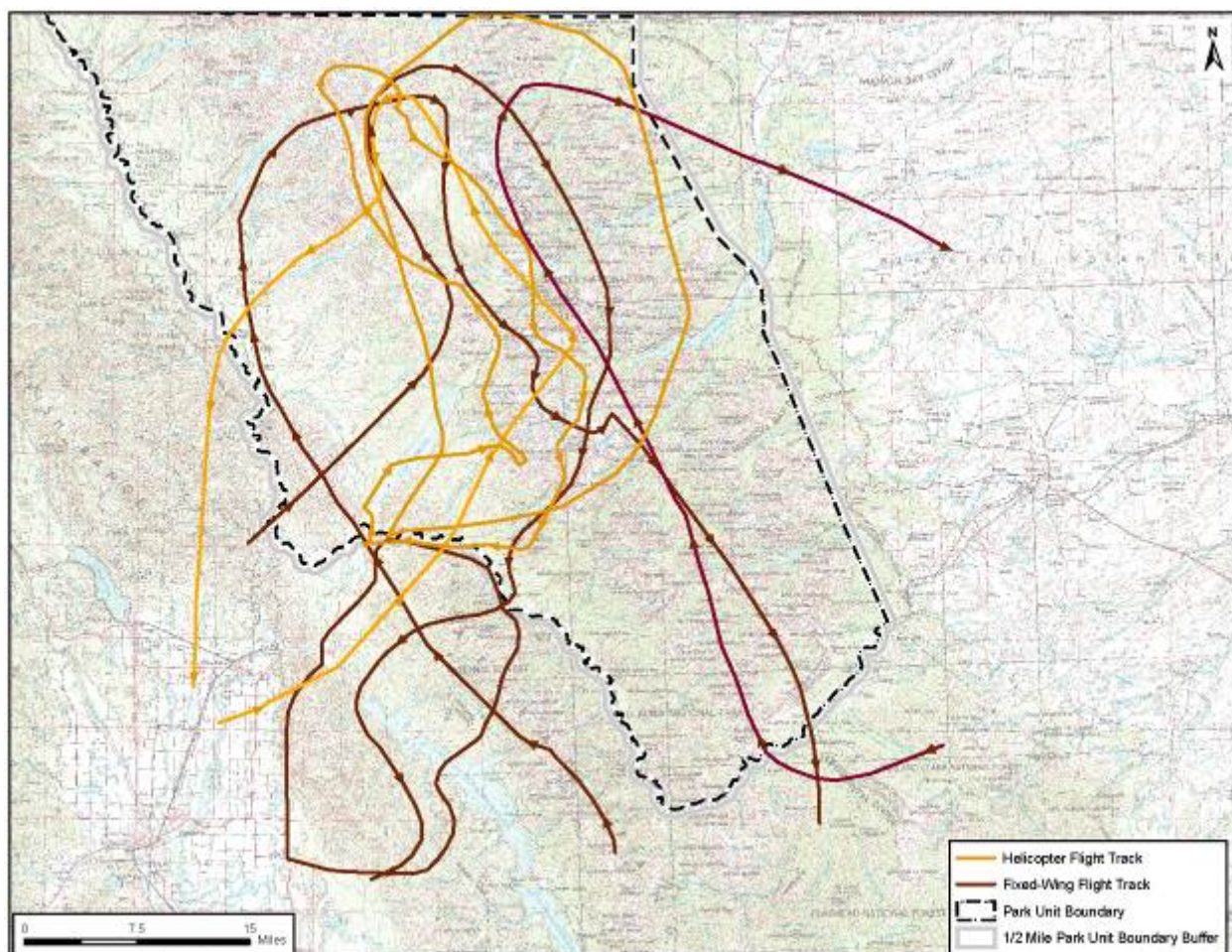


Figure 12. Air tour routes in the vicinity of Glacier.

2.6 Logistics/Access

In identifying potential measurement site locations, 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. Areas of limited accessibility include most of the central portions of the park. Access to these areas is via hiking or horseback. The famed Going-to-the-Sun Road, a National Historic Civil Engineering Landmark, is the only road through the heart of the park and crosses the Continental Divide. During landslides, the only other way to reach the other side of the park is to drive around the southern border or travel through Canada. Glacier NPS assisted the field team with the initial deployment at the sites with the more challenging access issues (e.g., Sperry Campground and Harrison Creek). Specific access considerations associated with each measurement site are discussed in Appendix A.

2.7 Glacier Acoustic Zones

As stated earlier, the vegetative land cover within a park is one of the key attributes affecting the acoustics as land cover directly affects how sounds propagate from a source to a receiver. Using Geographic Information System (GIS) data for vegetative land cover, the initial acoustic zones representing the two major land cover types in Glacier are bare rock/sand/clay and evergreen/conifer forest, which cover 95 percent of the park. The initial acoustic zones were discussed during a 1-day meeting held on August 5, 2004 between the FAA, the NPS, the Volpe Center, and Glacier NPS personnel. Based on Glacier NPS expertise with the soundscape of areas within the park, the following final acoustics were agreed upon (see Figure 13):

- *Alpine/Subalpine (Zone 1 – approximately 13 percent of the park):* Alpine communities begin on mountains above or just below the timberline of spruce and firs, either on gentle slopes where the soil has developed large meadow areas or on windswept slopes where cushion plants dominate. For Glacier, this zone includes the NLCD Perennial Ice/Snow and Bare Rock/Sand/Clay land cover categories predominantly occurring at higher elevations.
- *Deciduous Forest (Zone 2 - approximately 2 percent of the park):* Aspen/poplar and cottonwood are the more common deciduous trees and are found at lower elevations, usually along lakes and streams (less than 1 percent of park). The timberline on the eastern side of the park is almost 800 feet (250 m) lower than on the western side of the Continental Divide, due to exposure to the colder winds and weather of the Great Plains. West of the Continental Divide, the forest receives more moisture and is more protected from the winter, resulting in a more densely populated forest with taller trees. This zone includes the deciduous forest land cover category.
- *Coniferous Forest (Zone 3 - approximately 62 percent of the park):* Glacier is predominantly coniferous forest - home to various species of trees such as the Engelmann spruce, Douglas fir, subalpine fir, limber pine and western larch, which is a deciduous conifer, producing cones but losing its needles each fall. Above the forested valleys and mountain slopes, alpine tundra conditions prevail, with grasses and small plants eking out an existence in a region that enjoys as little as three months without snow cover. For Glacier, this zone includes the NLCD Evergreen and Mixed Forest land cover categories.
- *Herbaceous (Zone 4 - approximately 20 percent of the park):* These areas are dominated by herbaceous or grassland vegetation. Note: Although the meadow-like areas in Logan Pass

are at a high enough elevation to be considered an alpine/subalpine community, sound propagated over soft grass would be very different from sound propagated over bare rock. For Glacier, this zone includes the NLCD Grasslands, Herbaceous, Shrubland, and Pasture land cover categories.

- *Water (Zone 5 - approximately 3 percent of the park):* There are several large lakes within Glacier. As shown in Table 5, Glacier NPS did not request an acoustic zone for bodies of water. For this study, this zone (NLCD category – Open Water) was assigned the same ambient sound levels as the zone with the least amount of shielding (herbaceous) as best available data.

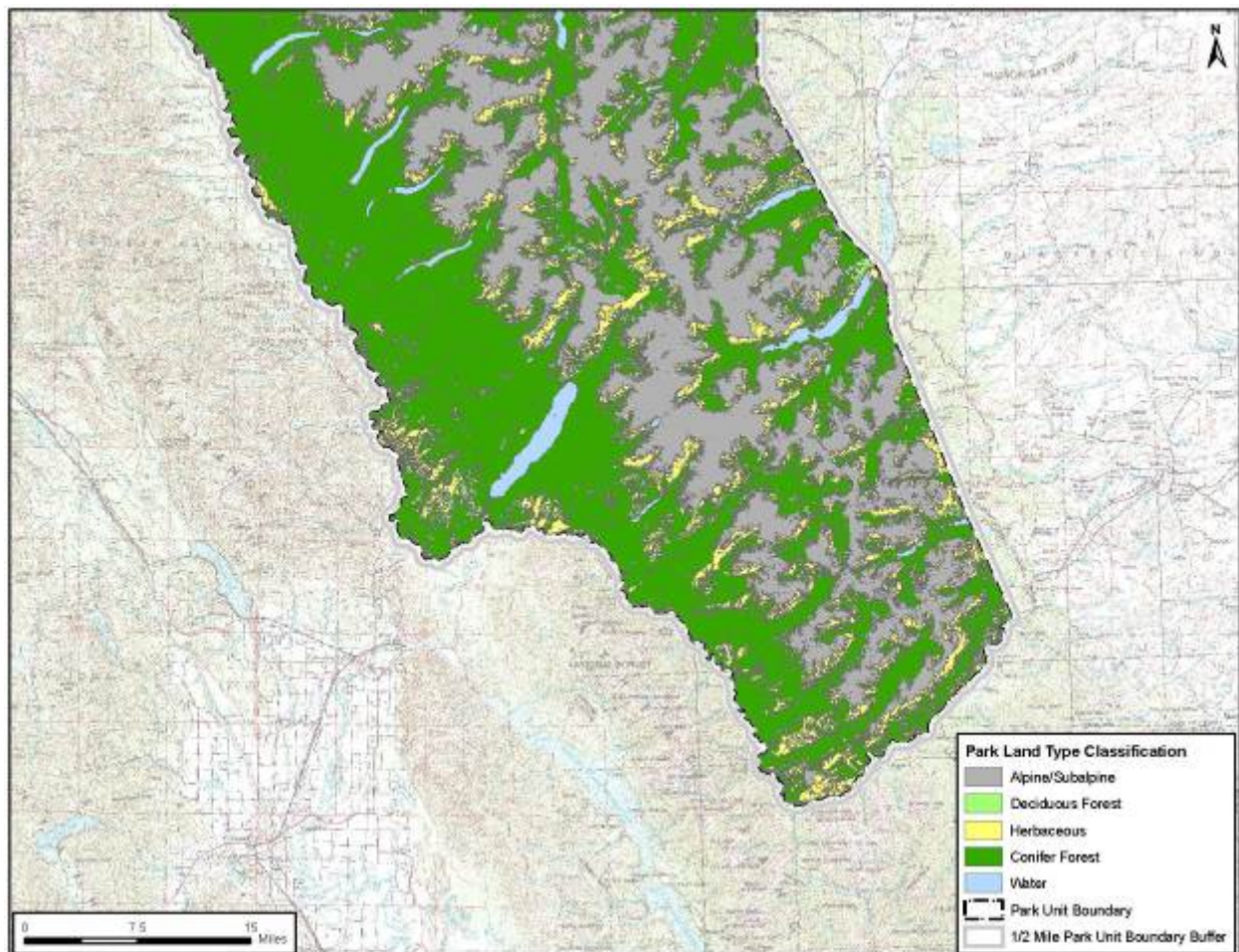


Figure 13. Acoustic zones based on land cover.

Table 5 presents a summary of the discussion of areas with similar vegetation and topography, number of monitoring systems available, and access considerations, which led to the final measurement site areas agreed upon and noted in the column labeled, “Site ID.” Figure 14 and Table 5 below summarize the final measurement sites selected. Appendix A contains individual descriptions and photographs of each measurement site location.

Table 5. Summary of Glacier site selection discussion and final measurement site locations.

Site #	Site ID	Site Name	Acoustic Zone	Vegetative Cover (NLCD Classification)	Topography	Wind	Geographic Area	Management Zone	Visitor Use	Wildlife Activity	Cultural Significance	Air Tour Activity	Accessibility
1	G02	Logan Pass	Alpine/Subalpine/ Herbaceous	Alpine / Grassland (Grassland)	Pass	Med - High	Going-to the Sun Road	Visitor Service	High	High	Yes	High	Easy
2		Mount Brown	Alpine/Subalpine/ Coniferous Forest	Alpine (Evergreen Forest)	Ridgetop	Medium	Going-to the Sun Road	Backcountry	Low	High	Yes	High	High
3	G08	Sperry	Alpine/Subalpine/ Coniferous Forest	Alpine / Subalpine (Transitional)	Mountaintop	Low	Going-to-the-Sun Road	Backcountry	Medium	Medium	Yes	High	Hard
4		Lunch Creek	Alpine/Subalpine/ Coniferous Forest	Sub Alpine (Evergreen Forest)	Cirque	Low - Med	Going-to-the-Sun Road	Visitor Service/ Backcountry	High	Medium	Yes	Medium High	Easy
5		St. Mary - 2 Dog Flats	Deciduous Forest/ Herbaceous	Aspen Forest / Grassland (Deciduous Forest/Grassland)	Foothill	Med - High	Going-to-the-Sun Road	Backcountry	High	Medium	No	Low	Easy
6		Belly River	Deciduous Forest/ Herbaceous	Aspen Forest / Grassland (Deciduous Forest/Grassland)	Valley Floor	Medium	Belly River	Backcountry	Medium	Medium	Yes	Low	Medium
7		Red Eagle Trail	Deciduous Forest/ Herbaceous	Mixed Aspen / Grassland (Deciduous Forest/Grassland)	Low Ridge	Medium	Going-to-the-Sun Road	Backcountry	Low	Medium	No	Low	Easy
8	G07	Swiftcurrent Trail	Coniferous Forest	Coniferous - Mixed Age (Evergreen Forest)	Valley Floor	Low - Med	Many Glacier	Backcountry	Medium	High	No	Medium	Easy
9	G03, G09	Lee Ridge Trail	Coniferous Forest	Coniferous Forest (Evergreen Forest)	Forested Ridge	Med - High	Belly River	Backcountry	Low	Medium	Yes	Low	Easy - Med
10		Blacktail Hills	Coniferous Forest	Coniferous Forest (Evergreen Forest)	Low Hills	High	Two Medicine / Middle Fork	Backcountry	High	Medium	No	Low	Medium
11	G05	Harrison Creek	Deciduous Forest	Aspen Forest (Deciduous Forest)	Valley Bench	Low	Middle Fork	Backcountry	Medium	Medium	No	High	Medium
12		Waterton Valley Trail	Coniferous Forest	Coniferous Forest (Evergreen Forest)	Valley Floor	Low	Belly River	Backcountry	Low	High	No	Low	Medium
13	G01	Lake McDonald - Ranger Station	Coniferous Forest	Coniferous Forest (Evergreen Forest)	Valley Floor	Low	Going-to-the-Sun Road	Visitor Service	High	High	Yes	High	Easy
14	G04	Two Medicine - Main Valley	Coniferous Forest	Coniferous Forest (Evergreen Forest)	Valley Floor	Medium	Two Medicine	Backcountry	High	Medium	Yes	Low	Easy
15	G06	North Fork Foot - Bowman	Coniferous Forest	Coniferous Forest (Evergreen Forest)	Valley Floor	Low	North Fork	Rustic	Medium	Low	Yes	Low	Easy
16		Apgar Lake	Herbaceous	Open Shrubland (Shrubland)	Ridgetop	Med - High	Going-to-the-Sun Road	Backcountry	Low	Medium	Yes	High	Medium
17		Howe Ridge	Herbaceous	Shrubland (Shrubland)	Low Ridge	Low	Going-to the Sun Road	Backcountry	Low	Medium	No	High	Easy

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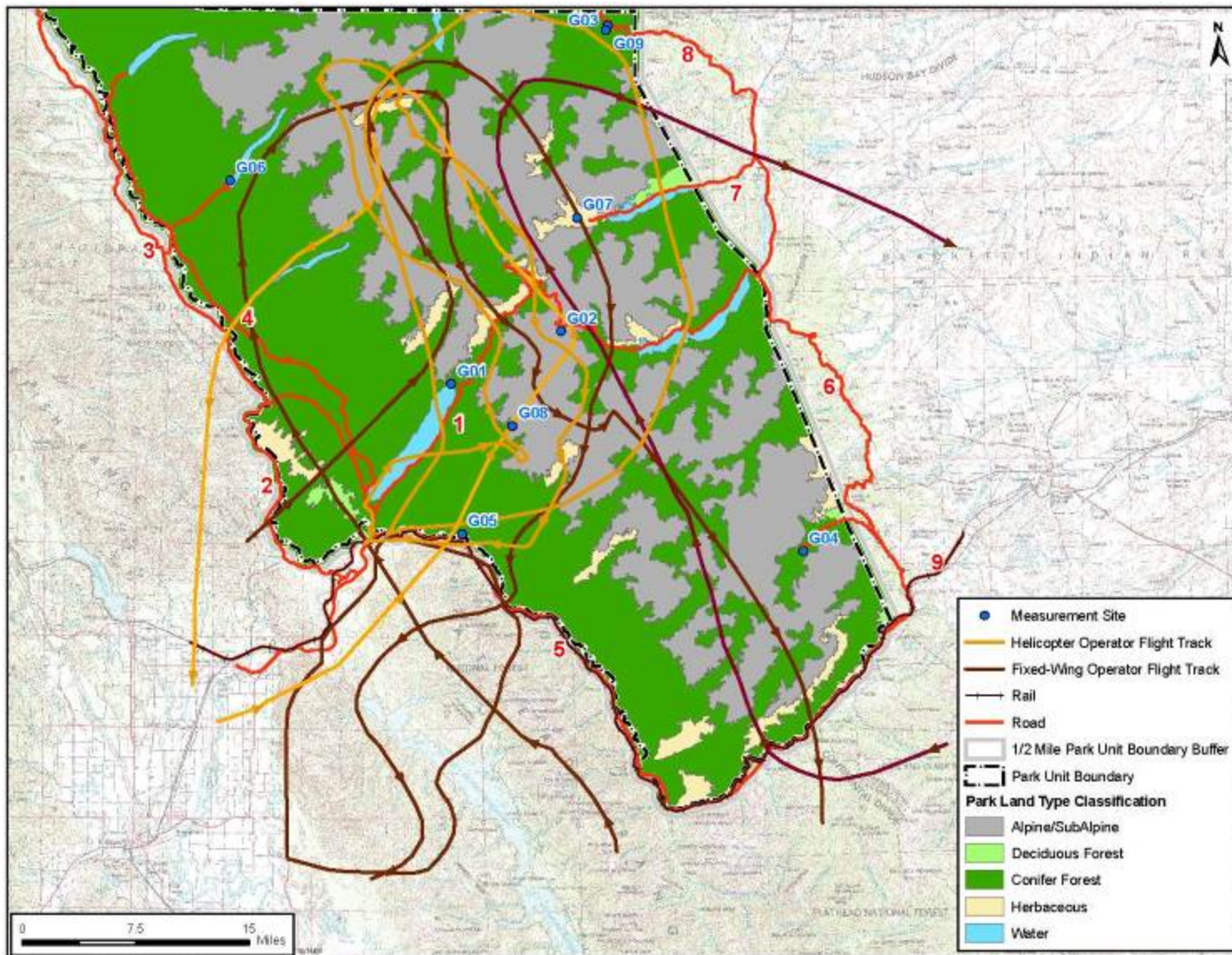


Figure 14. Acoustic zones, air tour routes, and final measurement sites for Glacier.

2.8 Temporal Considerations (Seasonal, Daily, and Duration)

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

2.8.1 Seasonal Considerations

Because the ultimate purpose of this data is to support impact assessment (if necessary) due to commercial air tours, if any, on park resources acoustic data should be collected during the season (summer and/or winter) when air tours occur (not necessarily during the peak month of the activity, but during a month representative of the season when the activity occurs). Generally, peak air tour season is driven by the peak visitor season, typically the summer. As such, summer measurements in August 2004 were agreed upon by FAA and NPS.

2.8.2 Time of Day Considerations

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. According to Flight Standards District Office personnel, the majority of Glacier air tours operate on a daily basis between the hours of 7 am and 7 pm. Consequently, although data will be collected continuously during the entire measurement duration, the specific hours to be analyzed for use in impact assessment will be daytime data measured during the time period 7 am to 7 pm.

2.8.3 Measurement Duration

Based on the Hawai'i Volcanoes analyses¹⁹, as well as a joint review of acoustic literature and other completed long-term NPS ambient studies in Bryce Canyon National Park and Arches National Park²⁰, a 3-dB variability was achieved between 10, 25, and 40 days, depending on individual site variables/characteristics. That is, it is expected that no more than a ± 3 dB difference between the true ambient sound level and the sound level will be calculated from the sample period. For Glacier, 10 to 18 days of acoustical and meteorological data were measured at each of the eight sites throughout the park. Since 2005, the FAA and NPS have jointly agreed that a minimum 25-day measurement period would be conducted for all ATMP-related acoustic monitoring to limit measurement uncertainty to 3 decibels. An exception to the 25-day requirement would be for measurements in close proximity to localized sound sources, which generally don't vary substantially in level, such as waterfalls, river rapids, 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. Even shorter periods may be adequate for waterfalls or rivers with very little variability and for which only attenuation data is needed.

3. INSTRUMENTATION

Ambient sound levels measured in remote areas of the country under low wind conditions often approach the threshold of human hearing. As a result, specialized low-level instrumentation is required to accurately measure these sounds. This section discusses the 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 $\frac{1}{3}$ -octave band noise measurements in outdoor environments. It is compact, light, rugged, and can run with external battery power, or solar panels, thus, enabling the system to store uninterrupted acoustic and wind data. Appendix B contains a more detailed description of the system.²¹ Seven NoiseLogger™ systems were used in collecting data in this study.

The system uses a large diameter windscreen and a $\frac{1}{2}$ -inch electret condenser microphone, interfaced with a sound level meter and a handheld personal computer for storing measured data using the NoiseLogger™ software. The system includes an ultrasonic anemometer to measure wind speed and direction. The output of the anemometer is also stored by the PDA via the NoiseLogger™ software. Figure 15 illustrates the basic components of the system.

3.1.1 Microphone System

The G.R.A.S. Model 40AQ and Model 40AE $\frac{1}{2}$ -inch, prepolarized microphones used in this study are electret condenser microphones. The random-incidence, frequency response of each microphone utilized in this study is shown in Appendix C. Being pre-polarized, the microphone functions as a closed system with regard to humidity, thus eliminating the potential for condensation in high humidity situations. Additionally, LD Model PRM902 preamplifiers were employed at each site.

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 1/3-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. Systems using two marine batteries provided enough power to support collection of data for approximately two weeks; whereas systems using a solar panel array allowed for continuous data collection, as long as a modest amount of direct sunlight was available during daylight hours.

3.2 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 16 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.²² One NoiseLogger Plus™ system was used in collecting data in this study.*

* This system was used at Site G06 for the following reasons: (1) it was located under the current air tour routes; and (2) it was located in an area with low visitor use.

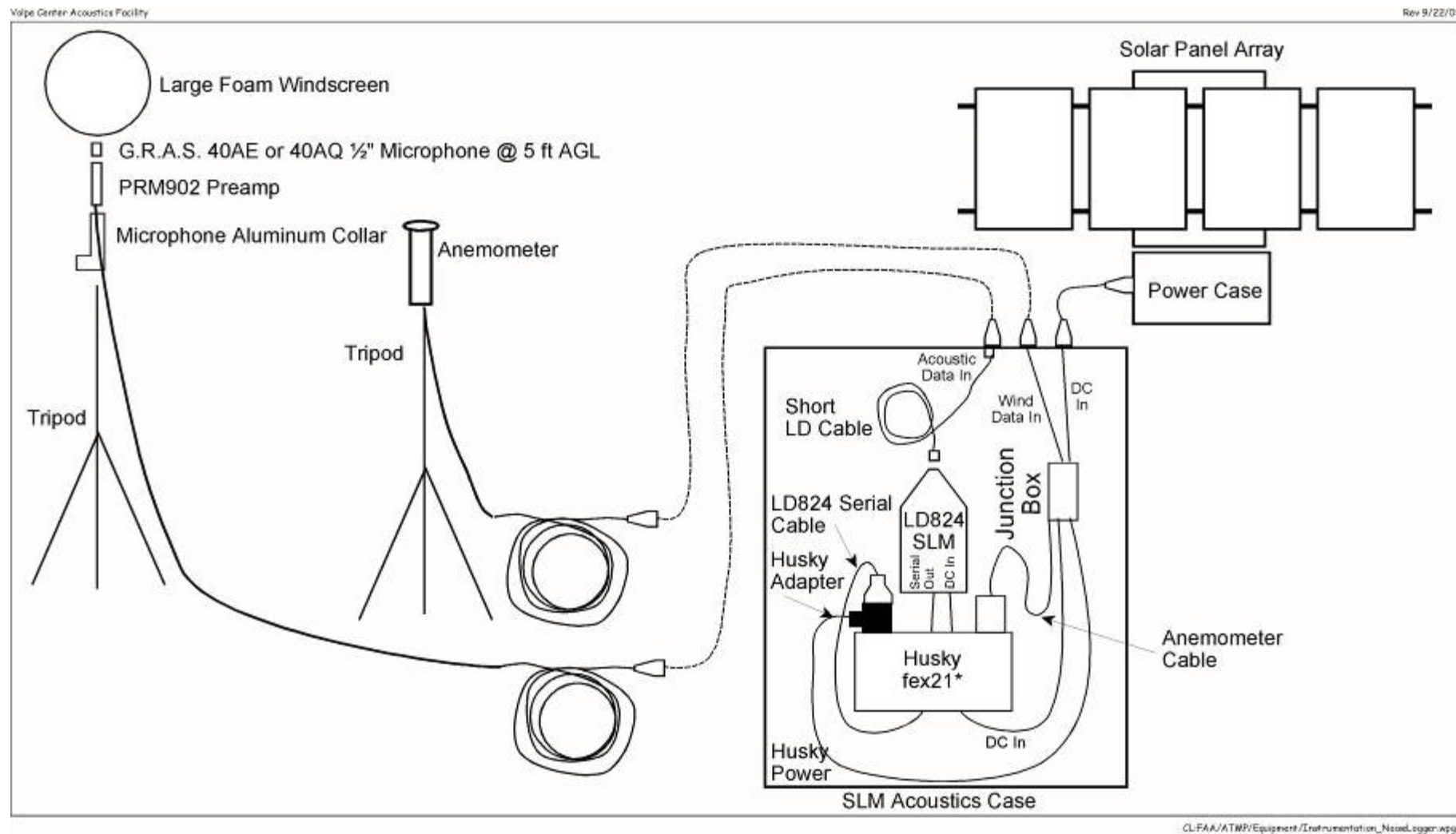


Figure 15. NoiseLogger™ continuous monitoring system.

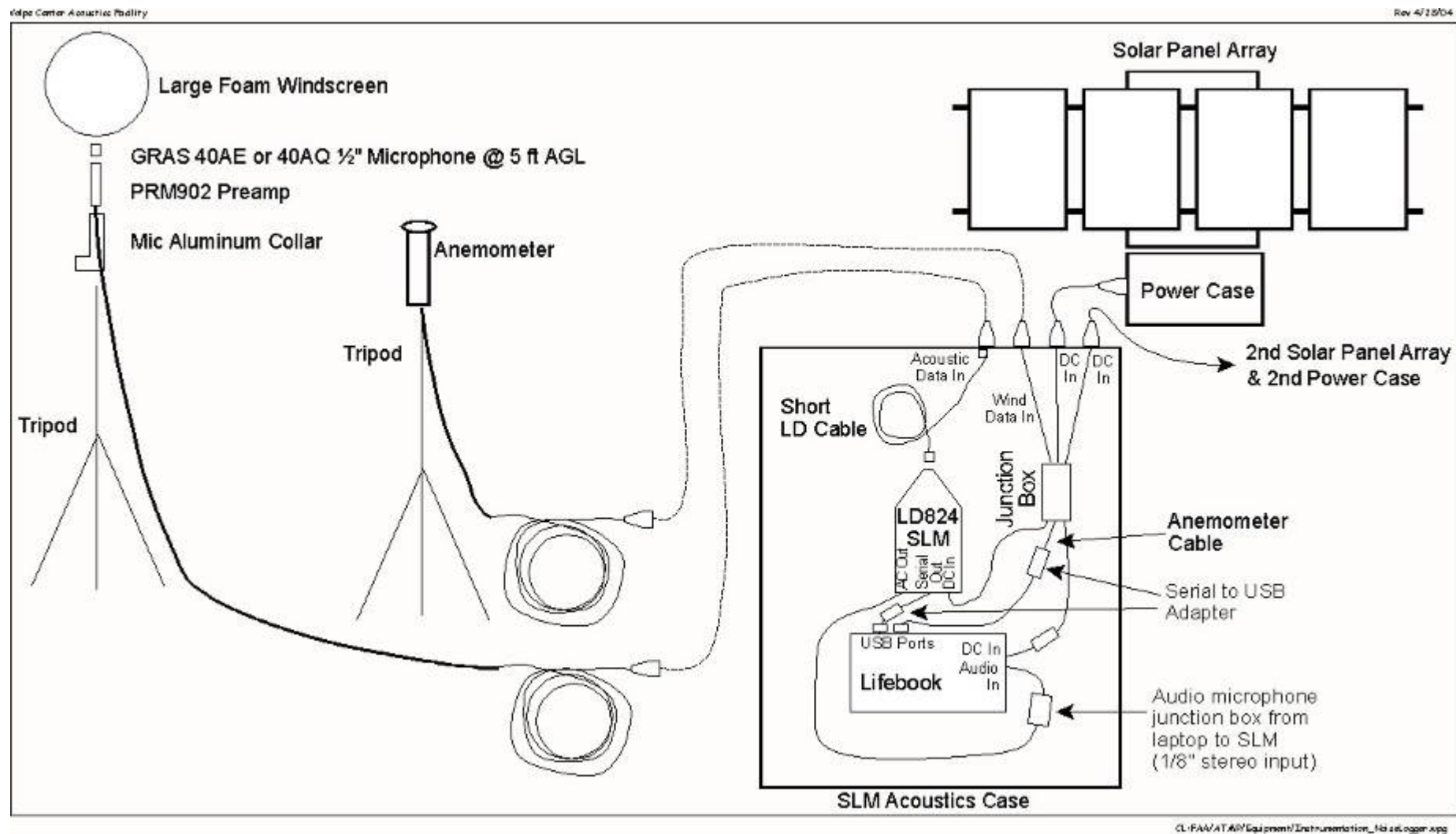


Figure 16. NoiseLogger Plus™ continuous monitoring system.

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 $\frac{1}{3}$ -octave-band analysis of measured low-level ambient sound level data. More detailed discussion on this system can be found in Reference 13. Figure 17 illustrates its basic components. VoLARE has been extensively tested and successfully used in previous FAA and NPS studies.^{12,13,14}

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 13, 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 $\frac{1}{3}$ -octave-band from 12.5 Hz to 20 kHz.

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

3.3.3 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.

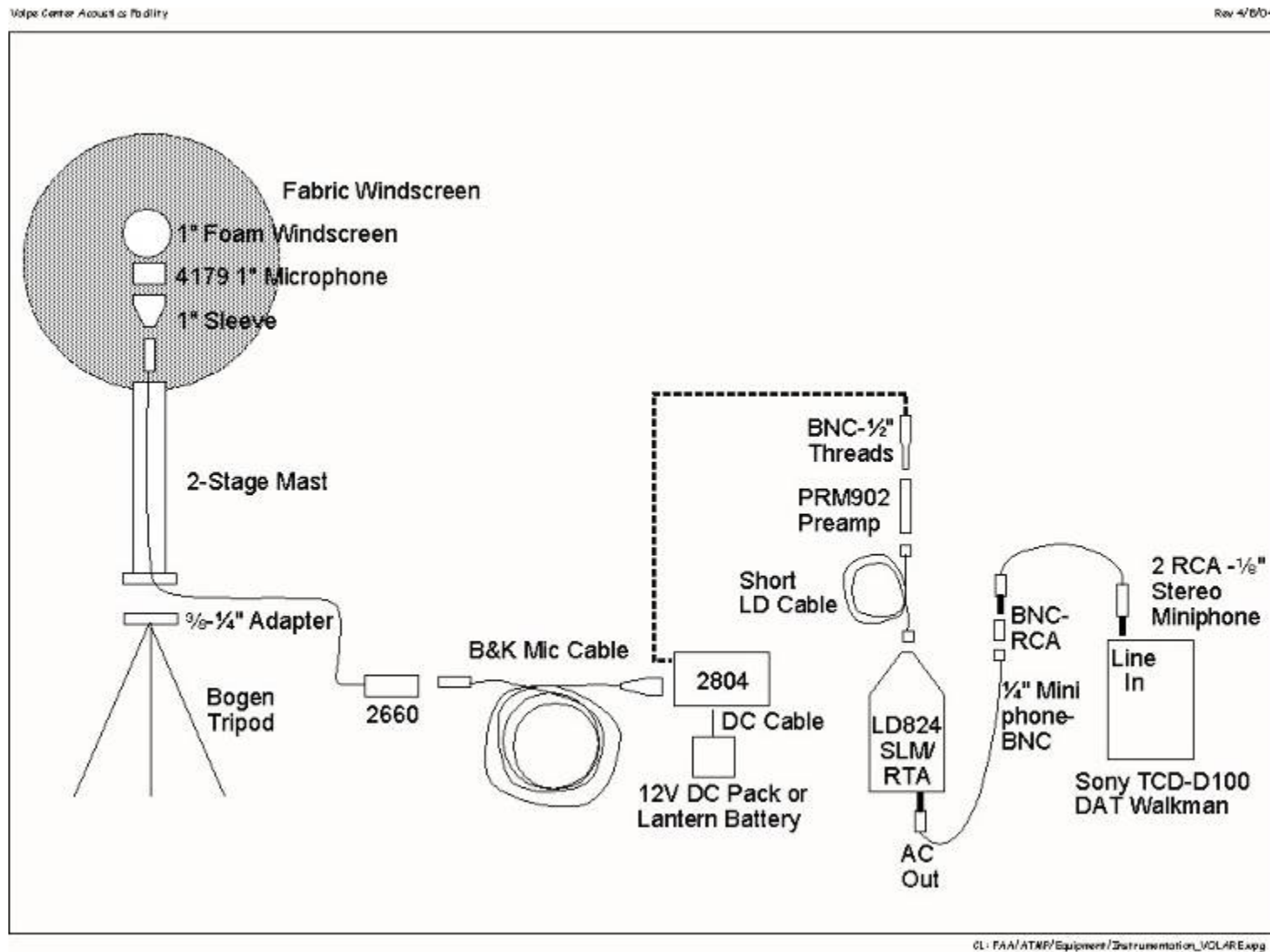


Figure 17. Volpe Low-Amplitude Recording Equipment (VoLARE) system.

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 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 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 1/3-octave band frequencies.

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4. FIELD MEASUREMENT PROCEDURES

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

4.1 NoiseLogger™ and NoiseLogger Plus™ System Deployment

Figure 18 and Figure 19 show the NoiseLogger™ and NoiseLogger Plus™ systems as deployed in the field at Sites G08 and G06, respectively.



Figure 18. NoiseLogger™ system deployment: Site G08.



Figure 19. NoiseLogger Plus™ system deployment: Site G06.

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

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

3. The solar panel array was deployed facing due south to ensure maximum exposure to daytime sunlight. Note: For the NoiseLogger Plus™ system, two solar panel arrays were deployed. If adequate sun exposure was not available for sites located within forested areas, marine batteries were used in place of the solar panel arrays.
4. All connections in the SLM system case were checked and a new CompactFlash™ card, which was used to store measured data, was inserted into the Husky™ H/PC prior to turning on the H/PC. Note: For the NoiseLogger Plus™ system, CompactFlash™ cards were not necessary as this system utilized the Fujitsu laptop computer and measured data were stored in its internal hard drive (see also Section 3.2).
5. The NoiseLogger™ program was retrieved from the CompactFlash™ card, then invoked. Note: Because CompactFlash™ cards were not necessary for the NoiseLogger Plus™ system, the NoiseLogger Plus™ program, stored in its internal hard drive, was invoked from the computer desktop.
6. Per the program instructions, the following information/action was entered/performed:
 - a. *Site information:* The unique three-character ID representing the site “number” (e.g., G08 for Site G08), and the site’s name (e.g., Sperry Campground) 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 6 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 6. 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 #25836	1243	FT702 #2080-77	1	G04
2	NoiseLogger™	A0843S	40AQ #38119	1276	FT702 #2080-56	2	G05
3	NoiseLogger™ Plus	A0844T	40AQ #38110	1268	FT702 #2080-88	3	Not Used
4	NoiseLogger™ Plus	A0845U	40AQ #38116	1282	FT702 #2080-68	4	G06
5	NoiseLogger™	A1148R	40AE #31802	1643	FT702 #2080-86	5	G08
6	NoiseLogger™	A1155P	40AE #24040	1630	Gill WindObserver #000528	6	G03_G09
7	NoiseLogger™	A1150K	40AE #24038	1678	FT702 #2110-42	7	G07

System #	System Type	LD824 Serial #	Microphone Type and Serial #	Preamplifier Serial #	Anemometer Type and Serial #	Windscreen #	Used at Site
8	NoiseLogger™	A1156Q	40AE #24034	1634	Gill WindObserver #000528	8	Not Used
9	NoiseLogger™	A1149S	40AE #31772	1647	FT702 #2080-87	9	G01
10	NoiseLogger™	A1151L	40AE #24021	1650	FT702 #2080-58	10	G02

- 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”) to LD Model 824 SLM (see Table 7 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 7. 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

7. For the NoiseLogger Plus™ system, digital audio recording settings were also selected:
 - a. *Sampling Rate:* Set to 20 kHz to collect most audible sounds. Equal to twice 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:* Box was “checked” to enable automatic wave file collection, then the option to record a 30-second wave file every 30 minutes was selected;

- d. *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;
 - e. *Threshold*: Typically set to 50 dBA for quiet sites, and 60 dBA for other sites. This was the sound level that is needed in order for an event-triggered, automatic wave file to begin collection;
 - f. *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;
 - g. *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);
 - h. *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.
8. 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.
9. 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.

4.2 VoLARE System Deployment

Figure 20 and Figure 21 show the microphone and recording instrumentation of the VoLARE system as deployed in the field at Site G03.



Figure 20. VoLARE microphone system deployment: Site G03.



Figure 21. VoLARE recording system deployment: G03.

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

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

4.3 Measurements

The following 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 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. 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 hierarchical order became audible to the observer. In addition to the three primary acoustic states, there were several sub-states as shown in Table 8.

