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FP-01 (JD8AC)

National Park Service
Fort Collins, CO 80525
VX-82 (JM008)

Baseline Ambient Sound Levels in *Dry Tortugas National Park*

Final Report
November 2012

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ON THE COVER
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13. ABSTRACT (Maximum 200 words) The Federal Aviation Administration (FAA) and the National Park Service (NPS), with the assistance of the U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) are developing Air Tour Management Plans (ATMPs) for all national parks with commercial air tours, with the exception of the Grand Canyon National Park (GCNP), tribal lands within or abutting the GCNP, air tour operations flying over or near the Lake Mead National Recreation Area solely as a transportation route to conduct an air tour over GCNP, Rocky Mountain National Park, and national park units located in Alaska. An important area of technical support is the determination of representative baseline ambient sound levels for the study parks. During the summer (August - September 2008) and winter (February – April 2009), the National Park Service conducted baseline ambient sound level measurements in Dry Tortugas National Park. Up to one month of acoustical and meteorological data were measured at one site within the park. This document summarizes the results of the noise measurement study.			
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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

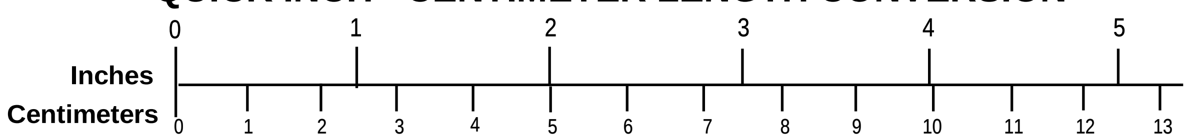
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

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

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EXECUTIVE SUMMARY

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

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

This document summarizes the noise measurement study undertaken to provide data for the baseline ambient noise environment in Dry Tortugas National Park (Dry Tortugas). As shown in Figure 1, Dry Tortugas is located in the State of Florida, approximately 70 miles west of Key West and is accessible only by private boats, charter boats, or seaplane.

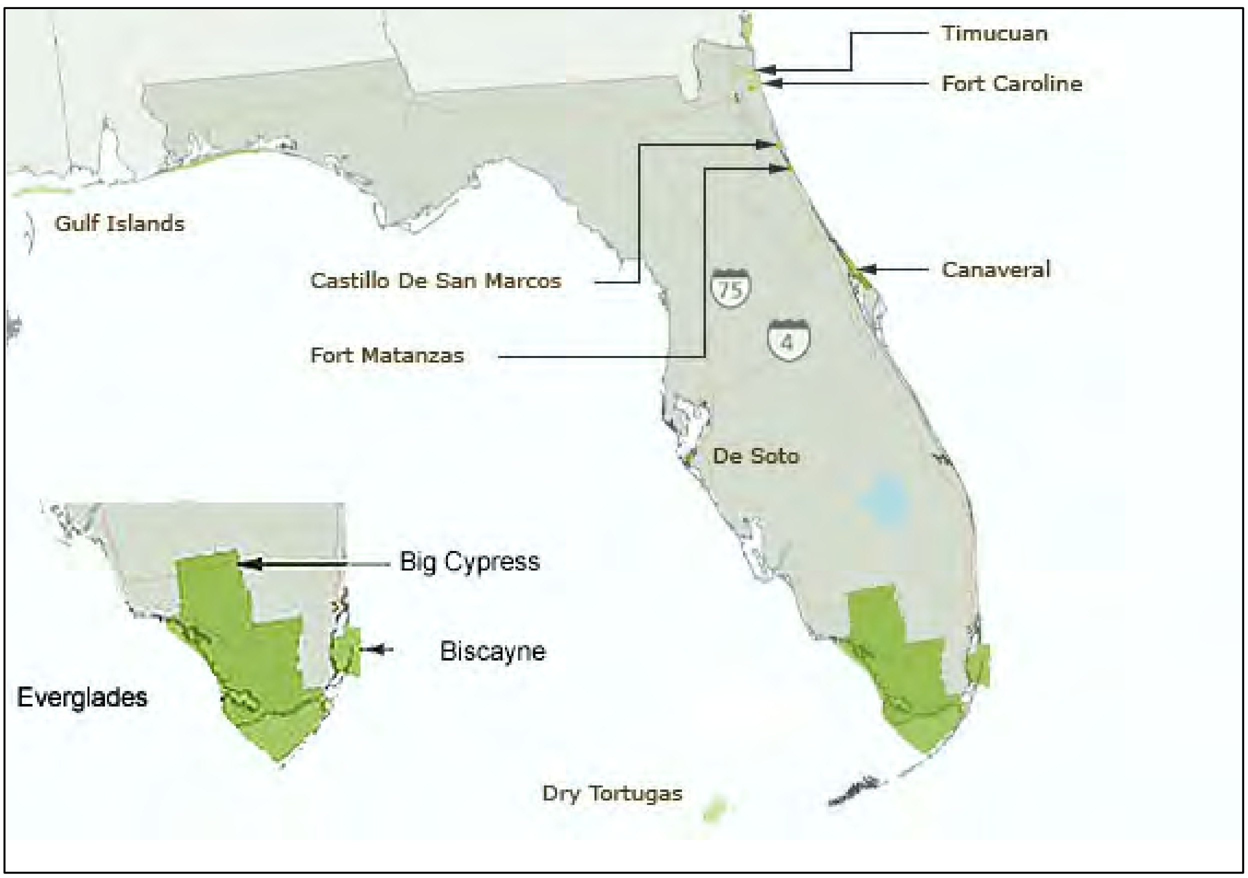

Figure 1. Location of Dry Tortugas National Park. [1]

The NPS Natural Sounds and Night Skies Division (NSNSD) performed acoustical monitoring during August/September 2008 and February/April 2009 as part of a joint measurement study conducted by the NSNSD and the Volpe Center to measure baseline ambient data that will be used to represent the summer and winter seasons, respectively, for four Florida Parks.

NPS Measured Parks:
- Everglades National Park (EVER)
- Dry Tortugas National Park (DRTO)

Volpe Measured Parks:
- Biscayne National Park (BISC)
- Big Cypress National Preserve (BICY)

Approximately one month of acoustical and meteorological data were measured at one site in the park.

In selecting sites for the above monitoring efforts, the primary goal 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 acoustic zones. See Figure 2.

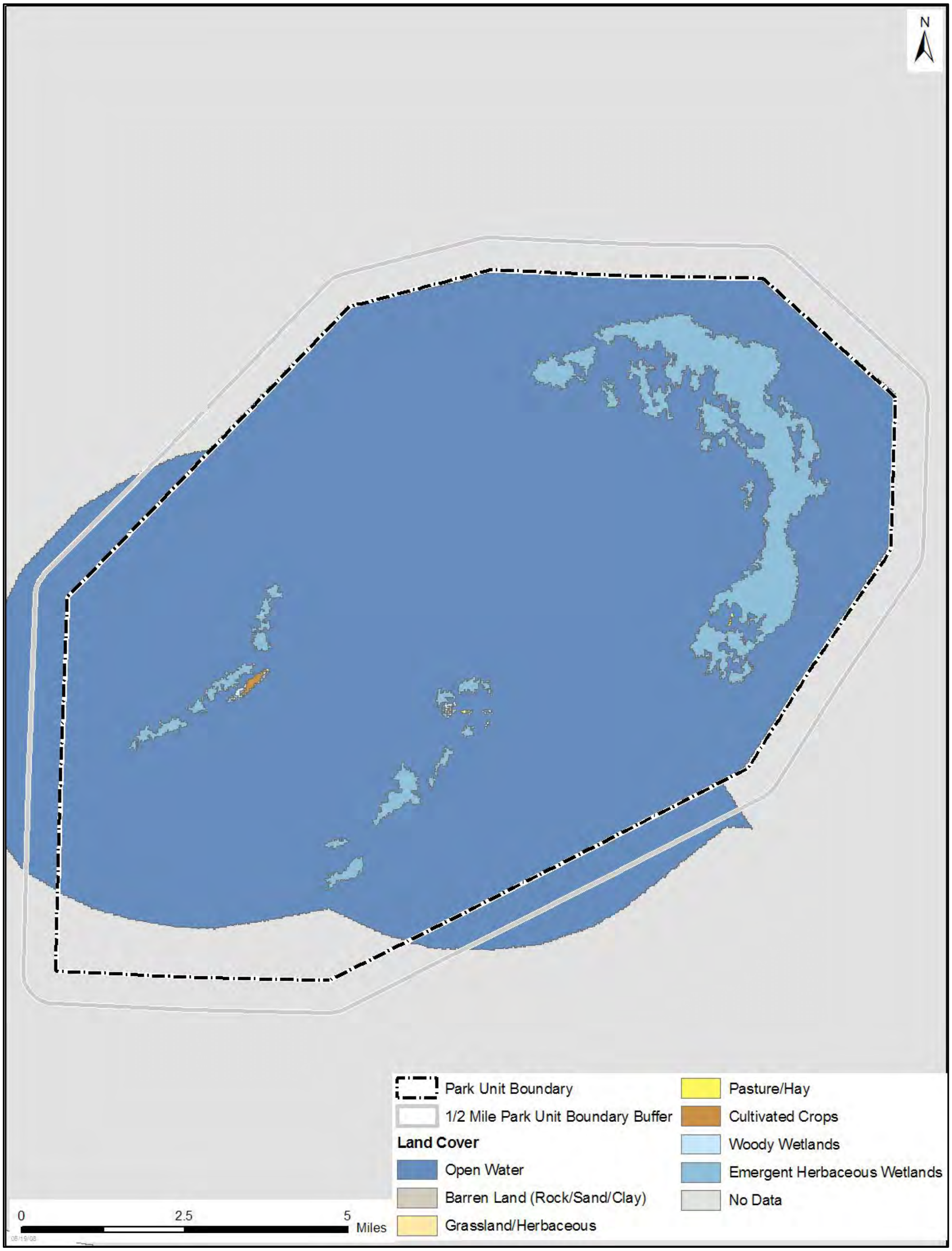

Figure 2. National Land Cover Database (NLCD) land cover types for Dry Tortugas.

Based on Figure 2, the following final acoustic zones were developed:*

- Developed Zone (< 1% of area)
- Wetlands Zone (2% of area)
- Open Water Zone (98% of area)

Table 1 and Figure 3 display the locations of the final acoustic zones and measurement site (see also additional discussion in Section 2).

Table 1. Summary of measurement site for Dry Tortugas.

Site ID	Site Name	National Land Cover Database Classification	Summer Coordinates (latitude/longitude in decimal degrees)	Winter Coordinates (latitude/longitude in decimal degrees)	Altitude (ft)	# Days of Data	
						Summer	Winter
DRTO 001	Fort Jefferson	Developed	24.62926° / 82.87163°	24.62863° / 82.87327°	1.6	4 days	49 days

* Because the ATMP Act includes the ½-mile outside the boundary of the national park, all zones also include land cover types located within the ½-mile buffer area.

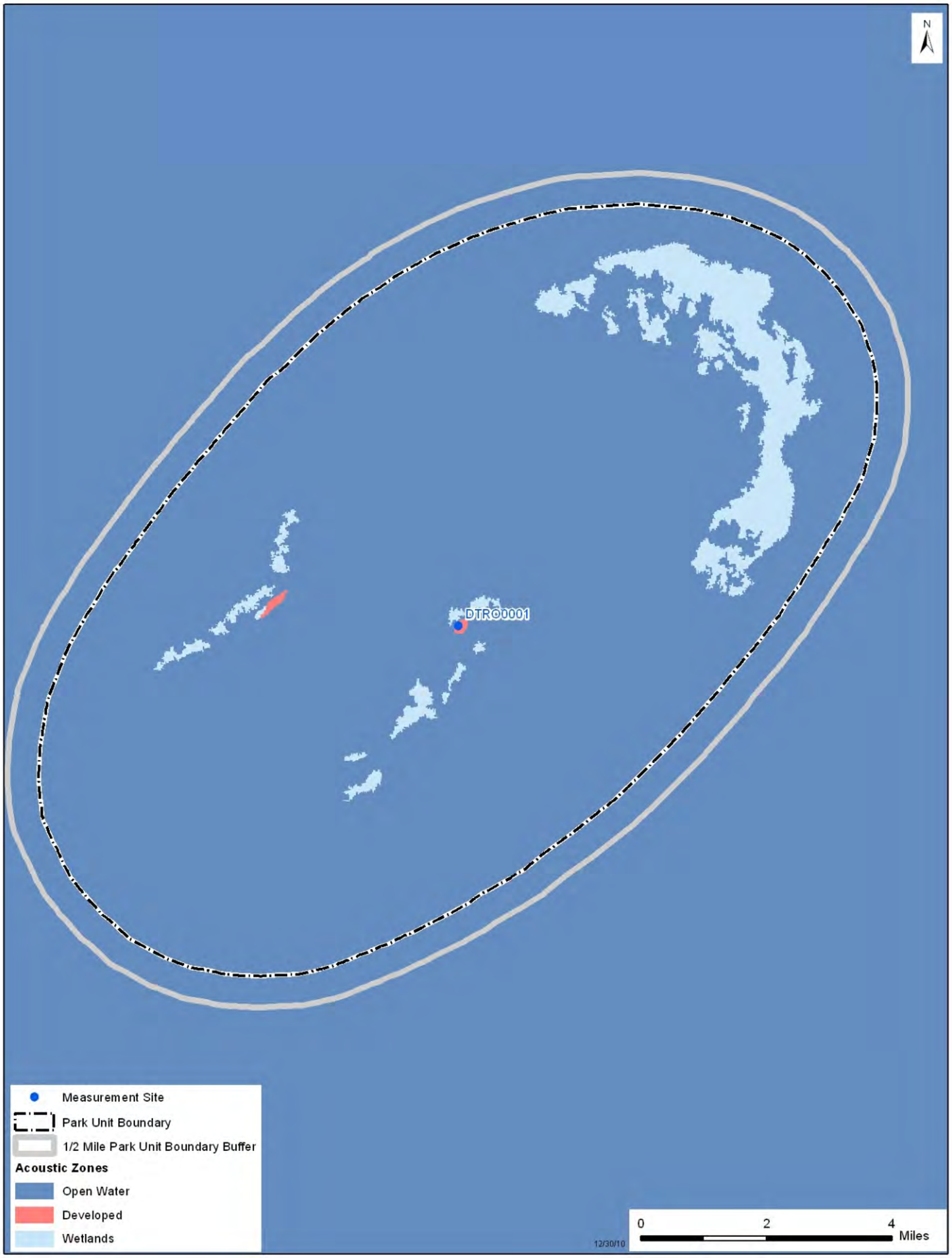

Figure 3. Final acoustic zones and measurement site for Dry Tortugas.

The following types of data were collected:

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

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

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

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

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

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

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

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

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

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

- *Acoustic Zone*: The acoustic zone in which the measurement site was located;
- *Site Name:* The name of the site;
- *Site ID*: The unique seven-character ID representing the site "number"; and

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

[†] As noted previously, because for most parks, the majority of air tour operations occur during the day, the FAA and NPS have agreed that the impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur. Accordingly, all ATMP analyses will be based on daytime ambient data.

- *Level of Visitor-Use*: A designator indicating expected visitor use (with “high” indicating sites such as overlooks, “moderate” indicating short hikes, and “low” indicating minimal or no visitor use such as in the wilderness/backcountry) in the measurement site area.

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

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

Table 2. Summary of measured ambient sound level data for both summer and winter seasons. [*]

Acoustic Zone	Site Name	Site ID	Total # Days	Existing Ambient						Existing Ambient Without Air Tours		Existing Ambient Without All Aircraft		Natural Ambient	
				Daytime Data (7 am to 7 pm)			Nighttime Data (7 pm to 7 am)			Daytime	Night-time	Daytime	Night-time	Daytime	Night-time
				L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)
Summer Season															
Developed	DRTO001	Fort Jefferson	4	47.9	45.3	36.3	47.7	46.3	40.6	45.3	46.3	44.7	46.3	37.8	46.2
Winter Season															
Developed	DRTO001	Fort Jefferson	49	50.5	46.0	42.1	45.9	43.5	40.1	46.0	43.5	45.8	43.5	42.1	40.1

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

Acoustic Zone	Site Name	Site ID	Level of Visitor-Use	% Time Audible							
				Daytime Data (7 am to 7 pm)				Nighttime Data (7 pm to 7 am)			
				Air Tour Aircraft	Other Aircraft	Other Human	Natural	Air Tour Aircraft	Other Aircraft	Other Human	Natural
Summer Season											
Developed	DRTO001	Fort Jefferson	High	0%	10%	64%	26%	0%	0%	1%	99%
Winter Season											
Developed	DRTO001	Fort Jefferson	High	1%	4%	93%	2%	0%	0%	100%	0%

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

The measured ambient values presented in Table 2 are assigned to each acoustic zone to develop an ambient "map" of a park. An ambient "map" is essentially a comprehensive grid of ambient sound levels throughout a study area. The 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.