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

Table 8. Acoustic state identifiers

Aircraft Intrusion Sub-States	Description	Human Intrusion Sub-States	Description	Natural Sounds 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 (Note: All sound level data measured during acoustic states identified with “Human Intrusion - Measurement Team” designations are not included in the data analysis.)	Other	Designates noise produced by other natural sources
Commercial Operator	Designates commercial operator				
General Aviation Operator	Designates general aviation operator				
Military Operator	Designates military operator				
Unknown Operator	Designates unknown operator (invoked primarily for aircraft, which are heard, but not seen)				
High Altitude	Designates high altitude aircraft (typically greater than 2000 ft above ground level, or AGL)				
Medium Altitude	Designates medium altitude aircraft (typically between 1000-2000 ft AGL)				
Low Altitude	Designates low altitude aircraft (typically below 1000 ft AGL)				

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5. DATA REDUCTION AND PROCESSING

This section summarizes the steps involved in the reduction and processing of the acoustic and meteorological data. Figure 22 presents a diagram of the individual types of data, which were used as inputs in the reduction process. These 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 collected at the national parks in support of the ATMP Program.

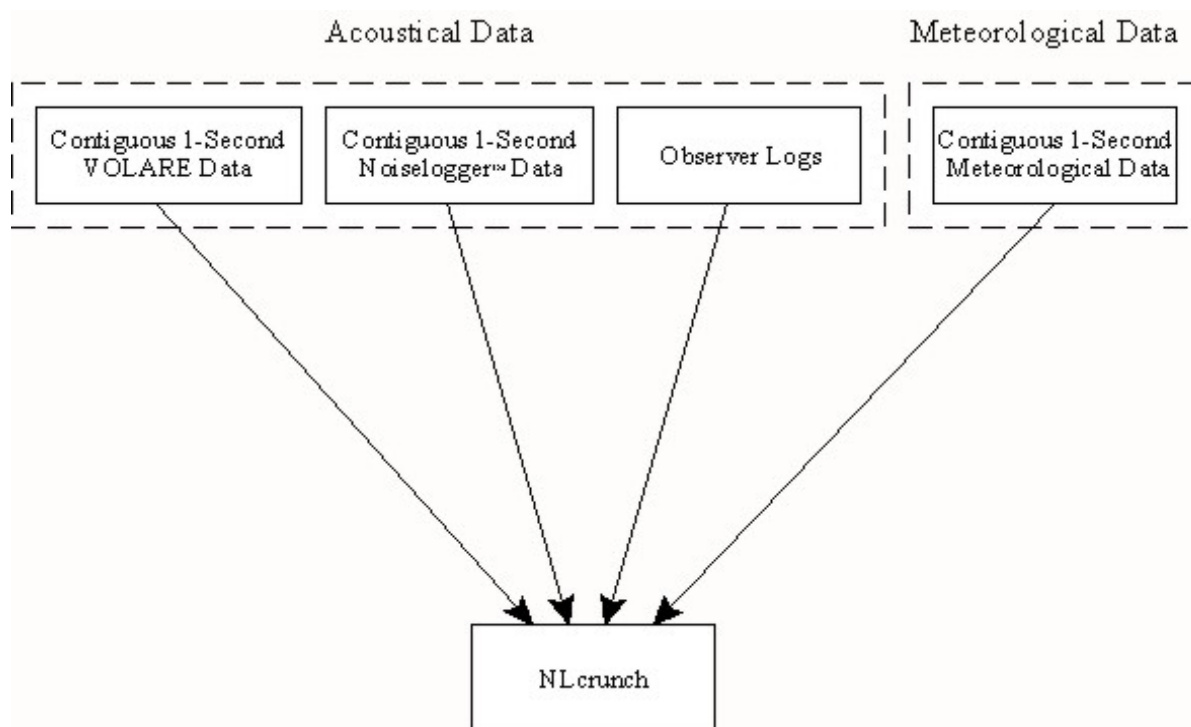


Figure 22. Flow diagram of data reduction process.

5.1 NoiseLogger™ and NoiseLogger Plus™ Acoustic and Meteorological Data Reduction

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

“TH13OB_Sxxx_YYYYMMDD.000,”

where “TH13OB_” is the default NoiseLogger™ header label, “Sxxx” is a unique four-character ID representing the site number (e.g., “SG01” represents Site G01), “YYYY” is the four-digit representation for the year, “MM” is the two-digit representation for the month, and “DD” is the

two-digit representation for the day of the month. The “.000” extension identifies these files as binary formatted.

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

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

5.2 VoLARE Acoustic Data Reduction

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

MMDDYYxx.slmdl”

where “MM” is the two-digit representation for the month, “DD” is the two-digit representation for the day of the month, “YY” is the two-digit representation for the year, and “xxx” is a unique three-character character ID representing the site (e.g., “G01” represents Site G01). The “.slmdl” extension identifies these files as binary formatted Larson Davis (LD) Model 824 sound level meter (SLM) files.

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

5.3 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

typographical errors, and remove blank rows. The files were then translated to Microsoft™ Excel format for input into NLcrunch.

5.4 Data Processing

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

5.4.1 Data Filters

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

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

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

- Data whose associated 1-second average wind speeds were greater than 11 mph (5 m/s). Note: Available data suggests that there is a high probability of microphone-induced distortion above this wind speed threshold; however, unless such wind

conditions occur more than 50 percent of the hour, exceedance metrics (e.g., L_{50} , L_{90}) will not likely be influenced. If necessary, a portion of this data may be included in the final data set. This process is referred to as “backfilling” (see Section 5.4.3).

- Data that were contaminated by field personnel (e.g., data potentially contaminated by field personnel handling instrumentation during the calibration process) and/or other activities atypical for that area; and
- Data in any given hour, for which greater than 25 percent of the samples are lost due to the above and previously listed system error factors. This ensures hours with only a few samples cannot bias the analysis. See also Section 5.4.2 for guidance on pooled versus un-pooled data, and Section 5.4.3 for guidance to potentially recover hourly datasets with data loss due to high wind conditions (i.e., backfilling).

5.4.2 Data Pooling

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

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

5.4.3 Data Recovery for High Wind

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

Based on Volpe analyses²³ of ambient data previously collected within parks, it was determined that up to 10% of any hourly measurement dataset can consist of high-wind data before a significant change to the statistical median (L_{50}) is observed. For the majority of measurement hours, this allowed for almost all of the measured data to be used in the hourly estimates (i.e., at the majority of sites measured, high-wind data represented less than 10% of the dataset).

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

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

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

5.4.4 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 effects 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 process was developed to adjust the NoiseLogger™

data for contamination effects of the system noise floor. Application of these adjustments provide for more accurate estimation of the true ambient sound levels without being limited by the equipment's electrical noise floor. Appendix D discusses the method used to determine the noise floor of each NoiseLogger™ systems, as well as the final noise-floor adjustments used during data reduction.

5.4.5 Sound Level Descriptors

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

- L_{eq} : The equivalent sound level determined by the logarithmic average of sound levels of a specific time period;
- L_{50} : A statistical descriptor describing the sound level exceeded 50 percent of a specific time period (i.e., the median); and
- L_{90} : A statistical descriptor describing the sound level exceeded 90 percent of a specific time period.

For each descriptor, both the broadband A-weighted sound level is determined and its associated $\frac{1}{3}$ -octave band un-weighted spectrum from 12.5 to 20,000 Hz. The process of computing the un-weighted one-third octave-band spectrum is virtually identical to the process for computing the broadband A-weighted sound level descriptors. The only difference is that the sound-level value is computed for un-weighted frequency-based sound levels rather than for broadband A-weighted sound levels. Specifically, the un-weighted sound level is computed individually for each $\frac{1}{3}$ -octave-band. The 33 un-weighted one-third octave-band sound levels (12.5 to 20,000 Hz) define the un-weighted sound level spectrum. This method of constructing the sound level spectrum means it is not an actual measured $\frac{1}{3}$ -octave band spectrum associated with a particular measurement sample, but a composite spectrum using the computed descriptor for each $\frac{1}{3}$ -octave-band.

5.4.6 Observer Log Descriptors

Periods of observer logging performed either in situ during sound-level data collection or later in the office or laboratory using high-quality digital recordings provides for an invaluable chronicle of the type, timing, and duration of the different sound sources that were audible during the observer log period (see also Section 4.3). These data not only provide a more complete characterization of the ambient environment, but also can be used to provide reasonableness checks with predicted audibility results from computer modeling efforts. Below are several commonly utilized metrics that can be determined from observer log data (the latter two are becoming more and more commonly found in NPS management plans):

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

6. DATA ANALYSIS

In support of this study, approximately two weeks of acoustic and wind data were measured at nine sites during August 2004. Figure 23 below shows the specific periods of time that data were collected at each site.

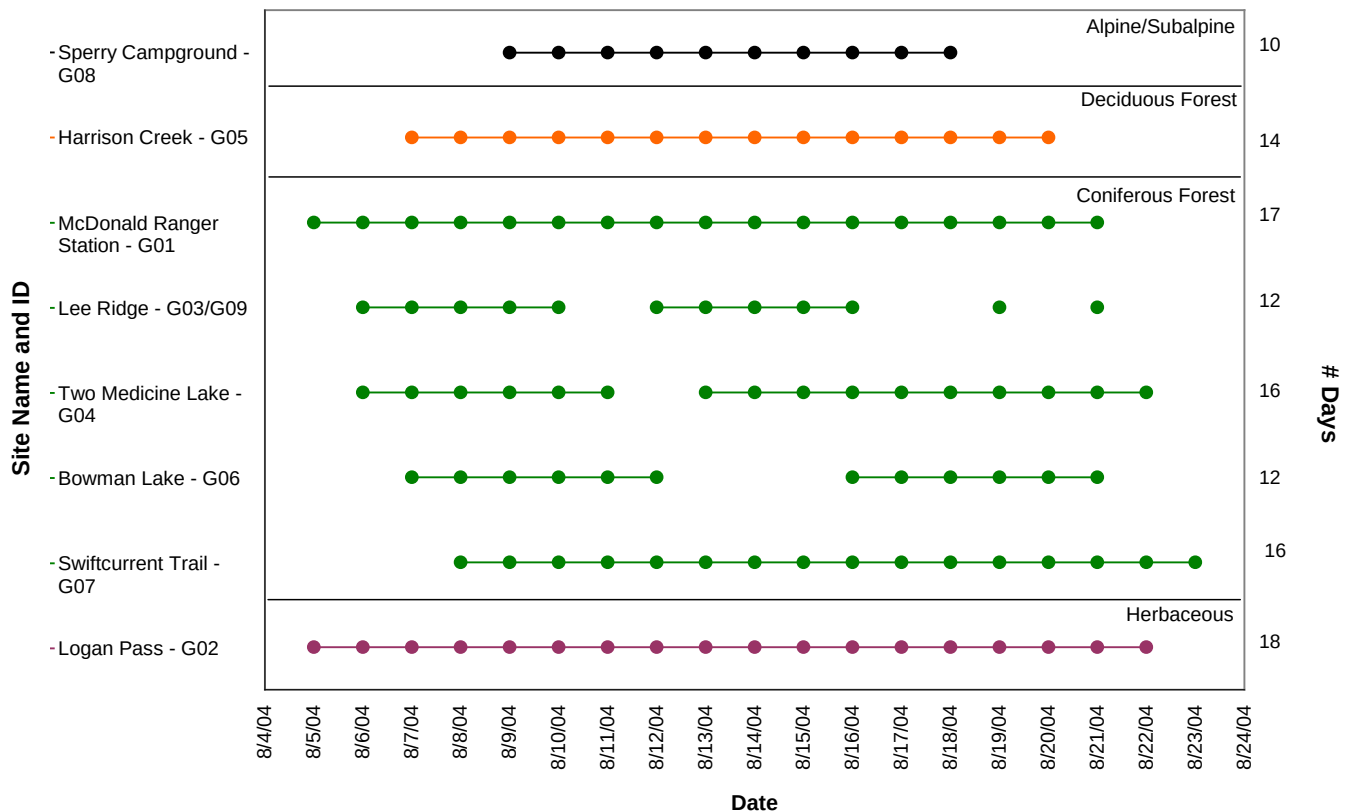


Figure 23. Baseline ambient data collection timeline for each site.

As stated in Section 1.1, the primary objective of this study was to quantify the baseline ambient sound levels within Glacier to establish a foundation from which potential noise impacts due to air tour operations can be subsequently assessed, if necessary. This was accomplished by developing a comprehensive grid of ambient sound levels (i.e., ambient *maps*) throughout the park.⁸ 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 (AEDT²⁴). The model 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 the data analyses performed, and the process used in the development of the Glacier 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 potentially allow for the transferability of measured ambient data to areas throughout Glacier.
- *Development of Ambient Descriptors (Section 6.3)* – Using the data in the acoustic observer logs, different characterizations of ambient can be estimated from the sound level 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 impact assessment. Diurnal trends were analyzed on an hourly basis with additional comparisons between overall daytime and nighttime sound levels.

For the purpose of assessing hourly trends in the data, sound level descriptors are computed for each individual hour;[†] then the median from individual hours across all days of the measurement period is determined (see also Section 5.4.2). Table 9 Table 11 present the results for all sites computed using each of the three noise metrics (L_{Aeq} , L_{50} , and L_{90}). These data are presented graphically for each individual site in Appendix A.

* Note: As discussed in Section 5.4.3, 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 $\frac{1}{3}$ -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

[†] As stated in Section 5.4.1 and 5.4.4, 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.

For the purpose of comparing daytime and nighttime data with overall (all hours) data, sound level descriptors are also computed for each individual hour; then the median from grouping individual hours during the daytime (7 am to 7 pm) and the median from grouping hours during the nighttime time periods (7 pm to 7 am) across all days is determined. Table 12 presents the differences between daytime and the overall sound levels. The influence of daytime sound sources (e.g., visitors and roadway traffic) and nighttime sound sources (e.g., insects) can be seen.

Note: As stated earlier in Section 2.8.2, 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. According to Flight Standards District Office personnel, the majority of Glacier air tours operate on a daily basis between the hours of 7 am and 7 pm. Consequently, although data will be collected continuously during the entire measurement duration, the specific hours to be analyzed for use in impact assessment will be daytime data measured during the time period 7 am to 7 pm.

Table 9. Average hourly sound levels - L_{Aeq} .

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
G01	36.1	38.5	34.0	32.0	32.8	32.5	33.4	34.8	34.7	35.9	39.2	36.8	36.3	35.2	35.2	39.6	35.2	42.3	35.9	35.4	34.9	35.9	40.2	36.0
G02	35.3	34.1	33.9	33.6	32.6	31.7	33.7	33.6	35.1	35.4	35.6	36.7	37.6	38.5	35.3	39.8	33.6	33.3	33.9	34.6	34.5	34.6	35.0	33.7
G03/G09	26.9	25.6	40.9	40.7	40.1	23.2	29.4	36.2	40.2	41.7	42.2	33.8	43.0	41.2	37.8	34.2	30.2	37.3	35.3	32.6	29.5	27.8	25.0	36.5
G04	39.5	38.5	36.3	34.8	33.9	37.8	36.2	34.1	34.7	39.3	43.2	39.0	38.9	37.0	41.3	35.6	34.4	35.1	36.4	32.7	41.9	45.0	45.1	42.0
G05	44.6	45.1	43.3	43.1	42.0	42.1	42.9	43.1	41.3	42.0	42.6	41.2	41.3	43.3	41.8	40.1	40.5	40.0	40.0	41.5	43.9	42.4	48.3	42.0
G06	32.2	25.7	22.3	19.8	18.3	18.5	27.6	28.6	29.0	32.8	29.3	28.4	29.2	27.5	29.7	42.0	38.9	30.6	40.5	42.0	35.7	44.0	47.5	47.7
G07	35.1	37.6	36.8	35.7	35.3	35.8	35.9	35.1	35.2	35.7	37.5	37.6	38.3	37.8	37.3	38.6	35.4	34.8	35.0	35.5	34.7	38.3	40.2	41.2
G08	35.5	35.8	37.2	34.8	35.5	35.6	35.6	35.7	35.9	35.4	36.0	36.6	36.2	36.0	35.3	35.6	35.2	39.5	36.2	33.7	35.9	37.4	38.3	37.5

Table 10. Average hourly sound levels - L_{50} .

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
G01	28.7	28.5	27.8	27.6	27.5	27.6	28.6	28.5	29.6	27.8	28.3	29.1	29.3	29.2	29.2	30.0	30.4	30.7	31.2	30.9	30.3	29.5	28.5	28.2
G02	33.7	33.7	33.8	33.3	32.2	30.8	31.5	32.0	29.9	29.5	29.3	29.9	30.5	30.7	30.5	30.6	30.4	30.6	30.9	32.2	33.6	33.7	33.7	33.1
G03/G09	21.9	22.1	22.4	28.8	21.5	22.3	23.1	28.3	27.8	33.4	36.9	27.4	29.4	34.8	34.9	30.3	26.4	28.1	28.5	26.7	23.6	22.7	21.7	22.2
G04	25.6	24.1	24.1	22.3	21.8	22.0	22.5	23.7	25.5	26.2	28.3	28.9	30.6	29.3	30.9	30.0	30.0	29.3	28.0	26.7	25.6	29.1	30.8	28.9
G05	28.2	27.4	26.5	26.0	25.7	25.9	30.2	32.4	33.0	33.2	33.0	32.9	33.7	33.9	33.4	32.9	32.3	31.9	32.0	32.5	33.5	32.0	30.8	28.4
G06	18.7	16.8	15.2	12.6	13.1	13.1	18.2	19.7	18.4	19.2	19.7	20.2	19.6	21.2	20.8	26.5	28.8	22.1	24.3	24.4	25.7	30.0	29.5	27.2
G07	34.3	34.9	34.9	34.6	34.7	35.6	35.5	34.0	30.7	29.7	28.4	28.1	30.2	31.6	32.1	31.7	31.3	32.0	32.1	32.5	33.7	34.7	34.8	34.8
G08	34.3	34.3	34.4	34.2	34.4	34.6	34.7	34.5	34.4	34.3	34.5	34.6	34.9	34.7	34.0	33.6	33.3	32.9	33.1	33.1	33.9	34.2	34.8	34.5

Table 11. Average hourly sound levels - L90.

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
G01	23.5	25.4	24.9	25.1	24.7	25.1	25.9	25.2	25.2	24.8	24.4	24.9	25.1	24.9	25.0	25.1	24.6	24.1	24.5	25.4	26.7	24.8	23.4	24.6
G02	31.2	30.6	30.4	29.7	29.5	28.8	29.1	29.0	27.2	26.7	27.1	27.8	28.4	28.5	28.6	28.2	28.4	28.6	28.8	30.0	31.0	31.6	31.5	30.9
G03/G09	21.2	21.2	21.4	21.8	19.3	19.3	21.9	22.1	22.0	26.4	28.6	23.5	22.9	24.6	27.3	23.4	22.8	22.9	21.9	20.9	19.6	20.7	20.9	16.4
G04	20.0	20.6	19.8	18.9	19.0	19.9	19.3	20.0	20.6	20.5	21.1	23.4	24.8	24.1	24.9	24.1	24.0	23.2	23.0	22.1	20.8	22.5	22.3	20.8
G05	23.0	22.6	21.6	20.5	20.4	21.4	23.6	24.7	26.2	26.5	26.8	27.0	27.2	28.3	27.5	27.1	26.4	26.0	25.2	26.3	26.5	25.6	24.7	23.5
G06	11.8	11.4	10.5	9.8	10.6	10.9	12.1	15.5	14.2	14.1	15.5	16.1	15.4	17.2	16.9	19.5	17.0	16.9	16.2	16.7	15.9	12.0	11.9	13.2
G07	29.5	29.3	29.2	29.5	30.0	30.9	31.9	29.7	27.6	26.9	26.3	25.9	26.6	27.2	27.3	27.7	28.4	28.7	29.4	29.7	30.2	30.7	29.4	30.4
G08	32.3	32.1	32.4	32.4	32.6	32.8	32.8	33.0	33.2	33.0	33.1	32.9	33.4	33.0	32.0	31.7	31.5	30.8	31.3	31.7	32.3	32.5	32.6	32.6

Table 12. Summary of day versus night diurnal trends.

Site #	Overall Average L _{Aeq} (dBA)	Overall Average L ₅₀ (dBA)	Overall Average L ₉₀ (dBA)	Daytime Average, 7am to 7pm, L _{Aeq} (dBA)	Daytime Average, 7am to 7pm, L ₅₀ (dBA)	Daytime Average, 7am to 7pm, L ₉₀ (dBA)	Nighttime Average, 7pm to 7am, L _{Aeq} (dBA)	Nighttime Average, 7pm to 7am, L ₅₀ (dBA)	Nighttime Average, 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)
G01	36.7	28.8	24.9	37.4	29.3	24.8	35.8	38.8	24.9	-0.7	-0.5	0.1	0.9	-10.0	0.0
G02	35.2	31.9	28.6	36.1	30.5	27.9	34.1	33.1	30.1	-0.9	1.4	0.7	1.1	-1.2	-1.5
G03/G09	37.6	25.9	21.1	38.7	29.7	22.7	36.1	22.6	20.2	-1.1	-3.8	-1.6	1.5	3.3	0.9
G04	39.6	27.1	20.7	38.3	28.4	22.1	40.4	25.6	20.1	1.3	-1.3	-1.4	-0.8	1.5	0.6
G05	42.9	31.3	24.1	41.6	32.9	26.5	43.9	29.0	22.9	1.3	-1.6	-2.4	-1.0	2.3	1.2
G06	39.8	20.5	12.7	35.6	21.0	16.1	41.8	19.5	11.5	4.2	-0.5	-3.4	-2.0	1.0	1.2
G07	37.1	33.7	28.1	36.7	31.1	27.1	37.4	34.7	30.1	0.4	2.6	1.0	-0.3	-1.0	-2.0
G08	36.3	34.2	32.3	36.3	34.1	32.2	36.2	34.2	32.4	0.0	0.1	0.1	0.1	0.0	-0.1
									Average	0.6	-0.5	-0.9	-0.1	-0.5	0.0

6.2 Acoustic Zone Analysis

As stated earlier in Section 2.7, 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. 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.¹⁹ Figure 24 displays the acoustic zones and measurement sites for Glacier as discussed in Section 2.7.

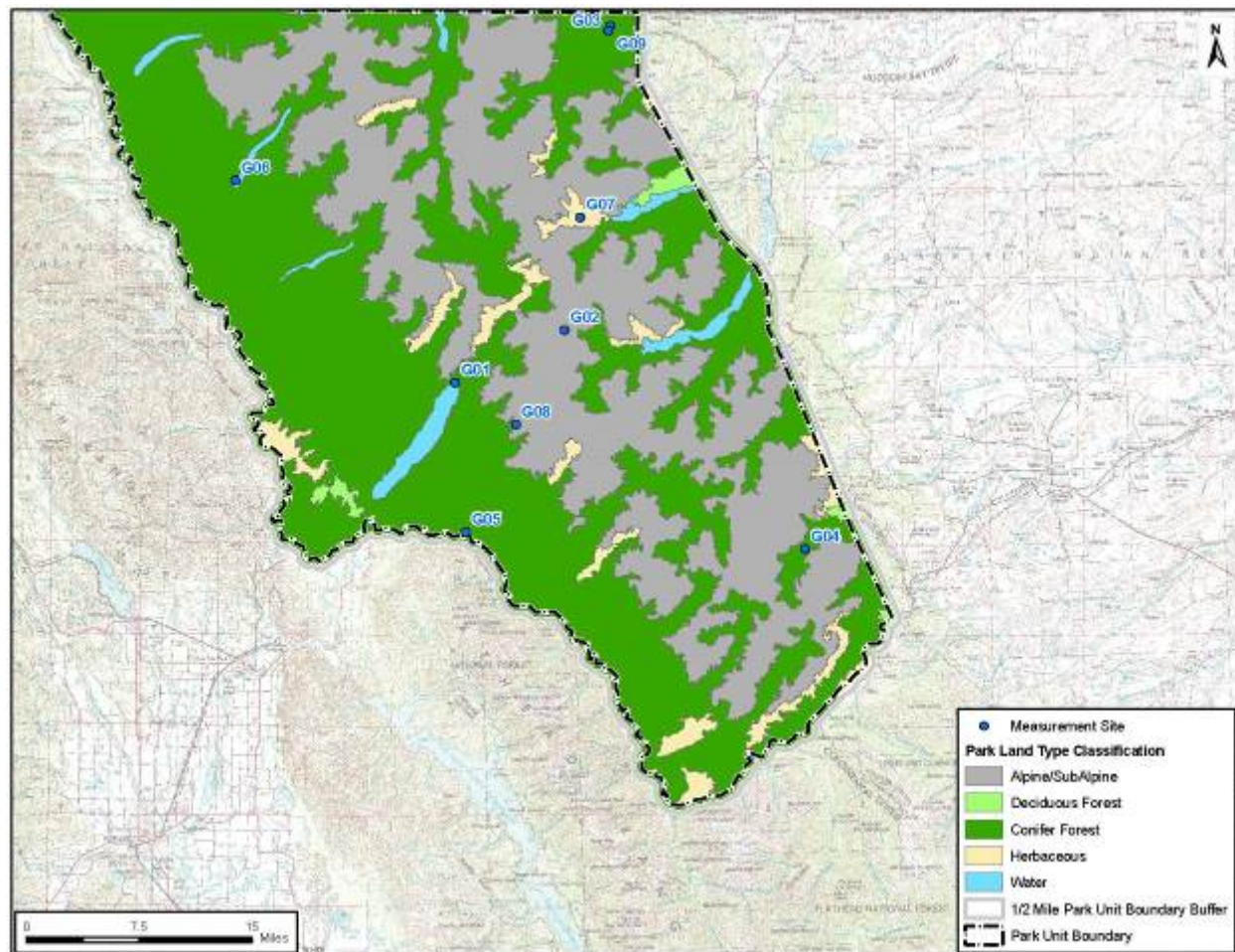


Figure 24. Acoustic zones and measurement sites for Glacier.

Using the hourly median sound levels measured during the daytime (7 am to 7 pm), two statistical methods were used to evaluate the site transferability hypothesis (Appendix E discusses the analysis methods used in greater detail): a Regression Analysis and the Kolmogorov-Smirnoff (K-S) Statistic. 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.

The following comparisons were performed to statistically assess ambient data collected at a pair of sites within Glacier 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. Figure 25 summarizes the results of comparing ambient data collected at pairs of sites within Glacier. Additionally, Figure 26 presents distribution plots of the number of samples of each sound pressure level measured during the daytime hours for each site.

From this analysis, there is statistical evidence to support the transferability of ambient data hypothesis. Four of the five coniferous forest sites (G01, G03, G04, and G07) showed similarity with each other, as well as to the aspen forest/grassland sites (G02 and G05). The sites that were the exception and showed dissimilarity were Sites G06 and G08. Site G06, which is near Bowman Lake, was observed to be the quietest site measured in the park. This is the most likely contributor to this site's dissimilarity to other sites measured within the park. However, in looking at the spectral data for the estimated Existing Ambient Without Air Tours and the Natural Ambient (see Figure 27 and Figure 28), it is interesting to see the similarity between Sites G06 and G03/G09, which is in the same landcover, but experiences more human activity. Site G08, which is Sperry Campground, was the most remote site measured in terms of visitation. As noted in the observer logs, sounds of a distant, but constant, moving water were audible – specifically, a waterfall. This is the most likely contributor to this site's dissimilarity to other sites measured within the park. Of the three parameters used for parameters, acoustic zone and land cover were shown to have the most relevance; visitor-use had the least.

			Acoustic Zone	3. Coniferous Forest	2. Aspen Forest/ Grasslands	3. Coniferous Forest	3. Coniferous Forest	2. Aspen Forest/ Grasslands	3. Coniferous Forest	3. Coniferous Forest	1. Alpine/ Subalpine
			NLCD Land Cover Classification	42 Evergreen Forest	71 Grasslands/ Herbaceous	42 Evergreen Forest	42 Evergreen Forest	41 Deciduous Forest	42 Evergreen Forest	42 Evergreen Forest	33 Transitional
			Site Category	Overlook	Overlook	Backcountry	Short Hike	Backcountry	Short Hike	Short Hike	Backcountry
Acoustic Zone	NLCD Land Cover Classification	Site Category	Site ID	G01	G02	G03	G04	G05	G06	G07	G08
3. Coniferous Forest	42 Evergreen Forest	Overlook	G01		SS	S	SS	S	F	SS	F
2. Aspen Forest/ Grasslands	71 Grasslands/ Herbaceous	Overlook	G02			S	S	S	S	SS	F
3. Coniferous Forest	42 Evergreen Forest	Backcountry	G03 and G09				SS	SS	S	SS	S
3. Coniferous Forest	42 Evergreen Forest	Short Hike	G04					S	S	SS	S
2. Aspen Forest/ Grasslands	41 Deciduous Forest	Backcountry	G05						F	SS	S
3. Coniferous Forest	42 Evergreen Forest	Short Hike	G06							F	F
3. Coniferous Forest	42 Evergreen Forest	Short Hike	G07								S
1. Alpine/ Subalpine	33 Transitional	Backcountry	G08								

Note: SS = Both tests passed, i.e., data showed strong similarity; S = One test passed, i.e., data showed some similarity; F = Both tests failed, i.e., data were not similar.

Figure 25. Results of similarity tests using daytime, hourly median sound levels for sites within Glacier.*

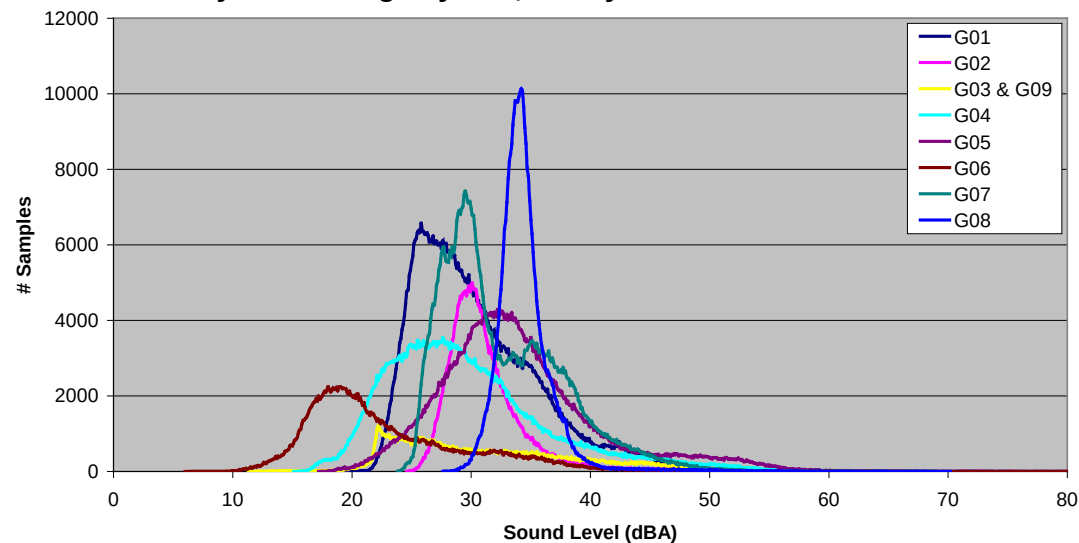


Figure 26. Daytime data distributions of 1-second sound level data collected at each sites.

* Appendix E discusses the two statistical methods that were used to evaluate the site transferability hypothesis.

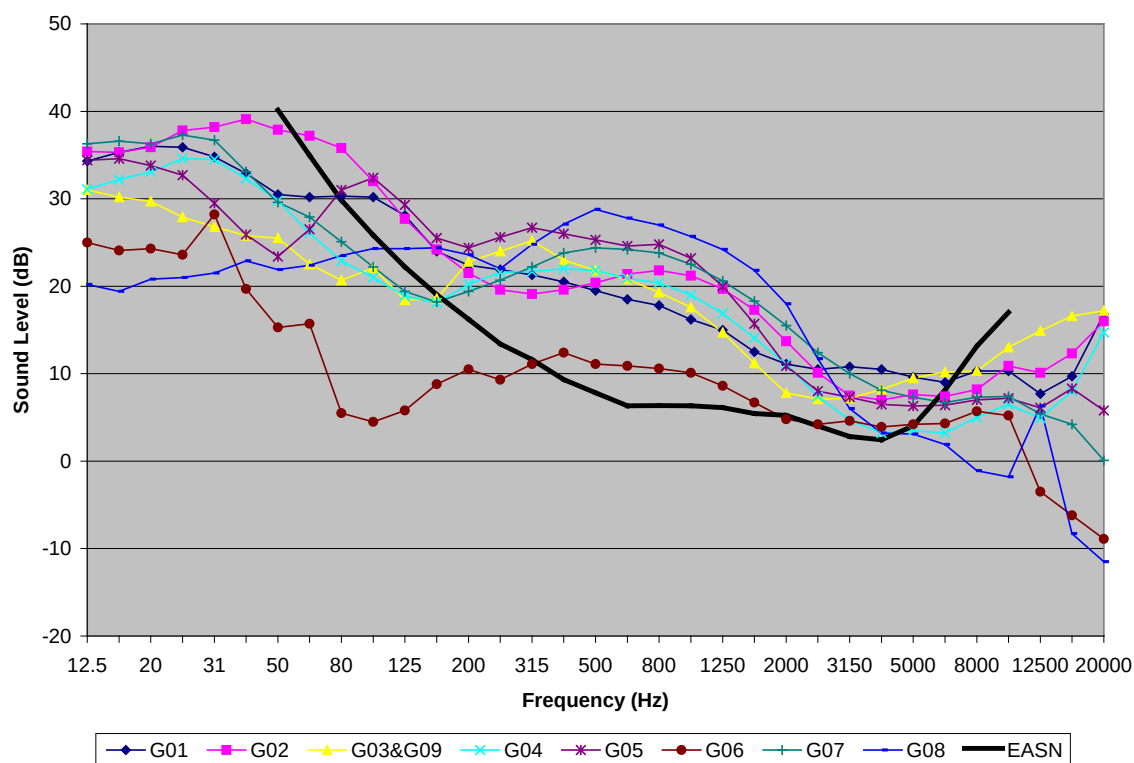


Figure 27. Spectral data for the Existing Ambient Without Air Tours (L_{50}) for each site.*

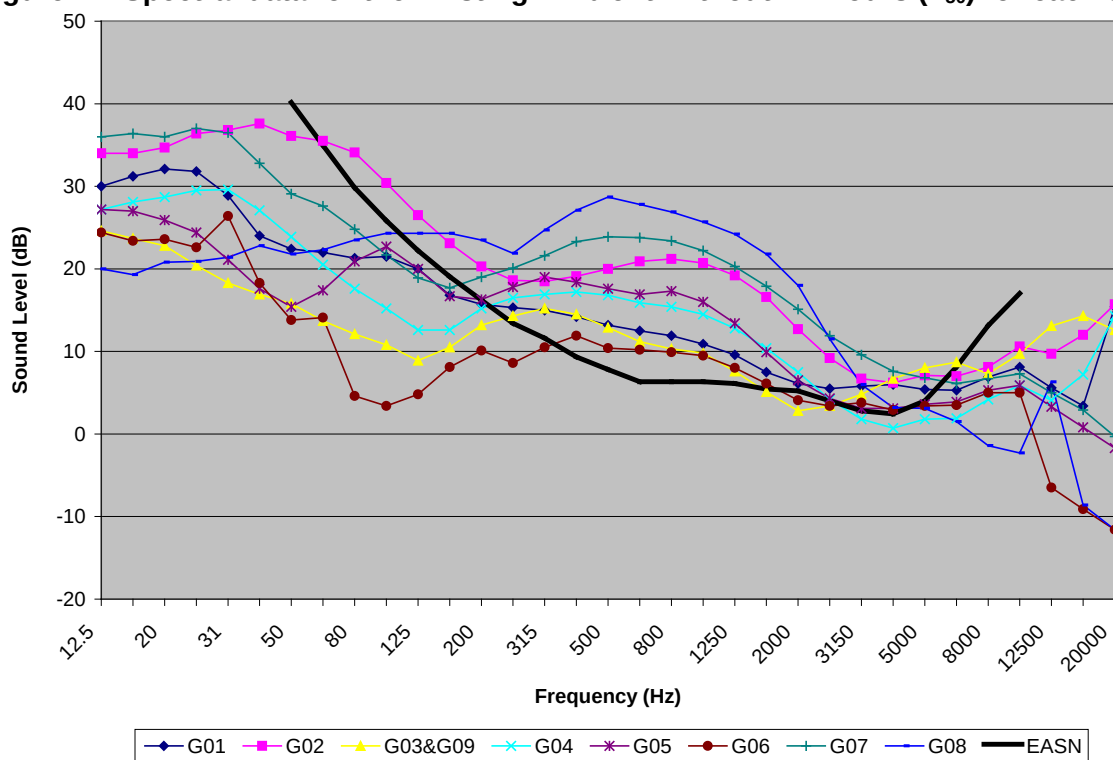


Figure 28. Spectral data for the Natural Ambient (L_{50}) for each site.*

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

6.3 Development of Ambient Descriptors

Using the data in the acoustic observer logs (see Figure 29), different characterizations of ambient can be estimated from the sound level data. The following four types of “ambient” characterizations are generally used and considered sufficient by the FAA and NPS in environmental analyses related to transportation noise:^{12,13,}

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

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

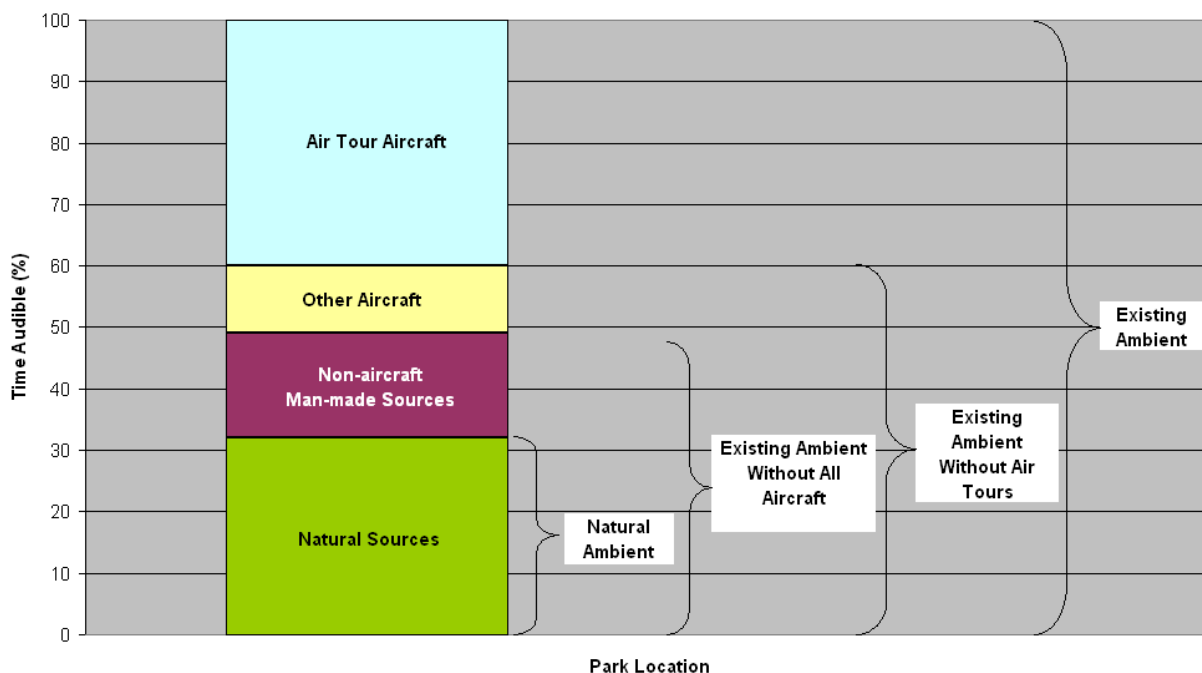


Figure 29. Graphical depiction of ambient definitions.*

If one considers the three sound level descriptors presented in Section 6.1 and the four types of ambient characterizations above, twelve ambient descriptors could potentially be computed as shown in Table 13.

Table 13. Matrix of twelve potential ambient descriptors.

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

From the above twelve potential ambient descriptors, only the first three can be readily computed. The computation of ambient types other than Existing Ambient is more challenging because different sound sources often overlap in both frequency and amplitude; there is currently no practical method to separate out acoustic energy of different sound sources (i.e., human-caused sounds imbedded with natural sounds). The two ambient descriptors agreed upon for use in any subsequent ATMP analyses (their development are discussed in Section 6.3.1) are:

- *Existing Ambient Without Source of Interest* – Descriptor 5 from the table above; and
- *Natural Ambient* – Descriptor 11 from the table above.

6.3.1 Computation of Ambients

The recommended method for the computation of the “Existing Ambient Without the Sound Source of Interest,” “Existing Ambient Without All Aircraft,” and “Natural Ambient” involves using the knowledge gained in the short-term *in situ* and off-site source logging data. This method was developed by performing a detailed data analyses conducted by the Volpe Center, working closely with the NPS, in comparing several approaches of estimating of the Natural Ambient and is comprised of the following steps:²³

1. From the short-term *in situ* and off-site logging, determine the percent time human-caused sounds are audible.
2. Sort, high-to-low, the A-weighted level data, derived from the short-term, one-second, one-third octave-band data (regardless of acoustic state), and remove the loudest percentage (determined from the percent time audible of human-caused sounds in the short-term observer logs) of sound-level data. For example, if from Step 1 above, it is determined that at a particular site, the percent time audible of all human-caused sounds is 40 percent, then the loudest 40 percent of the A-weighted level data is removed. The L_{50} computed from the remaining data is the estimated A-weighted natural ambient. This L_{50} , computed from the remaining data, can be mathematically expressed as an L_x of the entire dataset as follows (%TA is the percent of time human-caused sounds are audible in the short-term observer logs):

$$L_x = \frac{100 - \%TA}{2} + \%TA$$

For example, if non-natural sounds are audible for 40% of the time, L_0 to L_{40} corresponds to the loudest (generally non-natural) sounds, and L_{40} to L_{100} corresponds to the quietest (generally natural) sounds. The median of L_{40} to L_{100} data is L_{70} . Therefore, the A-weighted decibel value at L_{70} , the sound level exceeded 70 percent of the time, would be used for the entire dataset to characterize the natural ambient sound level.

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

octave-band spectrum associated with a particular measurement sample, but rather a composite spectrum derived from the L_x for each one-third octave-band.

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

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

6.4 Development of Ambient Maps

An ambient map is essentially a comprehensive grid of ambient sound levels throughout a study area. The measured data provide the base layer for the map and are then combined with the contributing effect of roads and localized noise sources, such as waterfalls, and river rapids, to develop a final, composite, ambient map of the park (see Section 6.4.1). Ambient maps are useful to: (1) graphically characterize the ambient environment throughout an entire study area; and (2) to establish baseline, or background values in computer modeling from which various noise-related descriptors may be computed (e.g., percentage of time aircraft sounds are above the ambient). The descriptors could then be used in the assessment of potential noise impacts due to aircraft operations.

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

- Define the input “objects”:
 - Define the park boundary in Universal Transverse Mercator (UTM)* coordinates to set the initial grid area boundary.†
 - Divide the park into a regular grid of points at a desired spacing using a Digital Elevation Model (DEM), which is a digital representation of a topographic surface typically used in GIS applications. Each point is assigned an elevation value and UTM coordinates from the DEM. Note: For Glacier, a grid spacing of 500 ft (152.4 m) was used.
 - Define the acoustic zone boundaries in UTM coordinates.
 - Simplify acoustic zones, as necessary (see Section 6.4.1).
 - 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.
- Assign a “measured” ambient sound level (and its associated one-third octave-band, unweighted spectrum) computed in Section 6.3.1, to each grid point within an acoustic zone based on the measurement site nearest to it.

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

- Define the location of localized noise sources. The distance to each roadway was calculated and assigned to each grid point.
- 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). This is performed 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 computed L_{Aeq} sound

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

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

level parameters were conservatively assumed to be equivalent to the L_{50} and L_{90} and, thus, used interchangeably as the “roadway” ambient.

The resultant ambient maps are presented in Section 7.

6.4.1 Acoustic Zone Simplification

As shown in Figure 13 (Section 2.7), although there were only five acoustic zones, their dispersion throughout the park yielded a large number of polygons (36068). Merging small areas into surrounding zones was an efficient process to simplify the many zones to a manageable number while still retaining a high level of polygonal boundary detail. To do this, the following criteria were used: 1) Any polygon that was less than 100 acres was merged into the surrounding polygon; and 2) Any additional small polygons that did not match the general pattern of land cover distribution and were at least 5 miles from road sources were merged. Applying these criteria produced the simplified acoustic zones used in this document. The simplified acoustic zones for Glacier are shown in Figure 30.*

* This method for simplifying zones is based on similar work done for noise analyses in Yellowstone and Grand Teton National Parks.

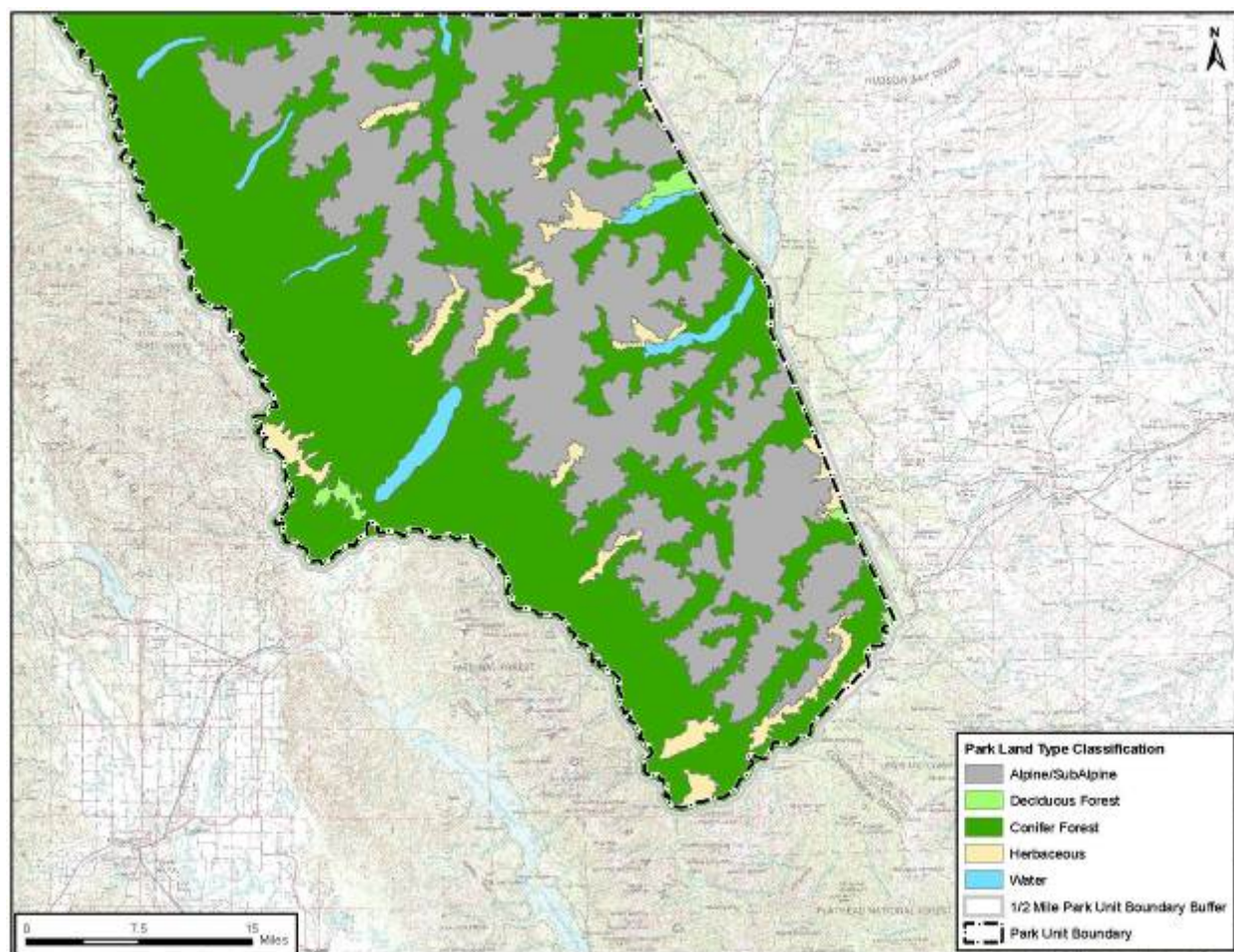


Figure 30. Acoustic zones based on land cover after simplification.

6.4.2 Ambient Mapping of Localized Sound Sources

As it is not feasible to carry out field data collection efforts in all areas of a park, the contributing effect of localized noise sources, such as waterfalls, river rapids, trains, and vehicles on roads, are typically modeled and combined with the measured sound levels to develop a composite, baseline, ambient “map” of a park for all ambient maps, except natural ambient (see Table 14). The combined (measured plus roadway, for example) ambient are computed by using energy-addition, i.e., sound levels in decibels were converted to energy prior to addition. Roadway sound sources were modeled using the Federal Highway Administration’s Traffic Noise Model® (TNM).^{3, 4} The railway sound source was modeled using a railway simulation model developed for the Florida Department of Transportation.⁵ For both models, the estimated drop-off rate, reflecting a continuous decrease in sound level as a function of increasing distance from each sound

source, was computed. For a non-time-varying source, such as roadway noise, the TNM-computed L_{Aeq} sound level parameters may be conservatively assumed to be equivalent to the L_{50} and L_{90} and, thus, used interchangeably as the “roadway” ambient. Figure 31 presents the modeled roadway/railway ambient map.

Table 14. Composite ambient maps.

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

In the vicinity of and within Glacier, there were nine localized sound sources (i.e., roadways and railways): Going-to-the-Sun Road, Camas Road, Outside North Fork Road, Inside North Fork Road, Routes 2, 49, 89, and 17, and the Burlington Northern and Santa Fe Railway. The following assumptions were made in the modeling:

- Roadway Traffic Volumes** – The traffic volume for an average day during the peak summer month in 2004 was obtained from the NPS Public Use Statistics Office website (<http://www2.nature.nps.gov/stats/>). Hourly volume is estimated by dividing the month’s volume by 31 days and 12 hours per day, which assumes the majority of traffic in Glacier occurs between 7 am and 7 pm – an assumption consistent with the typical operational hours that the majority of Glacier air tour operators conduct air tours. Additional assumptions include:
 - Going to the Sun Road includes all visitors entering the west entrance;
 - Traffic on Outside and Inside North Fork Roads is based upon the number of visitors to Polebridge; and
 - Number of heavy trucks is estimated at 3% of number of autos for major roadways outside of the park (i.e., Routes 2, 49, 89, and 17).
- Railway Traffic Volumes** – Information used in modeling railway activity* was based on discussions with Burlington Northern and Santa Fe Railway (BNSF) (<http://www.bnsf.com>). According to BNSF, operations average 30/day or approximately 2 operations/hr.

* Although Amtrak’s “Empire Builder” train also traverses the park, its operations were limited to once or twice daily. It is anticipated that its effect would be minimal on overall sound levels and, thus, not modeled.

Table 15. Roadway and railway traffic volume input.

Roadway/Railway Source Name	Vehicle Type	Estimated 2004 Annual Volume	Estimated Peak Month Hourly Volume
Going-to-the-Sun Road	Autos	287,170	772
Going-to-the-Sun Road	Buses	33,469	90
Going-to-the-Sun Road	Heavy Trucks	0	0
Camas Road	Autos	17,193	46
Camas Road	Buses	0	0
Camas Road	Heavy Trucks	0	0
Outside North Fork Road	Autos	6,029	16
Outside North Fork Road	Buses	0	0
Outside North Fork Road	Heavy Trucks	181	0
Inside North Fork Road	Autos	6,029	16
Inside North Fork Road	Buses	0	0
Inside North Fork Road	Heavy Trucks	0	0
Route 2 Southbound	Autos	50,459	136
Route 2 Southbound	Buses	0	0
Route 2 Southbound	Heavy Trucks	1,514	4
Route 49 to Route 89 (to Two Medicine)	Autos	36,864	99
Route 49 to Route 89 (to Two Medicine)	Buses	248	1
Route 49 to Route 89 (to Two Medicine)	Heavy Trucks	1,106	3
Route 89 (to Many Glacier)	Autos	75,239	202
Route 89 (to Many Glacier)	Buses	62	0
Route 89 (to Many Glacier)	Heavy Trucks	2,257	6
Route 89 to Route 17 to Route 6 (to Waterton Park)	Autos	10,000	27
Route 89 to Route 17 to Route 6 (to Waterton Park)	Buses	248	1
Route 89 to Route 17 to Route 6 (to Waterton Park)	Heavy Trucks	300	1
Burlington Northern & Santa Fe Railway	Trains	N/A	2

- *Traffic Speeds* – Modeled speeds within Glacier range from 15 to 50 mph (24.1 to 80.5 kph). An average speed of 50 mph was assumed for major roadways outside of the park; a speed of 35 mph (56.3 kph) was assumed for roadways within the park, with the exception of Inside North Fork Road where 25 mph (40.2 kph) was assumed; and a speed of 40 mph (64.4 kph) was provided by BNSF for the railway.
- *Ground Impedance* – Because much of the land cover in Glacier in vicinity of the roads was rocky shrubland, a moderately hard acoustical ground impedance was assumed using an effective flow resistivity of 1000 cgs/rayls. Additionally, sound levels were propagated through a “tree zone” to account for the attenuation effects of the dense forestry throughout the majority of the park.

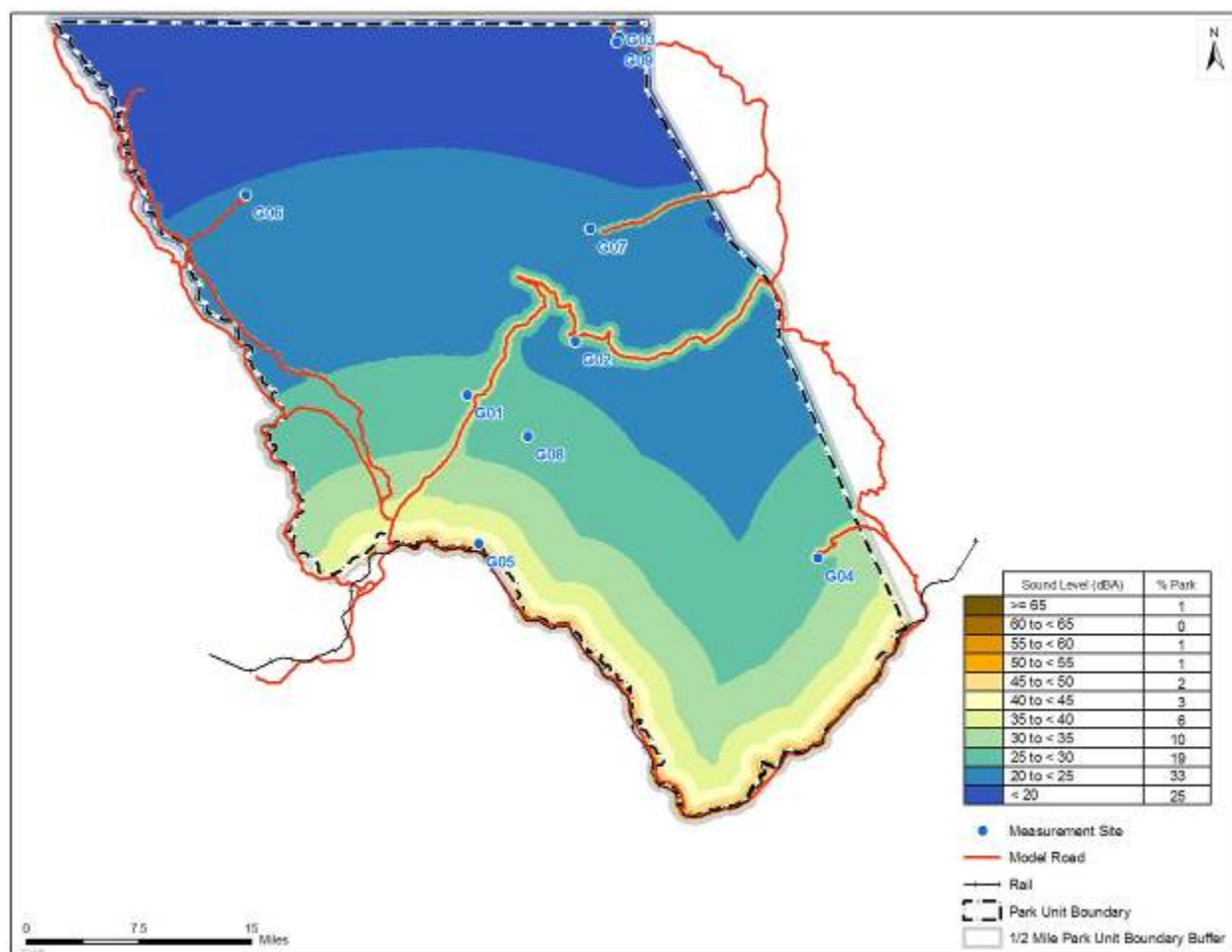


Figure 31. Modeled roadway and railway ambient map.

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7. RESULTS

This section summarizes 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 (Section 7.2).

Table 17 contains a summary of the ambient, sound level data measured at each measurement site. The table is arranged by acoustic zone, followed by measurement site number. The first four columns in the table are arranged as follows:

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

The remaining columns define the ambient sound levels represented by the data, as defined in Section 6.3.*

- For the Existing Ambient, the following metrics are computed:
 - *L_{Aeq}*: The equivalent, A-weighted sound level (in decibels). Presented is the energy-averaged value determined from daytime sound levels (7 am to 7 pm), taking into account the data from all days of measurements;
 - *L₅₀*: The *L₅₀* sound level (in decibels) determined by the sound level exceeded 50 percent of the daytime hours (7 am to 7 pm), taking into account the data from all days of measurements; and
 - *L₉₀*: The *L₉₀* sound level (in decibels) determined by the sound level exceeded 90 percent of the daytime hours (7 am to 7 pm), taking into account the data from all days of measurements.

* As noted previously, because for most parks, the majority of air tour operations occur during the day, the FAA and NPS have agreed that the impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur. Accordingly, any subsequent analyses will be based on daytime ambient data. For Glacier, only data measured during the time period of 7 am to 7 pm were used. This time period reflects typical operating hours for air tour operators conducting air tours in Glacier according to Flight Standards District Office personnel.

- For the Existing Ambient Without Air Tours, the Existing Ambient Without All Aircraft, and Natural Ambient:
 - L_{50}

Figure 32 and Figure 33 present the data in Table 16 graphically for each ambient type. Table 17, and Figure 35 present 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}).

Table 18 and Figure 36 contain a summary of the acoustic observer data logged at each measurement site. As discussed in Section 6.3.1, this data was used to estimate the four types of ambient defined in Section 6.0. The first seven columns in the table are arranged as follows:

- *Acoustic Zone*: The acoustic zone in which the measurement site was located;
- *Site Name*: The name of the site;
- *Site ID*: The unique three-character ID representing the site “number”;
- *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;
- *Level of Visitor-Use*: A designator indicating expected visitor use (with “high” indicating sites such as overlooks, “moderate” indicating short hikes, and “low” indicating minimal or no visitor use such as in the wilderness/backcountry) in the measurement site area;
- *Total Duration (hh:mm:ss)*: The duration of all acoustic observer logging performed at the measurement site.

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

aircraft or other human-made sounds could be heard.

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

In addition, Table 19 summarizes two additional metrics (per NPS request) determined using the acoustic observer logs taken during the ambient measurements:

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

The columns in the table are arranged as follows:

- *Acoustic Zone*: The acoustic zone in which the measurement site was located;
- *Site ID*: The unique three-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 (e.g., general aviation, commercial jet, and military) sounds were audible; and
- *Human*: Periods of time during which human noise sources (visitor- and mechanical-related) were audible.

Figures 48 through 56 present the modeled roadway and railway ambient map, as well as the resultant, six, baseline daytime ambient maps, respectively, per Table 16 above.

Table 16. Summary of measured ambient sound level data.

Acoustic Zone	Site Name	Site ID	Total # Days	Existing Ambient, All Data: L _{Aeq} (dBA)	Existing Ambient, All Data: L ₅₀ (dBA)	Existing Ambient, All Data: L ₉₀ (dBA)	Existing Ambient, 7am to 7pm: L _{Aeq} (dBA)	Existing Ambient, 7am to 7pm: L ₅₀ (dBA)	Existing Ambient, 7am to 7pm: L ₉₀ (dBA)	Existing Ambient Without Air Tours, 7am to 7pm: L ₅₀ (dBA)	Existing Ambient Without All Aircraft: L ₅₀ (dBA)	Natural Ambient: L ₅₀ (dBA)
1 Alpine/Subalpine	Sperry Campground	G08	10	36.3	34.2	32.3	36.3	34.1	32.2	34.0	34.0	34.0
2 Deciduous Forest	Harrison Creek	G05	14	42.9	31.3	24.1	41.6	32.9	26.5	32.6	32.6	25.7
3 Coniferous Forest	McDonald Ranger Station	G01	17	36.7	28.8	24.9	37.4	29.3	24.8	28.9	28.9	23.4
3 Coniferous Forest	Lee Ridge	G03/G09*	12	37.6	25.9	21.1	38.7	29.7	22.7	29.3	28.9	23.2
3 Coniferous Forest	Two Medicine Lake	G04	16	39.6	27.1	20.7	38.3	28.4	22.1	28.4	28.2	23.8
3 Coniferous Forest	Bowman Lake	G06	12	39.8	20.5	12.7	35.6	21.0	16.1	20.9	20.7	19.4
3 Coniferous Forest	Swiftcurrent Trail	G07	16	37.1	33.7	28.1	36.7	31.1	27.1	30.9	30.8	30.5
4 Herbaceous	Logan Pass	G02	18	35.2	31.9	28.6	36.1	30.5	27.9	30.3	30.3	29.6

* Due to access issues, site G03 was moved to another nearby clearing (site G09). Because of their proximity, however, the data for both sites were combined and treated as a single site.

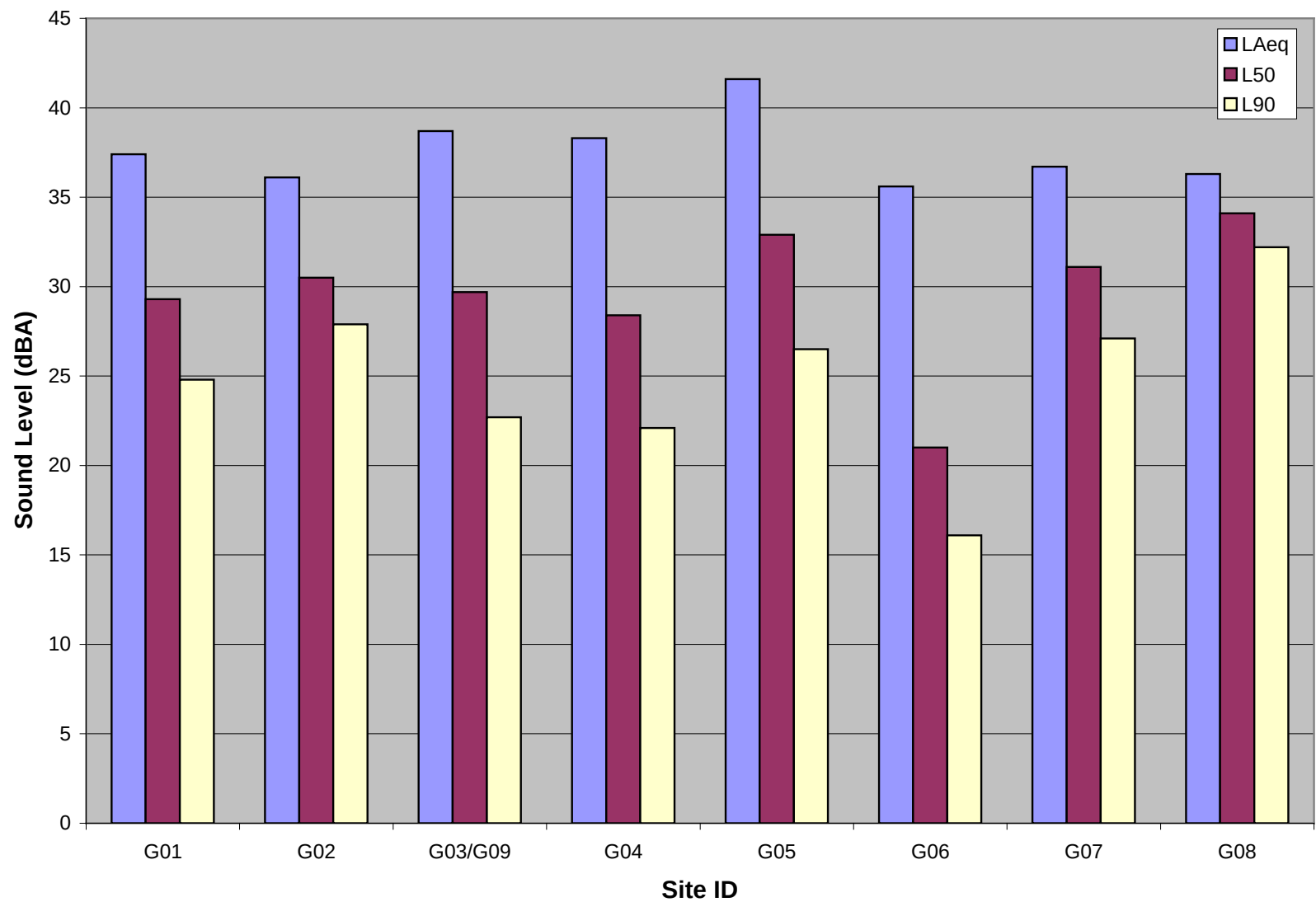


Figure 32. Summary of measured daytime ambient sound level data – Existing Ambient (L_{Aeq}, L₅₀, L₉₀).

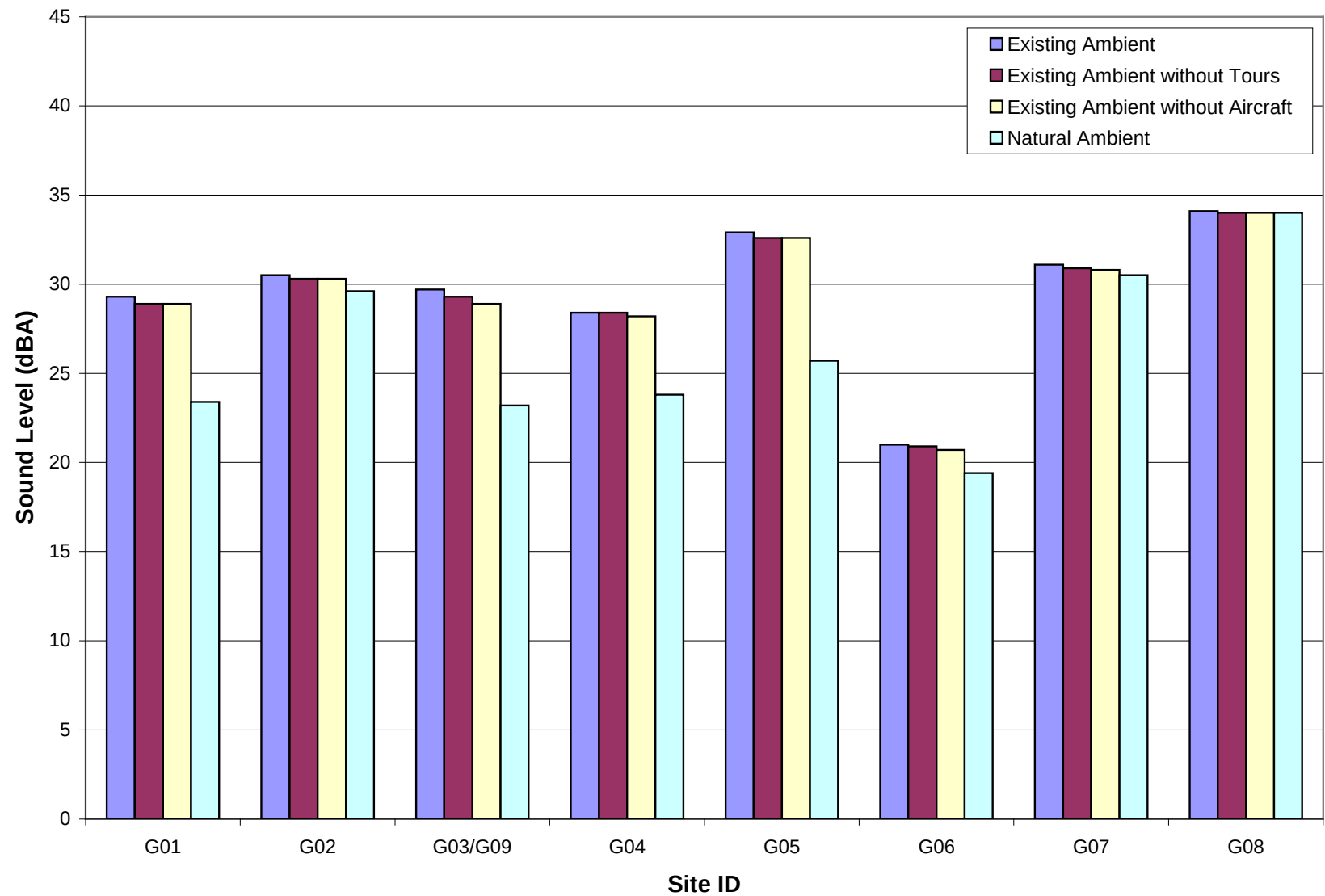


Figure 33. Summary of daytime measured ambient sound level data – L₅₀.

Table 17. Summary of measured, daytime (7 am to 7 pm), ambient sound level spectral data (L₅₀, dBA).

Frequency (Hz)	G01, Existing Ambient Without Tours:	G02, Existing Ambient Without Tours:	G03/G09, Existing Ambient Without Tours:	G04, Existing Ambient Without Tours:	G05, Existing Ambient Without Tours:	G06, Existing Ambient Without Tours:	G07, Existing Ambient Without Tours:	G08, Existing Ambient Without Tours:	G01, Natural Ambient	G02, Natural Ambient	G03/G09, Natural Ambient	G04, Natural Ambient	G05, Natural Ambient	G06, Natural Ambient	G07, Natural Ambient	G08, Natural Ambient
12.5	34.3	35.4	31.0	31.1	34.4	25.0	36.3	20.2	30.0	34.0	24.6	27.2	27.2	24.4	36.0	20.0
16	35.3	35.3	30.2	32.2	34.6	24.1	36.6	19.4	31.2	34.0	23.7	28.1	27.0	23.4	36.4	19.3
20	36.0	35.9	29.7	33.1	33.8	24.3	36.3	20.8	32.1	34.7	22.8	28.7	25.9	23.6	36.0	20.8
25	35.9	37.8	27.9	34.6	32.7	23.6	37.3	21.0	31.8	36.4	20.4	29.5	24.4	22.6	37.0	20.9
31	34.8	38.2	26.8	34.5	29.5	28.2	36.7	21.5	28.9	36.8	18.3	29.6	21.1	26.4	36.5	21.4
40	32.9	39.1	25.8	32.3	25.9	19.7	33.1	22.9	24.0	37.6	16.9	27.1	17.6	18.3	32.8	22.8
50	30.5	37.9	25.5	29.8	23.4	15.3	29.6	21.9	22.4	36.1	15.8	23.9	15.4	13.8	29.1	21.8
63	30.2	37.2	22.5	26.1	26.5	15.7	27.9	22.4	22.0	35.5	13.7	20.5	17.4	14.1	27.6	22.3
80	30.3	35.8	20.7	22.9	31.0	5.5	25.1	23.5	21.3	34.1	12.1	17.6	20.9	4.6	24.8	23.5
100	30.2	32.0	22.1	21.0	32.4	4.5	22.2	24.3	21.5	30.4	10.8	15.2	22.7	3.4	21.7	24.3
125	28.1	27.7	18.4	18.9	29.3	5.8	19.4	24.3	20.0	26.5	8.9	12.6	20.0	4.8	18.9	24.3
160	24.0	24.2	18.6	18.1	25.5	8.8	18.2	24.4	16.8	23.1	10.5	12.6	16.7	8.1	17.7	24.3
200	22.4	21.5	22.8	20.2	24.4	10.5	19.4	23.6	15.7	20.3	13.2	15.2	16.3	10.1	19.0	23.5
250	21.9	19.6	24.0	21.6	25.6	9.3	20.7	22.0	15.3	18.6	14.3	16.5	17.8	8.6	20.1	21.9
315	21.3	19.1	25.2	21.7	26.7	11.1	22.2	24.8	15.0	18.5	15.2	16.9	19.0	10.5	21.6	24.7
400	20.5	19.6	23.0	22.0	26.0	12.4	23.8	27.1	14.2	19.1	14.5	17.2	18.4	11.9	23.3	27.1
500	19.5	20.4	21.8	21.8	25.3	11.1	24.4	28.8	13.2	20.0	12.9	16.8	17.6	10.4	23.9	28.7
630	18.5	21.4	20.8	20.9	24.6	10.9	24.2	27.8	12.5	20.9	11.2	15.9	16.9	10.2	23.8	27.8
800	17.8	21.8	19.3	20.4	24.8	10.6	23.8	27.0	11.9	21.2	10.3	15.4	17.3	9.9	23.4	26.9
1000	16.2	21.2	17.6	19.0	23.2	10.1	22.5	25.7	10.9	20.7	9.8	14.5	16.0	9.5	22.2	25.7
1250	15.0	19.7	14.7	16.9	20.0	8.6	20.6	24.2	9.6	19.2	7.6	12.8	13.4	8.0	20.3	24.2
1600	12.5	17.3	11.2	14.1	15.7	6.7	18.3	21.8	7.5	16.6	5.1	10.4	9.9	6.1	17.9	21.8
2000	11.1	13.7	7.8	11.1	10.9	4.8	15.5	18.0	6.1	12.7	2.8	7.5	6.5	4.1	15.1	18.0
2500	10.5	10.1	7.1	7.4	8.0	4.2	12.4	11.7	5.5	9.2	3.4	4.2	4.3	3.4	11.9	11.5
3150	10.8	7.5	7.2	4.7	7.3	4.6	10.0	6.0	5.8	6.7	4.8	1.8	3.1	3.8	9.6	6.0
4000	10.5	7.0	8.2	3.2	6.5	3.9	8.1	3.2	6.0	6.2	6.7	0.7	3.1	2.9	7.6	3.2
5000	9.6	7.6	9.5	3.5	6.3	4.2	7.3	3.1	5.4	7.1	8.0	1.8	3.6	3.4	6.8	3.1
6300	9.0	7.4	10.2	3.2	6.4	4.3	6.7	1.9	5.3	7.0	8.7	1.9	3.9	3.5	6.1	1.5
8000	10.3	8.2	10.3	5.0	7.0	5.7	7.3	-1.1	6.9	8.1	7.3	4.2	5.3	5.0	6.7	-1.4
10000	10.3	10.9	13.0	6.5	7.2	5.2	7.4	-1.8	8.1	10.6	9.7	5.9	5.9	5.0	7.3	-2.3
12500	7.7	10.1	14.9	4.9	6.1	-3.5	5.4	6.3	5.6	9.7	13.1	4.1	3.3	-6.5	5.0	6.3
16000	9.7	12.3	16.6	8.0	8.3	-6.2	4.2	-8.3	3.4	12.0	14.3	7.2	0.8	-9.1	2.9	-8.6
20000	16.8	16.0	17.2	14.7	5.8	-8.9	0.1	-11.5	15.4	15.7	12.6	14.3	-1.7	-11.6	-0.3	-11.6