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

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

Figure 4 through Figure 7 present the two ambient maps, respectively, for the summer and winter seasons.

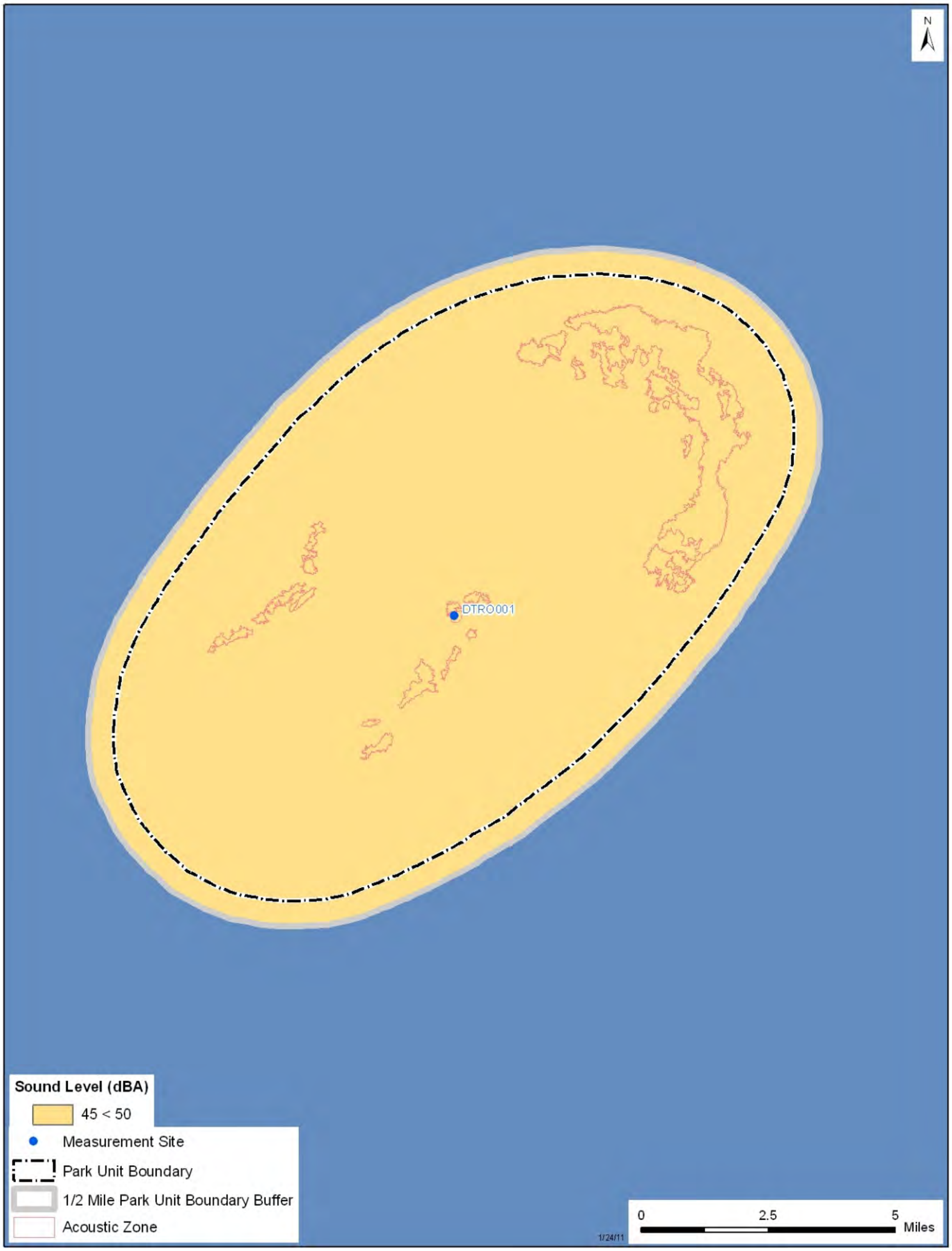

Figure 4. Baseline ambient map: Existing Ambient Without Air Tours (L_{50}) for the summer season.

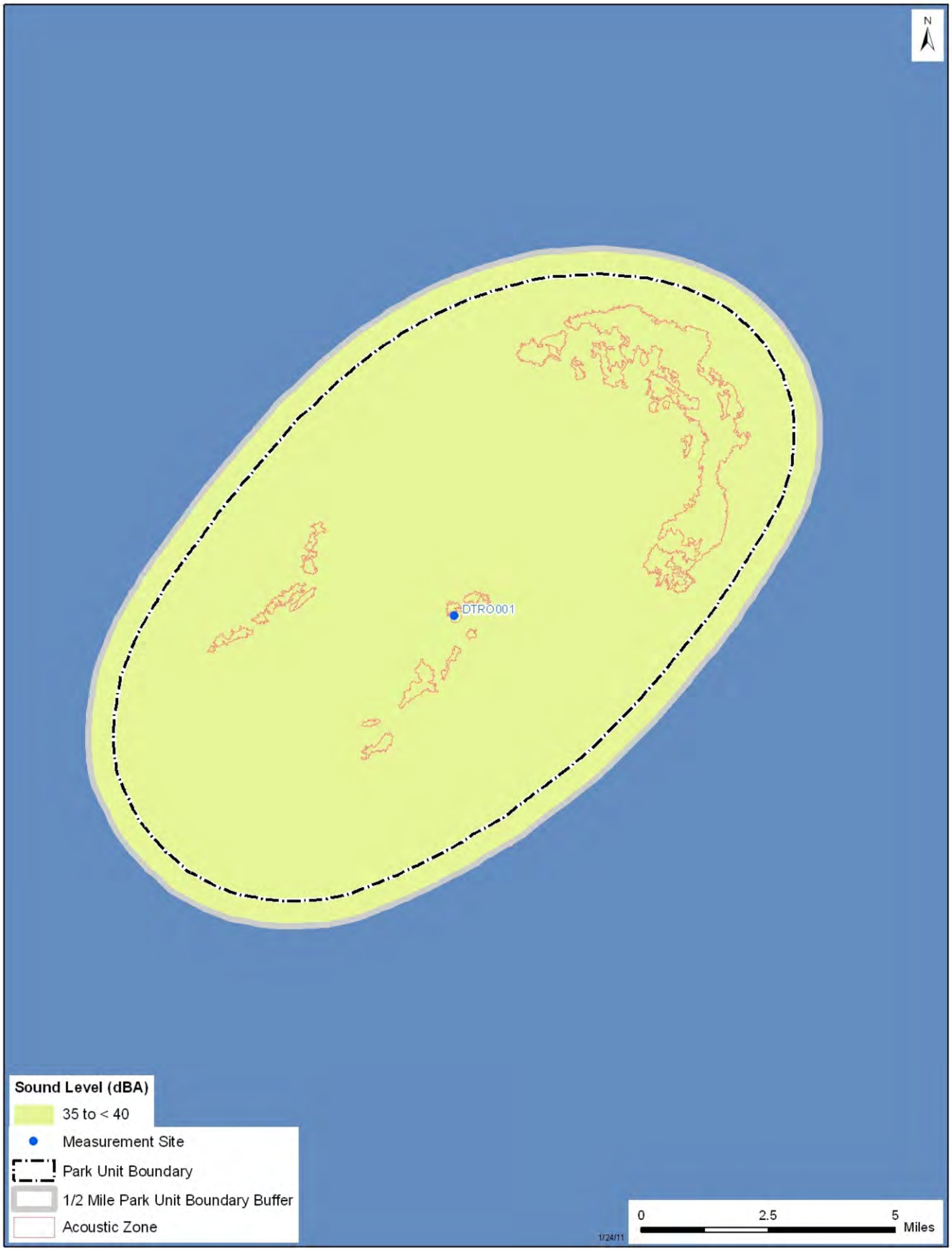

Figure 5. Baseline ambient map : Natural Ambient (L_{50}) for the summer season.

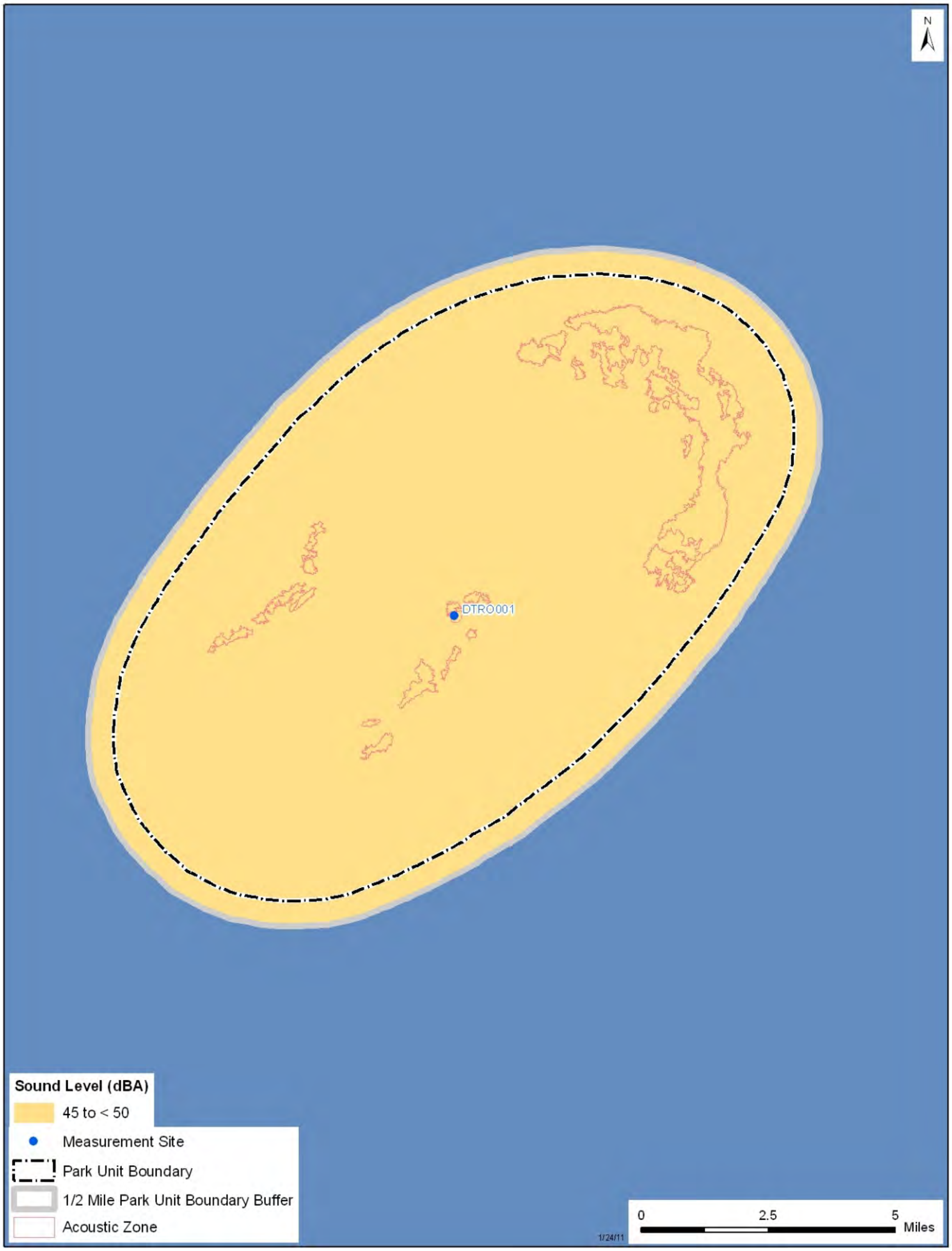

Figure 6. Baseline ambient map: Existing Ambient Without Air Tours (L_{50}) for the winter season.

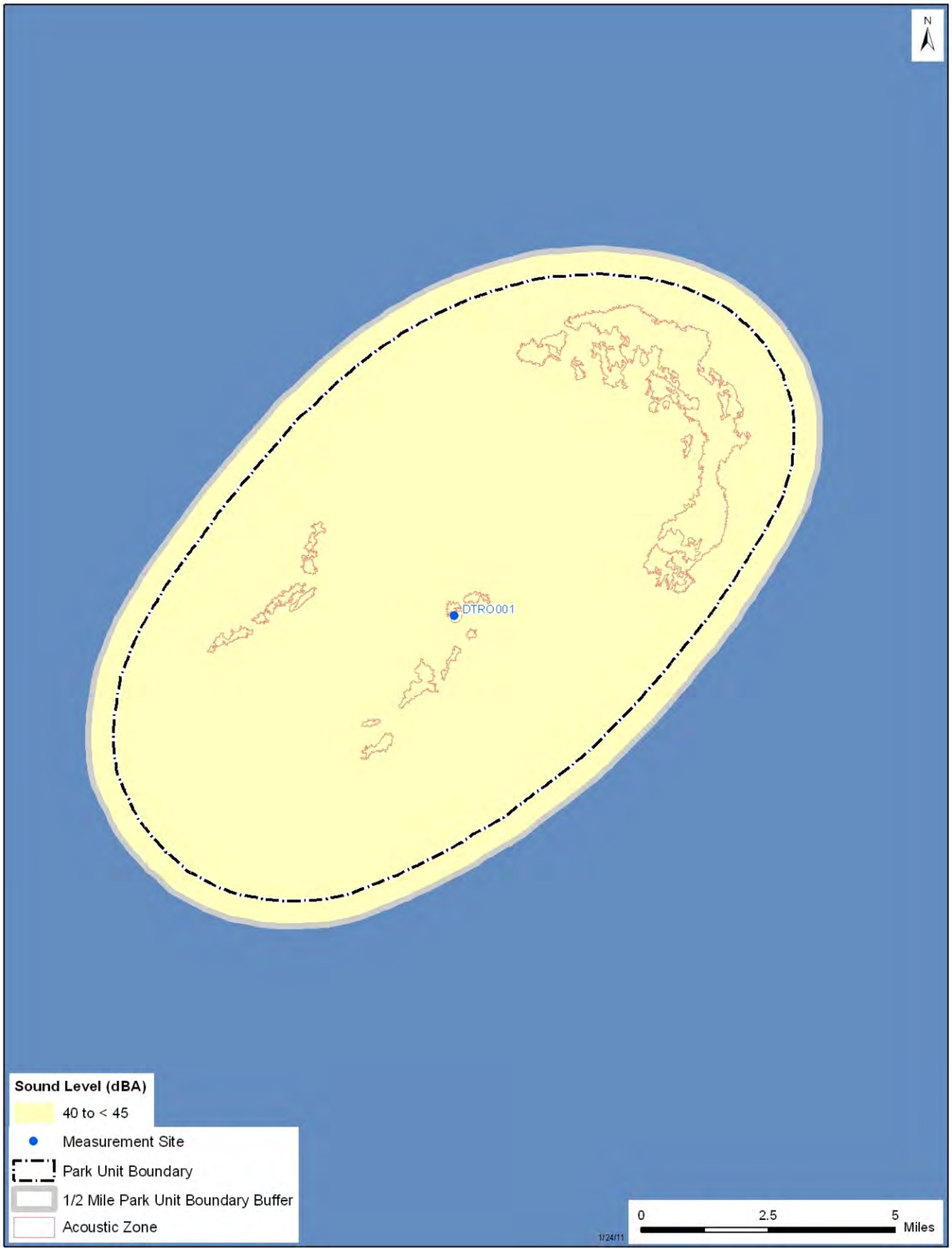

Figure 7. Baseline ambient map : Natural Ambient (L50) for the winter season.

1. INTRODUCTION

Congress passed the National Parks Air Tour Management Act of 2000 (NPATMA) to regulate commercial air tour operations over units of the National Park System.[2] NPATMA directed the Federal Aviation Administration (FAA) and the National Park Service (NPS), to develop Air Tour Management Plans (ATMPs) for all national parks with commercial air tours with the exception of the Grand Canyon National Park (GCNP), tribal lands within or abutting the GCNP, air tour operations flying over or near the Lake Mead National Recreation Area solely as a transportation route to conduct an air tour over GCNP, Rocky Mountain National Park, and national park units located in Alaska. The objective of the ATMPs is to develop acceptable and effective measures to mitigate or prevent significant adverse impacts, if any, from the air tours on the natural and cultural resources, visitor experiences, and tribal lands within the parks.

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

This document summarizes the noise measurement study undertaken to provide data for the baseline ambient noise environment in Dry Tortugas National Park (Dry Tortugas). The NPS performed acoustical monitoring during August/September 2008 and February/April 2009 as part of a joint measurement study conducted by the NPS and the Volpe Center to measure baseline ambient data that will be used to represent the summer and winter seasons, respectively, for four Florida Parks.