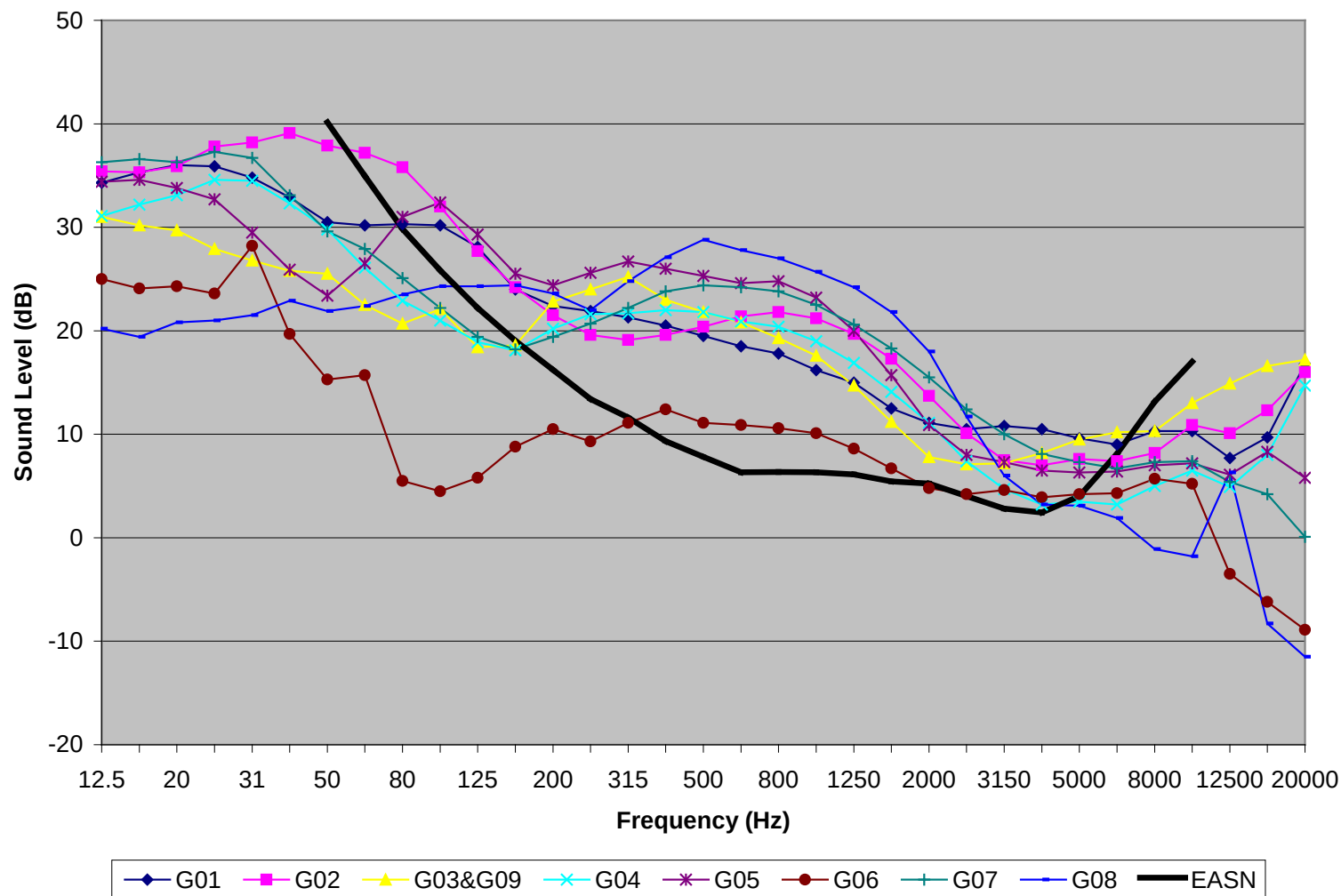


Figure 34. Spectral data for the Existing Ambient Without Air Tours (L_{50}) determined for each site.*

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

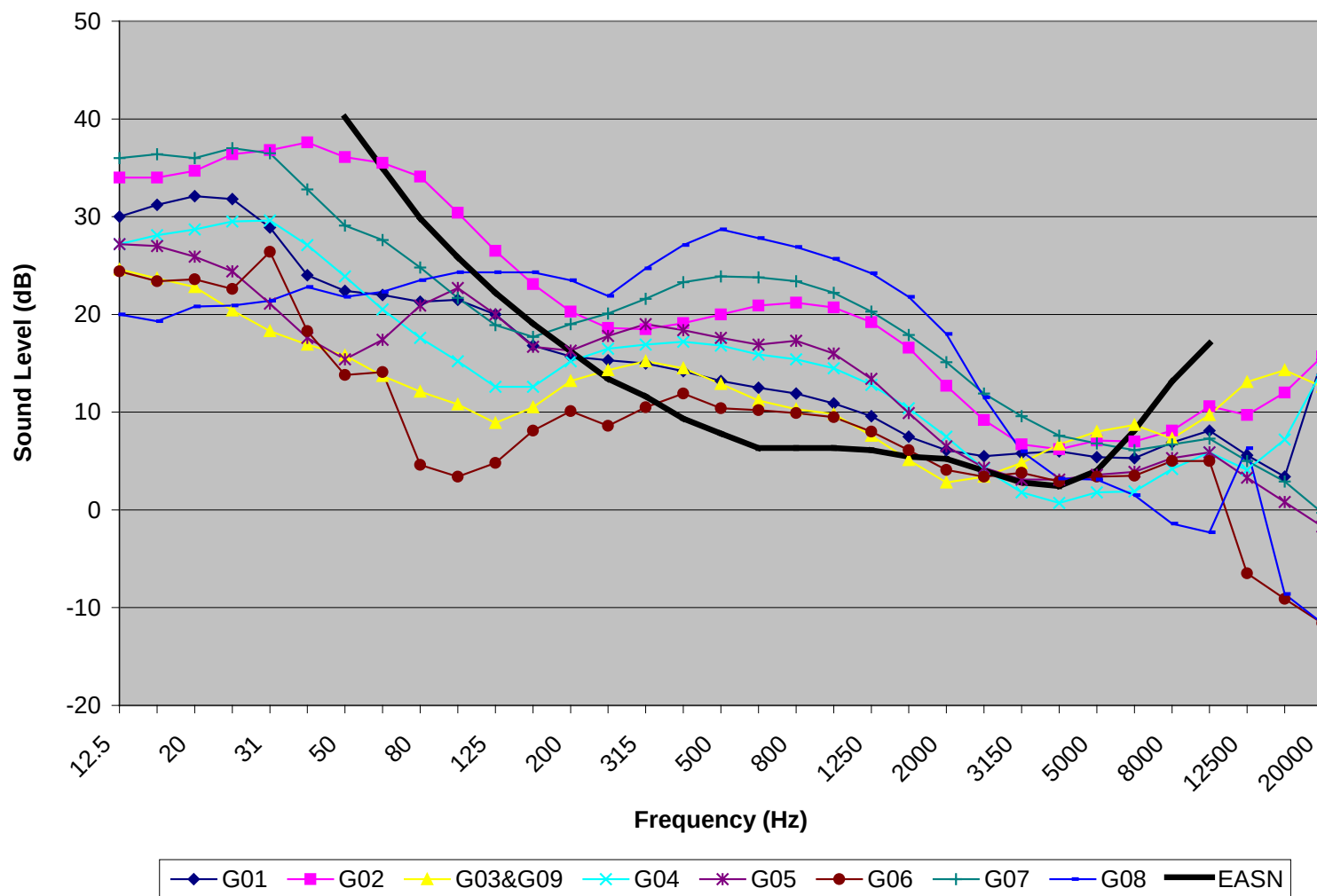


Figure 35. Spectral data for the Natural Ambient (L_{50}) determined for each site.*

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

Table 18. Summary of acoustic observer log data.

Acoustic Zone	Site Name	Site ID	Land Cover	General Management Plan Zone (Geographical Area)	Level of Visitor-Use	Total Duration (hh:mm:ss)	Air Tour Aircraft: % Time Audible	Other Aircraft: % Time Audible	Human: % Time Audible	Natural: % Time Audible
1 Alpine/ Subalpine	Sperry Campground	G08	42 Evergreen Forest	Backcountry (Going-to-the-Sun Road)	Low	4:36:35	3%	0%	3%	93%
2 Deciduous Forest	Harrison Creek	G05	42 Evergreen Forest	Backcountry (Middle Fork)	Low	5:10:17	4%	1%	80%	15%
3 Coniferous Forest	McDonald Ranger Station	G01	42 Evergreen Forest	Visitor Service (Going-to-the-Sun Road)	High	5:01:01	5%	1%	87%	7%
3 Coniferous Forest	Lee Ridge	G03/G09*	42 Evergreen Forest	Backcountry (Goat Haunt-Belly River)	Low	2:46:30	3%	3%	63%	32%
3 Coniferous Forest	Two Medicine Lake	G04	42 Evergreen Forest	Day Use (Two Medicine)	Moderate	3:45:11	0%	1%	54%	44%
3 Coniferous Forest	Bowman Lake	G06	42 Evergreen Forest	Backcountry (North Fork)	Moderate	5:19:26	1%	3%	8%	88%
3 Coniferous Forest	Swiftcurrent Trail	G07	42 Evergreen Forest	Day Use (Many Glacier)	Moderate	2:32:58	2%	2%	7%	89%
4 Herbaceous	Logan Pass	G02	71 Grasslands/Herbaceous	Day Use (Going-to-the-Sun Road)	High	5:01:21	5%	0%	20%	75%

* Due to access issues, site G03 was moved to another nearby clearing (site G09). Because of their proximity, however, the data for both sites were combined and treated as a single site.

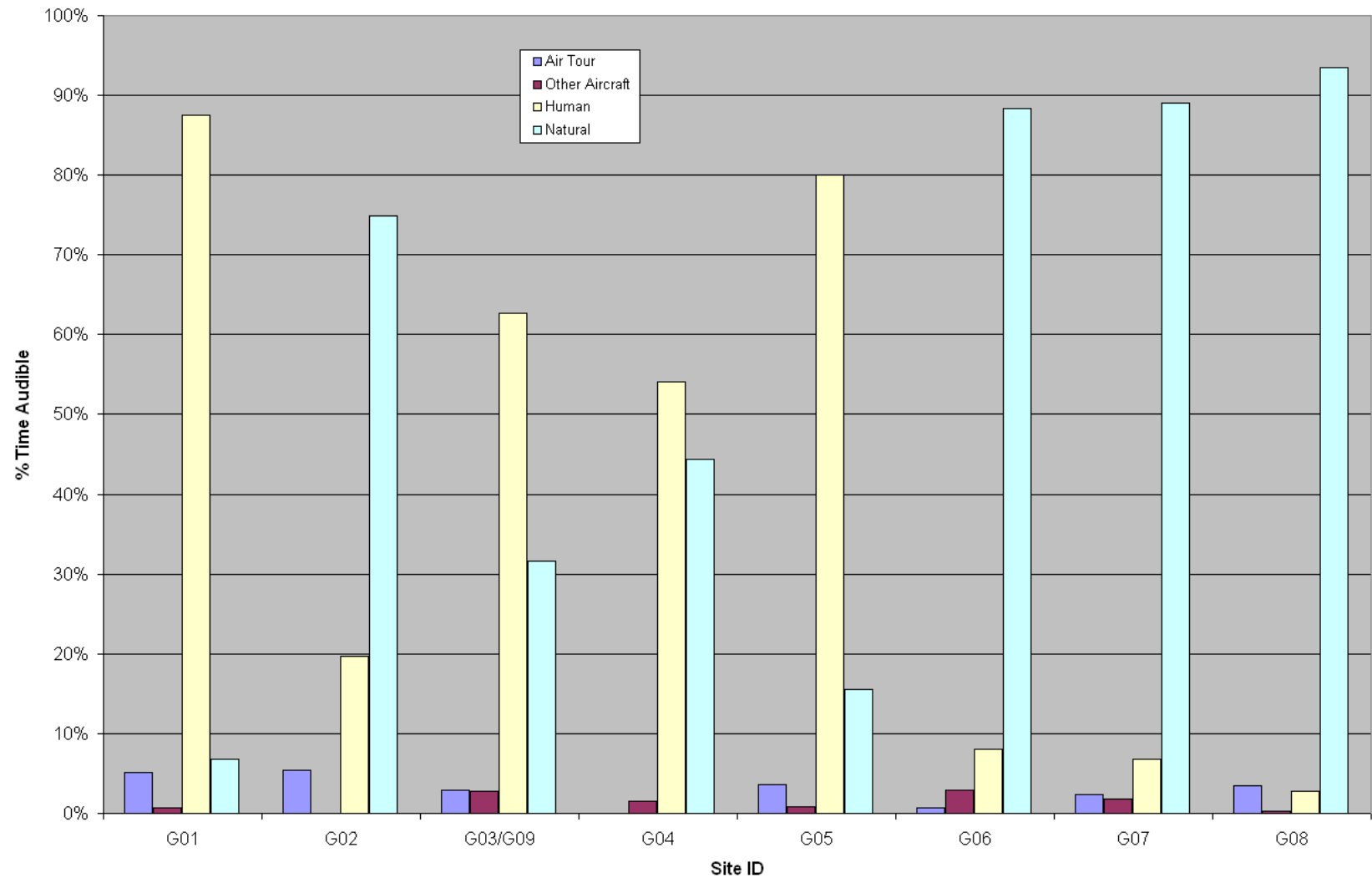


Figure 36. Summary of acoustic observer log data.

Table 19. Summary of acoustic observer log data: number of events per hour and noise-free interval.

Metric	Acoustic Zone	Site ID	Noise-Free Periods (Natural Events)	Air Tour Aircraft Events	Other Aircraft Events	Human Events
Number Periods/Events:	1: Alpine/Subalpine	G08	130	8	2	21
Mean Time (hh:mm:ss):	1: Alpine/Subalpine	G08	0:01:59	0:01:11	0:00:27	0:00:22
Minimum Time (hh:mm:ss):	1: Alpine/Subalpine	G08	0:00:03	0:00:44	0:00:26	0:00:06
Maximum Time (hh:mm:ss):	1: Alpine/Subalpine	G08	0:22:46	0:01:43	0:00:28	0:01:53
Total Time (hh:mm:ss):	1: Alpine/Subalpine	G08	4:18:24	0:09:29	0:00:54	0:07:48
Number Periods/Events:	2: Deciduous Forest	G05	79	8	2	90
Mean Time (hh:mm:ss):	2: Deciduous Forest	G05	0:00:37	0:01:54	0:01:23	0:02:45
Minimum Time (hh:mm:ss):	2: Deciduous Forest	G05	0:00:08	0:00:08	0:00:27	0:00:08
Maximum Time (hh:mm:ss):	2: Deciduous Forest	G05	0:05:33	0:03:23	0:02:18	0:35:31
Total Time (hh:mm:ss):	2: Deciduous Forest	G05	0:48:01	0:11:22	0:02:45	4:08:09
Number Periods/Events:	3: Coniferous Forest	G01	78	12	2	286
Mean Time (hh:mm:ss):	3: Coniferous Forest	G01	0:00:16	0:00:57	0:01:01	0:00:55
Minimum Time (hh:mm:ss):	3: Coniferous Forest	G01	0:00:05	0:00:10	0:00:55	0:00:07
Maximum Time (hh:mm:ss):	3: Coniferous Forest	G01	0:01:43	0:02:08	0:01:06	0:07:26
Total Time (hh:mm:ss):	3: Coniferous Forest	G01	0:20:28	0:15:18	0:02:01	4:23:14
Number Periods/Events:	3: Coniferous Forest	G03/G09	102	4	3	150
Mean Time (hh:mm:ss):	3: Coniferous Forest	G03/G09	0:00:31	0:00:42	0:01:31	0:00:42
Minimum Time (hh:mm:ss):	3: Coniferous Forest	G03/G09	0:00:04	0:00:09	0:01:23	0:00:07
Maximum Time (hh:mm:ss):	3: Coniferous Forest	G03/G09	0:03:57	0:02:39	0:01:37	0:12:16
Total Time (hh:mm:ss):	3: Coniferous Forest	G03/G09	0:52:39	0:04:55	0:04:32	1:44:24
Number Periods/Events:	3: Coniferous Forest	G04	199	0	4	217
Mean Time (hh:mm:ss):	3: Coniferous Forest	G04	0:00:30	0:00:00	0:00:50	0:00:34
Minimum Time (hh:mm:ss):	3: Coniferous Forest	G04	0:00:05	0:00:00	0:00:29	0:00:05
Maximum Time (hh:mm:ss):	3: Coniferous Forest	G04	0:08:43	0:00:00	0:01:24	0:08:04
Total Time (hh:mm:ss):	3: Coniferous Forest	G04	1:40:00	0:00:00	0:03:18	2:01:53
Number Periods/Events:	3: Coniferous Forest	G06	258	4	6	60
Mean Time (hh:mm:ss):	3: Coniferous Forest	G06	0:01:06	0:01:05	0:01:08	0:00:26

Metric	Acoustic Zone	Site ID	Noise-Free Periods (Natural Events)	Air Tour Aircraft Events	Other Aircraft Events	Human Events
Minimum Time (hh:mm:ss):	3: Coniferous Forest	G06	0:00:04	0:00:29	0:00:15	0:00:06
Maximum Time (hh:mm:ss):	3: Coniferous Forest	G06	0:27:30	0:01:42	0:02:33	0:01:20
Total Time (hh:mm:ss):	3: Coniferous Forest	G06	4:42:19	0:02:11	0:09:05	0:25:51
Number Periods/Events:	3: Coniferous Forest	G03/G09	102	4	3	150
Mean Time (hh:mm:ss):	3: Coniferous Forest	G03/G09	0:00:31	0:00:42	0:01:31	0:00:42
Minimum Time (hh:mm:ss):	3: Coniferous Forest	G03/G09	0:00:04	0:00:09	0:01:23	0:00:07
Maximum Time (hh:mm:ss):	3: Coniferous Forest	G03/G09	0:03:57	0:02:39	0:01:37	0:12:16
Total Time (hh:mm:ss):	3: Coniferous Forest	G03/G09	0:52:39	0:04:55	0:04:32	1:44:24
Number Periods/Events:	4: Herbaceous	G02	188	8	0	126
Mean Time (hh:mm:ss):	4: Herbaceous	G02	0:01:12	0:02:04	0:00:00	0:00:28
Minimum Time (hh:mm:ss):	4: Herbaceous	G02	0:00:05	0:00:15	0:00:00	0:00:05
Maximum Time (hh:mm:ss):	4: Herbaceous	G02	0:12:45	0:03:06	0:00:00	0:01:30
Total Time (hh:mm:ss):	4: Herbaceous	G02	3:45:42	0:16:29	0:00:00	0:59:10

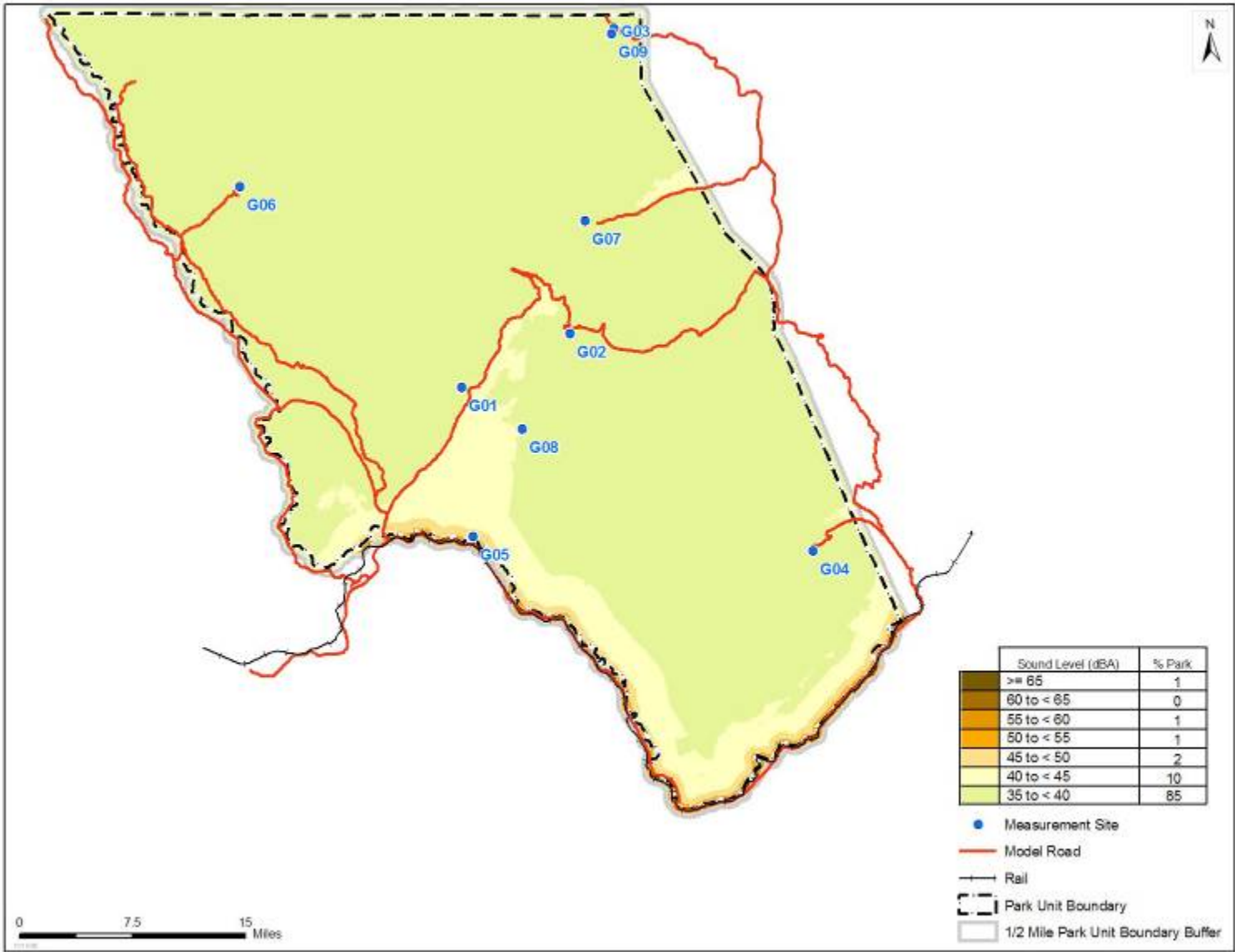
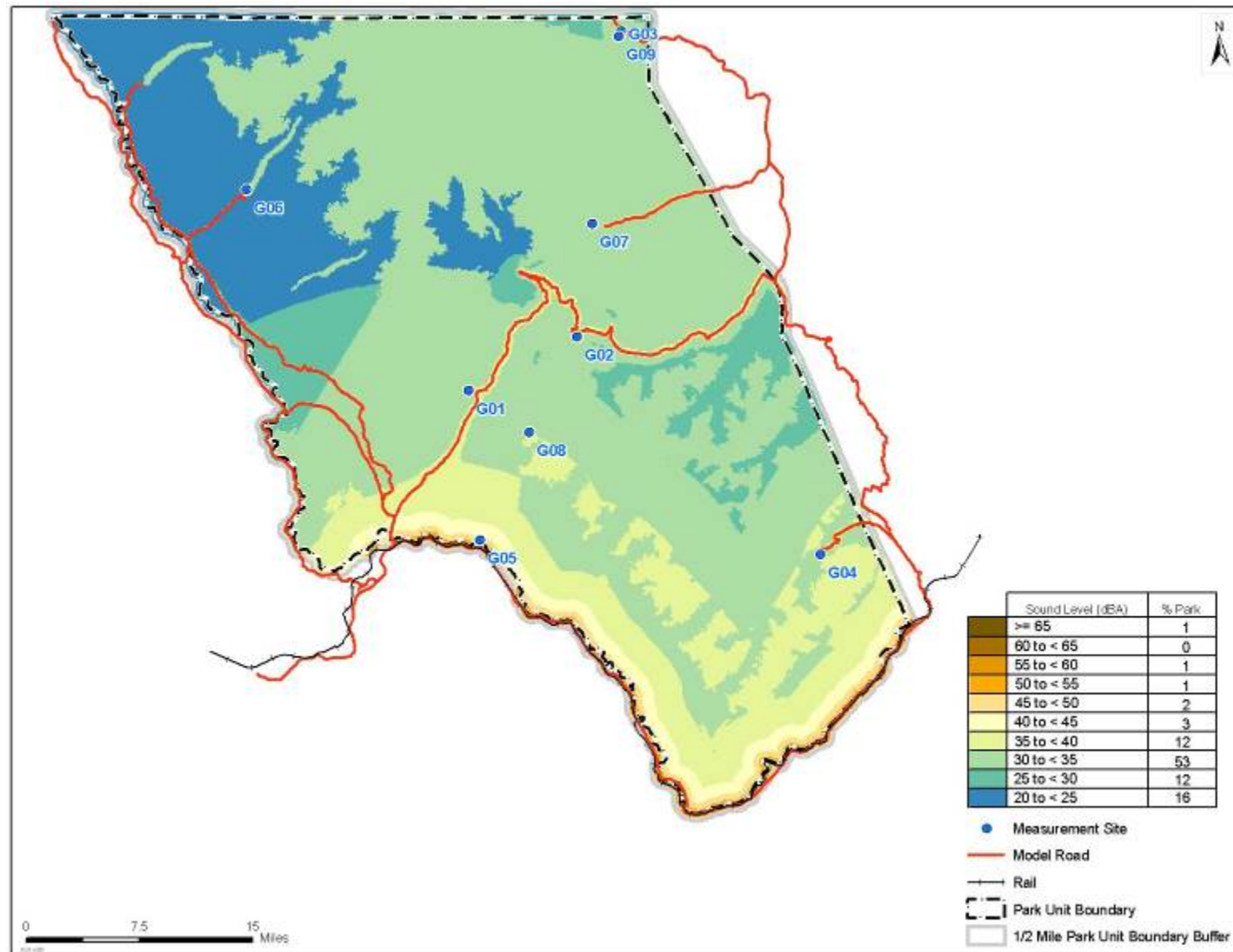
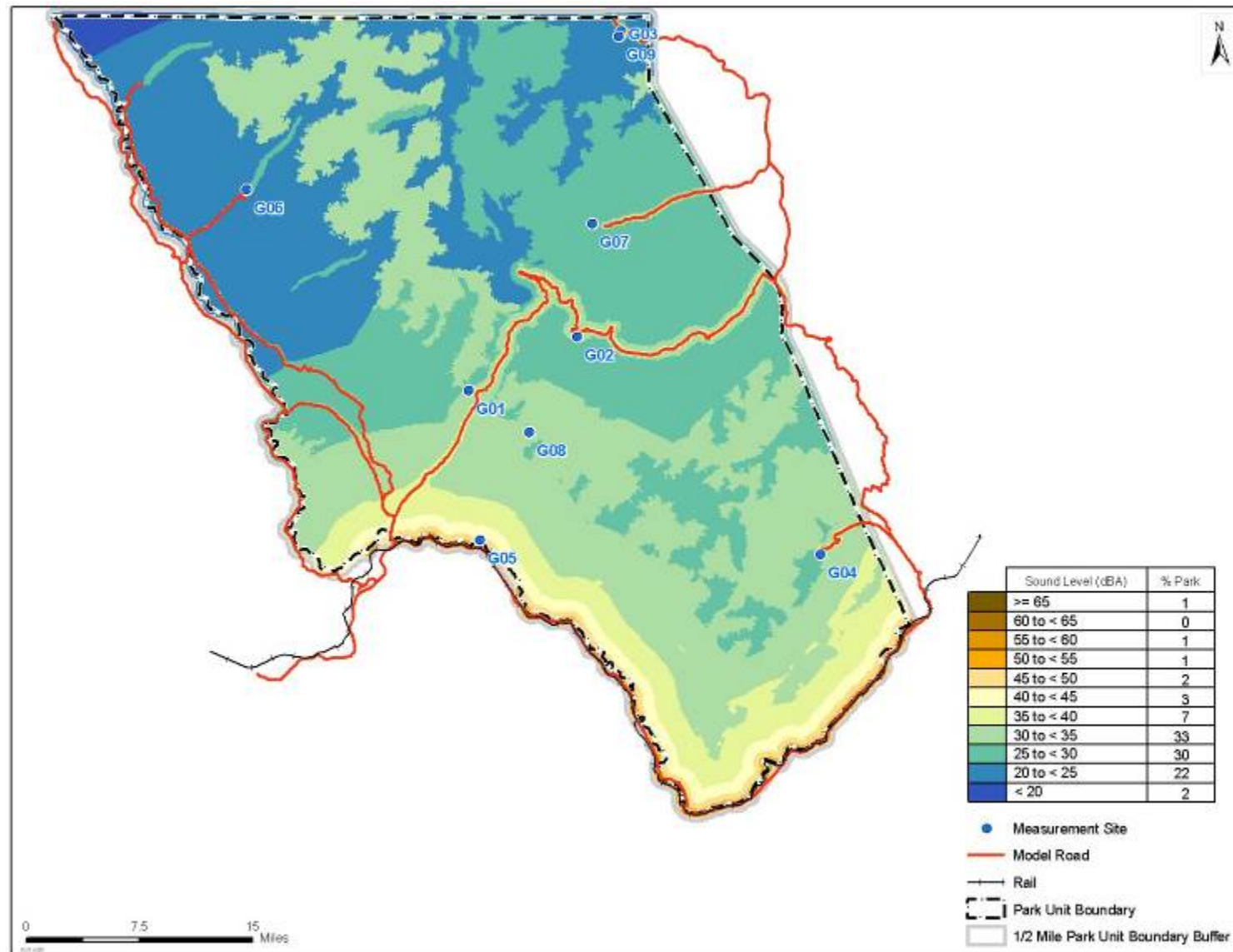


Figure 37. Baseline ambient map – Existing Ambient: L_{Aeq} .

Figure 38. Baseline ambient map – Existing Ambient: L₅₀.

Figure 39. Baseline ambient map – Existing Ambient: L₉₀.

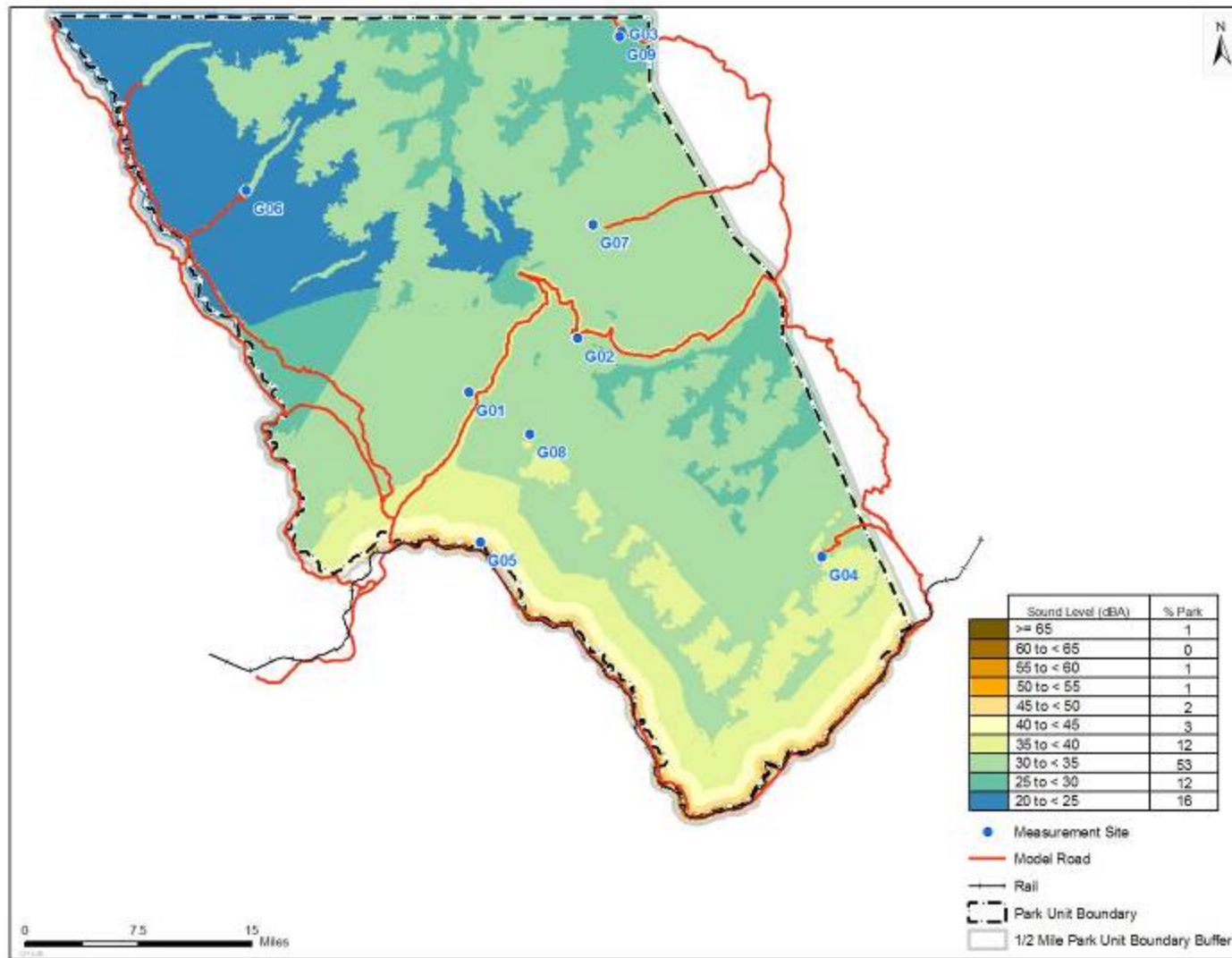


Figure 40. Baseline ambient map – Existing Ambient Without Air Tours: L₅₀.*

* As stated earlier, two ambient maps were agreed upon for use in ATMP analyses: the Existing Ambient Without Air Tours (L₅₀) and the Natural Ambient (L₅₀)

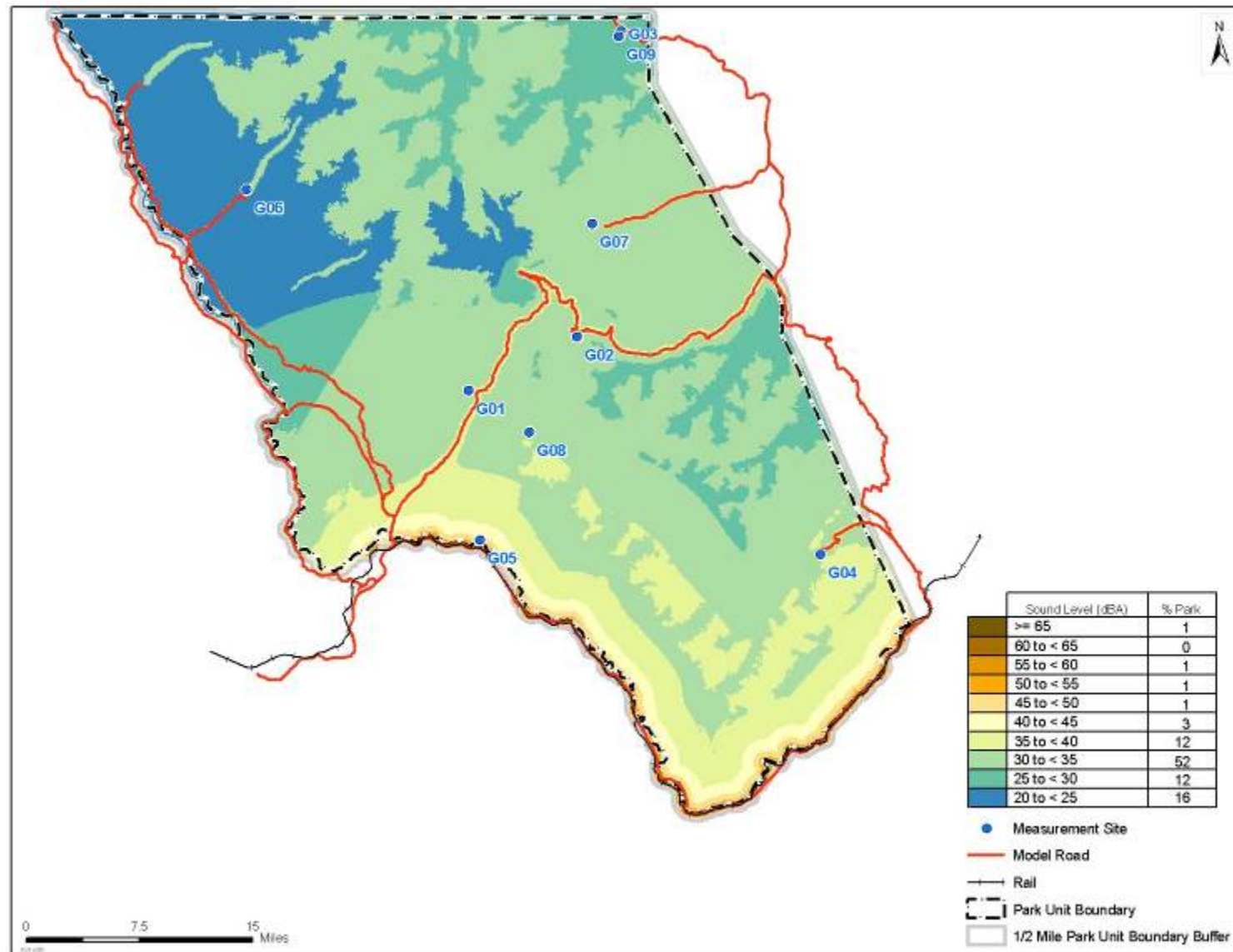


Figure 41. Baseline ambient map – Existing Ambient Without All Aircraft: L₅₀.

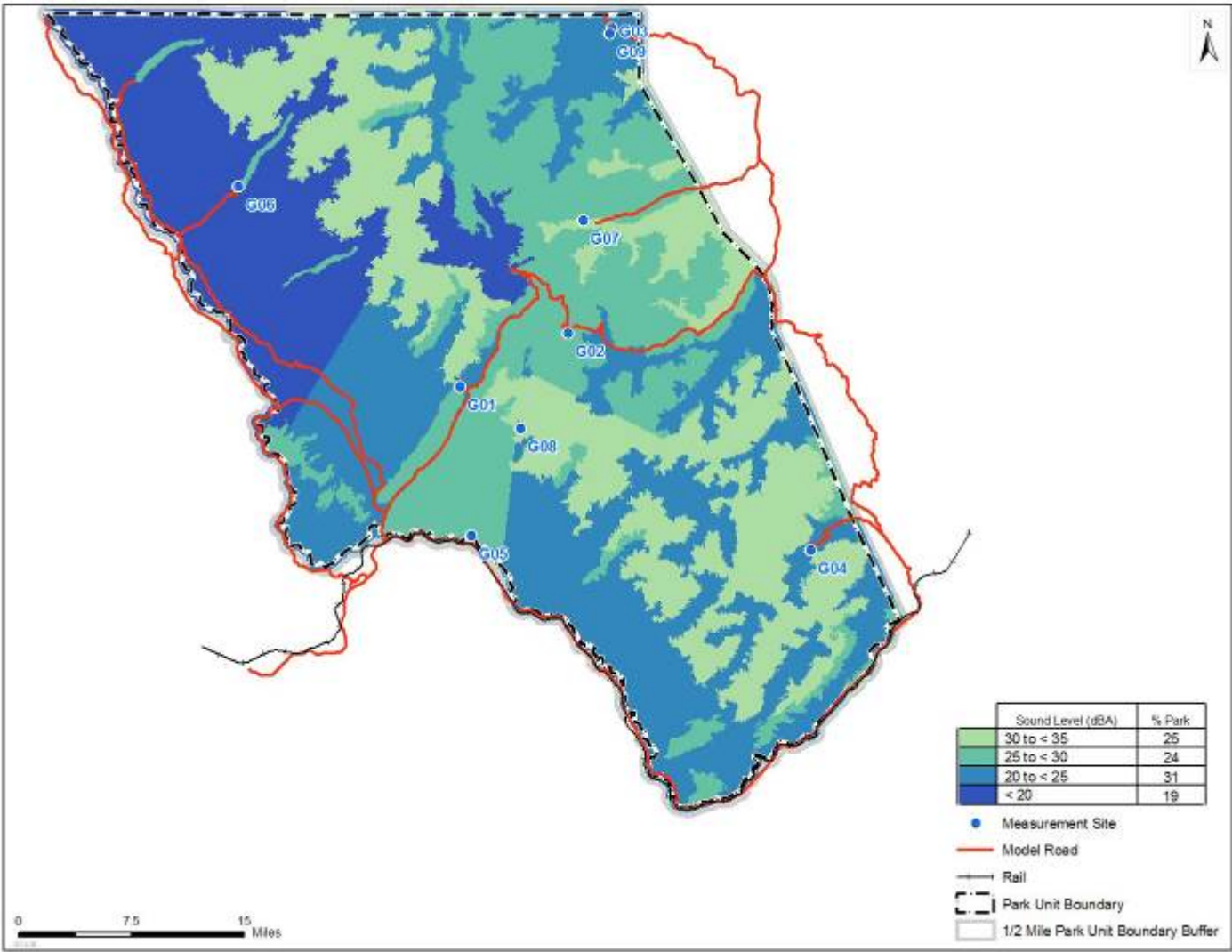


Figure 42. Baseline ambient map – Natural Ambient: L₅₀ *

* As stated earlier, two ambient maps were agreed upon for use in ATMP analyses: the Existing Ambient Without Air Tours (L₅₀) and the Natural Ambient (L₅₀)

APPENDIX A. MEASUREMENT SITE DETAILS

All Glacier measurement sites are shown in Figure 43 and described here in detail.

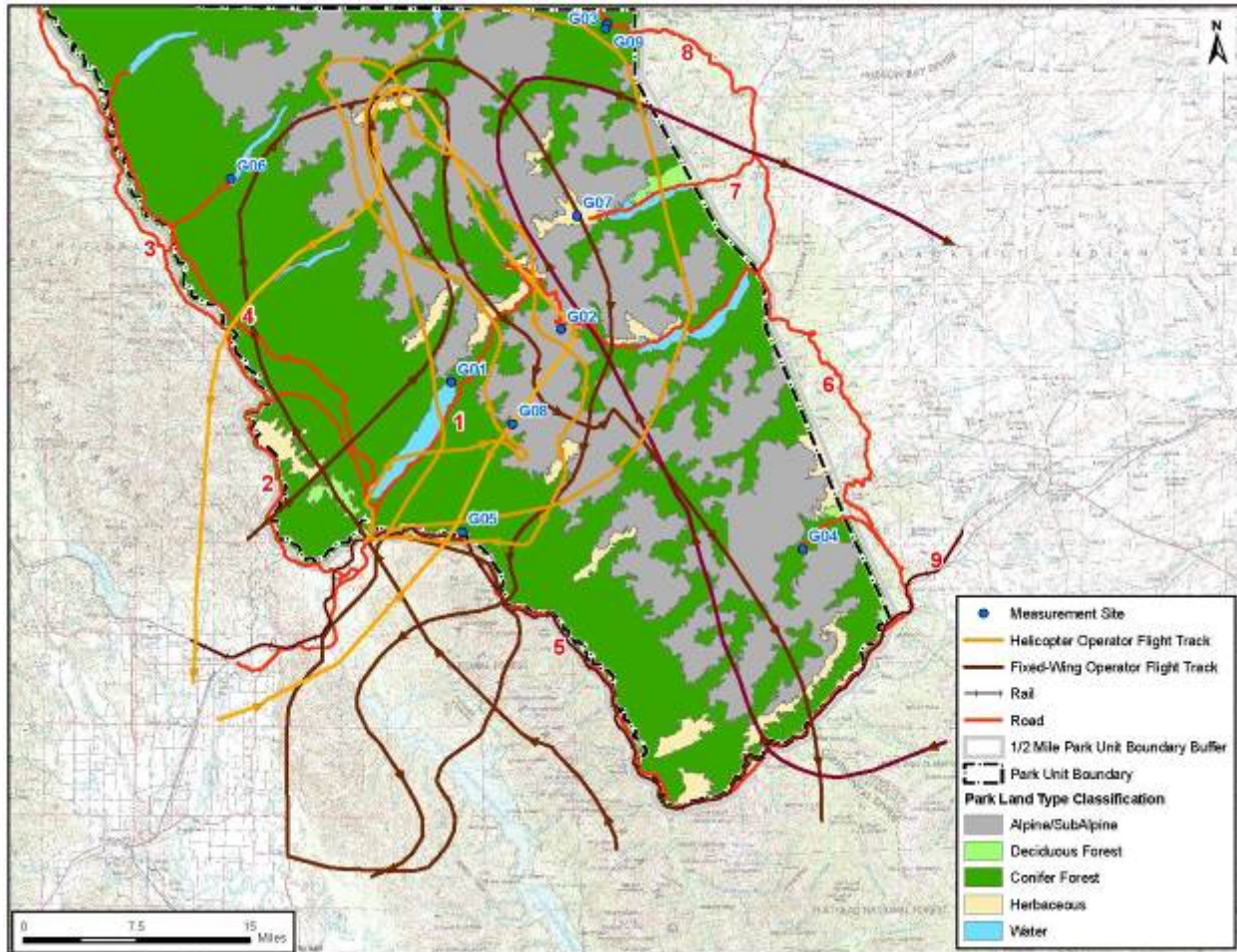


Figure 43. Final measurement sites for Glacier.

For each site, the following are included:

- A table providing site description and arranged as follows:
 - o *Site ID*: The unique three-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 *ATMP System # and Type*: The numeric identifier and type of the continuous monitoring system used at the site (see Table 6 in Section 4.1);

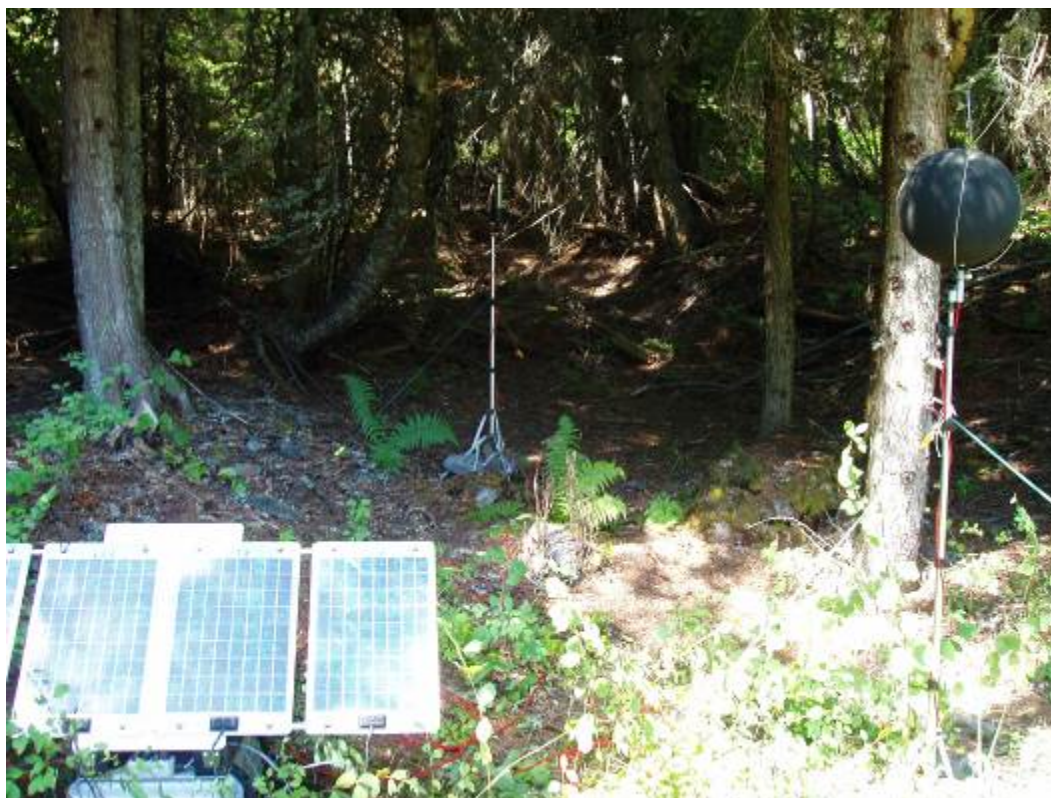
- *Latitude/Longitude (decimal degrees)*: The latitudinal and longitudinal location of the site in decimal degrees;
 - *Approximate Elevation (ft)*: The elevation of the site above mean sea level (MSL) in feet;
 - *Ecological Domain*: The geographic ecosystem unit of the site (see also Appendix E);
 - *Ecological Division*: The geographic ecosystem subunit of the site (see also Appendix E);
 - *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);
 - *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);
 - *Management Zone*: The NPS management zone that the site was located in (see also Section 2.4);
 - *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 (see also Section 2.4.1);
 - *Site Description*: A short textual description of the site;
 - *Access Considerations*: A short textual description of any access considerations related to the site; and
 - *Potential Sound Sources*: Per discussions with the NPS during final site selection (see Section 2.7) 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;
 - 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; and
-

- A pie chart presenting a comparison of types of sound sources that were audible during observer logging.

Note: As stated in Section 5.4, 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 and Appendix E.

A.1 Site G01 – Coniferous Forest Zone Measurement Site**Table 20. Site G01: description.**

Site ID	G01
Site Name	McDonald Ranger Station
# Measurement Days and Dates	17 days - August 5 to August 21, 2004
System # and Type	9 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	48.64263 / 113.87556
Approximate Elevation (ft)	3933
Ecological Domain (see Appendix E)	300 North American Dry Domain
Ecological Division (see Appendix E)	306 Rocky Mountain
Land Cover Class (see Appendix E)	4 Forested Upland
Land Cover Subclass (see Appendix E)	42 Evergreen Forest
General Management Plan Zone (see Section 2.4)	Visitor Service
Site Category (see Section 2.4.1)	Overlook
Site Description	Evergreen forest off road and horse corral
Access Considerations	Vehicle accessible
Potential Sound Sources	Aircraft, Vehicles, Visitors, Horses, Birds, Insects, Wind

**Figure 44. Site G01: Description and photograph.**

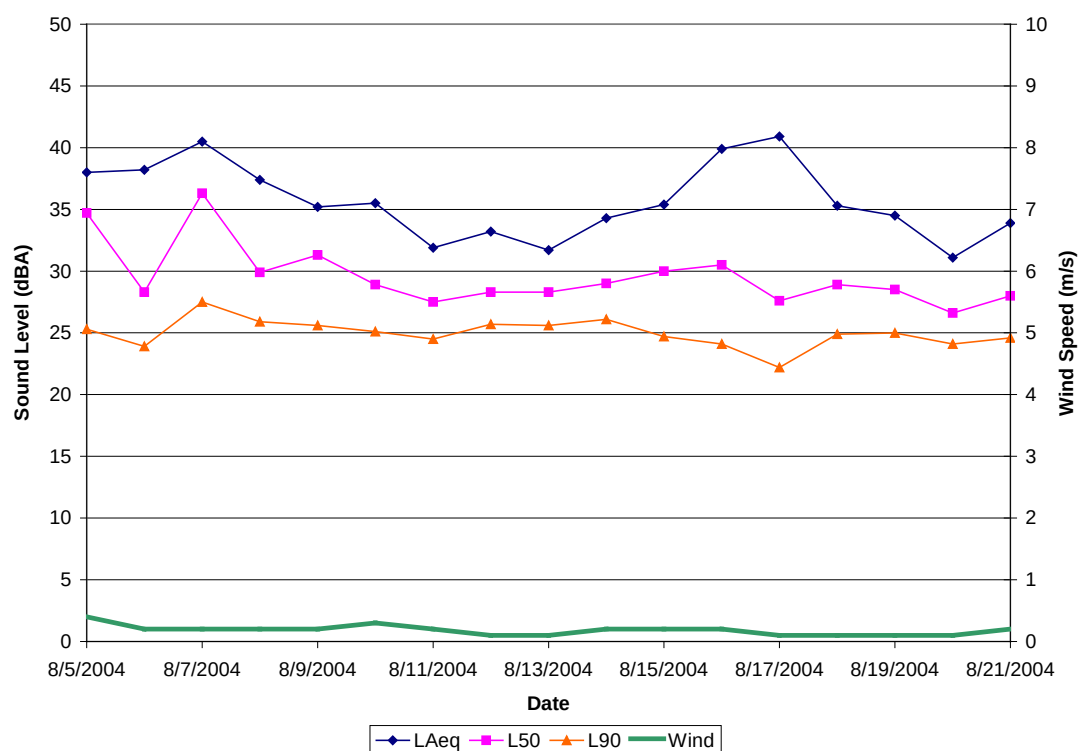


Figure 45. Daily sound levels and wind speeds: Site G01.

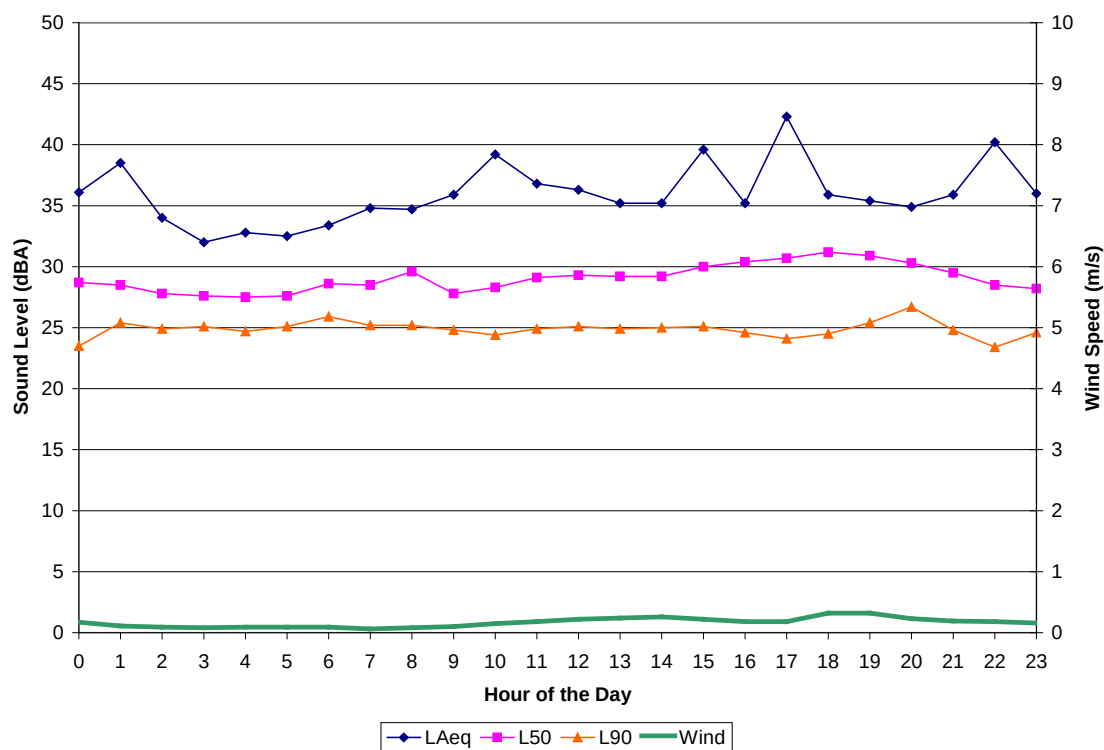


Figure 46. Average hourly sound levels and wind speeds: Site G01

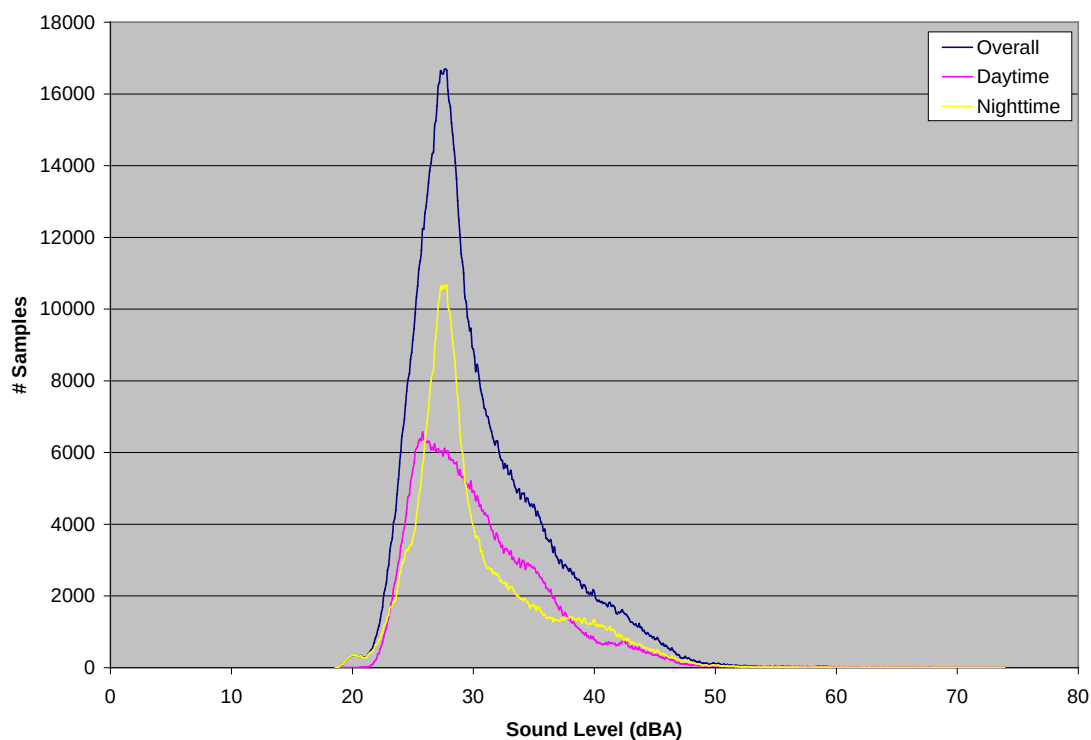


Figure 47. Distribution of data: Site G01.

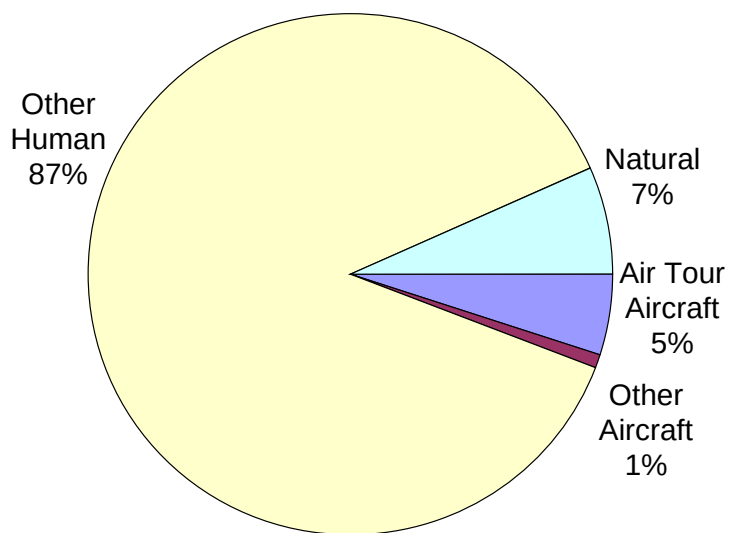


Figure 48. Distribution of sound sources audible during acoustic observer logging: Site G01.

This site was located on the north side of Lake McDonald near a small ranger station and horse corral. The equipment location was at the edge of a small fenced pasture in an otherwise densely forested area. The pasture area, which contained a water trough on its far side, was used for Park

Service equine resources. The water trough caused a dripping sound that was barely audible at the equipment location. The ground cover at the site was soft and mossy with pine needle and other forest debris. This area is characterized by a mix of natural and human activity with a large percentage of human audible sounds occurring during daytime hours. Audible human activity included boat traffic on McDonald Lake, distant vehicular traffic traveling to a nearby campsite, horses, and human voices. Audible aircraft included helicopters and some high-altitude jets. Frequent bird and insect vocalizations were also present at this site.

A.2 Site G02 – Herbaceous Zone Measurement Site**Table 21. Site G02: description.**

Site ID	G02
Site Name	Logan Pass
# Measurement Days and Dates	18 days - August 6 to August 22, 2004
System # and Type	10 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	48.69345 / 113.71692
Approximate Elevation (ft)	6675
Ecological Domain (see Appendix E)	300 North American Dry Domain
Ecological Division (see Appendix E)	306 Rocky Mountain
Land Cover Class (see Appendix E)	7 Herbaceous Upland Natural/Semi-natural Vegetation
Land Cover Subclass (see Appendix E)	71 Grasslands/Herbaceous
General Management Plan Zone (see Section 2.4)	Day Use
Site Category (see Section 2.4.1)	Overlook
Site Description	Grassy meadow behind visitor center
Access Considerations	Vehicle accessible
Potential Sound Sources	Aircraft, Vehicles, Visitors, Wind

**Figure 49. Site G02: Description and photograph.**

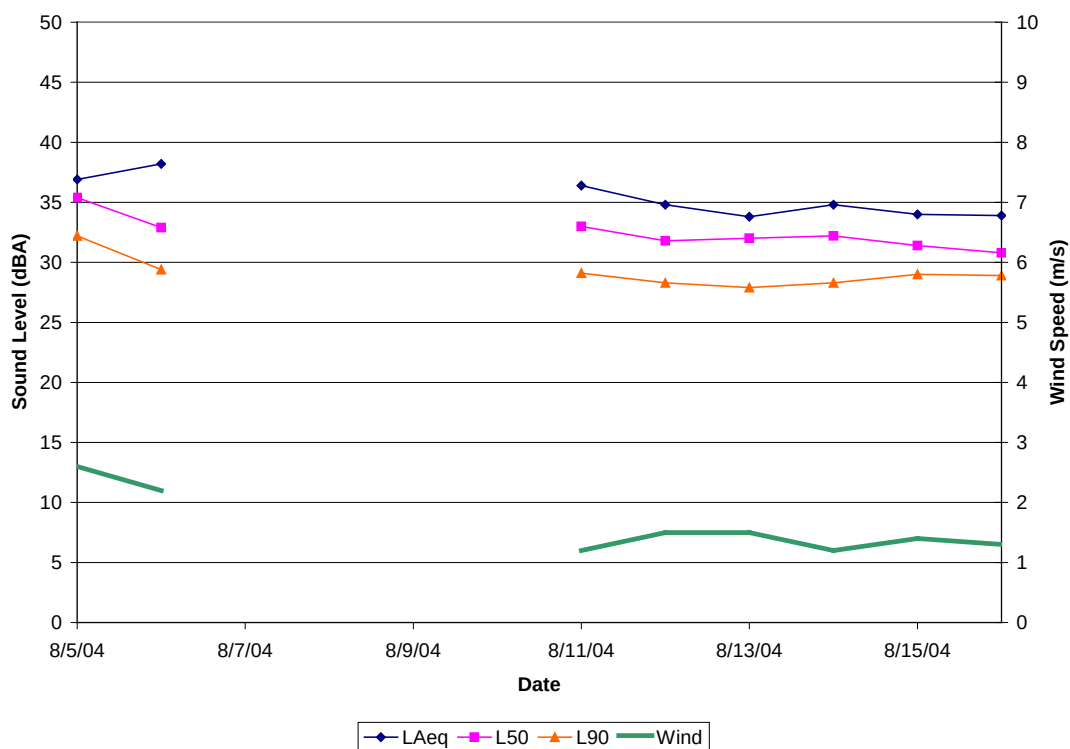


Figure 50. Daily sound levels and wind speeds: Site G02.

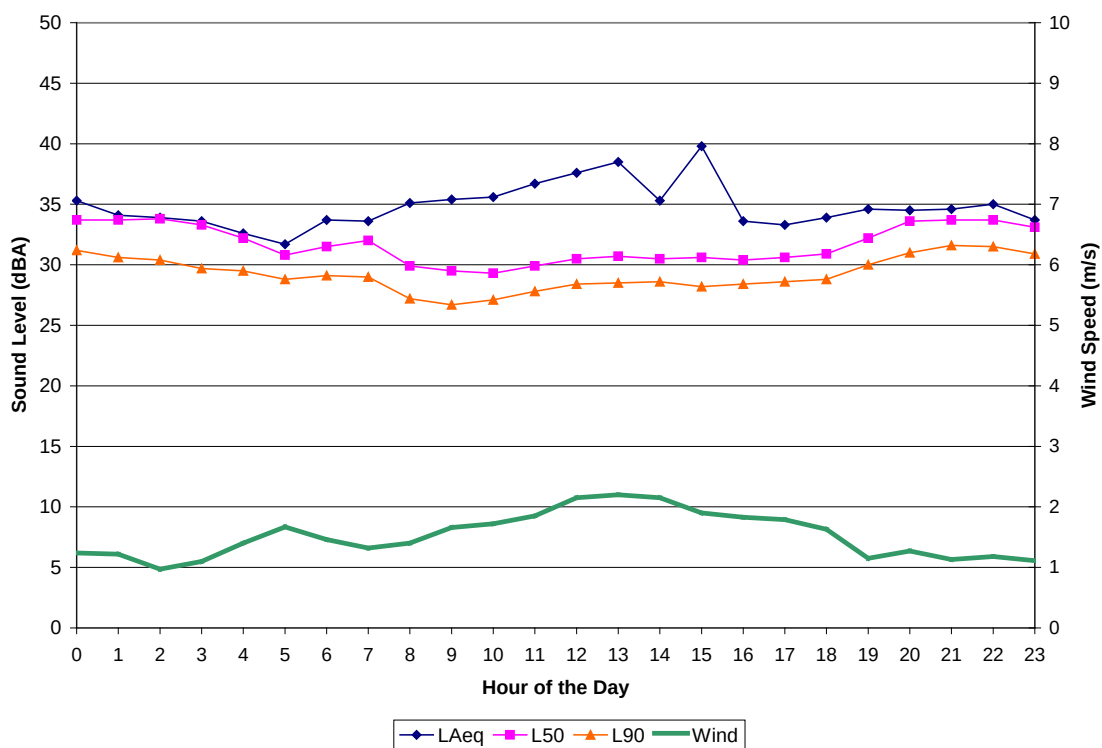


Figure 51. Average hourly sound levels and wind speeds: Site G02.

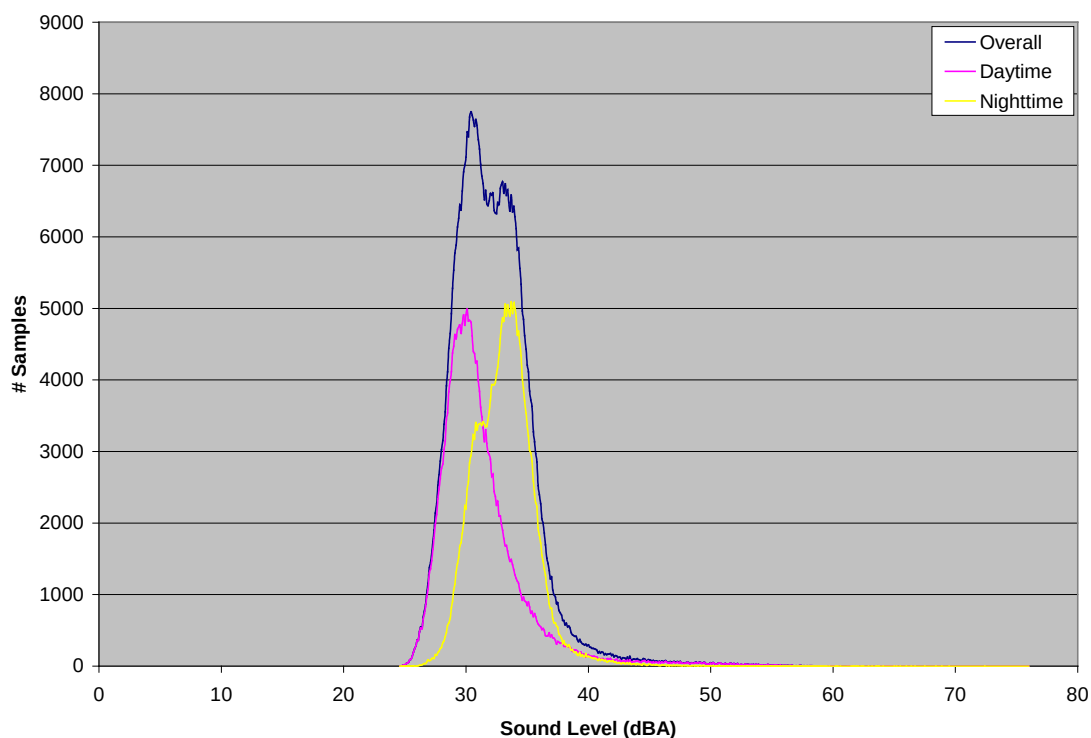


Figure 52. Distribution of data: Site G02.

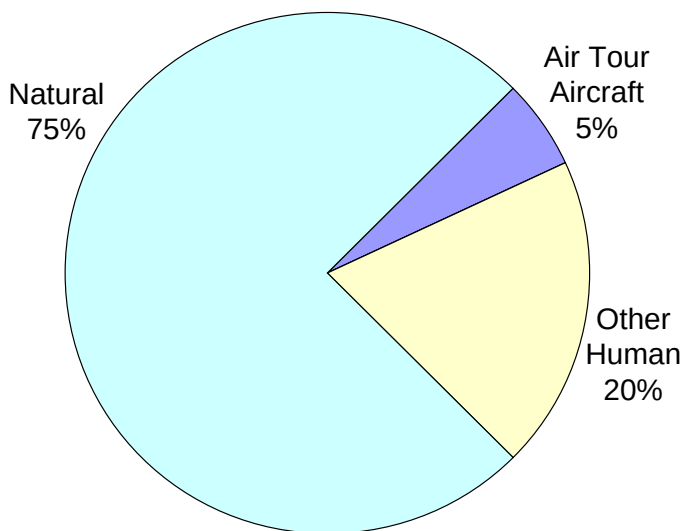


Figure 53. Distribution of sound sources audible during acoustic observer logging: Site G02.

The Logan Pass visitor center is located at the summit of Going-to-the-Sun Road along the Continental Divide. The visitor center is accessible only during the summer and when the road

is not closed due to avalanches. The site was in an open area (i.e., no trees nearby) and located within eyesight of a visitor area south of the trail to Hidden Lake. The ground cover at this site was grassy and soft, with the occasional large rock showing underneath the cover vegetation. Interestingly, this site exhibited slightly higher ambient sound levels at night than during the day – approximately 5 dBA. Running water was audible at the site (glacier runoff in a nearby river), along with vehicular traffic, helicopters and fixed-wing aircraft. Occasional motorcycles were also audible from the parking lot. The majority of audible sounds were natural.

A.3 Sites G03 and G09 – Coniferous Forest Zone Measurement Sites**Table 22. Sites G03 and G09: description.**

Site ID	G03 and G09
Site Name	Lee Ridge
# Measurement Days and Dates	G03: 5 days - August 6 to August 12, 2004 G09: 7 days - August 12 to August 21, 2004
System # and Type	6 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	G03: 48.98634 / 113.64983; G09: 48.98101 / 113.65308
Approximate Elevation (ft)	G03: 5594; G09: 5580
Ecological Domain (see Appendix E)	300 North American Dry Domain
Ecological Division (see Appendix E)	306 Rocky Mountain
Land Cover Class (see Appendix E)	4 Forested Upland
Land Cover Subclass (see Appendix E)	42 Evergreen Forest
General Management Plan Zone (see Section 2.4)	Backcountry
Site Category (see Section 2.4.1)	Backcountry
Site Description	Grass clearing off fire trail and within view of Chief Mountain
Access Considerations	G03 is a 1-mile hike and G09 is a 1.5-mile hike from Route 17
Potential Sound Sources	Aircraft Visitors, Vehicles, Birds, Insects, Wind

**Figure 54. Site G03: Description and photograph.**



Figure 55. Site G09: Description and photograph.

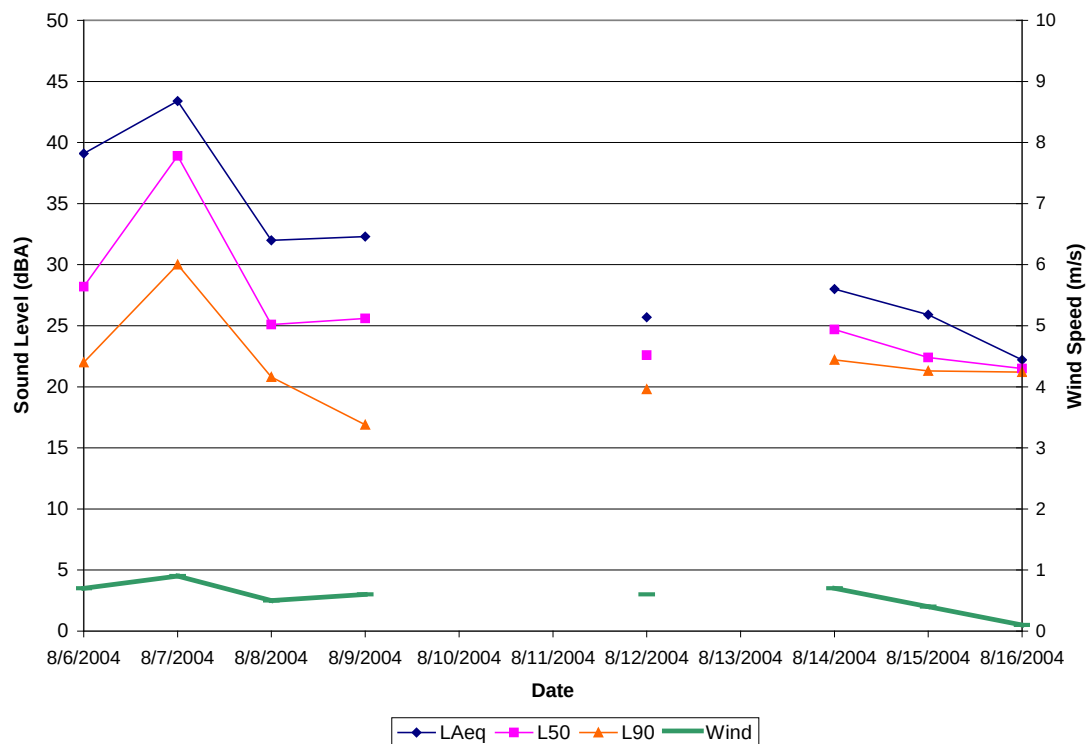


Figure 56. Daily sound levels and wind speeds: Sites G03 and G09.

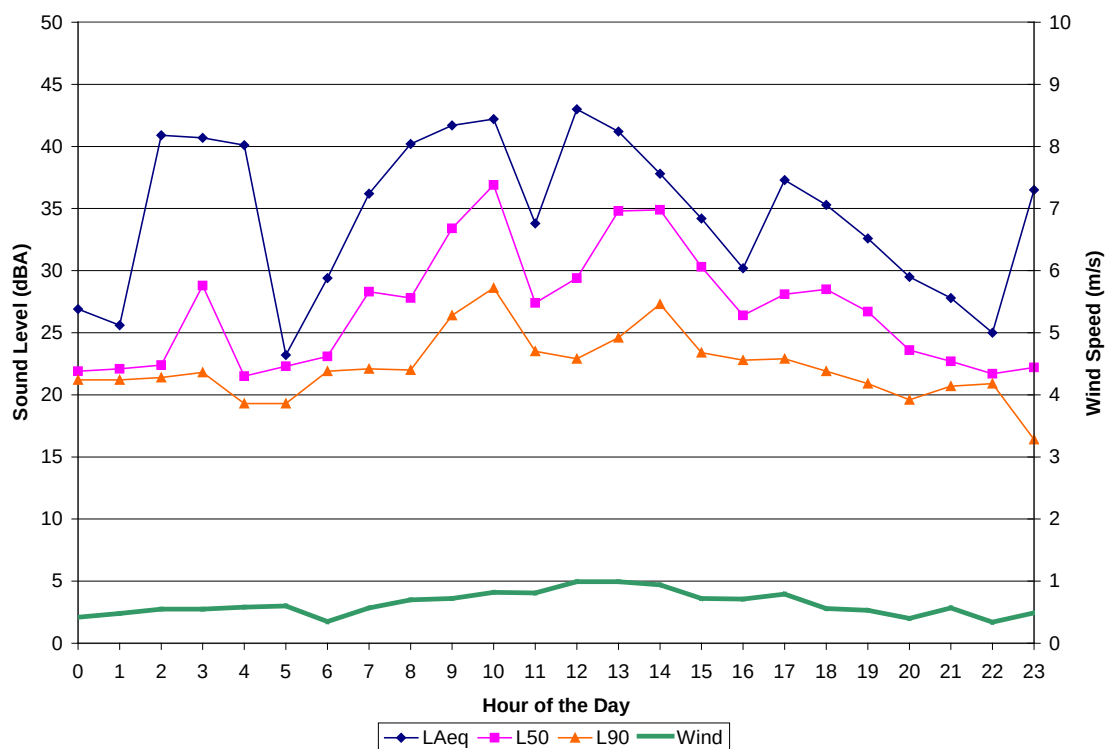


Figure 57. Long-term hourly sound levels and wind speeds: Sites G03 and G09.