NPS Measured Parks:
- Everglades National Park (EVER)
- Dry Tortugas National Park (DRTO)

Volpe Measured Parks:
- Biscayne National Park (BISC)
- Big Cypress National Preserve (BICY)

1.1 Objectives

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

- Establishing baseline ambient sound levels (both overall and frequency based) in key areas within a park;
- Establishing the different sound sources contributing to the baseline levels in key areas within a park;
- Modeling sound levels in other similar areas within a park for which resource constraints (or other issues) do not allow for direct measurements;

- Building a library of baseline ambient sound levels (both overall and frequency based), which may potentially be used in future ATMPs to generalize baseline ambient sound levels within similar types of parks, or park areas; and
- Provide input into the FAA's Integrated Noise Model (INM), which will be used to assess the complete acoustical environment within the entire park and aid in the assessment of a range of air tour alternatives. INM is a computer program used by over 700 organizations in over 50 countries to assess changes in noise impact. Requirements for INM use are defined in FAA Order 1050.1E, Environmental Impacts: Policies and Procedures, and Federal Aviation Regulations (FAR) Part 150, Airport Noise Compatibility Planning. In accordance with the results of the Federal Interagency Committee on Aviation Noise (FICAN) review ("Findings and Recommendations on Tools for Modeling Aircraft Noise in National Parks"), INM Version 6.2* is the best-practice modeling methodology currently available for evaluating aircraft noise in national parks and will be the model used for ATMP development.[3,4]

1.2 Report Organization

The presentation of this document, entitled "Baseline Ambient Sound Levels in Dry Tortugas National Park," begins with an executive summary. Section 1 presents an introduction and the objectives of this document. Section 2 overviews the process of measurement site selection with a brief description of the preliminary sites chosen. Section 3 discusses measurement methods, including instrumentation. Section 4 discusses data reduction. Section 5 discusses the results of the study. Section 6 discusses the development of ambient maps. A glossary and all related references are presented at the end of this document.

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

2. STUDY AREA AND SITE SELECTION

Dry Tortugas is located in the State of Florida as shown in Figure 8, approximately 70 miles west of Key West and is accessible only by private boats, charter boats, or seaplane. Designated a National Park in 1992 and encompassing nearly 100 square miles in south Florida.[5] Over 75,000 people visit the park annually.[6] Figure 9 provides a general overview of the areas within Dry Tortugas.

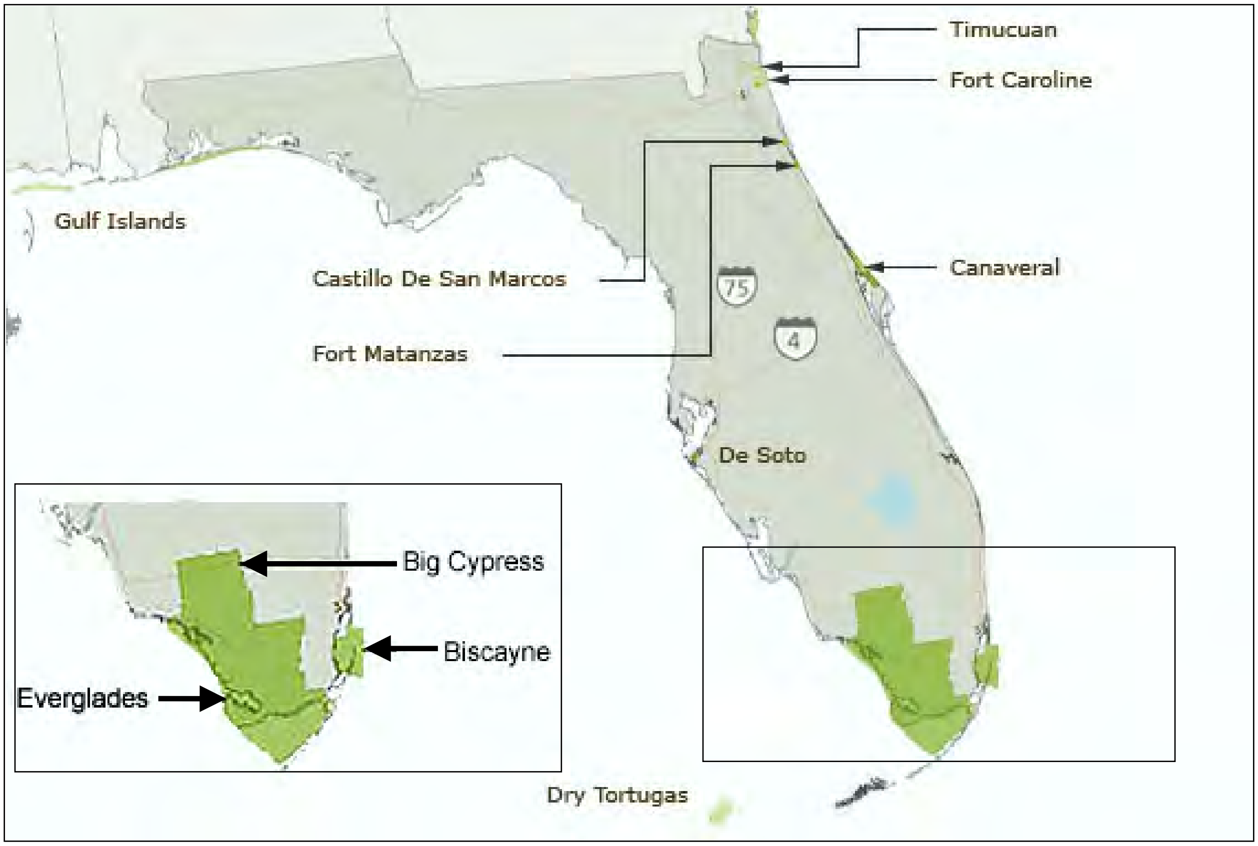

Figure 8. Location of Dry Tortugas National Park. [1]

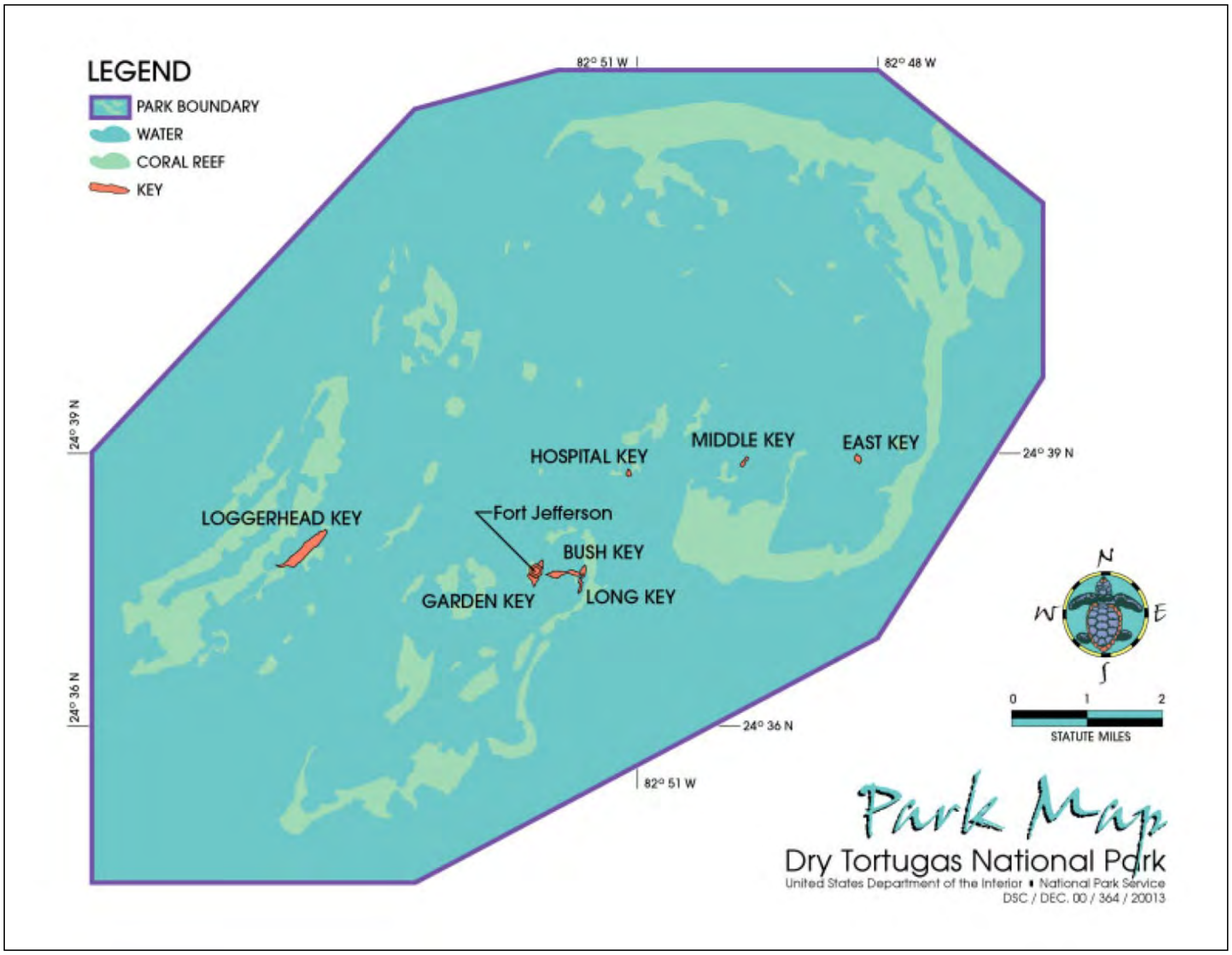

Figure 9. Overview map of Dry Tortugas. [5]

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.[7,8,9,10]

- *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 Dry Tortugas, and then combined with the following secondary criteria to determine the final sites selected (see Section 2.6):

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

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

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

2.2 Vegetation/Land Cover

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, as well as vegetation data provided by NPS, were used in the development of the acoustic zones. Measurement sites were selected to encompass as many of vegetative/topography types as possible.

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.[11]

Figure 10 provides an overview of the NLCD land cover in Dry Tortugas[*] used to develop initial acoustic zone recommendations, which included:

- Developed Zone (< 1% of area)
- Wetlands Zone (2% of area)
- Open Water Zone (98% of area)

[*] Because the ATMP Act includes the ½-mile outside the boundary of the national park, all zones also include land cover types located within the ½-mile buffer area.

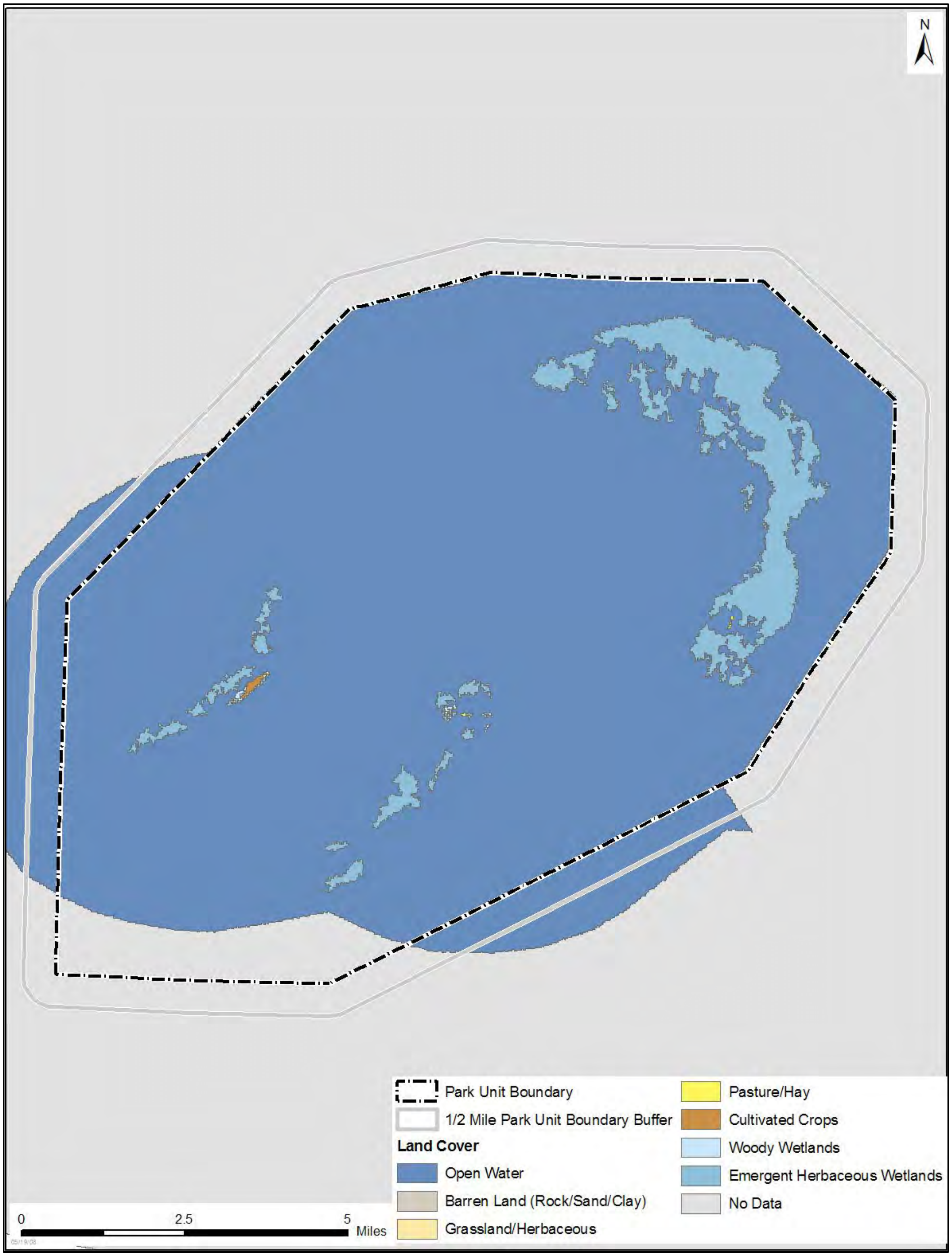

Figure 10. National Land Cover Database (NLCD) land cover types in Dry Tortugas.

2.3 Climate Conditions

Climatology can also affect baseline ambient sound levels, as sound propagates differently in cold dry regions as opposed to warm humid regions; and substantial differences in wildlife activity can also be expected with varying climatology. With the goal of potentially facilitating future data transferability between parks, all baseline acoustic data collected thus far have been organized by ecological division.[12] This approach has been closely coordinated with NPS personnel.[*]
Table 4 provides the monthly climate summary (averaged from 1924 to 1974) recorded by meteorological stations nearest the park.

Table 4. Monthly climate summary for Dry Tortugas.[13]

Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Wind Speed (mph)	11.8	11.9	12.0	12.2	10.5	9.6	9.4	9.2	9.5	10.8	12.0	11.7
Prevailing Direction	W	SE	SW	NEN	SE	S	ESE	SWS	ESE	NWN	ESE	WSW
Average Max Temp (F)	77	77	80	83	87	89	90	91	89	85	81	77
Average Min Temp (F)	65	65	68	72	75	77	78	78	77	74	70	66
Average Total Precipitation (in)	2	2	1	1	3	5	4	4	7	6	2	2
Average Total Snow Fall (in)	0	0	0	0	0	0	0	0	0	0	0	0
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0

2.4 Park Resources/Management Zones

Different zones designate different management purposes and the protection of different park resources (see Figure 11). Consideration of these zones is important in the site selection process.

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

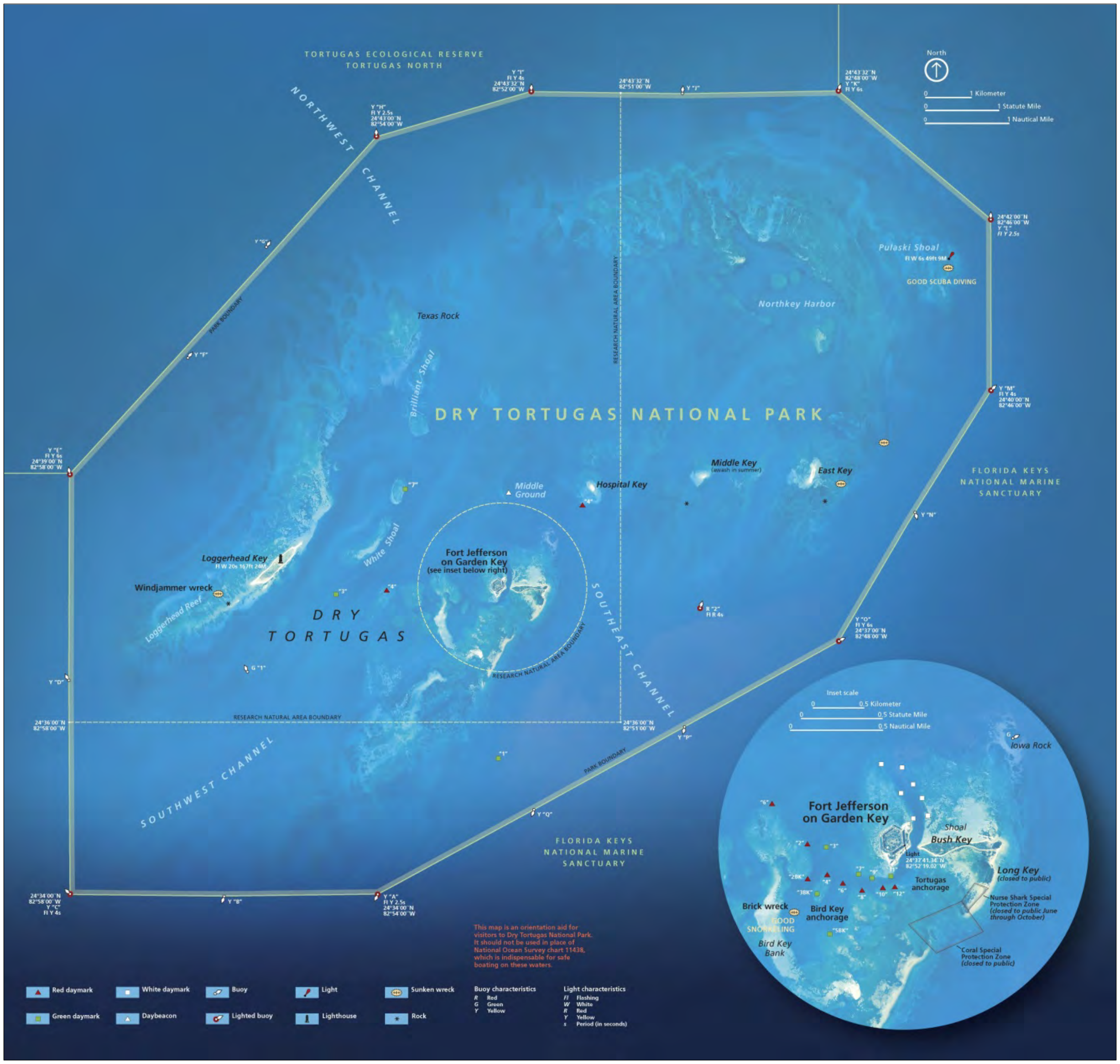

Figure 11. Dry Tortugas research natural areas. [5]

2.5 Commercial Air Tour Flight Routes

At the time of the acoustical monitoring study, there was one existing commercial air tour operator approved to provide 100 tours over Dry Tortugas annually. The map shown in Figure 12, which was provided to Volpe by FAA personnel, illustrates the typical air tour routes over Dry Tortugas.

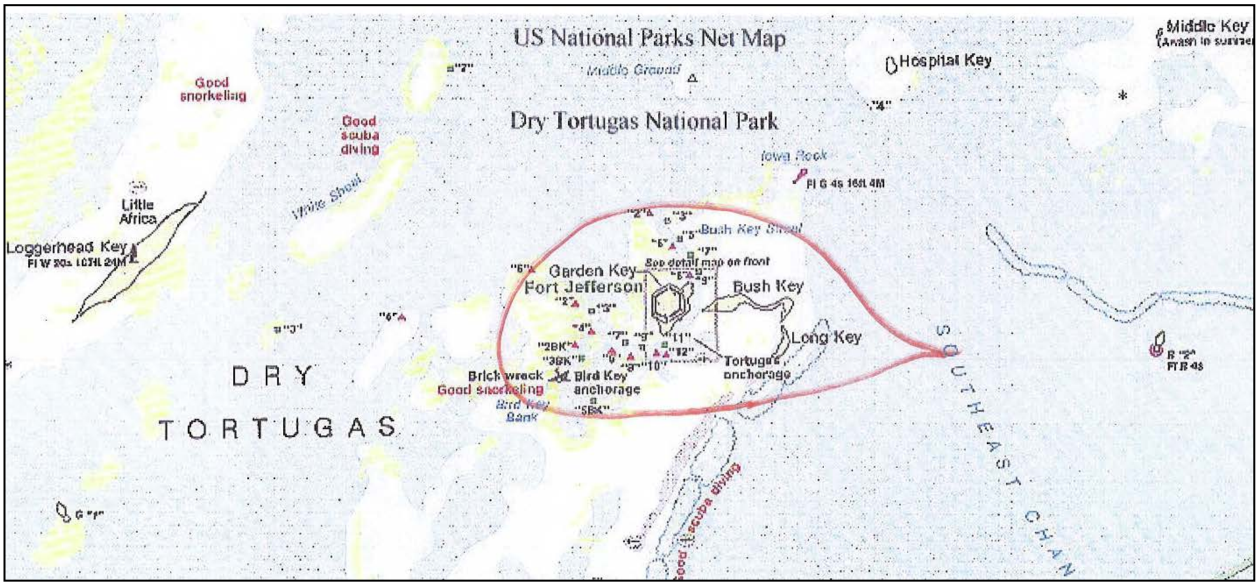

Figure 12. Air tour routes in the vicinity of Dry Tortugas.

2.6 Dry Tortugas Acoustic Zones

The final acoustic zones developed were:*

- Developed Zone (< 1% of area)
- Wetlands Zone (2% of area)
- Open Water Zone (98% of area)

With the goal of site selection to ensure at least one measurement location within each of the acoustic zones, Table 5 and Figure 13 display the locations of the final acoustic zones and measurement sites. Appendix A contains individual descriptions and photographs of each measurement site location.

Table 5. Summary of measurement site selected for Dry Tortugas.

Site ID	Site Name	National Land Cover Database Classification	Summer Coordinates (latitude/longitude in decimal degrees)	Winter Coordinates (latitude/longitude in decimal degrees)	Altitude (ft)	# Days of Data	
						Summer	Winter
DRTO 001	Fort Jefferson	Developed	24.62926° / 82.87163°	24.62863° / 82.87327°	1.6	4 days	49 days

* Because the ATMP Act includes the ½-mile outside the boundary of the national park, all zones also include land cover types located within the ½-mile buffer area.

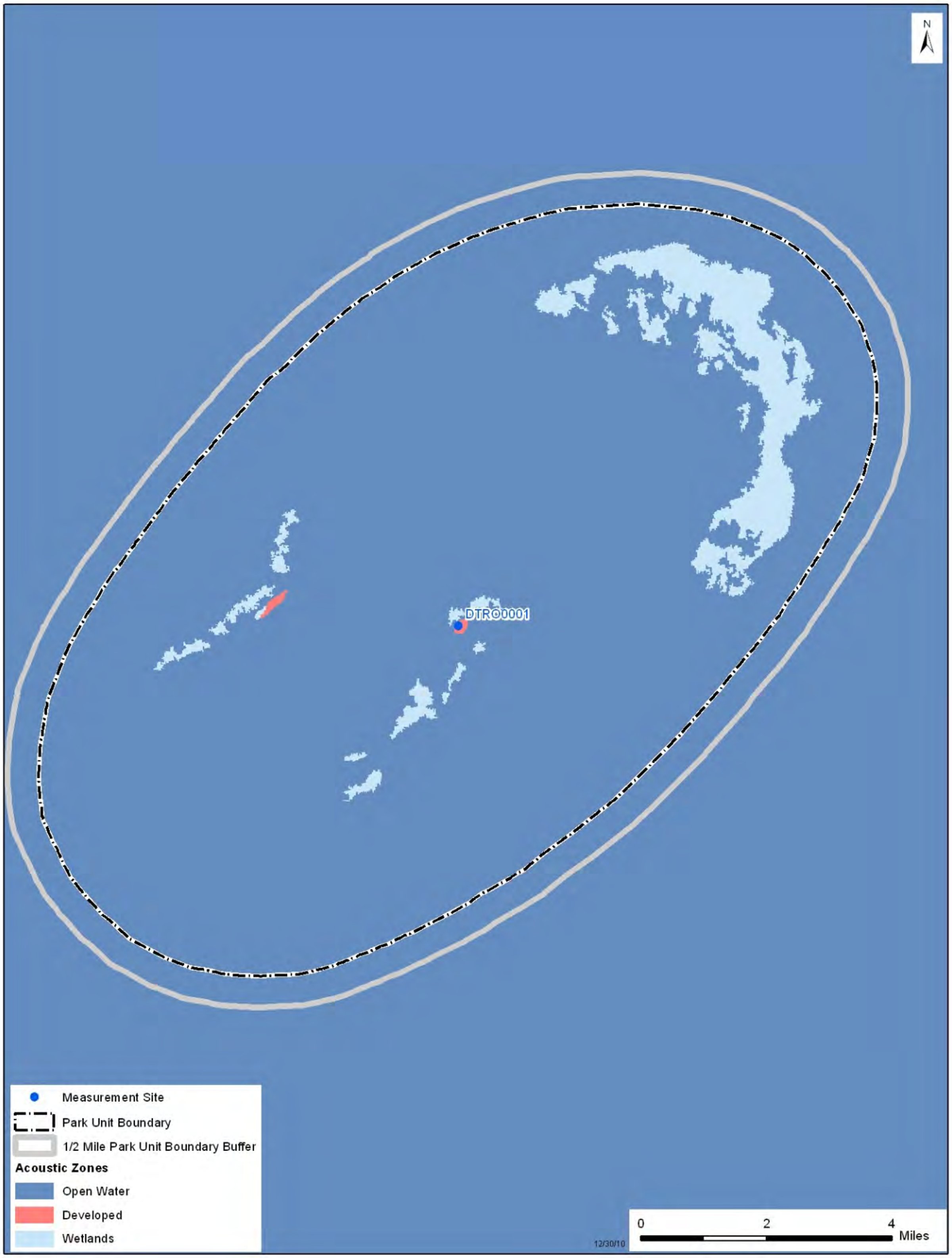

Figure 13. Final acoustic zones and measurement site for Dry Tortugas.

2.7 Temporal Considerations (Seasonal, Daily, and Duration)

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

2.7.1 Seasonal Considerations

Because the ultimate purpose of this data is to support impact assessment due to commercial air tours on park resources, acoustic data should be collected during the season (summer and/or winter) when air tours occur (not necessarily during the peak month of the activity, but during a month representative of the season when the activity occurs). Although air tours over Dry Tortugas are conducted only during winter, ambient measurements during both winter and summer seasons to provide data for both ATMP and soundscape purposes.

2.7.2 Time of Day Considerations

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

2.7.3 Measurement Duration

Based on long-term ambient data collected in Hawai`i Volcanoes National Park[14], as well as a joint review of acoustic literature and other relatively recent long-term NPS ambient studies in Bryce Canyon National Park and Arches National Park,[15] a 3-dB variability was achieved between 10, 25, and 40 days, depending on individual site variables/ characteristics. Since 2005, the FAA and NPS have jointly agreed that a minimum 25-day measurement period would be conducted for all future ATMP acoustic monitoring to limit measurement uncertainty to 3 decibels. An exception to the 25-day requirement would be for measurements in close proximity to localized sound sources, which generally don't vary substantially in level, such as waterfalls, river rapids, 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. METHODS

3.1 Automatic Monitoring

Larson Davis 831 sound level meters (SLM) were employed during the monitoring periods at Dry Tortugas. The Larson Davis SLM is a hardware-based, real-time analyzer which constantly records one second sound pressure level (SPL) and 1/3 octave band data, and exports these data to a portable storage device (thumb drive). These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards.

Each Larson Davis sampling station consisted of:

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

Each acoustic sampling station collected:

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

3.2 Source Identification/Observer Logging

In characterizing natural and non-natural acoustic conditions in a park, knowledge of the intensity, duration, and distribution of the sound sources is essential. Thus, during sound-level data collection, FAA and NPS have agreed that periods of observer logging "*in situ*" (i.e., on site and in real-time) and/or post measurements using high-quality digital recordings will be conducted in order to discern the type, timing, and duration of different sound sources. *In situ* observer logging takes full advantage of human binaural hearing capabilities, allows identification of sound source origin, simultaneous sound sources, and directionality, and closely matches the experience of park visitors. Off-site audio playback observer logging allows for sampling periodically throughout the entire measurement period (e.g., 10 seconds every 2 minutes) and repeated playback of the recordings (e.g. when the sound is difficult to identify). Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustic environment.

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4. DATA REDUCTION AND PROCESSING

This section summarizes the steps involved in the reduction and processing of the acoustic and meteorological data. These data were used by the Volpe Center as input to its data processing program, entitled NLcrunch. 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.

4.1 Data Processing

The NLcrunch program applies several quality assurance filters and checks (Section 4.1.1), and then several adjustments (Section 4.1.4) to the acoustic data prior to detailed data analysis.

4.1.1 Data Filters

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

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

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

- Data whose associated 1-second average wind speeds were greater than 11 mph (5 m/s). Note: Available data suggests that there is a high probability of microphone-induced distortion above this wind speed threshold; however, unless such wind conditions occur more than 50 percent of the hour, exceedence metrics (e.g., L_{50}, L_{90}) will not likely be influenced. If necessary, a portion of this data may be included in the final data set. This process is referred to as "backfilling" (see Section 4.1.3).
- 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 5.1.2 for guidance on pooled versus un-pooled

data, and Section 5.1.3 for guidance to potentially recover hourly datasets with data loss due to high wind conditions (i.e., backfilling).

4.1.2 Data Pooling

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

The FAA and NPS have agreed that ambient analysis for ATMP parks will be performed using unpooled, hourly summary data. Although prior studies[16] have shown that results for pooled analyses are generally more conservative (i.e., lower) than results for an hourly analysis, analyzing ambient data by hour helps to ensure hour-to-hour and day-to-day variation is addressed. For hourly data analyses, hourly datasets are discarded for those hours that contain less that 75 percent of "good" data. This ensures hours with only a few samples do not bias the analysis.

4.1.3 Data Recovery for High Wind

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

Based on recent Volpe analyses[17] of ambient data previously collected within ATMP parks, it was determined that up to 10% of any hourly measurement dataset can consist of high-wind data before a significant change to the statistical median (L_{50}) is observed. For the majority of measurement hours, this allowed for almost all of the measured data to be used in the hourly estimates (i.e., at the majority of sites measured for the ATMP project, high-wind data represented less than 10 percent of the dataset).

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

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

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

4.1.4 Data Adjustments

The following is the list of adjustments generally applied to acoustic data by the NLcrunch program, pending their availability:

- Gain adjustments, if available.
- Calibration adjustments, if available. 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, if available. These adjustments accounted for frequency response biases of the microphone and were provided by a microphone calibration facility.
- Windscreen frequency response adjustments, if available. These adjustments accounted for frequency response effects of the windscreen.
- Noise floor adjustments, if available. 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 acoustic 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.

4.2 Sound Level Descriptors

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

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

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

4.3 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. 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.

4.4 Ambient Descriptors

The following four types of "ambient" characterizations are generally used and considered sufficient by the FAA and NPS in environmental analyses related to transportation noise: [16,18,19]

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

case, all types of aircraft (i.e. commercial air tours, commercial jets, general aviation aircraft, military aircraft, and agricultural operations);* and

- *Natural Ambient:* The natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excluding all human and mechanical sounds.

If one considers the three sound level descriptors presented in Section 4.2 and the four types of ambient characterizations above, twelve ambient descriptors could potentially be computed as shown in Table 6.

Table 6. Matrix of twelve potential ambient descriptors

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

From the above twelve potential ambient descriptors, only the first three can be readily computed (see Section 4.5). The computation of ambient types other than Existing Ambient is more challenging because different sound sources often overlap in both frequency and amplitude; there is currently no practical method to separate out acoustic energy of different sound sources (i.e., human-caused sounds imbedded with natural sounds). The two ambient descriptors agreed upon for use in ATMP analyses are:

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

4.5 Calculation of Ambients

Using the data in the acoustic observer logs, different characterizations of ambient can be *estimated* from the sound level data. This method was developed by performing a detailed data analyses conducted by the Volpe Center, working closely with the NPS, in comparing several approaches of estimating of the Natural Ambient and is comprised of the following steps:[20]

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

the loudest 40 percent of the A-weighted level data is removed. The L_{50} computed from the remaining data is the estimated A-weighted natural ambient. This L_{50}, computed from the remaining data, can be mathematically expressed as an L_x of the entire dataset as follows (%TA is the percent of time human-caused sounds are audible in the short-term observer logs):

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

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

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

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

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

5. RESULTS

This section summarizes the results of the study. Included are an overall summary of the final, ambient sound levels for each measurement site (Section 5.1), time above results (Section 5.2), temporal trends (Section 5.3), and the acoustic observer data logged at each measurement site (Section 5.4).

Figure 14. Photograph of Site DRTO001 – summer and winter, respectively.

The DRTO001 measurement location was in two different positions for the summer and winter measurement period. The summer location was outside the Fort itself and near the shoreline while the winter measurement was conducted in the interior of the Fort. The summer measurement site was located at a position on the east shoreline of the island and near a maintenance facility. Fort Jefferson is located on a coastal Key and was subject to a wide variety of human and natural sounds. Human sounds included aircraft, watercraft, visitor voices, lawn maintenance equipment, and generator noise. Natural sources included birds (seafowl primarily), wind related sounds and surf and water lapping against the shore and also some insect noise in the summer. The summer measurement was truncated due to Tropical Storm events and equipment difficulties, the result being that there were four useable days of data for the summer measurement where the ATMP target is twenty five days of data.