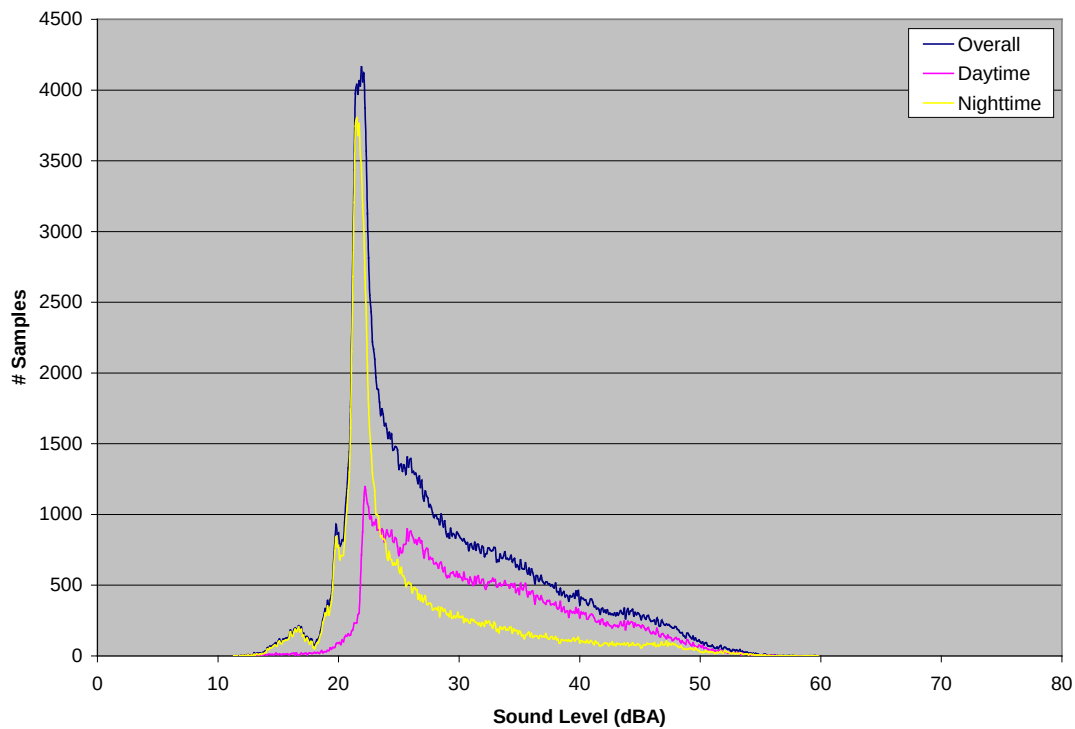


Figure 58. Data distributions: Sites G03 and G09.

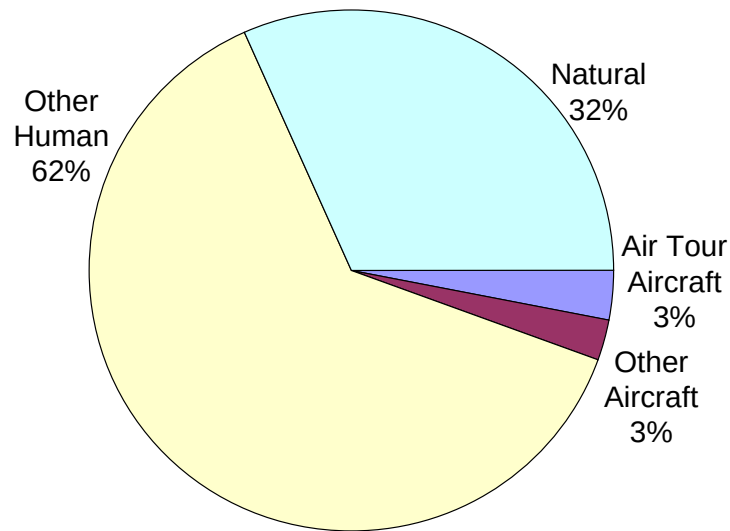


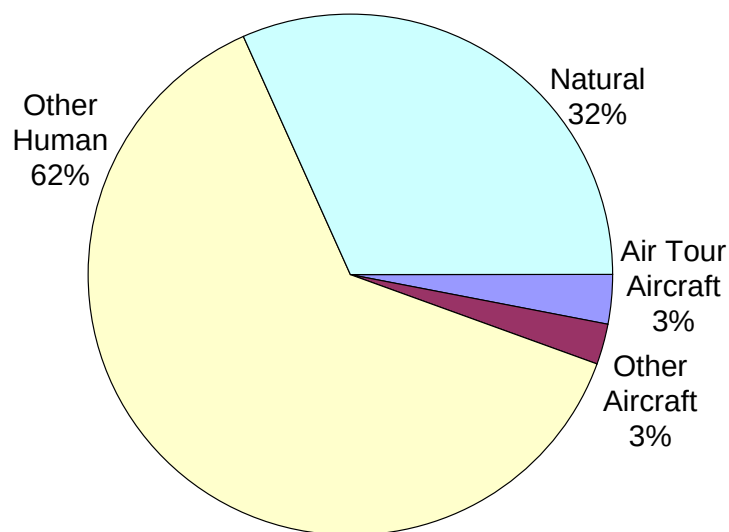
Figure 59. Distribution of sound sources audible during acoustic observer logging: Sites G03 and G09.

These two sites were located in the northeastern corner of the park in the Goat Haunt-Belly River area approximately 1.5 miles trail hike off Route 17. The first site (G03) was moved due to evidence of wildlife activity near the equipment. Both sites were located within an evergreen forested with thick, soft ground cover comprised of pine needles, decaying wood, moss, and grass. The second site (G09) was in a larger clearing within the forest. Note: Because of the cultural significance of nearby Chief Mountain, both sites were located within its view per NPS request.

The area was characterized by few hikers, distant traffic sounds and very distant lumber mill sounds. Because the lumber mill noise was audible during only one of the observer log sessions, but not during deployment or subsequent visits, this indicated the lumber mill source was intermittent and not in regular use. Occasional fixed-wing aircraft and high-altitude jets were also audible. Natural sounds were primarily wind in the foliage with some bird vocalizations. The hourly data showed the site experienced higher daytime sound levels than nighttime, which is typical for locations where roadway activity are audible, even low-levels. The L_{Aeq} sound levels in the hourly data are indicative of the vehicular pass-bys.

A.4 Site G04 – Coniferous Forest Zone Measurement Site**Table 23. Site G04: description.**

Site ID	G04
Site Name	Two Medicine Lake
# Measurement Days and Dates	16 days - August 6 to August 22, 2004
System # and Type	1 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	48.48222 / 113.36833
Approximate Elevation (ft)	5266
Ecological Domain (see Appendix E)	300 North American Dry Domain
Ecological Division (see Appendix E)	306 Rocky Mountain
Land Cover Class (see Appendix E)	4 Forested Upland
Land Cover Subclass (see Appendix E)	42 Evergreen Forest
General Management Plan Zone (see Section 2.4)	Day Use
Site Category (see Section 2.4.1)	Short Hike
Site Description	Small shrub/grass-covered clearing in evergreen forest off trail
Access Considerations	½-mile hike from parking lot
Potential Sound Sources	Aircraft, Watercraft, Visitors, Birds, Insects, Water, Wind

**Figure 60. Site G04: Description and photograph.**

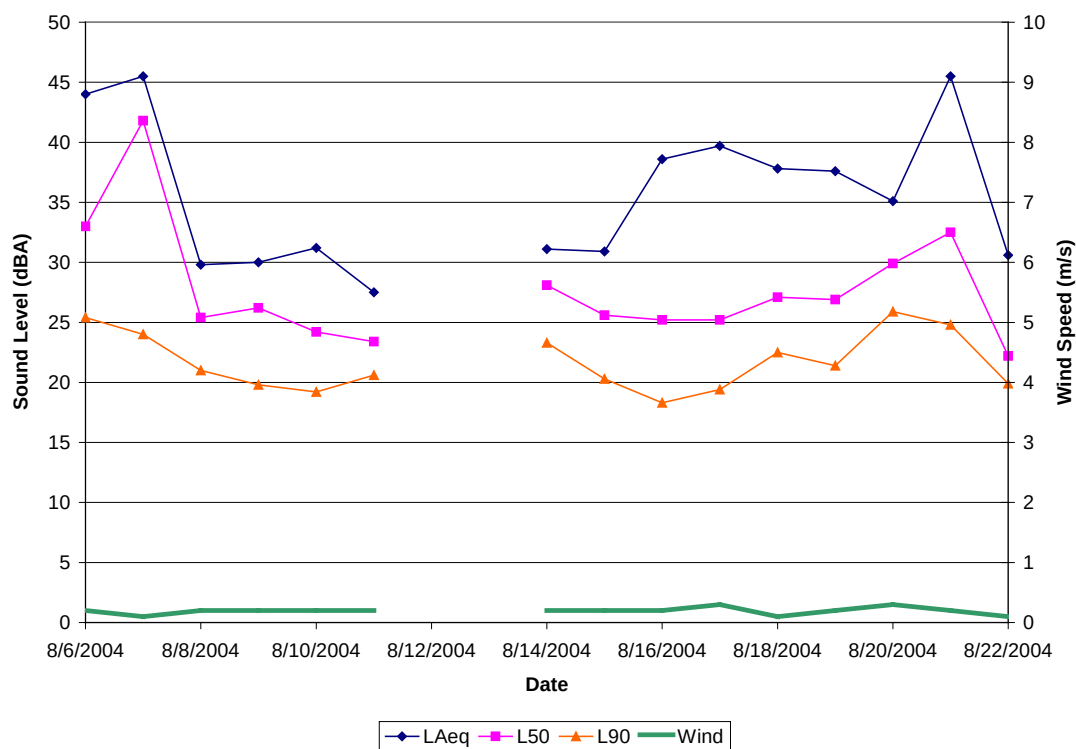


Figure 61. Daily sound levels and wind speeds: Site G04.

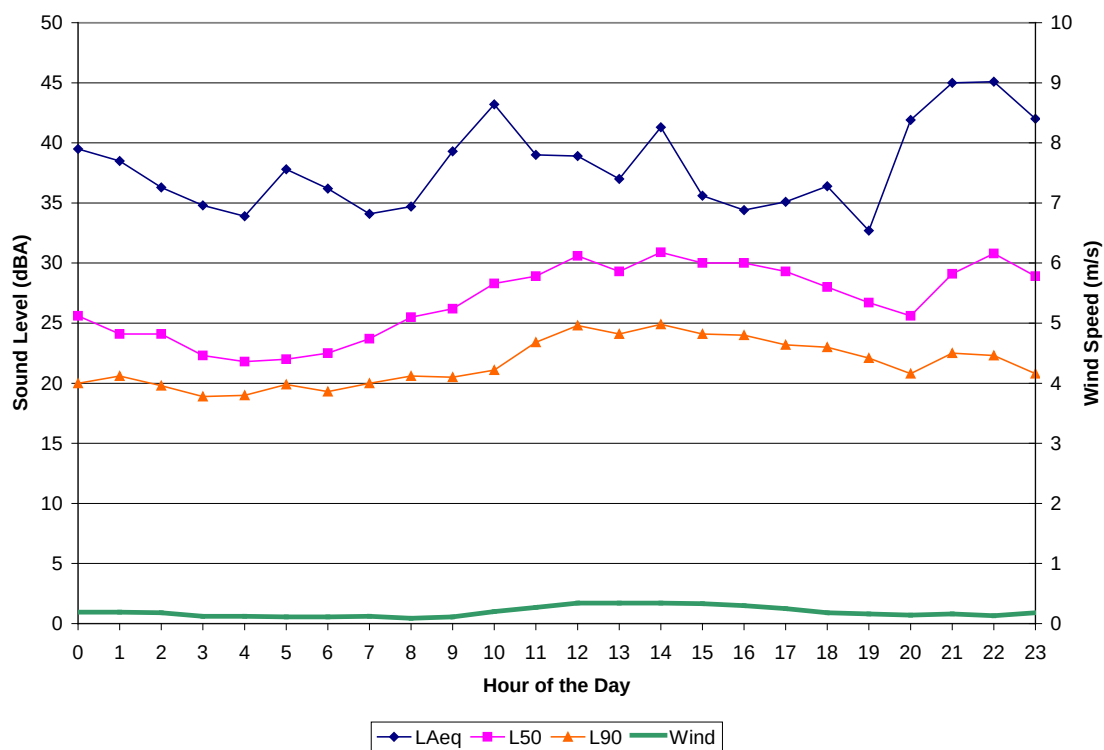


Figure 62. Long-term hourly sound levels and wind speeds: Site G04.

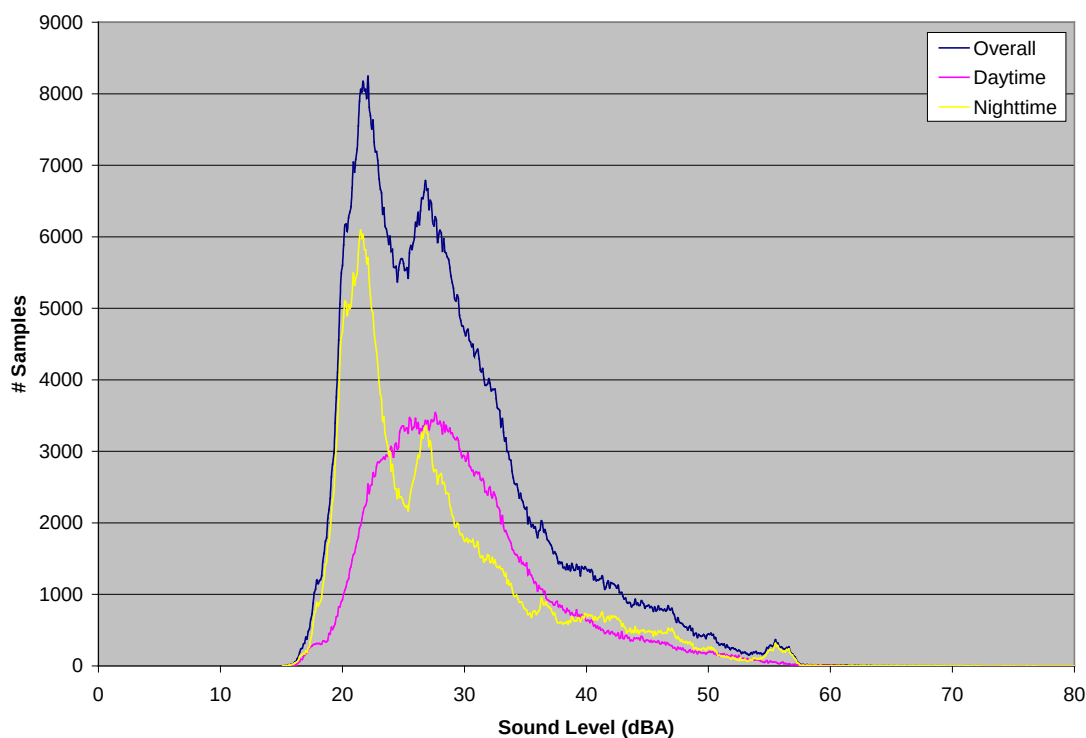


Figure 63. Data distributions: Site G04.

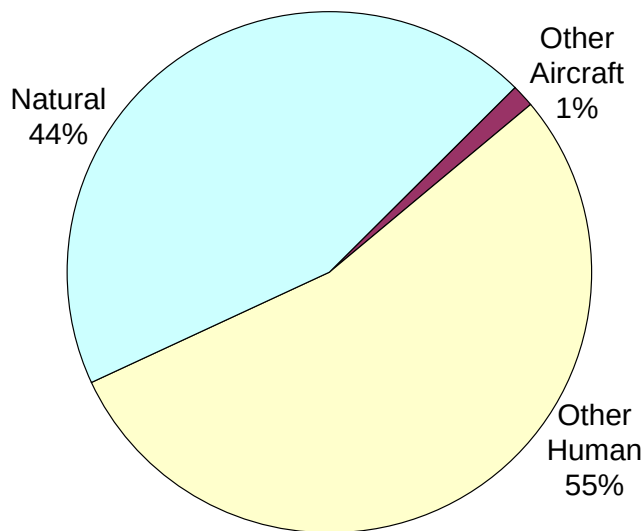


Figure 64. Distribution of sound sources audible during acoustic observer logging: Site G04.

This site was located in the Two Medicine Lake area, which is in the southeastern portion of the park. The site was off accessible via the South Shore trail within a densely forested area. The

ground cover was soft and comprised of pine needles, decaying wood, moss, and grass. The daytime ambient sound levels at this site covered a wide range. The site experienced sounds from hikers, boats on the lake and automobiles in the distant parking area. Local NPS staff offered a boat tour that departed several times a day, which meant heavier visitor-related sounds were present during and after the designated launch times. Distant aircraft activity was audible, but infrequent. Nighttime sound levels were also widely varied, but dominated by lower sound levels. The natural sounds at this site were primarily wind through the foliage and some wildlife activity.

A.5 Site G05 – Deciduous Forest Zone Measurement Site**Table 24. Site G05: description.**

Site ID	G05
Site Name	Harrison Creek
# Measurement Days and Dates	14 days - August 7 to August 20, 2004
System # and Type	2 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	48.49885 / 113.85956
Approximate Elevation (ft)	3393
Ecological Domain (see Appendix E)	300 North American Dry Domain
Ecological Division (see Appendix E)	306 Rocky Mountain
Land Cover Class (see Appendix E)	4 Forested Upland
Land Cover Subclass (see Appendix E)	41 Deciduous Forest
General Management Plan Zone (see Section 2.4)	Backcountry
Site Category (see Section 2.4.1)	Backcountry
Site Description	On a hillside in an evergreen forest
Access Considerations	2-mile hike after fording Flathead River
Potential Sound Sources	Aircraft, Train Horn, Watercraft, Visitors, Birds, Insects, Water, Wind

**Figure 65. Site G05: Description and photograph.**

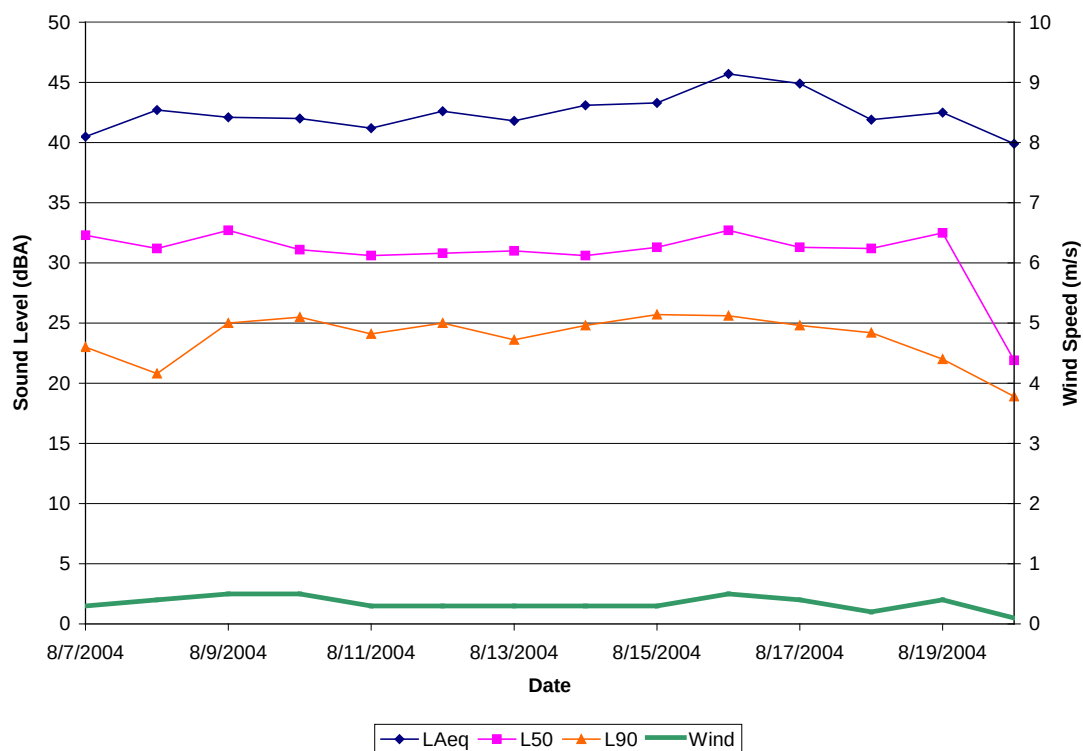


Figure 66. Daily sound levels and wind speeds: Site G05.

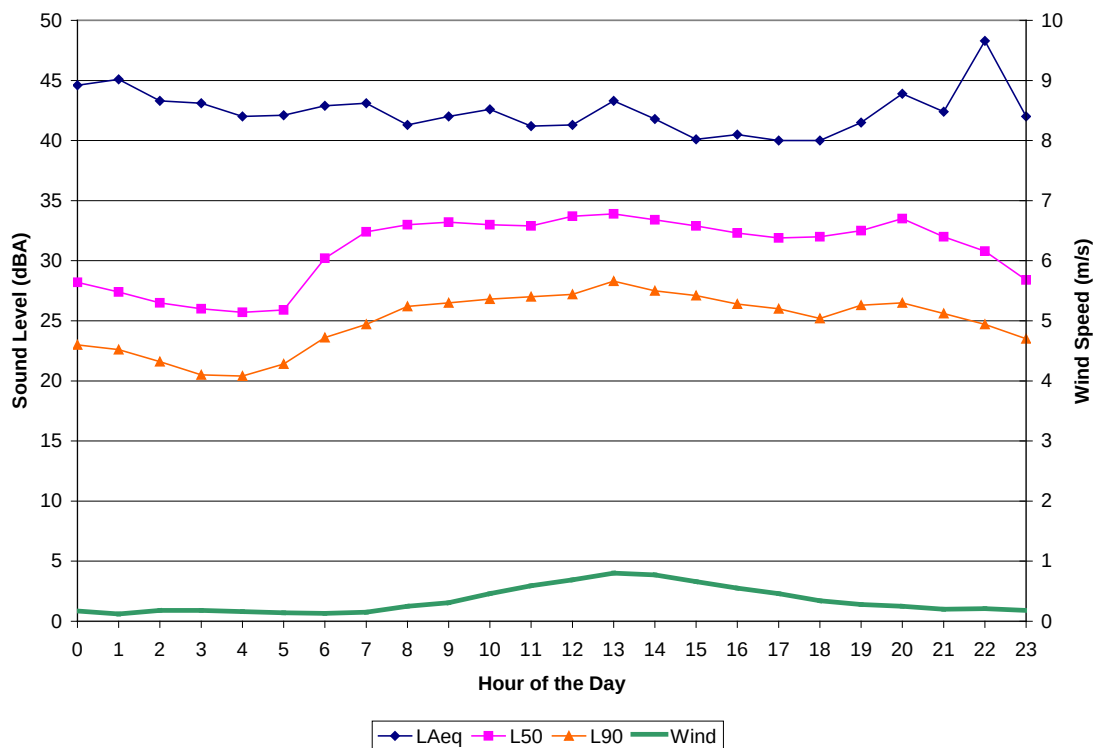


Figure 67. Long-term hourly sound levels and wind speeds: Site G05.

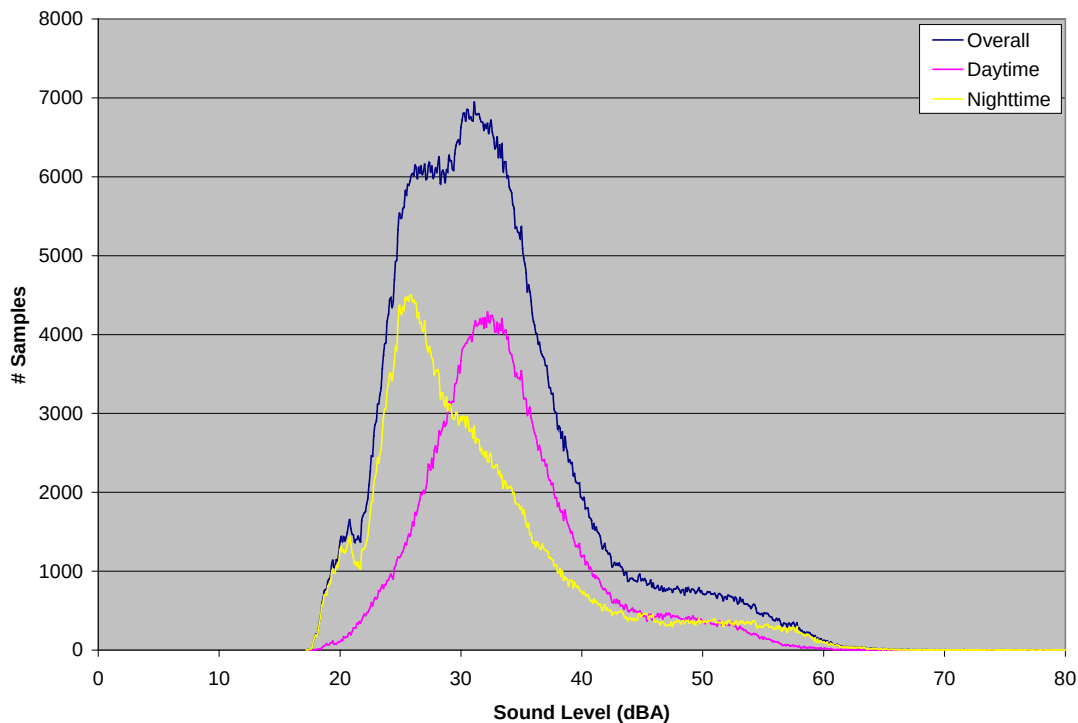


Figure 68. Data distributions: Site G05.

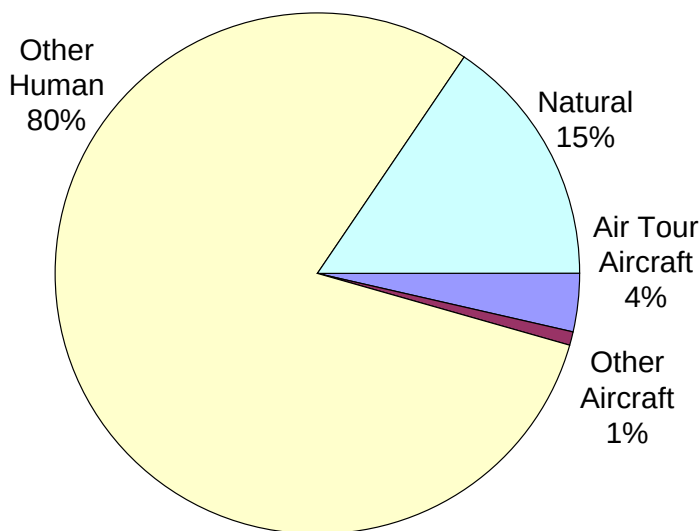


Figure 69. Distribution of sound sources audible during acoustic observer logging: Site G05.

This site was located within a poplar forest (deciduous) in Middle Fork area next to Harrison Creek on the southwest side of the park. Local NPS provided assistance to the field team in

fording Flathead River for all site visits. The ground cover was soft with forest debris. The distribution data shows that daytime ambient sound levels were higher than at night and were widely varied. The dominant sounds heard were vehicular traffic on Route 2, occasional helicopter and fixed-wing aircraft activity, as well as periodic train events. A 100 Hz “bump” in the spectra data could be seen during train events, possibly due to the low frequency engine-related rumbling. Human voices could be heard from rafters on Flathead River. Natural sounds included mostly wind noise and some wildlife activity.

A.6 Site G06 – Coniferous Forest Zone Measurement Site

Table 25. Site G06: description.

Site ID	G06
Site Name	Bowman Lake
# Measurement Days and Dates	12 days - August 7 to August 21, 2004
System # and Type	4 (NoiseLogger Plus™)
Latitude / Longitude (decimal degrees)	48.83662 / 114.19691
Approximate Elevation (ft)	4166
Ecological Domain (see Appendix E)	300 North American Dry Domain
Ecological Division (see Appendix E)	306 Rocky Mountain
Land Cover Class (see Appendix E)	4 Forested Upland
Land Cover Subclass (see Appendix E)	42 Evergreen Forest
General Management Plan Zone (see Section 2.4)	Backcountry
Site Category (see Section 2.4.1)	Short Hike
Site Description	Dense evergreen forest
Access Considerations	1/4 -mile off trail after 2-mile hike along Bowman Lake
Potential Sound Sources	Aircraft, Watercraft, Visitors, Birds, Insects, Water, Wind

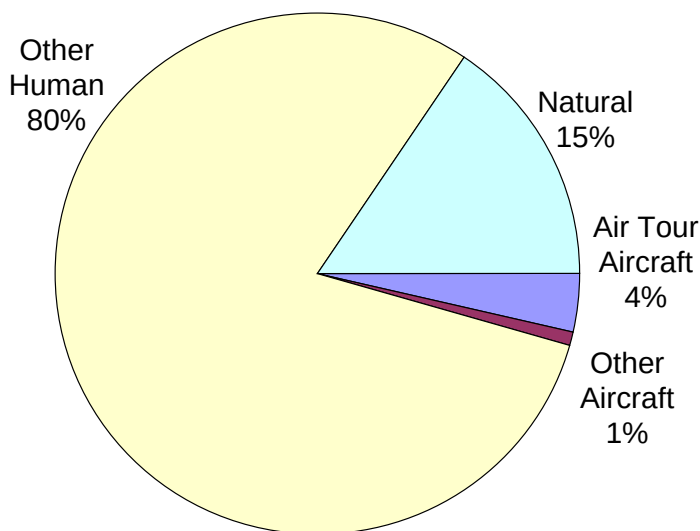


Figure 70. Site G06: Description and photograph.

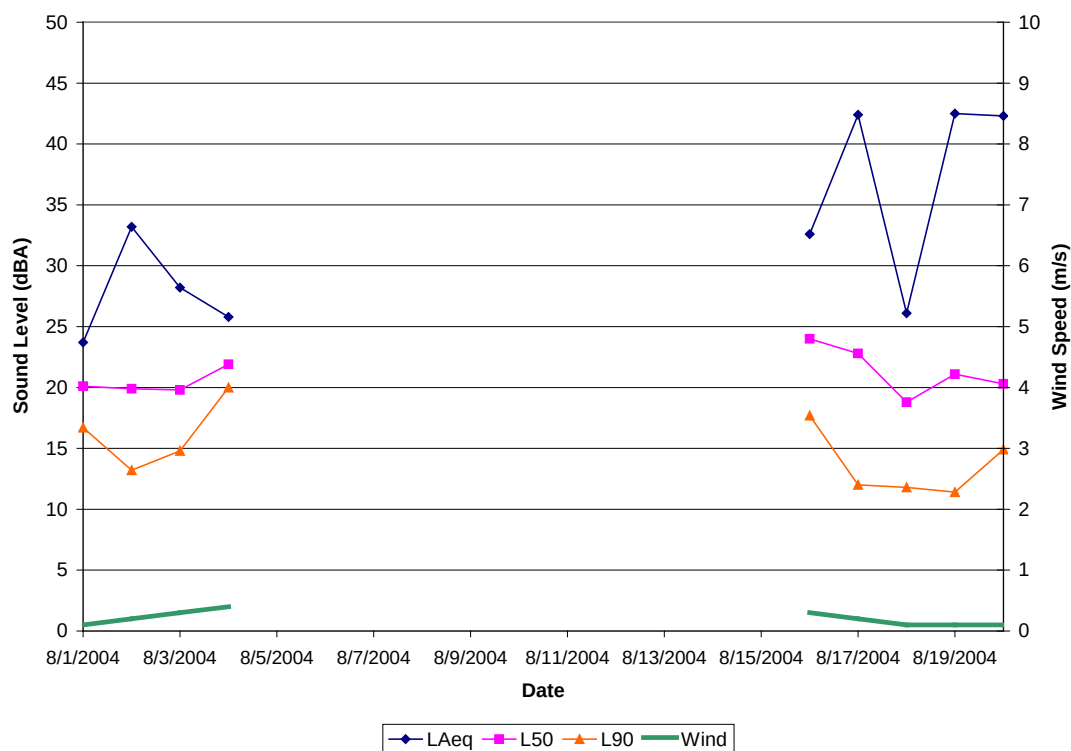


Figure 71. Daily sound levels and wind speeds: Site G06.

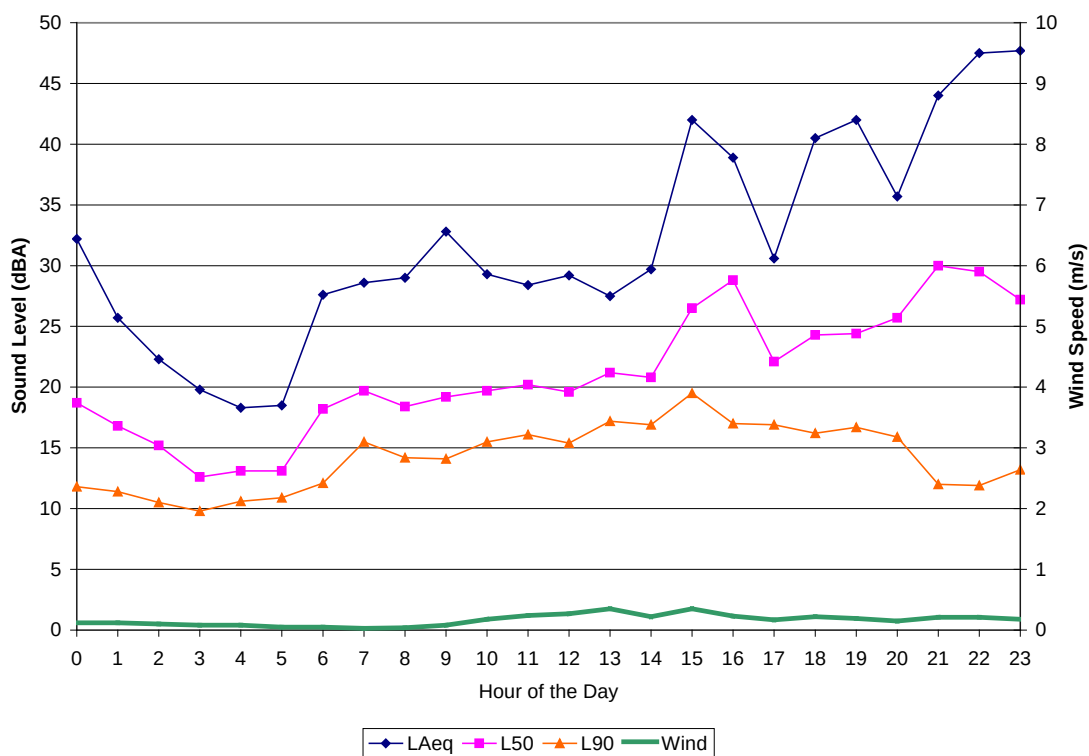


Figure 72. Long-term hourly sound levels and wind speeds: Site G06.

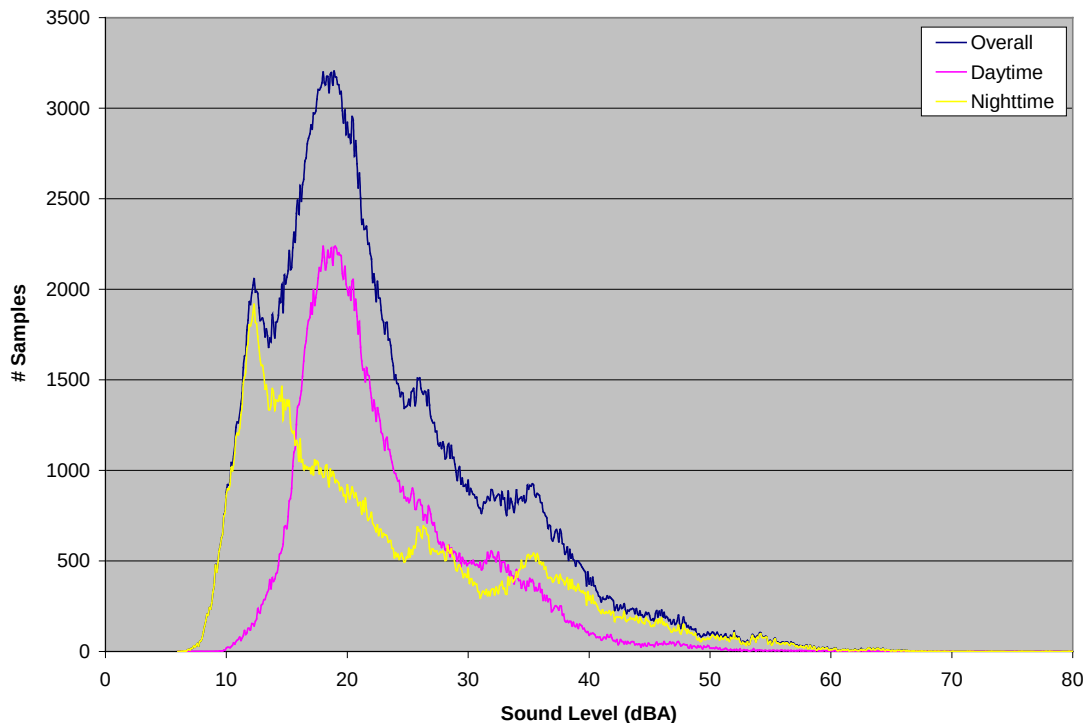


Figure 73. Data distributions: Site G06.

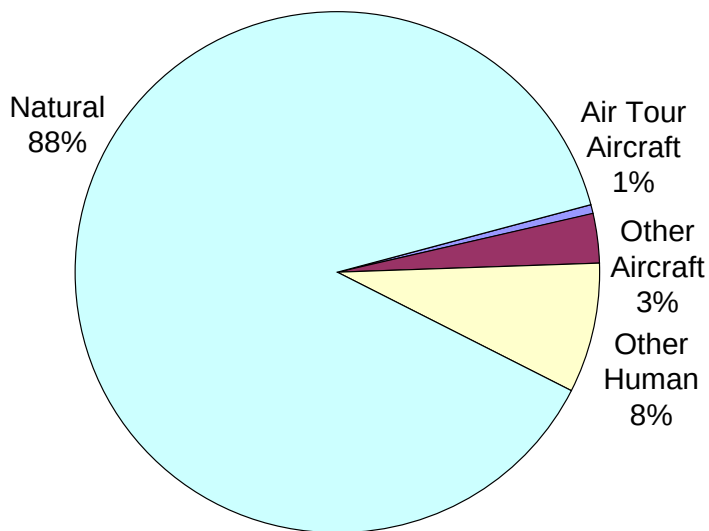


Figure 74. Distribution of sound sources audible during acoustic observer logging: Site G06.

This site was located in the northwestern corner of the park, near the southwestern edge of Bowman Lake. The area was remote with a pristine lake, a quiet surrounding forest, and a nearby campground. The ground cover was soft with forest debris. Sound levels at this site

were generally below 30 dBA with the median sound level for both daytime and nighttime time periods about 23 dBA. The site did experience some boat activity on the lake, but was otherwise relatively quiet. Dominant natural sounds include wind in the foliage and some wildlife activity. There were a few fixed-wing aircraft audible, but distant.

A.7 Site G07 – Coniferous Forest Zone Measurement Site**Table 26. Site G07: description.**

Site ID	G07
Site Name	Swiftcurrent Trail
# Measurement Days and Dates	16 days - August 8 to August 23, 2004
System # and Type	7 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	48.80208 / 113.69401
Approximate Elevation (ft)	5122
Ecological Domain (see Appendix E)	300 North American Dry Domain
Ecological Division (see Appendix E)	306 Rocky Mountain
Land Cover Class (see Appendix E)	4 Forested Upland
Land Cover Subclass (see Appendix E)	42 Evergreen Forest
General Management Plan Zone (see Section 2.4)	Day Use
Site Category (see Section 2.4.1)	Short Hike
Site Description	Small clearing in evergreen forest; off trail
Access Considerations	1.5-mile hike
Potential Sound Sources	Aircraft, Visitors, Birds, Insects, Wind

**Figure 75. Site G07: Description and photograph.**

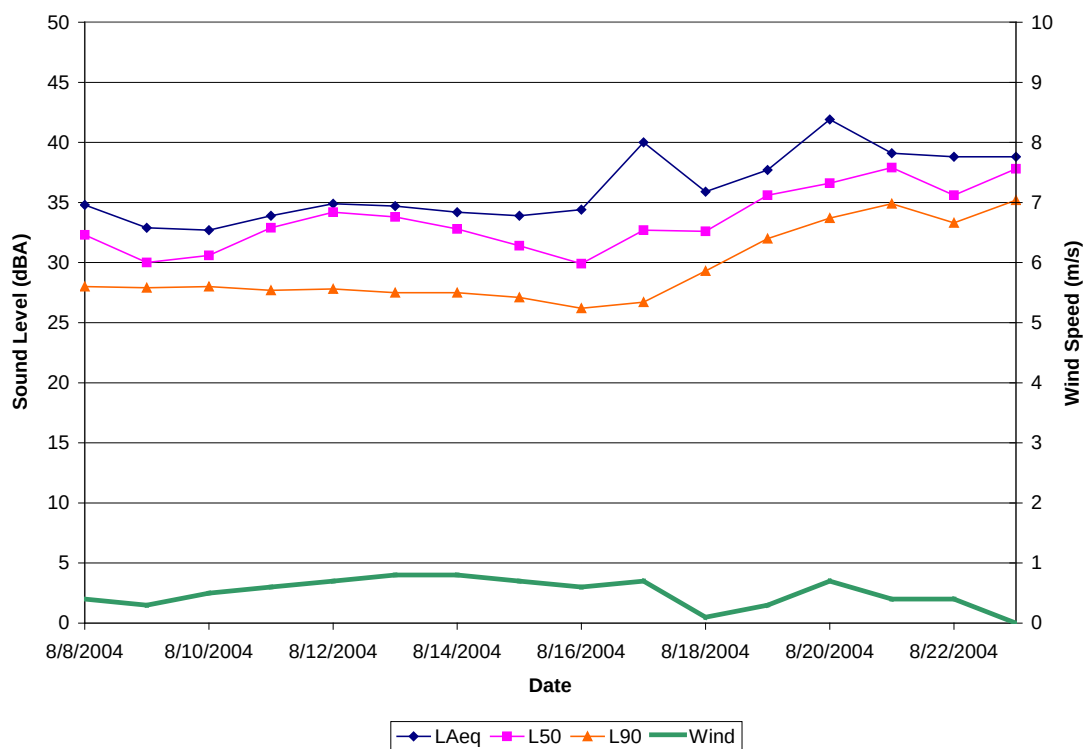


Figure 76. Daily sound levels and wind speeds: Site G07.

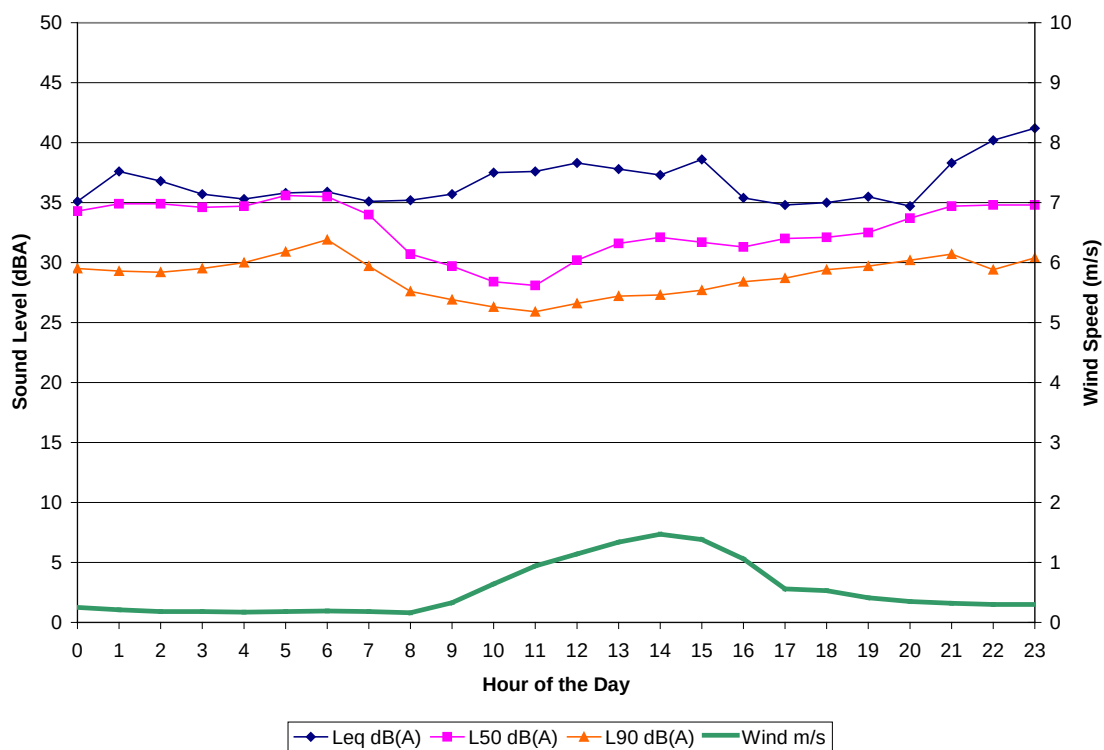


Figure 77. Long-term hourly sound levels and wind speeds: Site G07.

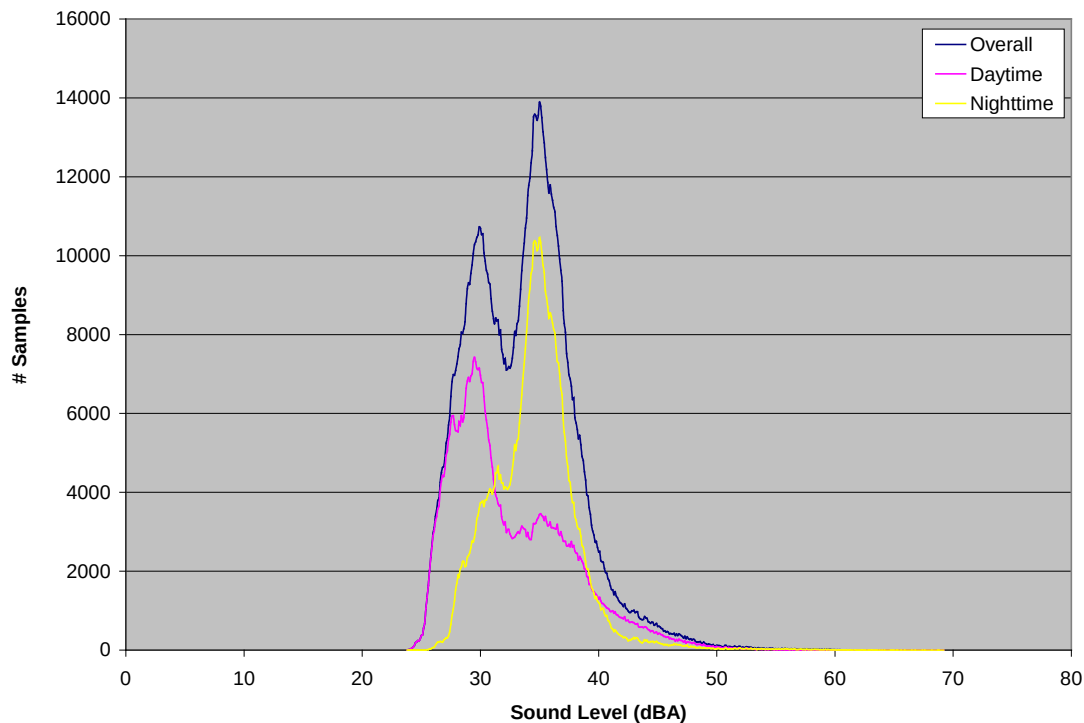


Figure 78. Data distributions: Site G07.

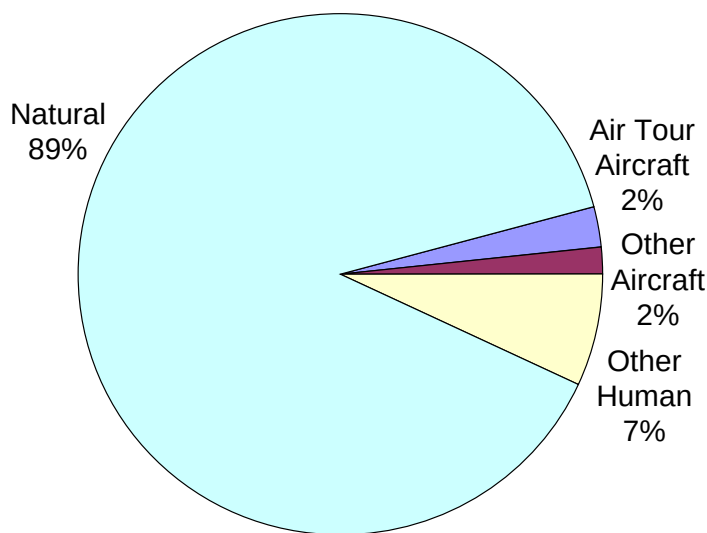


Figure 79. Distribution of sound sources audible during acoustic observer logging: Site G07.

This site was located in the Many Glacier area off the heavily traveled Swiftcurrent Trail, which follows Redrock Lake. The surrounding forest was mixed deciduous and conifers with a soft and grassy ground cover. Nighttime ambient sound levels were louder than daytime, which were

attributed to increased insect activity. During the day, the dominant natural sounds were running water, wind through the foliage, and wildlife activity. Human caused sounds included hikers with occasional helicopter and high-altitude jet activity.

A.8 Site G08 – Alpine/Subalpine Zone Measurement Site**Table 27. Site G08: description.**

Site ID	G08
Site Name	Sperry Campground
# Measurement Days and Dates	10 days - August 9 to August 18, 2004
System # and Type	5 (NoiseLogger™)
Latitude / Longitude (decimal degrees)	48.6024 / 113.7872
Approximate Elevation (ft)	6619
Ecological Domain (see Appendix E)	300 North American Dry Domain
Ecological Division (see Appendix E)	306 Rocky Mountain
Land Cover Class (see Appendix E)	4 Forested Upland
Land Cover Subclass (see Appendix E)	42 Evergreen Forest
General Management Plan Zone (see Section 2.4)	Backcountry
Site Category (see Section 2.4.1)	Backcountry
Site Description	Rocky / grassy surface just before campground entrance
Access Considerations	6.5-mile hike up Gunsight Mountain
Potential Sound Sources	Aircraft, Visitors, Goats, Wind

**Figure 80. Site G08: Description and photograph.**

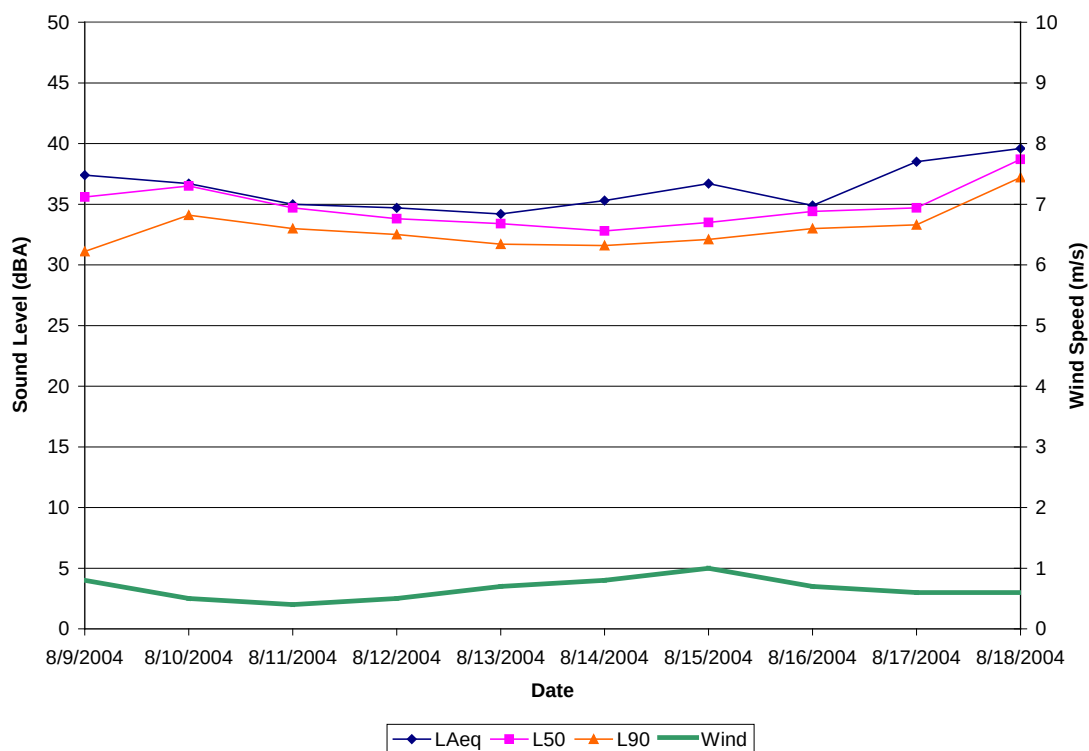


Figure 81. Daily sound levels and wind speeds: Site G08.

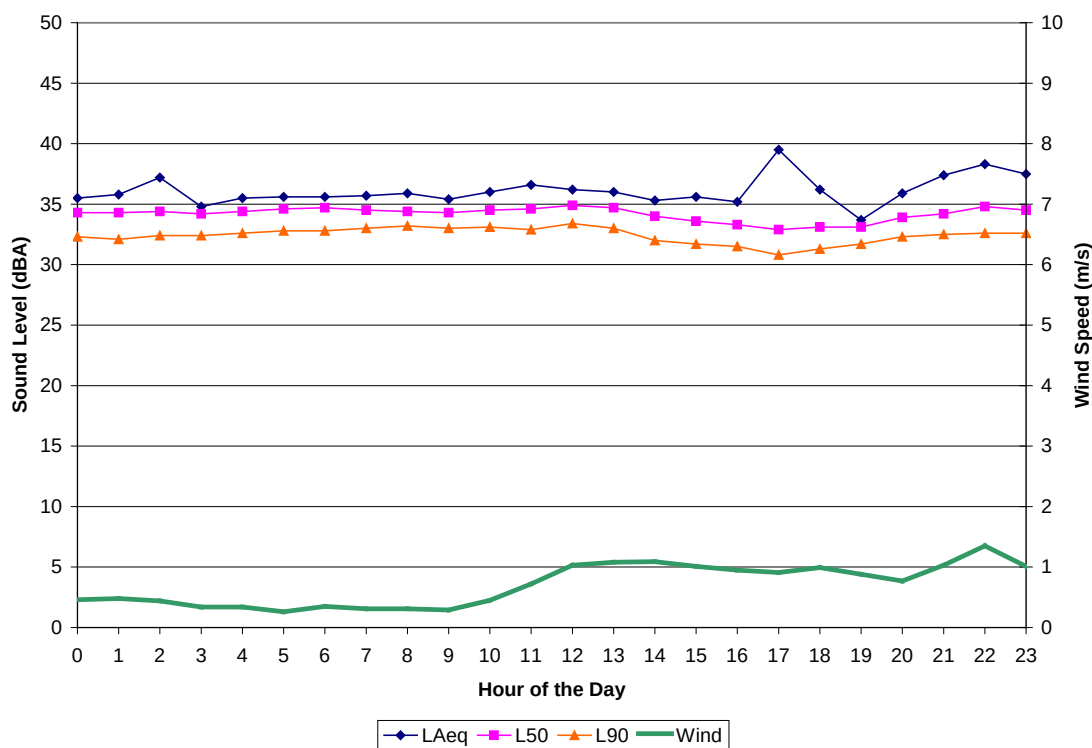


Figure 82. Long-term hourly sound levels and wind speeds: Site G08.

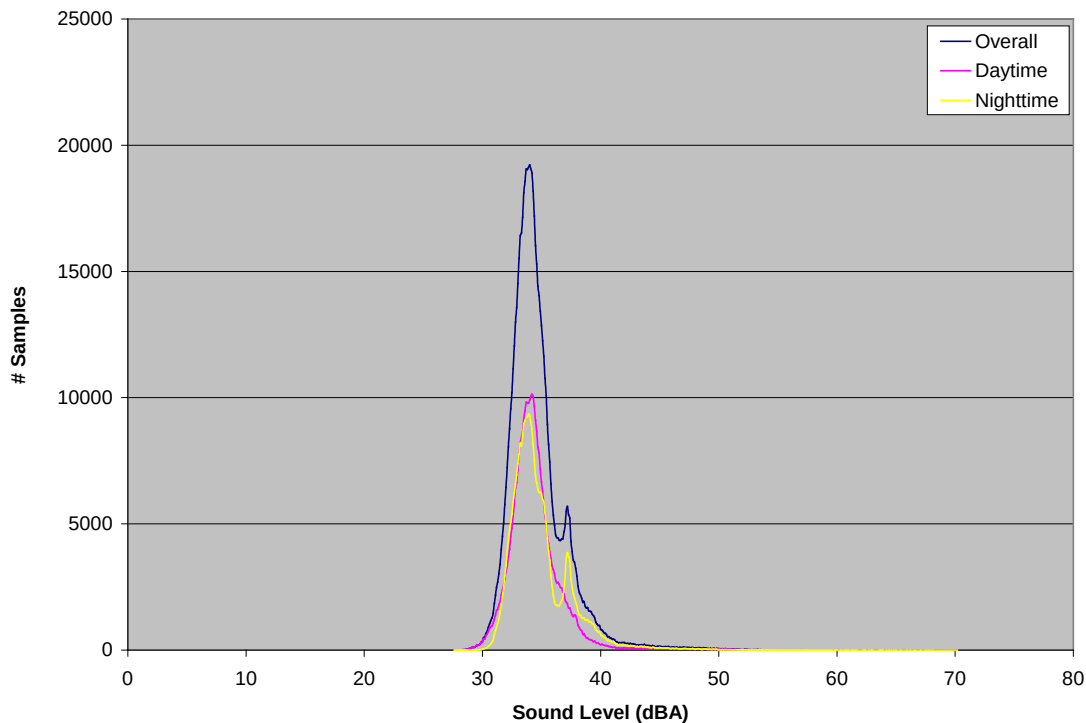


Figure 83. Data distributions: Site G08.

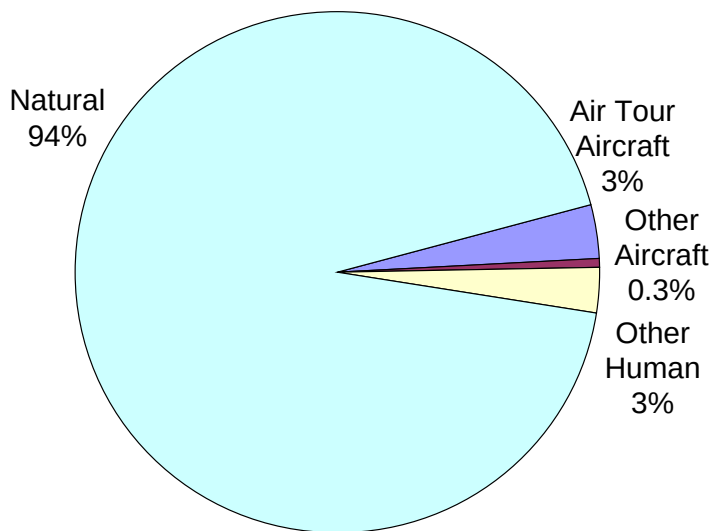


Figure 84. Distribution of sound sources audible during acoustic observer logging: Site G08.

This site was located near Sperry Campground – accessible via hiking or horseback approximately 6.5 miles on a trail, which starts near Lake McDonald Lodge. The equipment was placed approximately 0.5 miles from Sperry Chalet towards the Campground area. The ground

was hard rock with sparse higher elevation scrub and conifers consistent with an alpine environment. Sound sources that were audible were primarily natural. These included a distant waterfall in the background, along with wildlife and insect sounds. Human activity at this site included occasional hikers, campground visitors, and some helicopter activity.

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 28 and Figure 85 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 28 and Figure 86 illustrate the basic components to this system.

B.2 Instrumentation List**Table 28. 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



Figure 85. NoiseLogger™ continuous monitoring system.

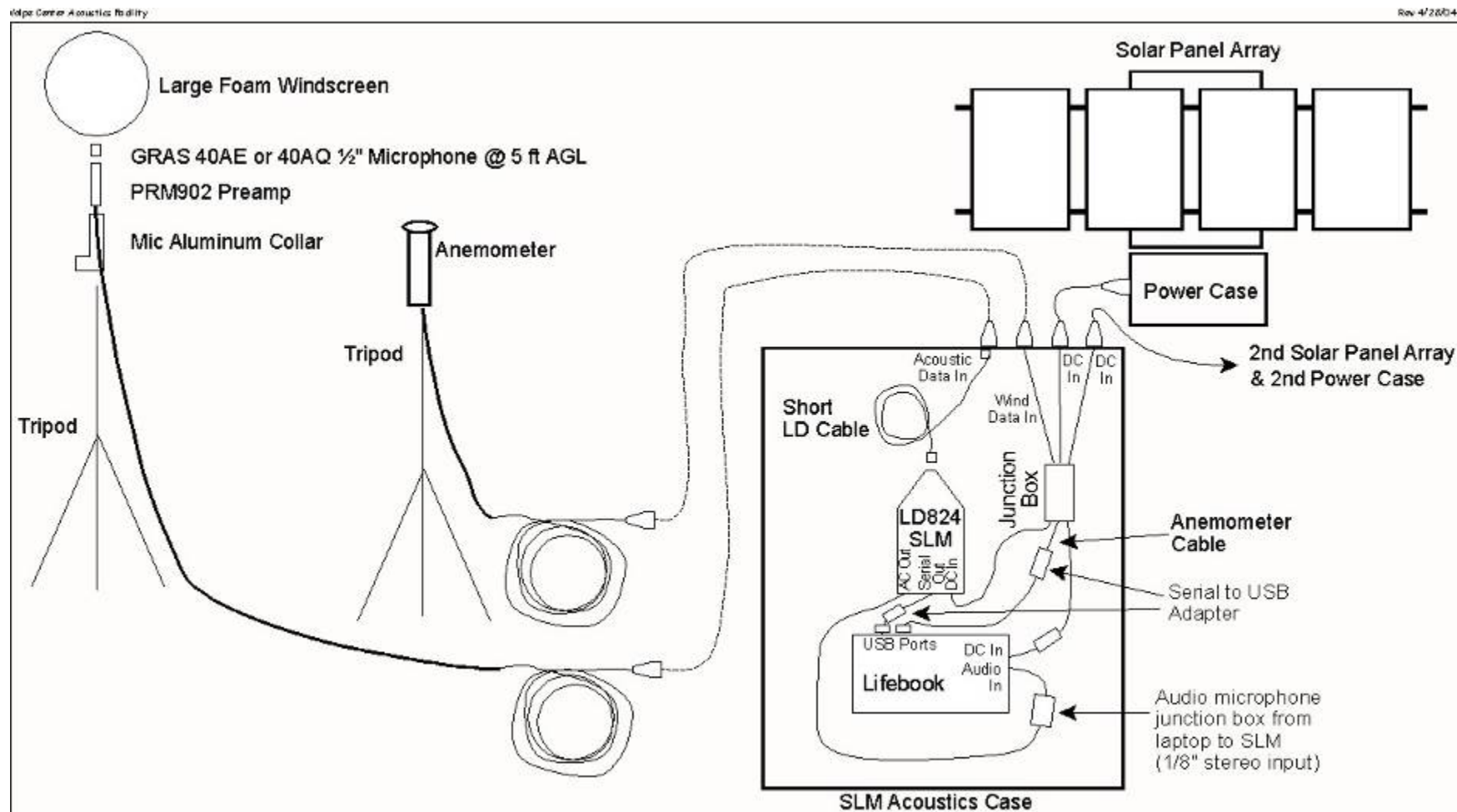


Figure 86. NoiseLogger Plus™ continuous monitoring system.

OL-FAA/ATAP/Equipment/Instrumentation_NoiseLogger.vpg

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 87) to tripod.
 - a. If using a Gill WindObserver II anemometer, connect one end of anemometer cable (red cable, black connector, 6-pin connector with twist locking collar) to the base of the anemometer. Mount anemometer on tripod.
 - b. If using a FT702 anemometer, the anemometer is stored in the SLM acoustics case. Remove mount from anemometer. Screw the mount onto the tripod. Connect one end of anemometer cable to the base of the anemometer THRU the mount. Secure anemometer to mount using hex key and screws.
3. Adjust tripod height such that top of the anemometer sensor is 5 ft (1.5 m) above the ground.
4. Orient the anemometer properly toward North direction (look for the “N” marked on the anemometer). A compass can be found in the calibration kit.
5. Carefully wrap the anemometer cable around the tripod or tie with zip-ties, so that it will not hit the tripod in the wind. Connect other end of cable to the SLM case external connector.
6. Anchor the tripod to the ground or a nearby stationary object using the rope, stakes, and sandbags, as necessary, so that it will not sway in the wind.



Figure 87. 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 88.
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 89). 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.

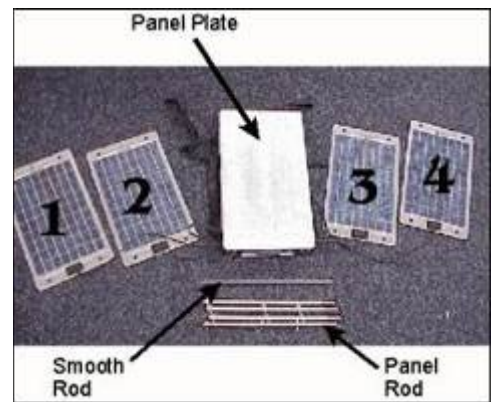


Figure 89. Unpack solar array.

3. Place left inner orange loop on the right upper panel plate tube; place right inner orange loop on the left upper panel plate tube (see Figure 90).
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.”

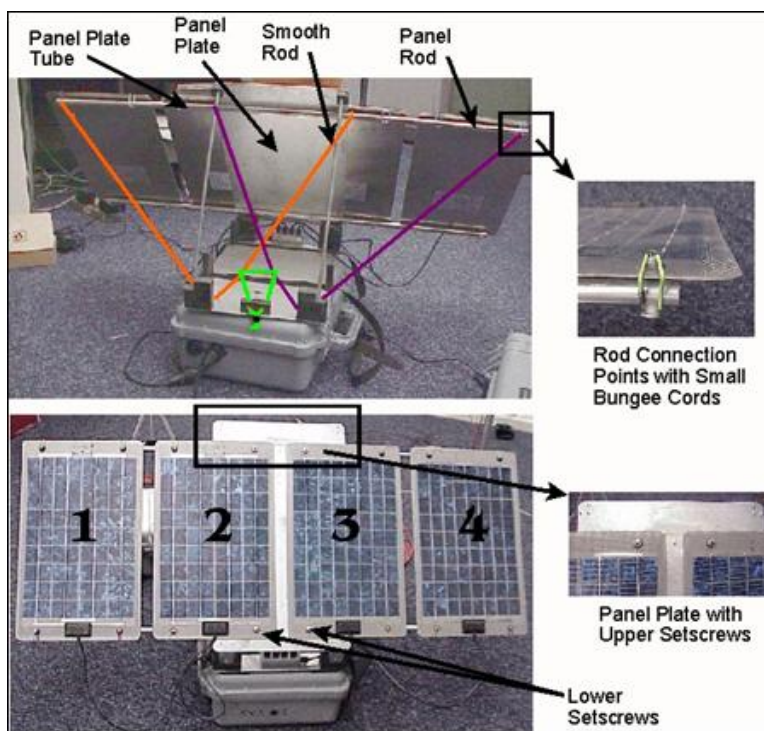


Figure 90. Solar panel array setup

6. Tighten the “X” pattern by pulling the small string loop at the base of the “X” and raising the tension knob (see Figure 91).
7. Insert the two lower panel rods into the tubes at the bottom of the “panel plate.”



Figure 91. 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 92, specifically verify that the silver connector/red cable is connected to right Husky™ com port and the black Husky™ adapter/beige serial cable is connected to the left com port, also that the small black cable is connected to the side of the black Husky™ adapter. Verify also that the cable from the “Mic In” connector to the top of the LD824 is connected.

4. Open the plastic back plate to the Husky™ by squeezing the two clips on the back of the Husky™ and check to ensure a 128-MB CompactFlash™ card (Storage Card) is in one of the two card slots. Restore the back plate.
5. Power up the Husky™ by pressing the red center button below the screen. Note: If the Husky™ hasn't been turned on for a long time, the unit may display several screens to calibrate the touch screen and perform time zone setup on the unit.

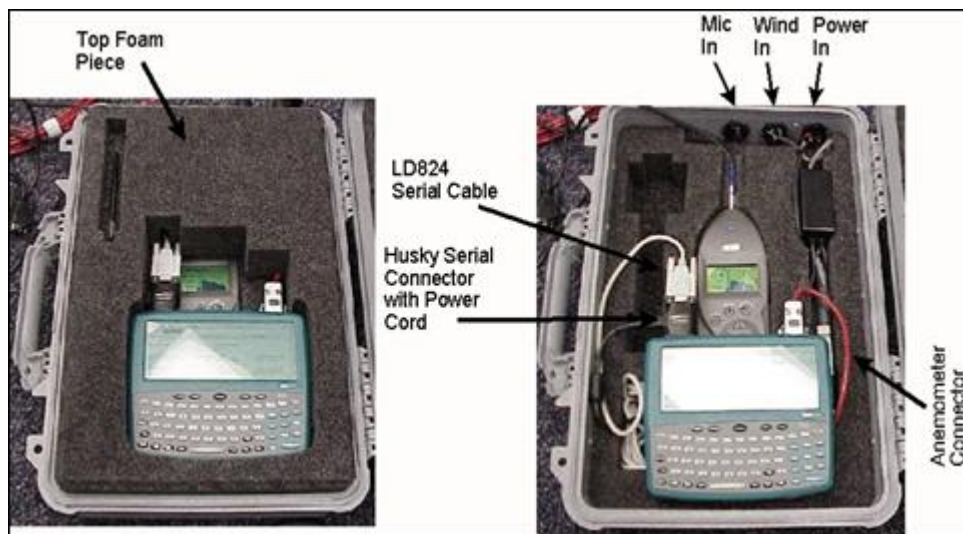


Figure 92. SLM acoustics case.

6. Power up the LD824 by pressing the lighted green (left-most) button on the front panel. Note: The LD824 may power up automatically when the Husky™ is started.
7. Reset/reboot the Husky™ by pressing both the contrast and brightness buttons on either side of the power button.
8. Using the red tip of the stylus, select “My Handheld PC” icon on the desktop.
9. A Windows browser is displayed. Select the “Storage Card” directory to access the 128-MB CompactFlash™ card. Select the “NoiseLogger™ ver 2.1.0.0” folder and then run the NoiseLogger.exe program by double clicking the filename with the stylus.
10. An “About NoiseLogger” dialog is displayed. Select OK.
11. Per the program instructions, enter a unique three-character ID representing the site “number” (e.g., G06 for Site G06), and the site’s name (e.g., Bowman Lake).
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 93, 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.

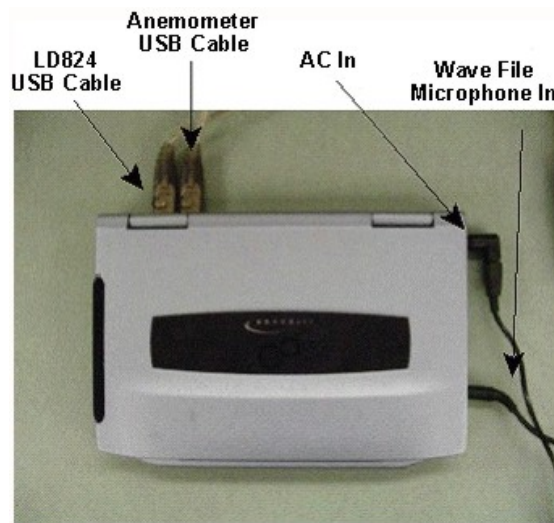


Figure 93. NoiseLogger Plus™ Fujitsu™ computer.

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., G06 for Site G06), and the site’s name (e.g., Bowman Lake).
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 94). A calibrator can be found in one of the calibration kits.
Note: To ensure the calibrator is seated properly, gently rotate it clockwise ¼ turn.
3. Carefully apply power to calibrator by pressing the left button on the calibrator (94-dB setting).



Figure 94. System calibration.

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 29 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 29. 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 ¼ turn.
4. Carefully apply power to calibrator by pressing the left button on the calibrator (94-dB setting).
5. Select the [Collect Data] button. Verify that the anemometer cable is connected to the Husky™ and select [Yes].
6. Verify that the sound level being reporting on the computer screen is approximately 94 dB for A, C, and flat weighting. Note: During strong wind conditions, it may be difficult to observe a steady calibration signal. In such instances, cover the calibrator and mic/preamp assembly with a bag (such as the solar array accessories bag), taking care not to disturb the

microphone and calibrator during this process.

7. After about 30 seconds, stop data collection by selecting the [Stop Collection] button. Select [Yes] to verify.
8. 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.6.1 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.6.2 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.6.3 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 95).
16. Close panel plate over the top of the stack of panels and secure with black straps.



Figure 95. Packing the solar panel array.

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

APPENDIX C. INSTRUMENTATION FREQUENCY RESPONSE ADJUSTMENTS

All NoiseLogger™ 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 30 and Figure 96). It should be noted that the microphones used at Sites G04, G05, and G06 were GRAS Model 40AQ microphones, while the other systems used GRAS Model 40AE microphones (see also Table 6 in Section 4.1).

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

Table 30. Microphone frequency responses.

Frequency (Hz)	Frequency Band	Site G01	Site G02	Site G03	Site G04	Site G05	Site G06	Site G07	Site G08	Site G09
12.5	11	0	0	0	0	0	0	0	0	0
16	12	0	0	0	0	0	0	0	0	0
20	13	-0.03	0.03	0.06	-0.06	0	-0.03	0	-0.03	0.06
25	14	0.02	0.02	0.1	0.05	0	-0.1	-0.01	0.06	0.1
31	15	0.01	-0.01	-0.01	-0.04	0	0.01	0	0.02	-0.01
40	16	0.04	-0.01	-0.01	-0.03	0	0	0.01	-0.01	-0.01
50	17	0.02	0.01	0.01	-0.04	0	0	0	0.03	0.01
63	18	0.03	0.02	0.01	-0.06	0	0.04	0	0	0.01
80	19	0.01	0	0.03	-0.04	0	0.02	-0.02	0.01	0.03
100	20	0	-0.01	0.01	-0.03	0	0	0.01	0.03	0.01
125	21	0.01	0.02	0.02	-0.04	0	0.02	0.01	0.02	0.02
160	22	0	0	0.01	-0.04	0	0.02	0.01	-0.04	0.01
200	23	0.01	-0.01	0.03	-0.04	0	0.01	0	0.04	0.03
250	24	0	0	0	0	0	0	0	0	0
315	25	-0.01	0	0.01	-0.04	0	0	-0.01	0.02	0.01
400	26	-0.02	-0.02	0.01	-0.04	0	0.02	0	0	0.01
500	27	-0.02	-0.03	-0.01	-0.04	0	0.03	-0.01	-0.02	-0.01
630	28	-0.03	-0.04	-0.02	-0.05	-0.032	0.01	-0.01	-0.04	-0.02
800	29	-0.06	-0.06	-0.04	-0.05	-0.003	0.01	-0.04	-0.05	-0.04
1000	30	-0.06	-0.09	-0.03	-0.04	-0.009	0.01	0	-0.04	-0.03
1250	31	-0.08	-0.17	-0.05	-0.05	-0.006	0.01	-0.03	-0.06	-0.05
1600	32	-0.15	-0.22	-0.09	-0.06	0.001	0.02	-0.07	-0.18	-0.09
2000	33	-0.26	-0.36	-0.18	-0.07	0.037	0.03	-0.14	-0.29	-0.18
2500	34	-0.43	-0.52	-0.33	-0.09	0.067	0.04	-0.27	-0.47	-0.33
3150	35	-0.65	-0.88	-0.49	-0.6	0.123	0.11	-0.42	-0.71	-0.49
4000	36	-1.05	-1.34	-0.86	-0.1	0.068	0.12	-0.74	-1.09	-0.86
5000	37	-1.55	-1.88	-1.31	-0.14	0.006	0.15	-1.13	-1.5	-1.31
6300	38	-2.09	-2.38	-1.8	-0.12	0.217	0.25	-1.6	-1.91	-1.8
8000	39	-2.4	-2.62	-2.19	0.17	0.504	0.66	-2.05	-2.11	-2.19
10000	40	-2.96	-2.97	-2.57	-0.15	0.744	0.22	-2.67	-2.15	-2.57
12500	41	-3.82	-3.32	-3.33	-1.57	0.858	-1.59	-3.73	-2.86	-3.33
16000	42	-4.6	-4.02	-3.87	-2.83	-0.366	-3.18	-4.77	-4.12	-3.87
20000	43	-7.75	-8.06	-5.63	-6.31	-3.45	-6.27	-8.21	-8.13	-5.63

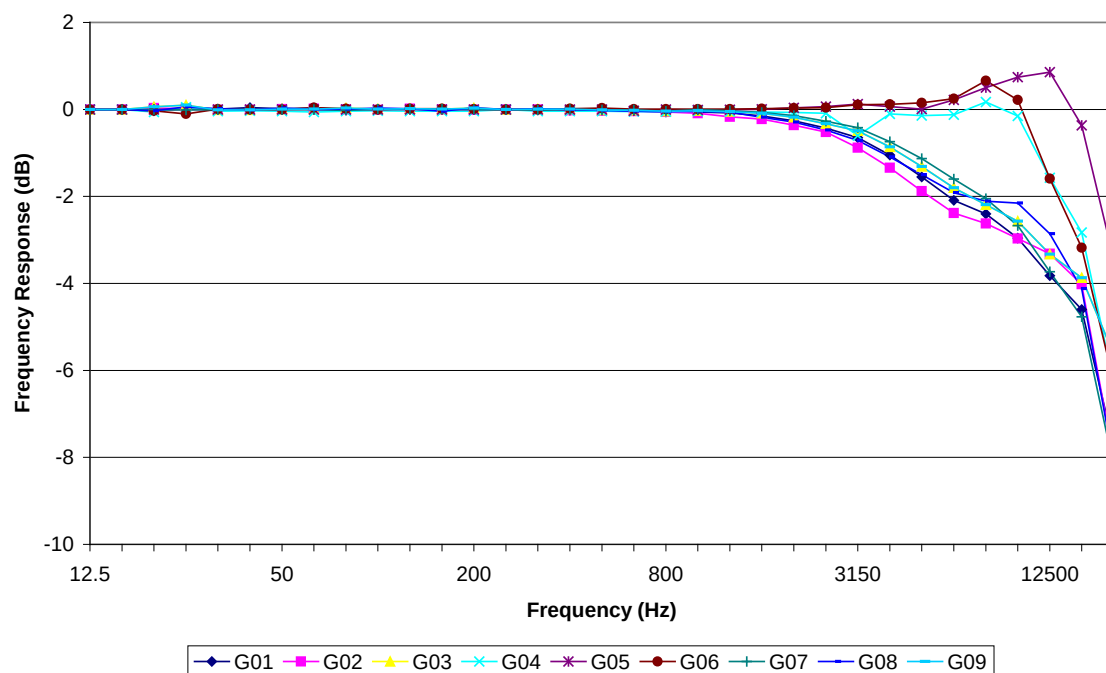


Figure 96. Microphone frequency responses.