The DRTO001 measurement location was moved in the winter measurement from the coastal, seashore position to a location inside the Fort itself. Inside the Fort, the soundscape was primarily defined by human activities related to the Fort, including construction noise.

Additional, unique sounds were apparent inside the Fort as well, including the sound of wind rushing through the Fort structure. Winter human sources of sound included diesel engine sounds, watercraft, visitor conversation and children's voices. Construction noise was also apparent in the winter, including generators. Natural sources of sound in the winter measurement included birds, wind related sounds, and some surf noise was noted. There was no audible insect presence in the winter measurement.

5.1 Summary Results

The following figures and tables are presented:

- Figure 15: A plot of the overall daytime[*] L_{50} sound level computed for each site with all days included for the summer and winter seasons, respectively (a few points of interest outside the parks are also shown for comparison purposes only). The figure also shows a dark line above and below each plotting symbol, which indicate the 95% confidence interval on the results[†];
- Table 7 contains a summary of the ambient, sound level data measured at each measurement site for both summer and winter seasons; and
- Table 8 through Table 9, and Figure 16 through Figure 23 present the associated spectral data for the two ambient maps agreed upon for use in ATMP analyses: Existing Ambient Without Air Tours (L_{50}) and Natural Ambient (L_{50}).

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

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

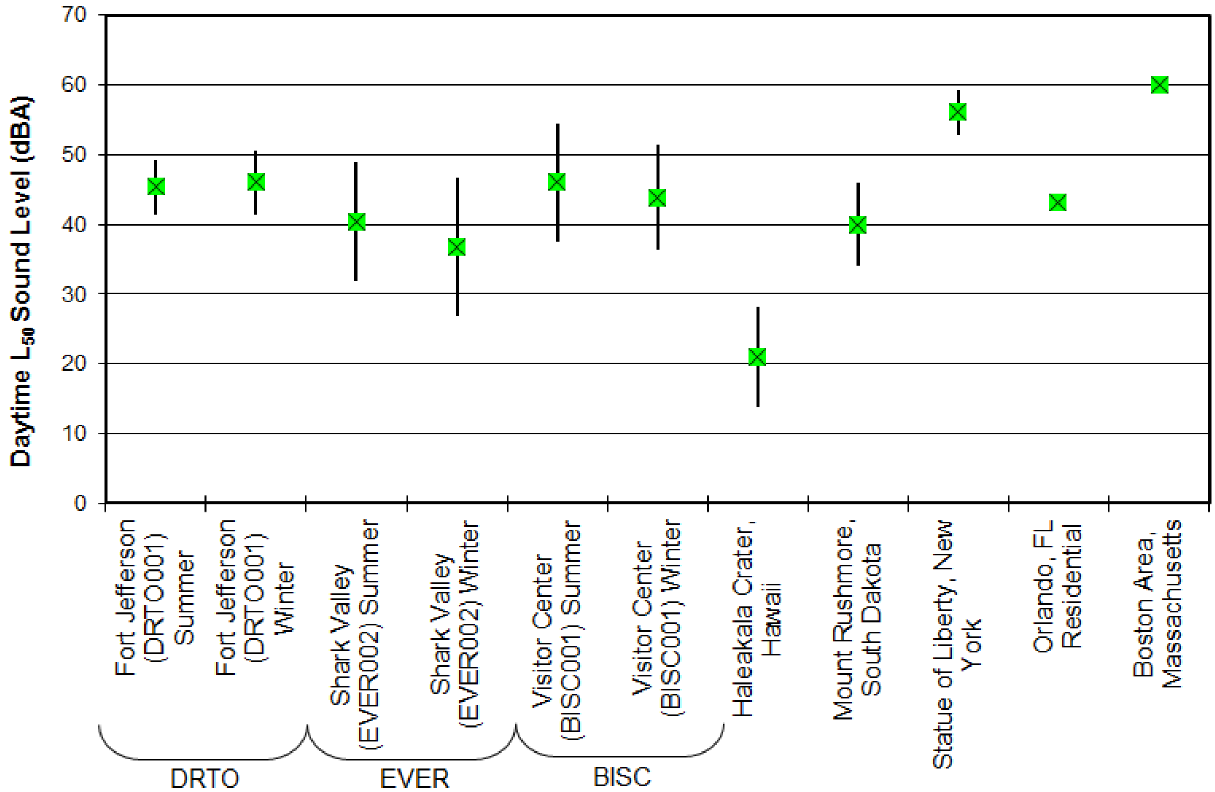

Figure 15. Comparison of overall daytime L_{50} sound levels for all sites for the summer and winter seasons.*

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

Table 7. Summary of measured ambient sound level data for both summer and winter seasons. [*]

Acoustic Zone	Site Name	Site ID	Total # Days	Existing Ambient						Existing Ambient Without Air Tours		Existing Ambient Without All Aircraft		Natural Ambient	
				Daytime Data (7 am to 7 pm)			Nighttime Data (7 pm to 7 am)			Daytime	Night-time	Daytime	Night-time	Daytime	Night-time
				L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)	L_{50} (dBA)
Summer Season															
Developed	DRTO001	Fort Jefferson	4	47.9	45.3	36.3	47.7	46.3	40.6	45.3	46.3	44.7	46.3	37.8	46.2
Winter Season															
Developed	DRTO001	Fort Jefferson	49	50.5	46.0	42.1	45.9	43.5	40.1	46.0	43.5	45.8	43.5	42.1	40.1

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

Table 8. Summary of measured, daytime and nighttime ambient sound level spectral data for the summer season.*

Frequency (Hz)	Existing Ambient Without Air Tours L_{50} (dB)		Natural Ambient L_{50} (dB)	
	Daytime (7 am to 7 pm)	Nighttime (7 pm to 7 am)	Daytime (7 am to 7 pm)	Nighttime (7 pm to 7 am)
	DRTO001	DRTO001	DRTO001	DRTO001
12.5	46.7	31.6	37.3	40.0
16	44.0	29.0	35.6	36.7
20	41.0	27.9	33.6	33.9
25	39.3	28.0	33.8	31.9
31	39.8	30.3	33.5	38.9
40	35.7	29.8	29.5	38.6
50	37.5	31.6	34.0	34.3
63	38.2	33.8	35.8	36.6
80	35.4	27.1	30.4	32.4
100	32.0	27.7	29.8	30.7
125	35.7	28.0	30.7	31.6
160	31.4	25.2	27.5	27.7
200	30.1	25.5	27.2	28.1
250	29.9	25.3	27.1	28.4
315	30.8	26.7	28.1	29.7
400	31.7	28.6	29.3	30.9
500	33.3	30.6	30.9	32.7
630	34.7	32.0	32.4	34.2
800	35.7	32.7	33.3	35.0
1000	35.3	33.0	33.0	35.4
1250	35.1	32.6	32.7	35.4
1600	34.7	32.0	32.3	35.2
2000	34.4	32.3	31.3	36.0
2500	33.9	31.7	30.3	36.2
3150	32.2	29.4	28.1	33.9
4000	29.1	27.0	25.8	31.3
5000	27.5	26.5	24.1	30.5
6300	25.8	25.2	22.4	28.9
8000	24.0	24.9	20.8	28.4
10000	23.2	22.7	20.2	26.6
12500	21.8	21.1	19.2	24.8
16000	19.7	19.1	18.2	21.6
20000	18.8	18.5	18.5	19.2

* As discussed in Section 4.5, the spectral data associated with the L_{50} exceedence level is constructed by determining the L_{50} from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

Table 9. Summary of measured, daytime and nighttime ambient sound level spectral data for the winter season.*

Frequency (Hz)	Existing Ambient Without Air Tours L_{50} (dB)		Natural Ambient L_{50} (dB)	
	Daytime (7 am to 7 pm)	Nighttime (7 pm to 7 am)	Daytime (7 am to 7 pm)	Nighttime (7 pm to 7 am)
	DRTO001	DRTO001	DRTO001	DRTO001
12.5	45.2	44.9	38.5	39.1
16	43.2	42.2	37.5	37.2
20	42.4	40.6	37.5	36.4
25	42.4	40.3	37.7	36.0
31	43.0	40.0	39.1	36.6
40	55.1	40.8	52.3	38.0
50	67.1	41.2	64.7	39.2
63	54.5	52.8	52.4	51.2
80	43.9	39.6	40.8	37.9
100	44.1	37.8	41.3	36.1
125	47.1	45.1	44.7	43.2
160	40.9	36.9	38.5	35.1
200	37.9	33.1	35.8	31.7
250	35.3	31.6	33.2	29.8
315	34.3	32.3	31.7	29.9
400	34.3	33.9	31.9	31.5
500	34.4	33.9	32.0	32.3
630	34.7	34.3	33.0	32.7
800	33.8	33.5	31.9	31.9
1000	34.0	34.1	31.9	32.3
1250	33.2	32.8	31.2	31.4
1600	32.1	31.4	30.3	30.1
2000	33.4	32.3	31.3	30.8
2500	34.4	32.3	32.0	30.5
3150	30.8	27.9	28.2	26.3
4000	25.0	24.8	22.7	22.1
5000	22.8	21.3	19.3	19.3
6300	21.2	21.1	16.9	18.9
8000	17.3	14.8	13.2	11.6
10000	14.6	12.5	10.5	8.7
12500	11.0	9.2	7.6	5.8
16000	6.6	4.2	3.7	1.9
20000	1.9	0.4	0.3	-0.7

* As discussed in Section 4.5, the spectral data associated with the L_{50} exceedence level is constructed by determining the L_{50} from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

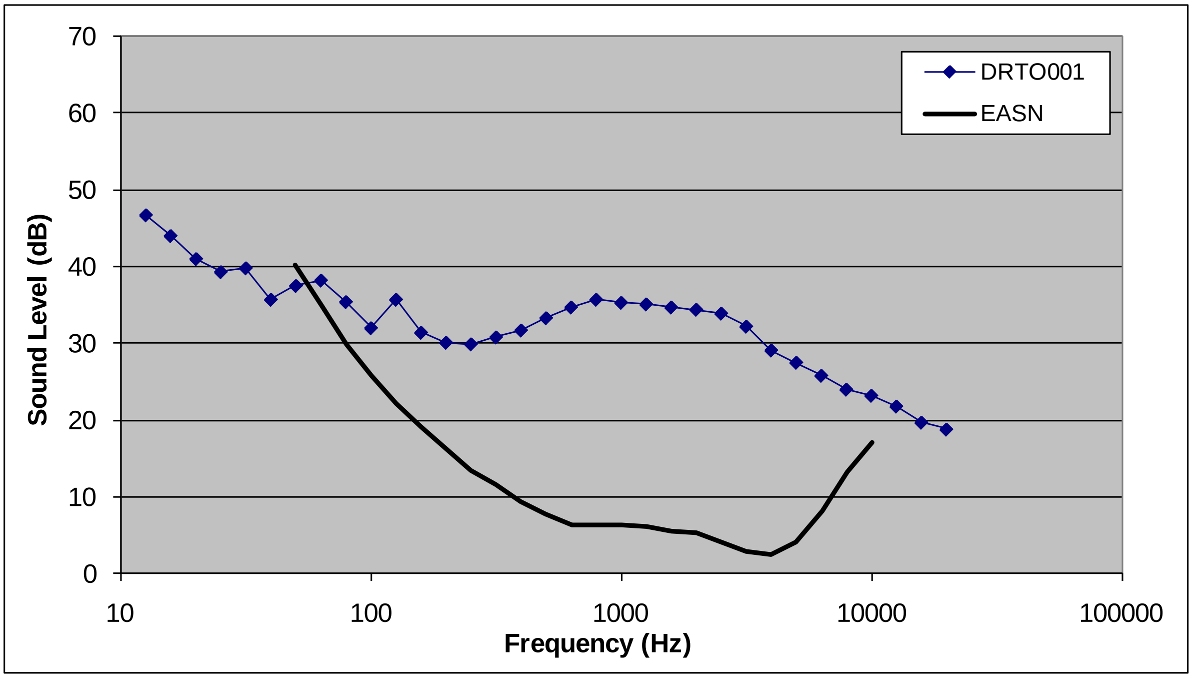

Figure 16. Daytime spectral data for the Existing Ambient Without Air Tours (L_{50}) for each site for the summer season.*

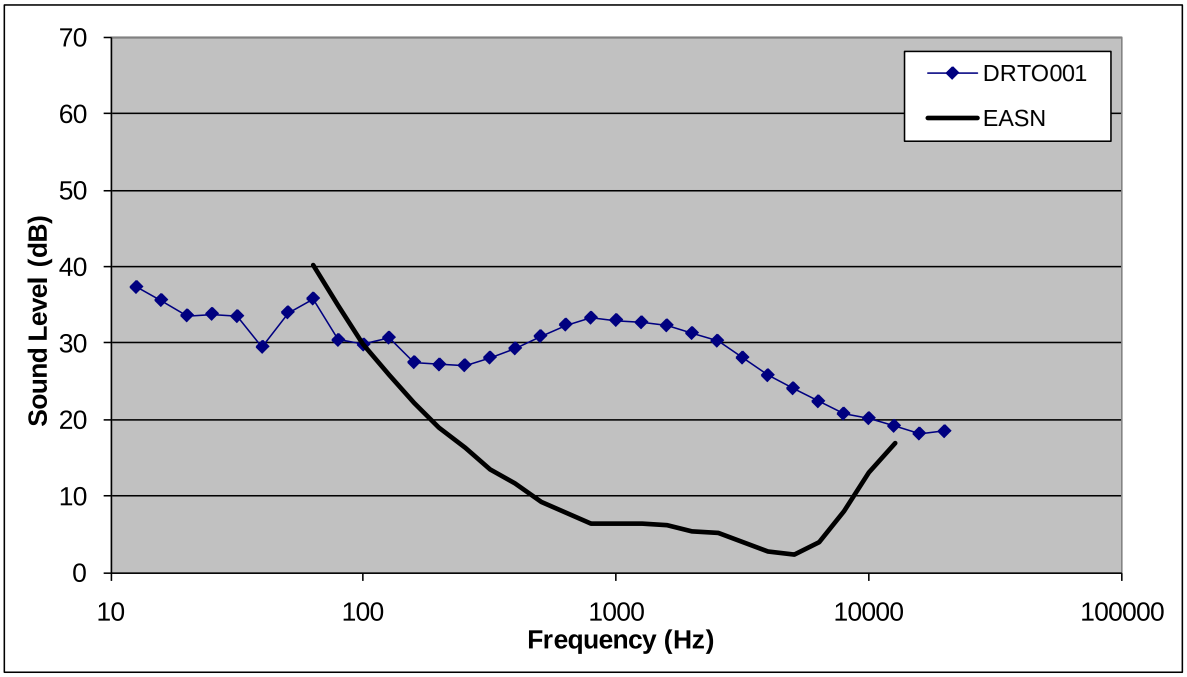

Figure 17. Daytime spectral data for the Natural Ambient (L_{50}) for each site for the summer season. *

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

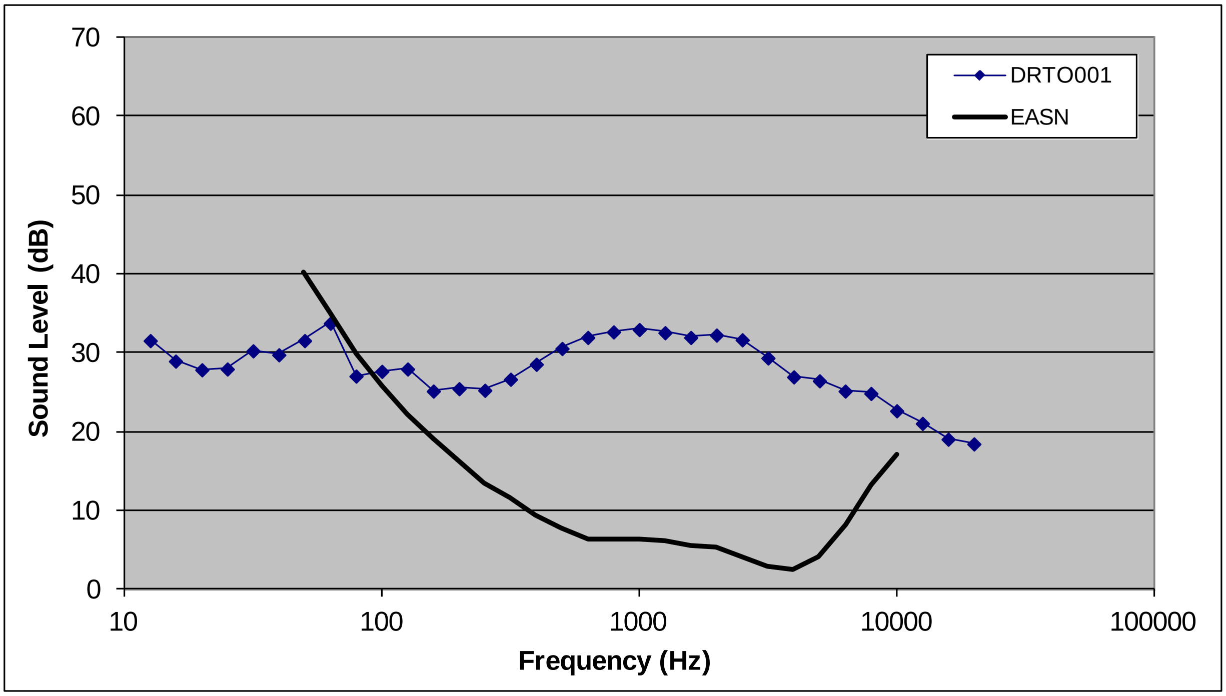

Figure 18. Nighttime spectral data for the Existing Ambient Without Air Tours (L_{50}) for each site for the summer season. *