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 deployed at Sites G01, G02, G03, G07, G08, and G09, and the second batch was used with systems deployed at Sites G04, G05, and G06. The attenuation of both sets of windscreens was measured by HMMH utilizing a diffuse sound source and is shown as a function of frequency in Table 31 and Figure 97.²⁵

Table 31. Windscreen frequency responses.

Frequency (Hz)	Frequency Band	Site G01	Site G02	Site G03	Site G04	Site G05	Site G06	Site G07	Site G08	Site G09
12.5	11	0	0	0	0	0	0	0	0	0
16	12	0	0	0	0	0	0	0	0	0
20	13	0	0	0	0	0	0	0	0	0
25	14	0	0	0	0	0	0	0	0	0
31	15	0	0	0	0	0	0	0	0	0
40	16	0	0	0	0	0	0	0	0	0
50	17	0	0	0	0	0	0	0	0	0
63	18	0	0	0	0	0	0	0	0	0
80	19	0	0	0	0	0	0	0	0	0
100	20	0	0	0	0	0	0	0	0	0
125	21	-0.07	-0.07	-0.09	-0.07	-0.07	-0.07	-0.07	-0.07	-0.09
160	22	-0.16	-0.16	-0.03	-0.16	-0.16	-0.16	-0.16	-0.16	-0.03
200	23	-0.17	-0.17	-0.11	-0.17	-0.17	-0.17	-0.17	-0.17	-0.11
250	24	-0.09	-0.09	-0.13	-0.09	-0.09	-0.09	-0.09	-0.09	-0.13
315	25	-0.24	-0.24	-0.21	-0.24	-0.24	-0.24	-0.24	-0.24	-0.21
400	26	-0.44	-0.44	-0.28	-0.44	-0.44	-0.44	-0.44	-0.44	-0.28
500	27	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28
630	28	-0.57	-0.57	-0.24	-0.57	-0.57	-0.57	-0.57	-0.57	-0.24
800	29	-0.4	-0.4	-0.21	-0.4	-0.4	-0.4	-0.4	-0.4	-0.21
1000	30	-0.16	-0.16	0.41	-0.16	-0.16	-0.16	-0.16	-0.16	0.41
1250	31	0.46	0.46	1.02	0.46	0.46	0.46	0.46	0.46	1.02
1600	32	0.85	0.85	1.35	0.85	0.85	0.85	0.85	0.85	1.35
2000	33	1.09	1.09	1.4	1.09	1.09	1.09	1.09	1.09	1.4
2500	34	1.13	1.13	2.01	1.13	1.13	1.13	1.13	1.13	2.01
3150	35	1.26	1.26	2.28	1.26	1.26	1.26	1.26	1.26	2.28
4000	36	1.66	1.66	2.66	1.66	1.66	1.66	1.66	1.66	2.66
5000	37	2.14	2.14	2.93	2.14	2.14	2.14	2.14	2.14	2.93
6300	38	2.51	2.51	3.57	2.51	2.51	2.51	2.51	2.51	3.57
8000	39	3.05	3.05	4.13	3.05	3.05	3.05	3.05	3.05	4.13
10000	40	3.74	3.74	5.04	3.74	3.74	3.74	3.74	3.74	5.04
12500	41	4.16	4.16	5.76	4.16	4.16	4.16	4.16	4.16	5.76
16000	42	4.64	4.64	6.53	4.64	4.64	4.64	4.64	4.64	6.53
20000	43	6.15	6.15	7.18	6.15	6.15	6.15	6.15	6.15	7.18

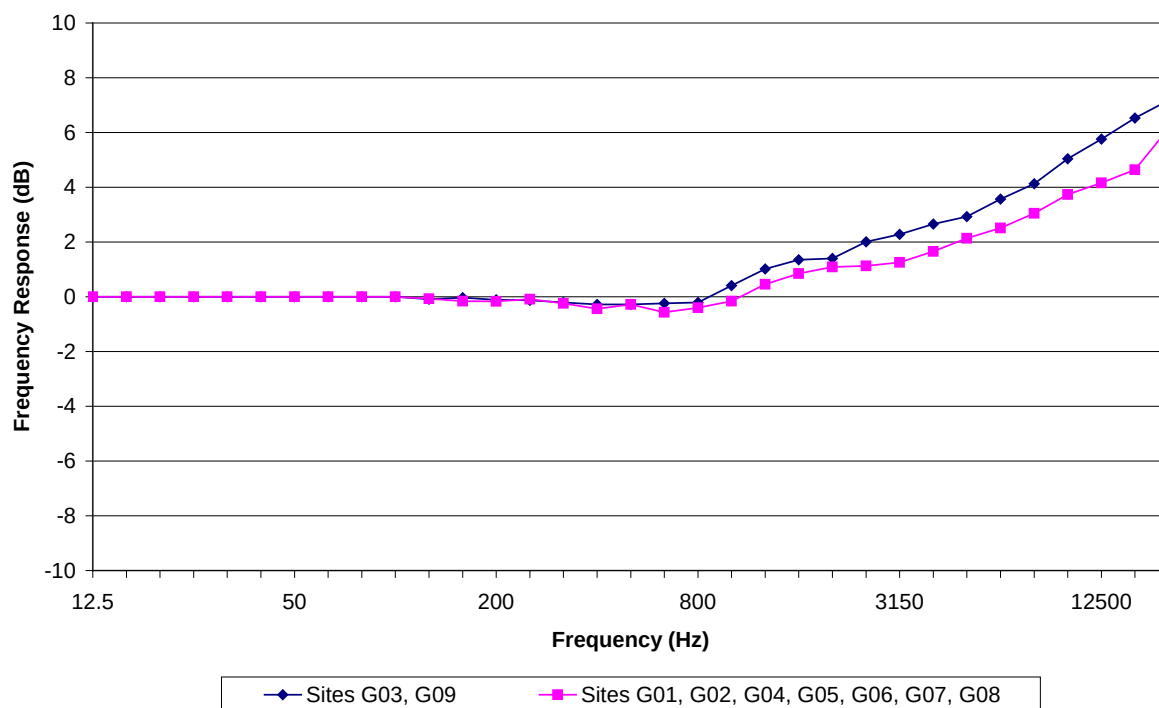


Figure 97. Windscreen frequency responses.

APPENDIX D. INSTRUMENTATION NOISE FLOOR ADJUSTMENTS

Documented ambient noise levels measured in remote areas of the country under low wind conditions (such as in national parks) often approach the threshold of human hearing. As a result, specialized low-level instrumentation is required to accurately measure these sounds. Measurements in support of this study were performed with two primary types of systems: the robust, long-term, NoiseLogger™ system; and the ultra-sensitive, short-term, VoLARE system (see Section 3 for detailed system descriptions). The NoiseLogger™ system has the capability of measuring sound levels down to approximately 15 to 20 dBA; and the VoLARE system has the capability of measuring sound levels below 0 dBA. A process was developed, to adjust the NoiseLogger™ data for contamination effects of the system noise floor. Because of the VoLARE system's ability to measure sound levels below that of the NoiseLogger™ systems, data measured simultaneously using the VoLARE system were used to check for reasonableness against the NoiseLogger™ data adjusted using the developed method. Application of these adjustments provide for more accurate estimation of the true ambient sound levels without limitations of the equipment's electrical noise floor. This appendix presents the method used to determine the noise floor of each of eleven NoiseLogger™ systems, as well as the final noise-floor adjustments used during data reduction.

D.1 Method

The process used for noise floor adjustments described herein combines several elements of the method presented by HMMH in Reference 26, as well as other additional criteria developed by the Volpe Center.¹⁹

For each NoiseLogger™ system, the noise floor of each one-third octave frequency band (bands 11 through 43 or 12.5 Hz through 20 kHz, respectively) was determined using only data samples collected during low wind conditions (i.e., wind speeds between 0 m/s and 0.5 m/s) to eliminate any potential influences due to wind. This data is grouped into 0.1 dB sound level 'bins' for analysis.

- (1) For each band the "preliminary noise-floor mean", is determined by finding the lowest 0.1 dB sound level bin which contains at least 5% of the total data and can be considered an

inflection point on the SPL histogram. The preliminary mean may consist of not only system noise, but also ambient noise.

- (2) The preliminary mean is adjusted using a process which is based on the assumptions that: a) the actual noise floor of the system varies from moment to moment, and that this variation has a Gaussian distribution, and b) the data below the preliminary mean should be most representative of the system noise floor without ambient noise. A Gaussian distribution is constructed using only the data below the preliminary mean. The mean of this constructed distribution is considered the true mean of the noise floor data.
- (3) The process of determining the true mean can be error-prone and result in a ‘jagged’ or discontinuous curve (noise floor as a function of frequency), especially when few sound level measurements exist near the noise floor. These jagged peaks (discontinuities) are eliminated (removed) by applying a smoothing function to the true-mean data. Theoretically, the noise floor of a system should have a relatively smooth shape as a function of frequency.
- (4) At some sites, the amount of data near the noise floor is not sufficient to allow for proper estimation of either the preliminary or true mean. This occurs most often at frequencies below 1000 Hz. In these instances, the noise floor of the system was assumed to be similar to another site where the exact same system (microphone, preamp, and LD824) was used.

D.2 Resultant Noise Floors

Table 32 and Figure 98 show the resultant noise floor levels used for each site obtained using the above method.

Table 32. Derived noise floors for each site.

Frequency (Hz)	Frequency Band	Site G01	Site G02	Site G03	Site G04	Site G05	Site G06	Site G07	Site G08	Site G09
12.5	11	18.1	8.7	16.7	18.0	14.4	18.2	13.8	15.8	15.6
16	12	16.1	7.3	15.8	16.6	14.0	16.3	14.0	14.8	14.2
20	13	14.7	5.9	14.8	15.7	13.5	14.0	14.0	13.7	12.5
25	14	13.5	4.6	13.4	14.5	11.8	11.9	13.6	12.4	11.0
31	15	11.8	3.4	12.0	13.1	8.2	9.2	13.0	11.0	9.2
40	16	10.5	2.2	10.6	11.5	5.4	6.1	11.8	9.6	7.7
50	17	8.5	1.2	8.8	10.0	2.9	4.0	10.0	7.6	6.2
63	18	6.5	0.3	7.3	8.6	1.0	2.0	8.5	5.8	5.1
80	19	4.5	-0.5	5.8	7.1	0.0	0.7	6.4	4.1	4.0
100	20	2.5	-1.1	4.4	5.6	-0.9	-0.2	4.4	2.2	3.0
125	21	1.0	-1.5	3.3	4.1	-1.5	-0.5	3.0	1.0	2.1
160	22	0.6	-1.8	2.6	2.7	-1.9	-0.6	1.5	0.1	1.5
200	23	0.4	-2.1	2.0	1.5	-2.2	-0.7	0.5	-0.6	1.2
250	24	-0.4	-2.1	1.7	0.7	-2.3	-0.8	-0.6	-0.9	1.0
315	25	-0.4	-2.0	1.6	0.2	-2.3	-0.8	-0.5	-0.9	0.9
400	26	-0.4	-1.6	1.7	0.0	-2.3	-0.7	-0.4	-0.9	1.0
500	27	-0.4	-1.4	1.8	0.1	-2.1	-0.6	0.0	-0.6	1.2
630	28	0.0	-0.6	1.9	0.3	-1.8	-0.5	0.4	-0.2	1.6
800	29	0.4	-0.2	2.2	0.5	-1.5	-0.2	1.0	0.4	1.8
1000	30	0.8	0.6	2.5	0.7	-1.0	0.6	1.8	1.0	2.2
1250	31	1.1	1.1	2.9	0.9	-0.5	1.7	2.6	1.6	2.6
1600	32	2.0	1.8	3.4	1.4	0.0	2.7	3.0	2.0	2.8
2000	33	2.5	2.5	3.9	2.0	0.7	3.5	3.2	2.5	3.1
2500	34	3.0	3.1	4.7	2.8	1.6	4.0	3.3	4.1	3.3
3150	35	3.6	3.6	5.3	3.6	2.5	4.5	4.0	4.5	3.6
4000	36	4.2	4.1	6.1	4.3	3.5	5.3	5.0	4.8	4.0
5000	37	5.0	4.4	6.4	4.7	4.5	6.0	5.6	4.9	4.5
6300	38	4.8	4.6	6.6	5.1	5.1	6.7	5.7	4.9	4.9
8000	39	4.7	4.7	6.7	5.2	5.3	7.0	5.6	5.2	5.3
10000	40	4.6	4.7	6.8	5.2	5.3	7.2	5.5	5.2	5.6
12500	41	4.4	4.6	6.9	4.9	5.1	7.4	5.0	4.7	5.8
16000	42	4.1	4.5	6.9	4.2	4.5	7.3	4.7	4.6	5.9
20000	43	3.9	4.3	7.0	3.5	4.2	6.7	4.6	4.4	6.2

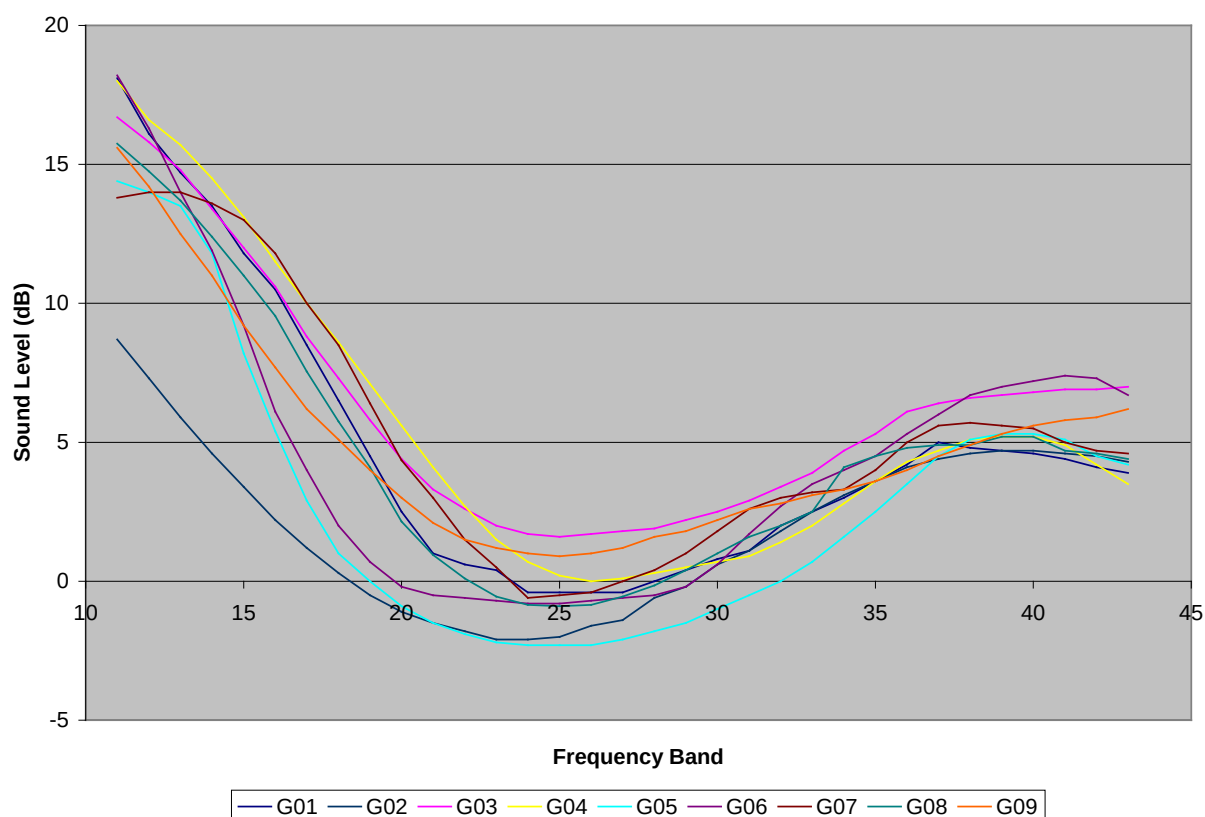


Figure 98. Derived noise floors for each site.

D.3 Applying Noise Floor Adjustments

The algorithm used in applying noise floor adjustments is based on HMMH's work as presented at the Inter-Noise Conference in August 2002.²⁵ The method applies the noise floor adjustments as an energy subtraction from the sound levels in each frequency band, whenever the measured-band sound level is within 1 dB of the noise floor of the system. At the $\frac{1}{3}$ -octave frequency band where the subtraction criterion is no longer met, the remainder of the spectrum (out to $\frac{1}{3}$ -octave frequency band 43, or 20 kHz) is extrapolated downward using a constant slope. The overall A-weighted sound level is then computed using the reconstructed spectrum

D.4 Comparison with VoLARE Data

As stated earlier, because of the VoLARE system's ability to measure sound levels below that of the NoiseLogger™ system, data measured simultaneously using the VoLARE system were used to validate the noise floor adjustments applied to NoiseLogger™ data, which approached or were below the "noise floor" of the NoiseLogger™ systems. In comparing raw NoiseLogger™ and

VoLARE data, it was observed that the NoiseLogger™ low-level data tended to fluctuate around VoLARE levels. As a result, small variations of raw NoiseLogger™ sound levels in the vicinity of the floor level caused large and usually short variations in the adjusted NoiseLogger™ sound levels. To resolve these fluctuations, raw 1-second L_{eq} samples were time-averaged to 30- and 120-second samples for this part of the analysis. Figure 99 presents a comparison for data collected at Glacier site G06 using a time-history plot of 120-second L_{eq} 's. As shown, the adjusted NoiseLogger™ data follows the trend of the raw NoiseLogger™ data. Definite improved overall agreement is seen between the adjusted NoiseLogger™ data and the higher quality VoLARE data.

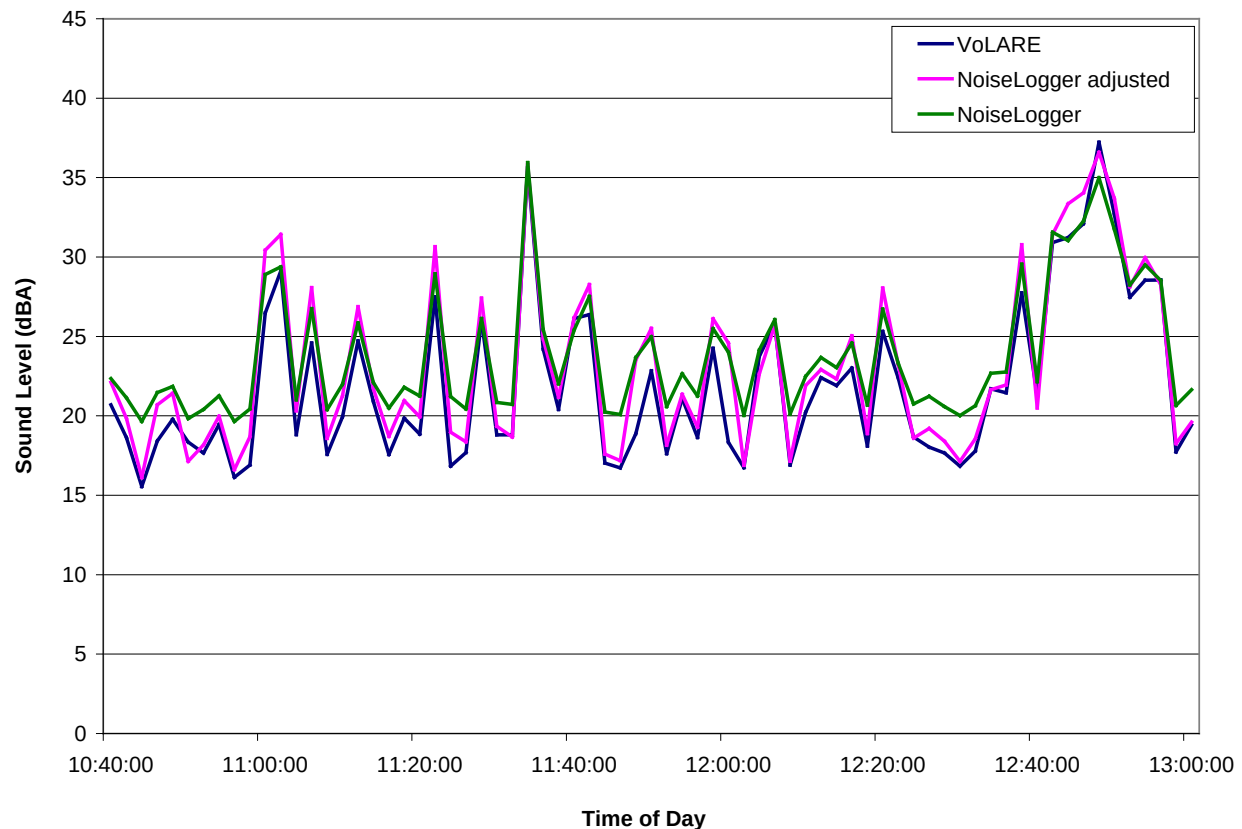


Figure 99. Comparison of adjusted NoiseLogger™ with raw and VoLARE data for Glacier National Park site G06.

It should be noted that comparisons between adjusted NoiseLogger™ and VoLARE data are based on two underlying assumptions: (1) the VoLARE data represents a more accurate measurement; and (2) the method used to develop noise floor adjustments is accurate. The first

assumption is confirmed with the VoLARE's ultra-sensitive microphone affording it the ability to measure well below the noise floor of the NoiseLogger™ system. The second assumption has shown good results with comparisons performed thus far with Glacier and other ATMP parks, including Hawai'i Volcanoes, Haleakala, and Badlands data. Because this method tends to determine the lowest noise floor of a system for all of the sites measured with the system, the adjustments are predisposed to under-correct measured sound levels. Currently, these under-corrections have not been shown to be significant.

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.¹⁹

The concept of transferability of data is currently a working hypothesis.²⁷ An area of justified concern is the reliability of transferred ambient data in the dynamic outdoor environment of a national park - be it data from one area of a park to another area within the same park, or data from one park to a completely different park. It is presently hypothesized that after a critical mass of baseline ambient sound level data have been collected, it will be statistically viable to begin generalizing data measured in one park to regions possessing similar attributes in other parks. What is not currently known, however, is how many park measurement studies will be needed to achieve statistical reliability and scientific defensibility of ambient data as this type of effort has never been attempted before. The transferability hypothesis, if proven sound, will not preclude measurements entirely in other parks, but it should greatly reduce the scope of required measurements. It is anticipated that some baseline ambient sound level measurements will be necessary in all parks. The purpose of a limited measurement campaign (probably a few days in even the later parks included in the ATMP program) is to statistically prove the hypothesis of transferability of baseline ambient sound level data on a park-by-park basis, and, as important, secure public acceptance of the environmental compliance documents prepared for individual parks.

In developing acoustic zones within a national park,* land cover (Section 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 will be primarily determined by land cover and climate regions within that park, and not park size. Acoustic zones may then be further subdivided based on factors such as park management zones, visitor-use, and wildlife habitats. For example, Hawai'i Volcanoes National Park is approximately 400 square miles with an estimated 9 acoustic zones based on land cover and topographical information. LMNRA, 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.²⁸

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 33).²⁹ Glacier's land cover distribution using the NLCD categories is shown in Table 34. This classification approach has been closely coordinated with NPS personnel.*

Table 33. 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.

* 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	32 Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Barren	33 Transitional	Areas of sparse vegetative cover (less than 25% of cover) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).
Forested Upland	41 Deciduous Forest	Areas dominated by trees where 75% Or more of the tree species shed foliage simultaneously in response to seasonal change.
Forested Upland	42 Evergreen Forest	Areas dominated by trees where 75% or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Forested Upland	43 Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75% of the cover present.
Shrubland	51 Shrubland	Areas dominated by shrubs; shrub canopy accounts for 25-100% of the cover. Shrub cover is generally greater than 25% when tree cover is less than 25%. Shrub cover may be less than 25% in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25% and shrubs cover exceeds the cover of the other life forms.
Non-Natural Woody	61 Orchards/Vineyards/ Other	Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.
Herbaceous Upland Natural/Semi-natural Vegetation	71 Grasslands/ Herbaceous	Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25%, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.
Herbaceous Planted/Cultivated	81 Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of 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 34. Land cover subclass distribution in Glacier.

Land Cover Class	Land Cover Subclass	Area (Sq. Mi.)
Water	11 Open Water	49.8
Water	12 Perennial Ice/Snow	5.3
Developed	21 Low Intensity Residential	0.2
Developed	22 High Intensity Residential	0.0
Developed	23 Commercial/Industrial/Transportation	1.3
Barren	31 Bare Rock/Sand/Clay	210.2
Barren	32 Quarries/Strip Mines/Gravel Pits	0.0
Barren	33 Transitional	0.9
Forested Upland	41 Deciduous Forest	23.8
Forested Upland	42 Evergreen Forest	1,024.4
Forested Upland	43 Mixed Forest	2.2
Shrubland	51 Shrubland	233.6
Non-Natural Woody	61 Orchards/Vineyards/Other	0.0
Herbaceous Upland Natural/Semi-natural Vegetation	71 Grasslands/Herbaceous	94.5
Herbaceous Planted/Cultivated	81 Pasture/Hay	2.1
Herbaceous Planted/Cultivated	82 Row Crops	0.0
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	8.2
Wetlands	92 Emergent Herbaceous Wetlands	1.0
	<i>Total *</i>	1,657.4

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 100.³⁰ With the goal of

* Because the ATMP Act applies to all commercial air tour operations within the ½-mile outside the boundary of a national park, these numbers include these areas. Additionally, although a portion of Glacier lies in Canada, ATMP development will only pertain to areas within the United States. Therefore, the total area of all land cover types is larger than the total area of the park, but excludes those areas that are within Canada.

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.*

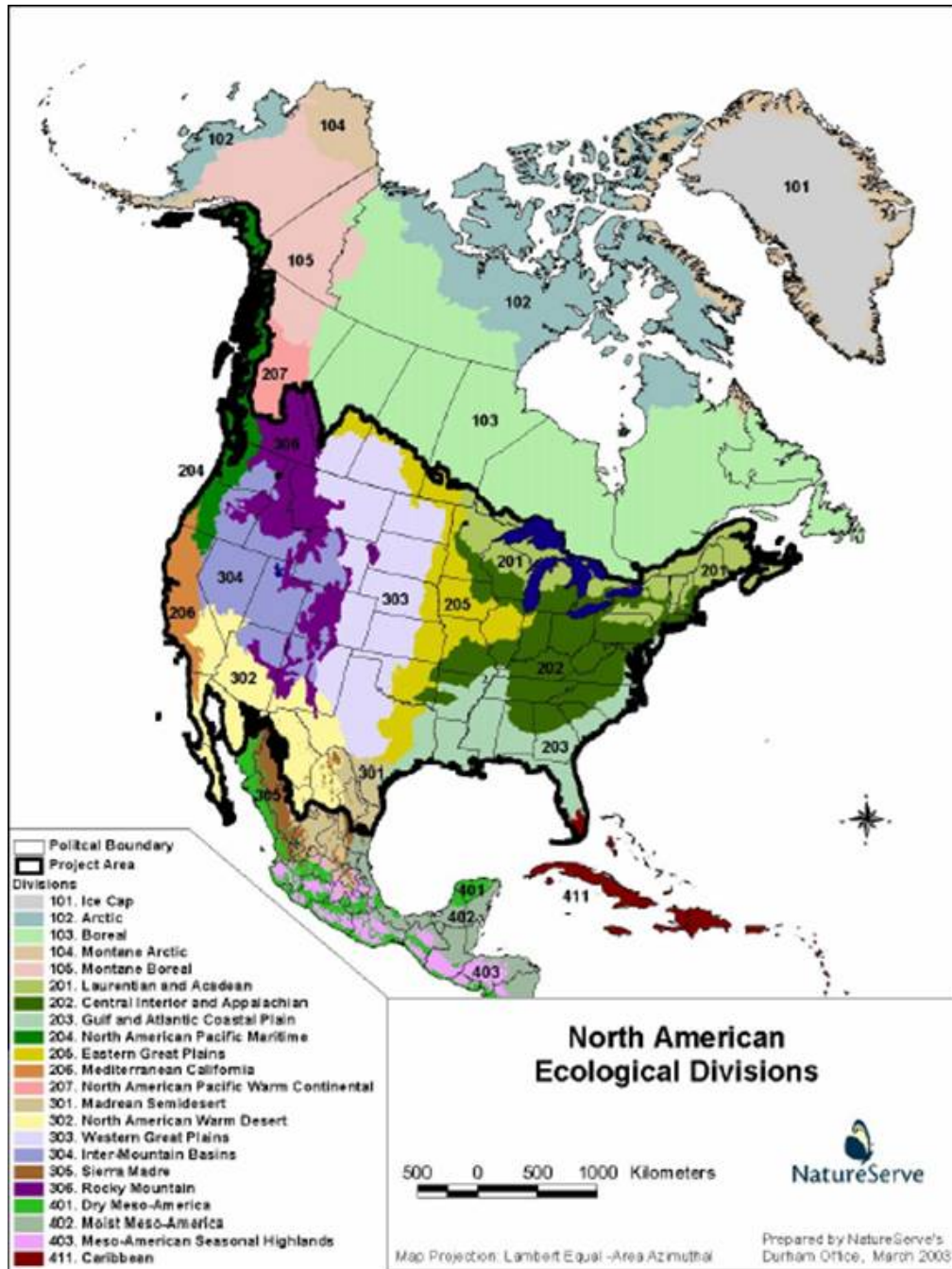


Figure 100. NatureServe ecological divisions of North America.

* 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.

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 D.3.1) and the Kolmogorov-Smirnoff (K-S) Statistic (see Section D.3.2). These two methods were used in tandem to assess acoustic similarity. If a site combination passed both methods it was considered strong evidence that the sites were similar. If a site combination failed both methods, it was an indication that the sites were different. Cases where one method indicated similarity and the other method was contradictory were evaluated individually and a final decision was made after review of the results and pertinent site information.

E.3.1 Regression Analysis

Although sound-level data, whose associated wind speed was greater than 5 m/s (see Section 5.4.1), were not used in data analyses, it was still considered likely that wind speed would affect the hourly median sound levels (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.³¹ 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 the median (L_{50}) of 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 Glacier 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 later ATMP parks with additional land cover types and within other ecological divisions, it is anticipated that the analysis of acoustic zones may be expanded to a larger scale, possibly nationwide.

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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 32 through 36.

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).

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.

CIRQUE - An amphitheatre-like valley of glacial origin, formed by glacial erosion at the head of the glacier.

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

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

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

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

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

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

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

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

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

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

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

L₅₀ - A statistical descriptor describing the sound level exceeded 50 percent of a specific time period. For example, from a fifty-sample measurement period with the samples sorted from highest sound level to lowest sound level, the twenty-fifth sound level is the 50-percentile exceeded sound level.

L₉₀ - A statistical descriptor describing the sound level exceeded 90 percent of a specific time period. For example, from a fifty-sample measurement period with the samples sorted from highest sound level to lowest sound level, the forty-fifth sound level is the 90-percentile exceeded sound level.

L_{AE} (see Sound Exposure Level)

LAeq (see Equivalent Sound Level)

LASmx (see Maximum Sound Level)

Ldn (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 Congress³⁶

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.³⁷

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

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

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

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

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

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

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

SOFT GROUND - Any highly absorptive surface in which the phase of the sound energy is changed upon reflection; examples include terrain covered with dense vegetation or freshly fallen snow. (Note: At grazing angles greater than 20 degrees, which can commonly occur at

short ranges, or in the case of elevated sources, soft ground becomes a good reflector and can be considered hard ground).

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

SOUND EXPOSURE LEVEL (SEL, denoted by the symbol L_{AE}) –

Over a stated time interval, T (where $T=t_2-t_1$, in seconds), ten times the base-10 logarithm of a given time integral of squared instantaneous A-weighted sound pressure, divided by the product of the squared reference sound pressure of $20 \mu\text{Pa}$, 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).

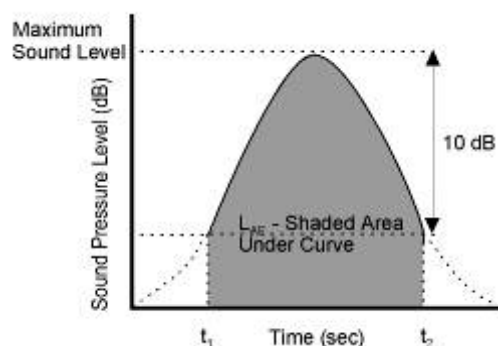


Figure 101. Graphical representation of LAE

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.

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

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)

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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 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.
- ⁴ Menge, Christopher W., Christopher F. Rossano, Grant S. Anderson, and Christopher J. Bajdek, FHWA Traffic Noise Model, Version 1.0: Technical Manual, Report Nos. FHWA-PD-96-010 and DOT-VNTSC-FHWA-98-2, Cambridge, MA: John A. Volpe National Transportation Systems Center, 1998.
- ⁵ Wayson R. and MacDonald J., Simulation Modeling of Railroad Noise to Assist in Environmental Document Preparation, FDOT No. BD548/RPWO#13, August 2006.
- ⁶ National Parks Air Tour Management Act of 2000. Public Law 106-181, 114 Stat. 61, Title VIII, Section 801, April 2000.
- ⁷ 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.

- ⁸ 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.
- ⁹ National Park Service. <http://www.nps.gov/glac/index.htm>.
- ¹⁰ National Park Service: Glacier National Park – Geology
<http://www.nps.gov/glac/resources/geology.htm>.
- ¹¹ National Park Service Public Use Statistics Office.
<http://www2.nature.nps.gov/mpur/index.cfm>
- ¹² 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.
- ¹³ 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.
- ¹⁴ Roof, C., Rapoza, A., Fleming, G., Read, D. and, 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, 2003 (to be published).
- ¹⁵ 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.
-

- ¹⁶ Final General Management Plan and Environmental Impact Statement Volume I: Glacier National Park. West Glacier, MA: U.S. Department of the Interior, National Park Service, July 1999.
- ¹⁷ National Park Service: Glacier National Park – Frequently Asked Questions <http://www.nps.gov/glac/faq.htm#1>.
- ¹⁸ General Management Plan/Environmental Impact Statement: Glacier National Park. Flathead and Glacier Counties, MT: U.S. Department of the Interior, National Park Service, April 1999.
- ¹⁹ 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, August 2016.
- ²⁰ NPS report on ambient sound levels in Arches National Park and Bryce Canyon National Park (to be published).
- ²¹ Macdonald, J., Lee, C., and Scarpone, C., NoiseLogger™ System Reference, Cambridge, MA: John A. Volpe National Transportation Systems Center, April 2003.
- ²² Macdonald, J., Lee, C., and Scarpone, C., NoiseLogger Plus™ System Reference, Cambridge, MA: John A. Volpe National Transportation Systems Center, April 2003.
- ²³ Rapoza, A., MacDonald, J., Hastings, A., Scarpone, C., Lee, C., and Fleming, G., Development of Improved Ambient Computation Methods in Support of the National Parks Air Tour Management Act, Report No. DOT-VNTSC-NPS-11-08, Cambridge, MA: John A. Volpe National Transportation Systems Center, October 2008.
- ²⁴ 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.
- 25 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.
- 26 Horonjeff, Richard C., Ross, Jason, C., Overcoming Instrument Noise Floors When Measuring In Quiet Environments, Inter-Noise 2002, Paper No. N599F, Dearborn, Michigan: Institute of Noise Control Engineering, August 19-21, 2002.
- 27 National Parks Air Tour Management Plan (ATMP) Program Implementation Plan, Cambridge, MA: John A. Volpe National Transportation Systems Center, September 2005.
- 28 Lee, Cynthia and Fleming, Gregg, Proposed FY04 Acoustic Monitoring Plan, Cambridge, MA: John A. Volpe National Transportation Systems Center Acoustics Facility, March 2004.
- 29 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.
- 30 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.
- 31 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.
- 32 "Acoustical Terminology," American National Standard, ANSI S1.1-1994, New York:
-

- American National Standards Institute, 1994.
- ³³ “Procedures for Outdoor Measurement of Sound Pressure Level,” American National Standard, ANSI Standard S12.18-1994, New York: American National Standards Institute, 1994.
- ³⁴ 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.
- ³⁵ “Specification for Sound Level Meters,” American National Standard, ANSI Standard S1.4-1983 (R 1990), New York: American National Standards Institute, 1990.
- ³⁶ Report on Effects of Aircraft Overflights on the National Park System, Washington, DC: National Park Service, July 1995.
- ³⁷ “Soundscape Preservation and Noise Management,” Director’s Order #47, Washington, DC: National Park Service, December 2000.