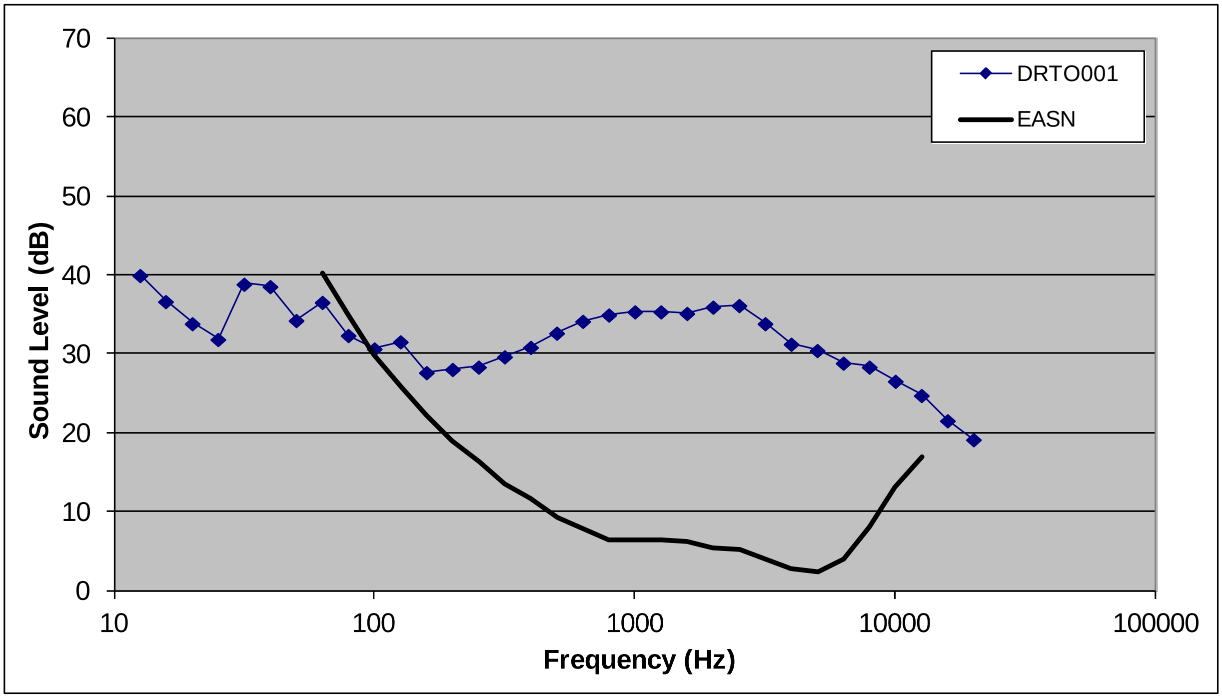

Figure 19. Nighttime spectral data for the Natural Ambient (L_{50}) for each site for the summer season. *

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

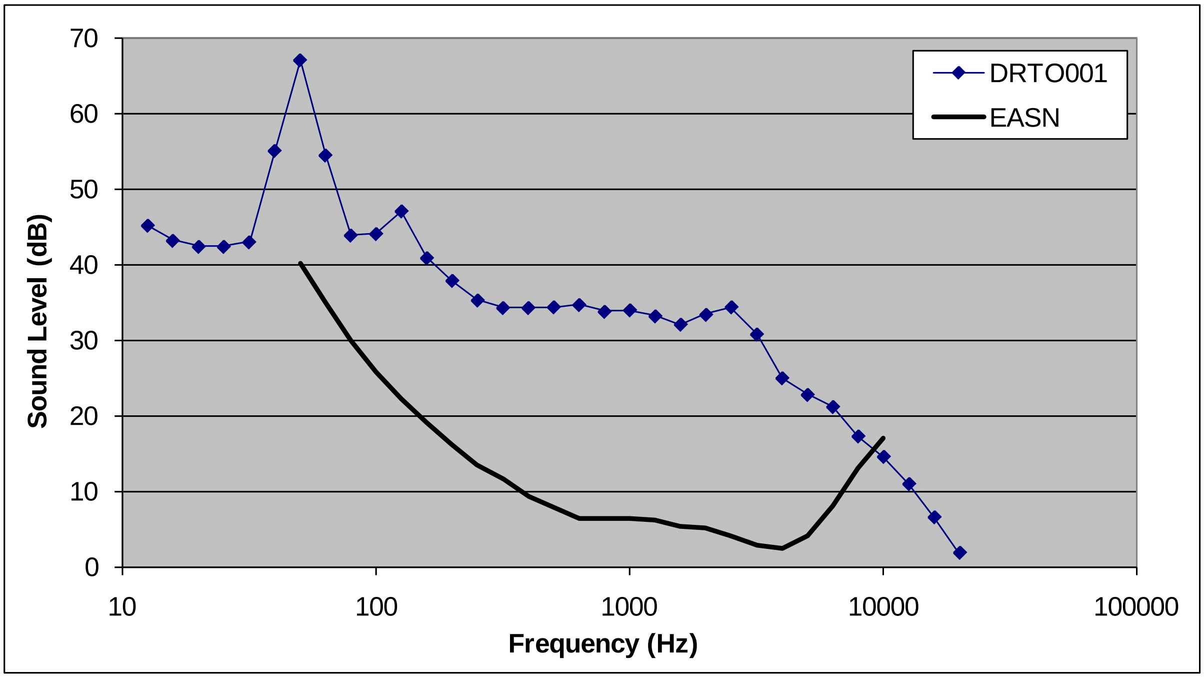

Figure 20. Daytime spectral data for the Existing Ambient Without Air Tours (L_{50}) for each site for the winter season.*

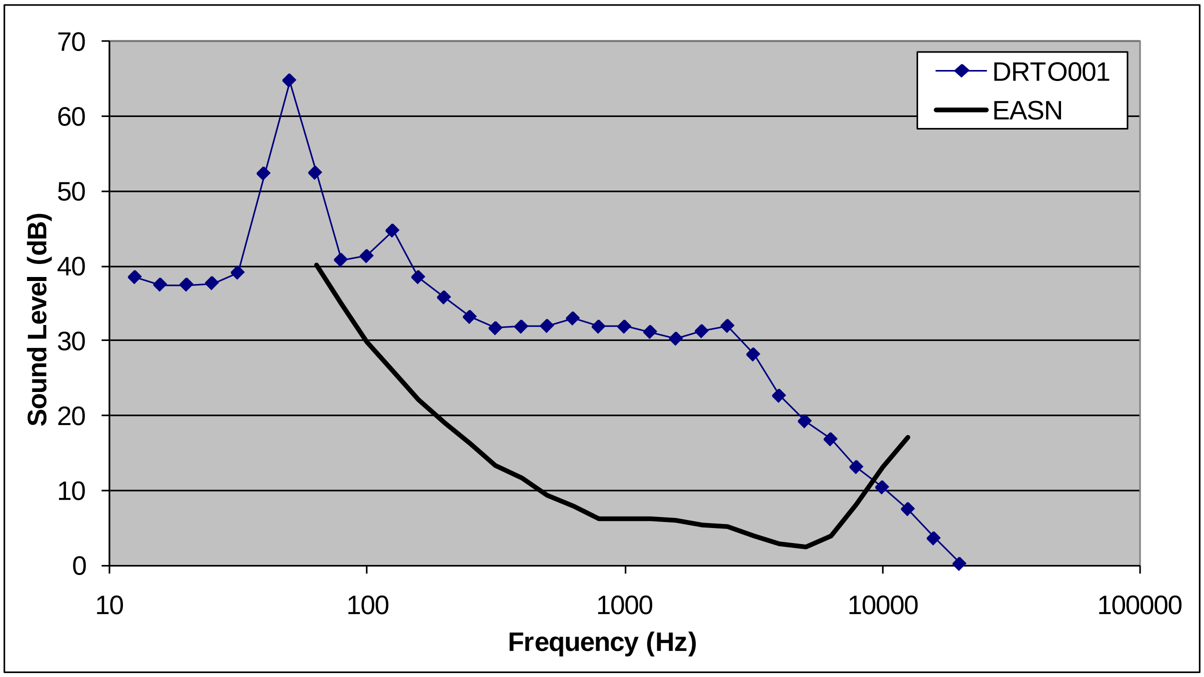

Figure 21. Daytime spectral data for the Natural Ambient (L_{50}) for each site for the winter season.*

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

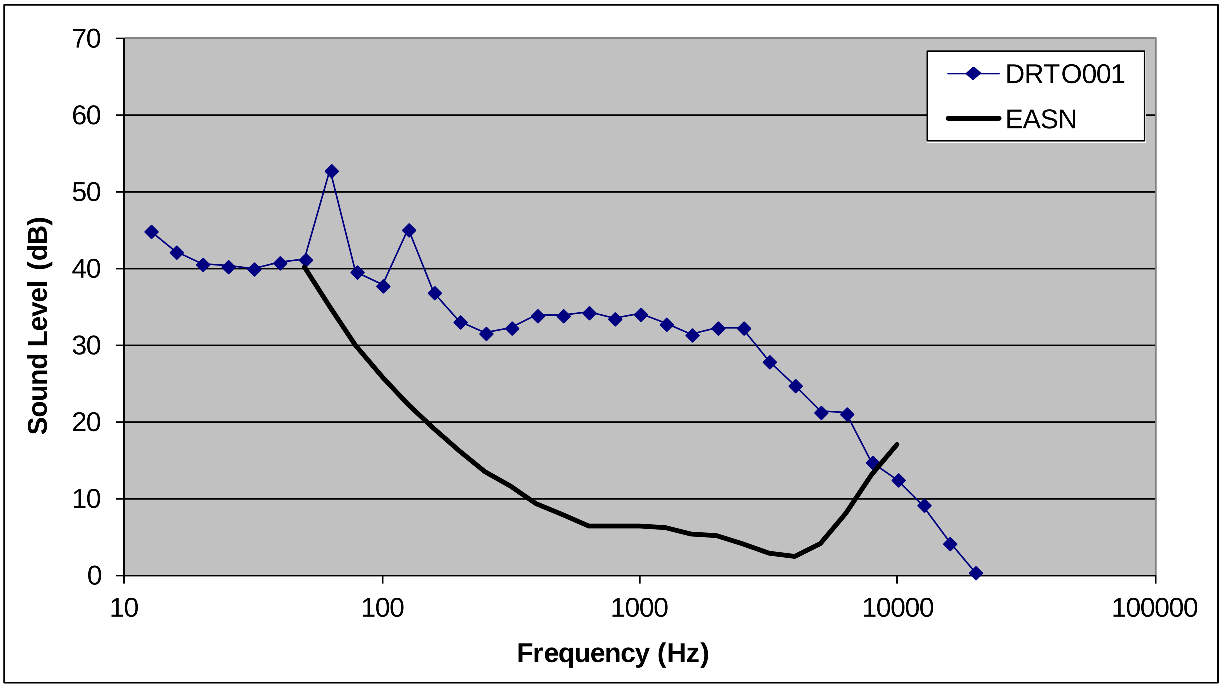

Figure 22. Nighttime spectral data for the Existing Ambient Without Air Tours (L_{50}) for each site for the winter season.*

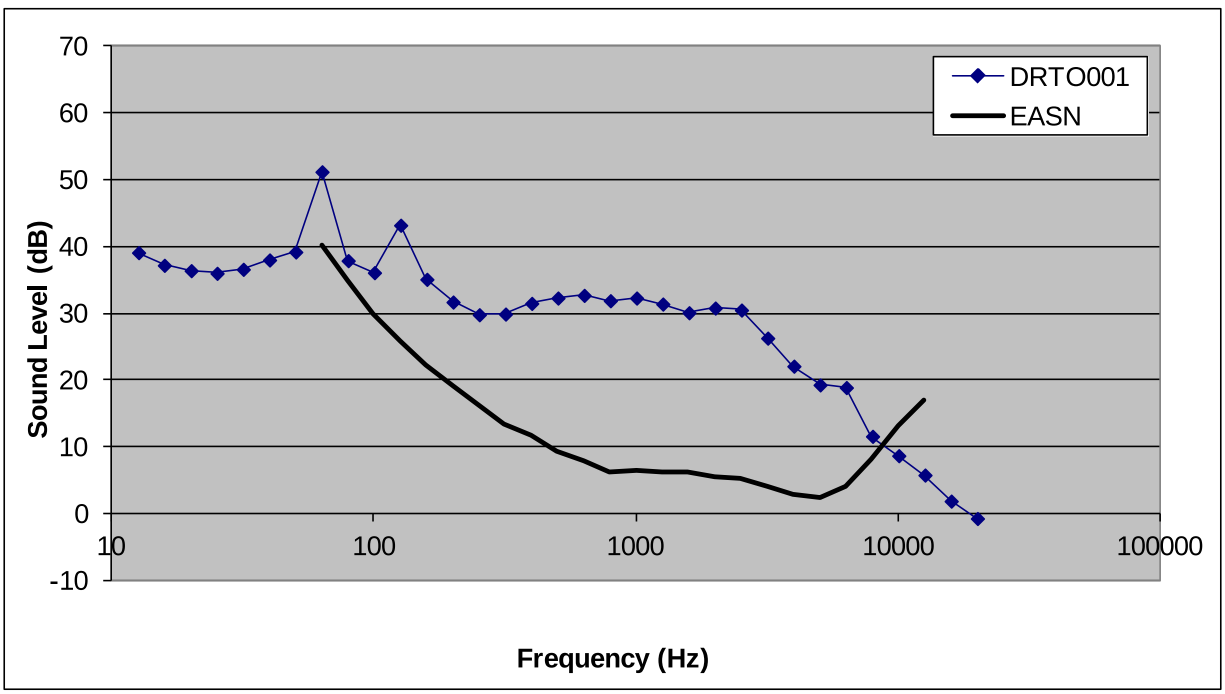

Figure 23. Nighttime spectral data for the Natural Ambient (L_{50}) for each site for the winter season.*

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

5.2 Time Above Results

The Time Above metric indicates the amount of time that the sound level exceeds specified decibel values. In determining the current conditions of an acoustical environment, the NPS examines how often sound pressure levels exceed certain decibel values that relate to human health and speech. The NPS uses these values for making comparisons, but should not be construed as thresholds of impact. Table 10 reports the percent of time that measured levels were above four decibels values at each of the Dry Tortugas measurement locations. The first decibel value, 35 dBA, addresses the health effects of sleep interruption.[21] The second value addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA.[22] The third value, 52 dBA, is based on the Environmental Protection Agency's speech interference threshold for speaking in a raised voice to an audience at 10 meters.[23] This value addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m (3 ft). Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

Table 10. Percent Time Above results for the summer season

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Summer Season									
DRTO 001	Fort Jefferson	93%	52%	5%	0%	100%	62%	3%	0%
Winter Season									
DRTO 001	Fort Jefferson	100%	61%	9%	1%	100%	34%	3%	0%

5.3 Temporal Trends

This section discusses the daily and diurnal trends of the data.

- Daily trends are shown on a 24-hour basis. Figure 24 and Figure 25present distribution plots of the number of 1-second samples of each sound pressure level measured during daytime and nighttime hours, and daytime/nighttime combined for the summer and winter seasons, respectively.
- Figure 26 and Figure 27present the daily sound levels using three hourly A-weighted metrics (L_{Aeq}, L_{50}, and L_{90} - refer to Terminology for definitions), as well as average daily wind speeds over the entire measurement period for the summer and winter seasons, respectively. For the purpose of assessing daily trends in the data, sound level descriptors are computed for each individual hour; then the median from the 24 hours each day is determined. Dips and increases in daily sound levels are usually an indication of passing inclement weather and localized events. This data is useful in visually identifying potential anomalies in the data.

Data anomalies would then be further examined from data recorded by the sound level meter and/or recorded audio samples.

- Diurnal trends are shown on an hourly basis. Figure 28 and Figure 29 present the hourly sound levels using three hourly A-weighted metrics (L_{Aeq}, L_{50}, and L_{90} - refer to Terminology for definitions), as well as average hourly wind speeds over the entire measurement period for the summer and winter seasons, respectively. Sites with a strong daytime diurnal pattern typically indicate the presence of human activity largely influencing the sound levels at those sites. Sites with a nighttime pattern typically indicate the presence of insect activity. Sites with little discernible pattern, e.g., somewhat constant across all hours, typically indicates a constant sound source. Examples of constant sound sources include nearby generators or shoreline surf. This data is also useful in visually identifying potential anomalies in the data.

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

The sound level distributions and hourly sound level results indicate that the summertime sound levels were similar during daytime and night time periods (the nighttime overall median sound level was 1 dBA higher than during the day). This normally indicates a constant sound source in the area and the action of the wind and surf near the measurement location is the primary reason for similar levels during day and night. The winter measurements resulted in louder daytime levels (approximately 3 dBA louder than at night) and this was due to the heavy human presence near the winter measurement location during daytime hours. There is a noticeable decrease in the summer hourly sound level at the 4:00 p.m. hour and this corresponded to a lull in bird activity, winds, surf sounds and aircraft/watercraft sounds during this time period. The winter hourly sound levels indicate the presence of loud events near the measurement system - this can be seen in the hourly L_{Aeq} results. The L_{Aeq} metric is much more sensitive to loud, short duration events than the L_{50} metric. Lawn maintenance activities were taking place near the measurement system during the day of April 4, 2009, causing elevated levels during the morning and afternoon hours for that day.

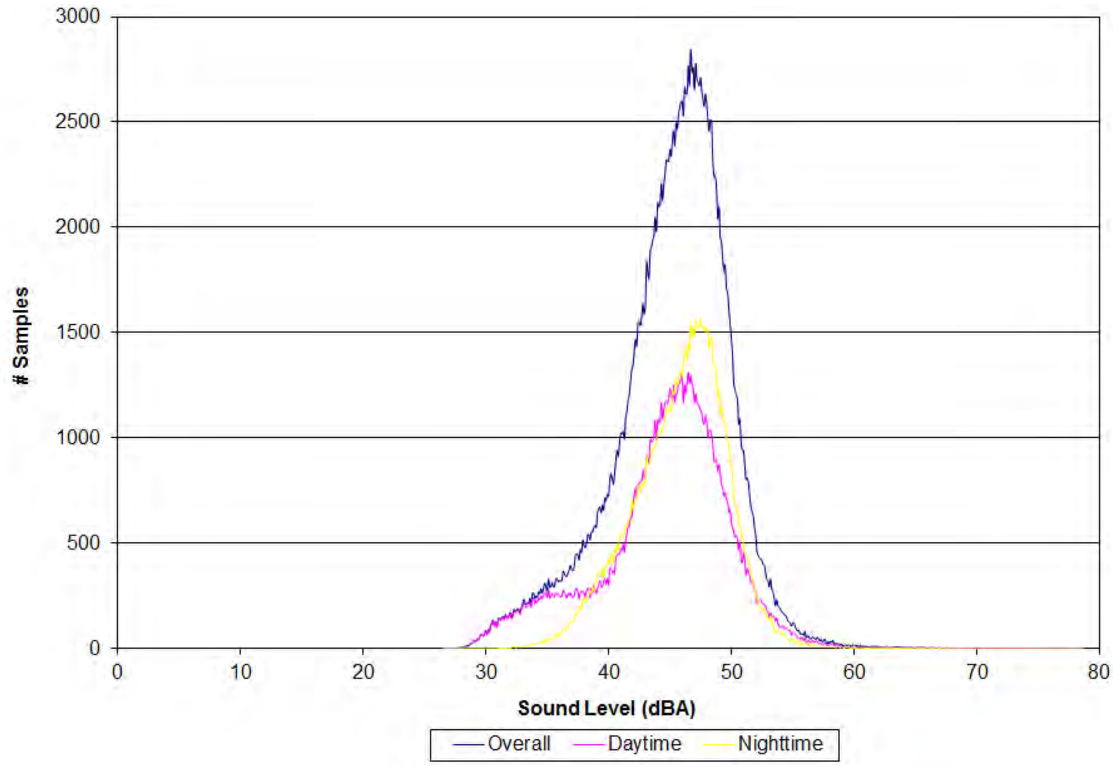

Figure 24. Distribution of data for Site DRTO001 for summer season.

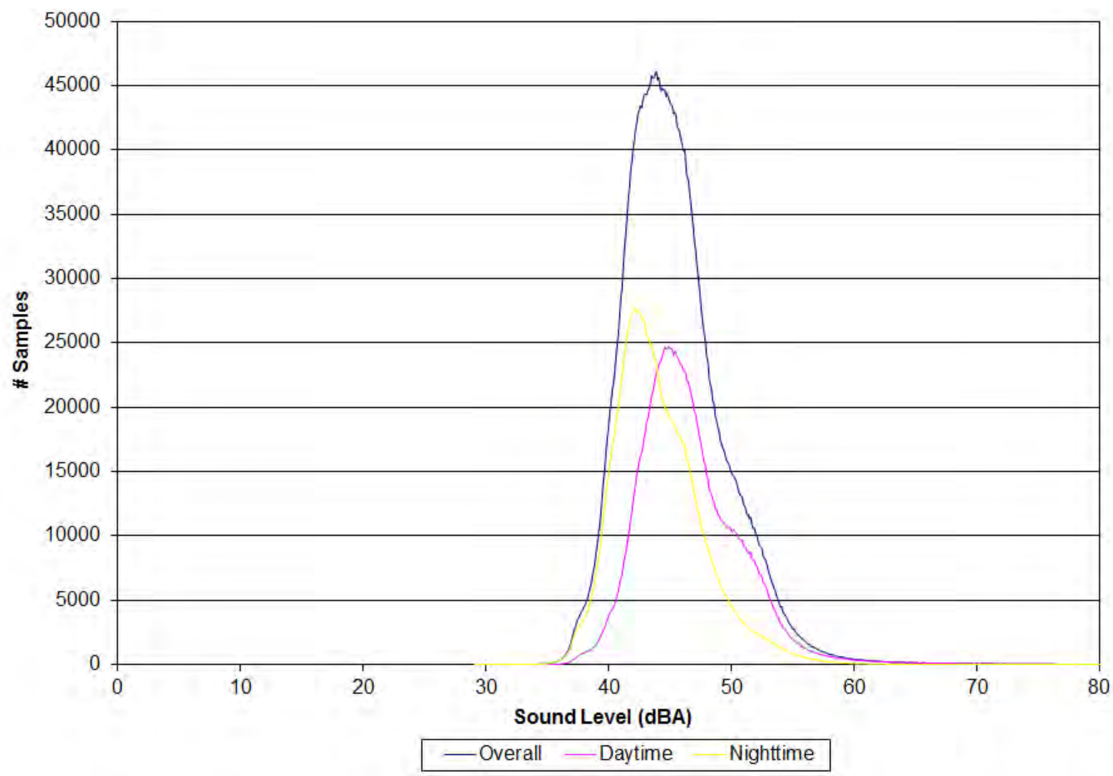

Figure 25. Distribution of data for Site DRTO001 for winter season.

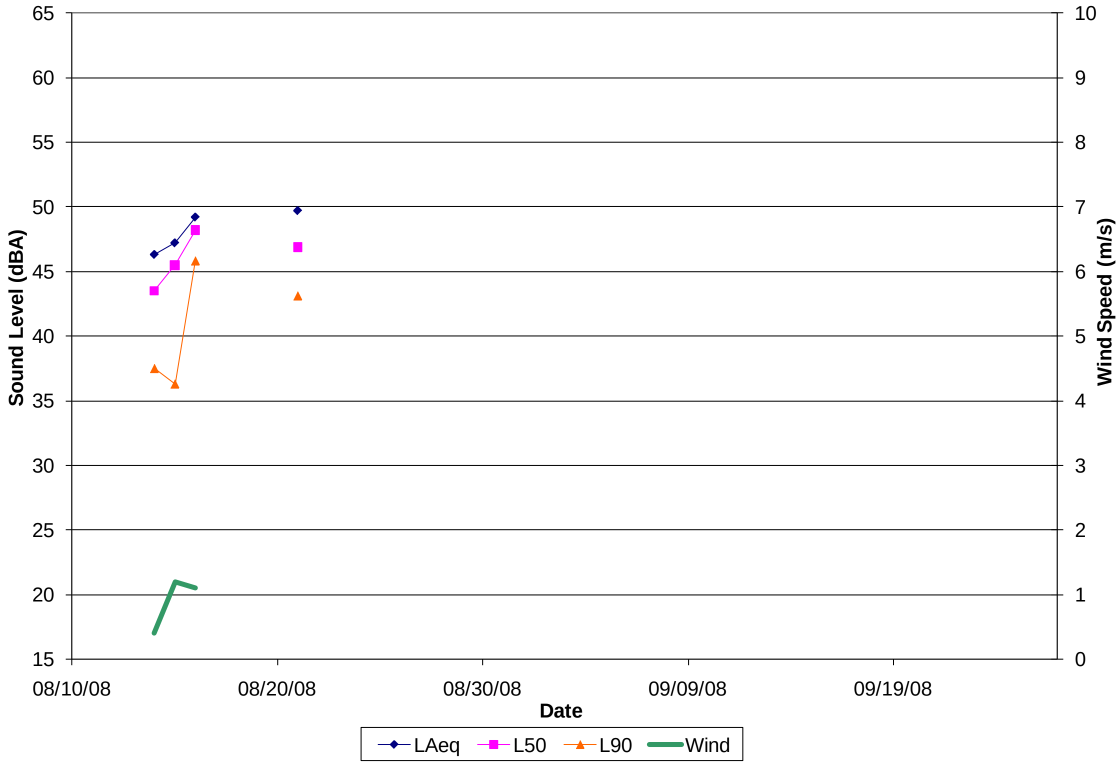

Figure 26. Daily sound levels and wind speeds for the summer season.

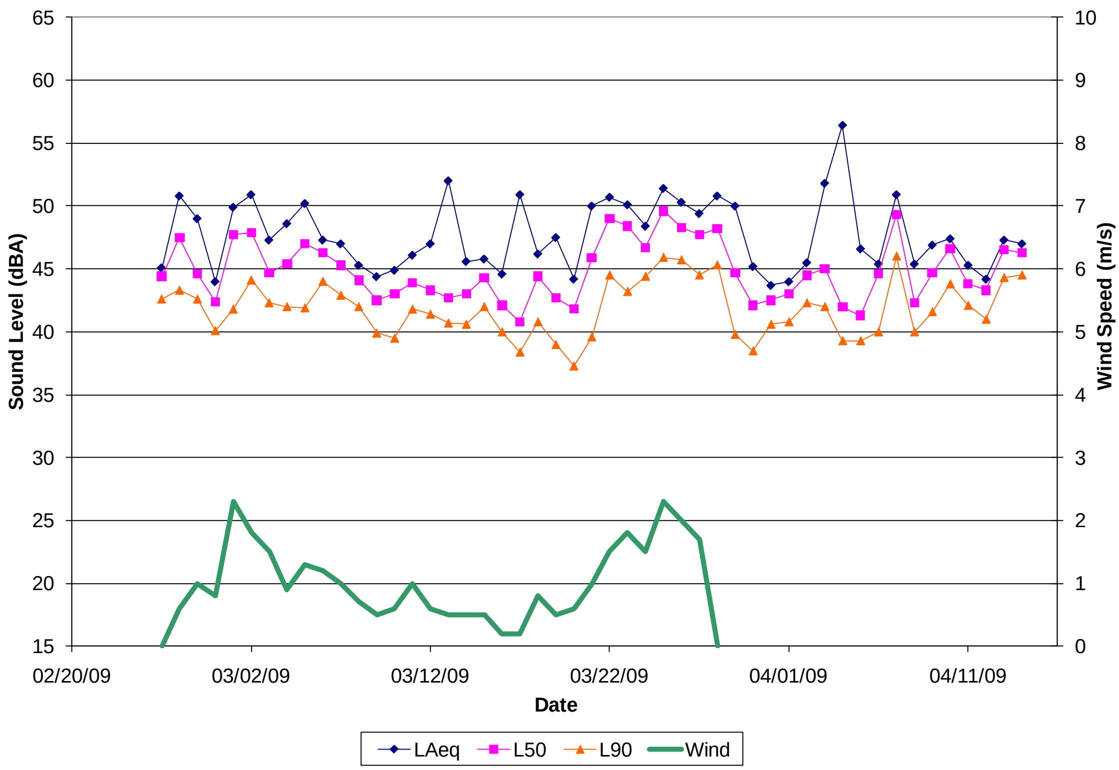

Figure 27. Daily sound levels and wind speeds for the winter season.

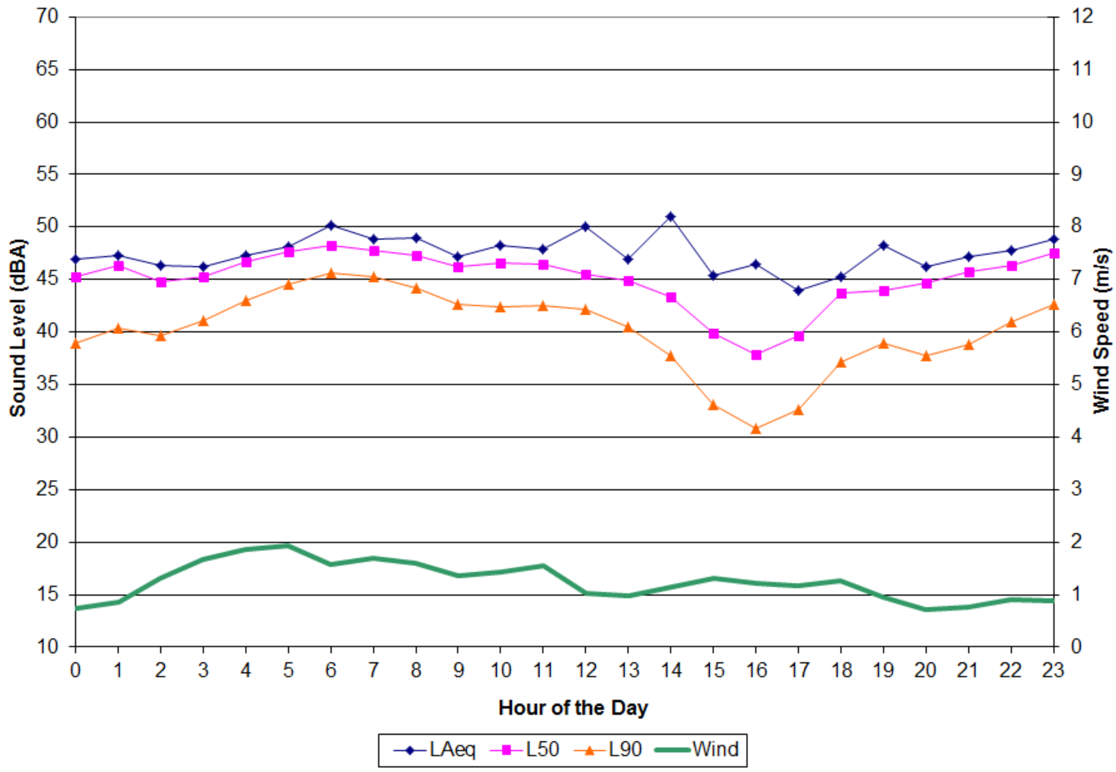

Figure 28. Hourly L_{50} sound levels for the summer season.

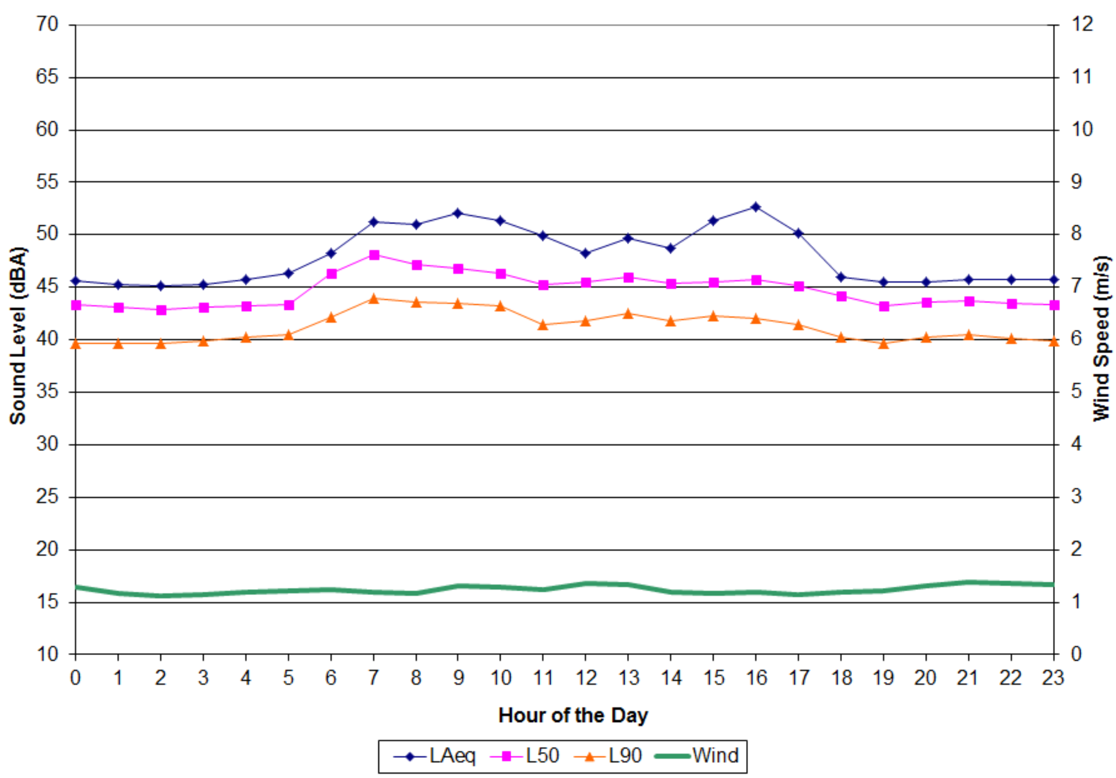

Figure 29. Hourly L_{50} sound levels for the winter season.

5.4 Acoustic Observer Log Results

Figure 30, Figure 31, and Table 11 provides a summary of the acoustic observer data logged at each measurement site. This information gives an indication of the amount of time that certain sources are present at each site. Using the data in the acoustic observer logs, different characterizations of ambient can be *estimated* from the sound level data (see Section 4.5). The first four columns in the table are arranged as follows:

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

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

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

On-site observations and off-site review of recorded audio data concluded that human sources were very prevalent during daytime hours (7 am to 7 pm) in the summer season - accounting for 68% of the sounds heard at this site (98% in the winter). Aircraft were audible 4% of the daytime during the summer; 5% during the winter. Sounds from visitors (e.g., conversation, music, and watercraft use) were audible 64% of the daytime during the summer; 93% during the winter. The winter human audibility was higher, owing to the activity in and around the Fort. Watercraft were also more audible in the winter season even though the measurement system was at an interior location. Wind and wind related sounds were the most dominant natural source at this location followed by water and birds. Bird activity was more audible in the summer (location may have influenced this as well).

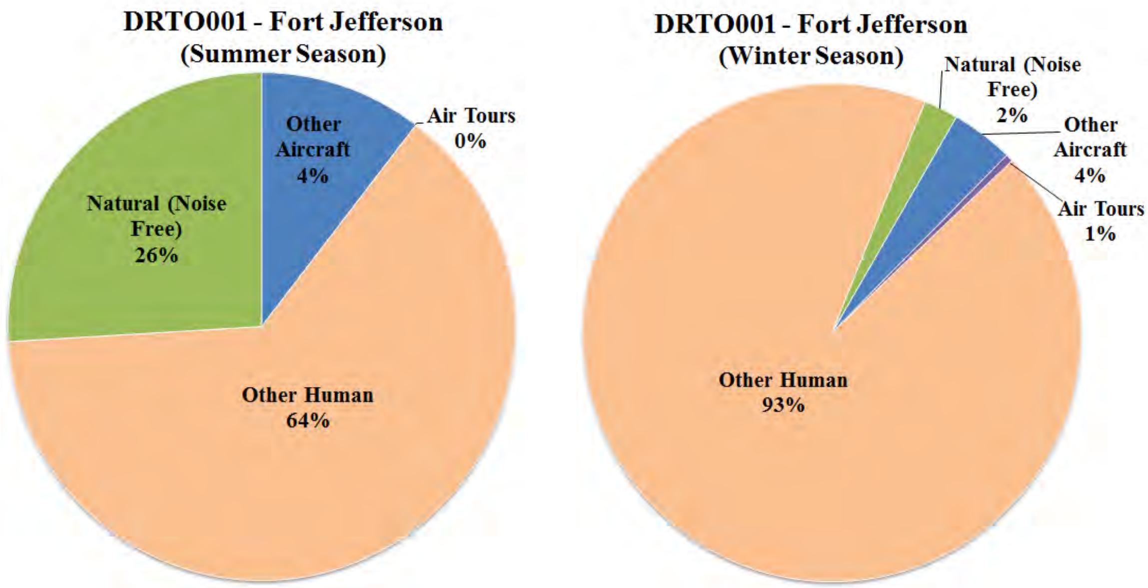

Figure 30. Distribution of sound sources audible (in situ and office listening combined) for Site DRTO001 for winter season - daytime.

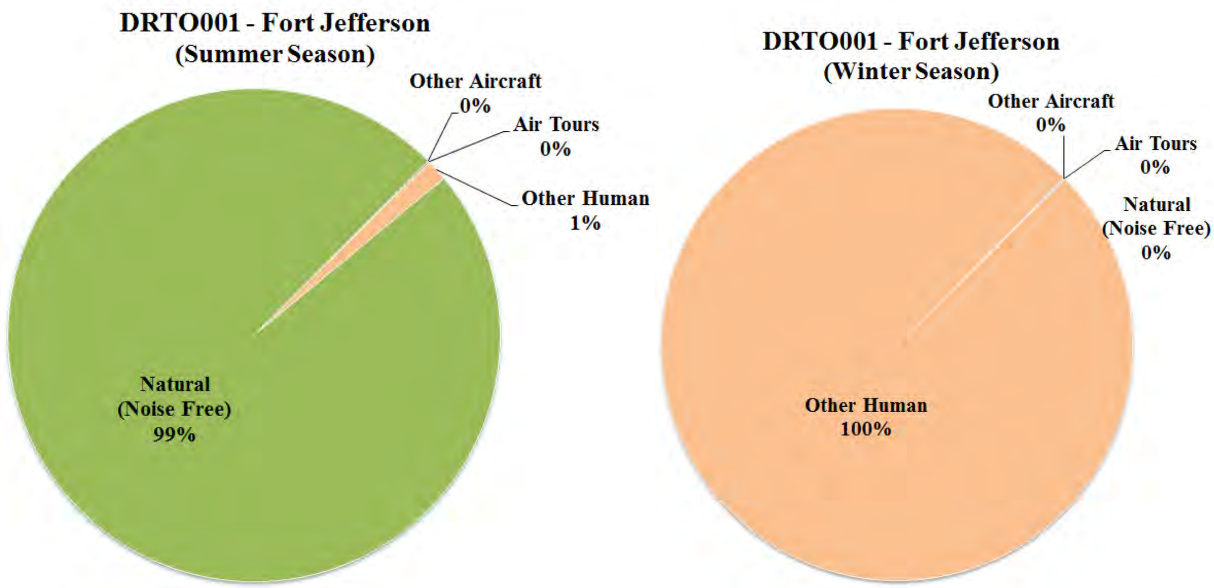

Figure 31. Distribution of sound sources audible (in situ and office listening combined) for Site DRTO001 for winter season - nighttime.

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

Acoustic Zone	Site Name	Site ID	Level of Visitor-Use	% Time Audible – Daytime Data (7 am to 7 pm) – Air Tour Aircraft	Daytime – Other Aircraft	Daytime – Other Human	Daytime – Natural	Nighttime Data (7 pm to 7 am) – Air Tour Aircraft	Nighttime – Other Aircraft	Nighttime – Other Human	Nighttime – Natural
Summer Season											
Developed	DRTO001	Fort Jefferson	High	0%	10%	64%	26%	0%	0%	1%	99%
Winter Season											
Developed	DRTO001	Fort Jefferson	High	1%	4%	93%	2%	0%	0%	100%	0%

6. AMBIENT MAPPING

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

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 Dry Tortugas, a grid spacing of 500 ft (152.4 m) was used.
  - Define the acoustic zone boundaries in UTM coordinates.
  - Define the location of each measurement site.
- Assign a "measured" ambient sound level (and its associated one-third octave-band, unweighted spectrum), to each grid point within an acoustic zone based on the measurement site nearest to it (see Section 6.1).

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

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

The resultant ambient maps are presented in Section 6.3.

* The UTM system provides coordinates on a worldwide flat grid for easy manipulation in GIS applications.
† Because the ATMP Act applies to all commercial air tour operations within the ½-mile outside the boundary of a national park, the park boundary included a ½-mile buffer.

6.1 Assignment of Measured Ambient Data to Acoustic Zones

As discussed in Section 2.6, areas of like vegetation, topography, elevation, and climate were grouped into "acoustic zones," with the assumption that similar wildlife, physical processes, and other sources of natural sounds occur in similar areas with similar attributes. With the goal of site selection to ensure at least one measurement location within each of the acoustic zones, "measured" ambient sound level (and its associated one-third octave-band, unweighted spectrum) for each measurement site is assigned to an acoustic zone. Because there was only one monitoring site for Dry Tortugas, data measured at that site were applied throughout the park.

6.2 Ambient Mapping of Localized Sound Sources

The contributing effect of localized noise sources, primarily vehicles on roads, but may also include trains, waterfalls, and river rapids, are typically modeled and combined with the measured sound levels to develop a composite, baseline, ambient "map" of a park for all ambient maps, except natural ambient. 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),[24] where the estimated drop-off rate, reflecting a continuous decrease in sound level as a function of increasing distance from each sound source, was computed. For a non-time-varying source, such as roadway noise, the TNM-computed L_{Aeq} sound level parameters may be conservatively assumed to be equivalent to the L_{50} and L_{90} and, thus, used interchangeably as the "roadway" ambient.

Because there were no roads within Dry Tortugas, no TNM modeling were needed.

6.3 Final Ambient Maps

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

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

Figure 32 through Figure 35 present the four ambient maps for the summer and winter seasons, respectively.

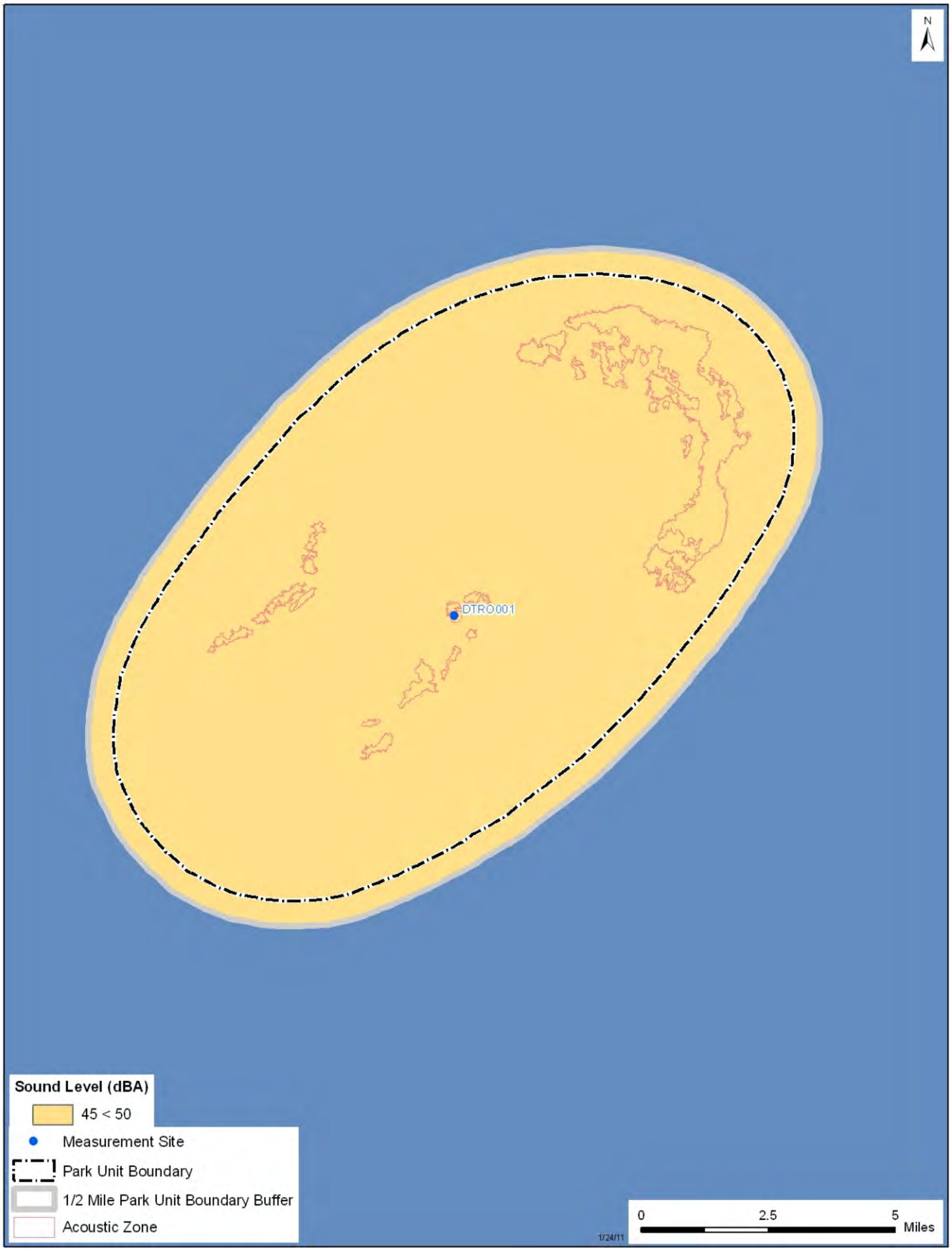

Figure 32. Baseline ambient map: Existing Ambient Without Air Tours (L_{50}) for the summer season.

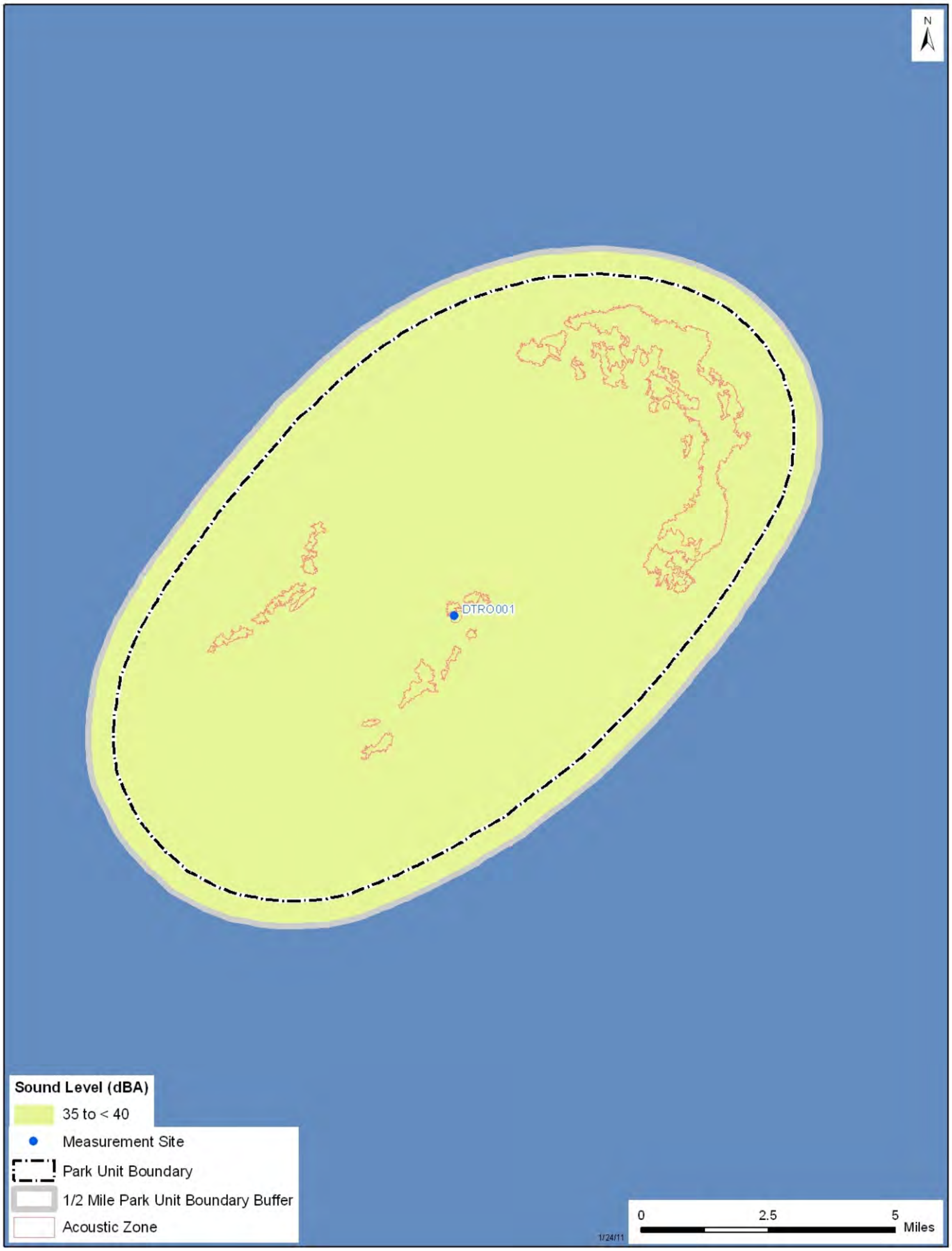

Figure 33. Baseline ambient map : Natural Ambient (L_{50}) for the summer season.

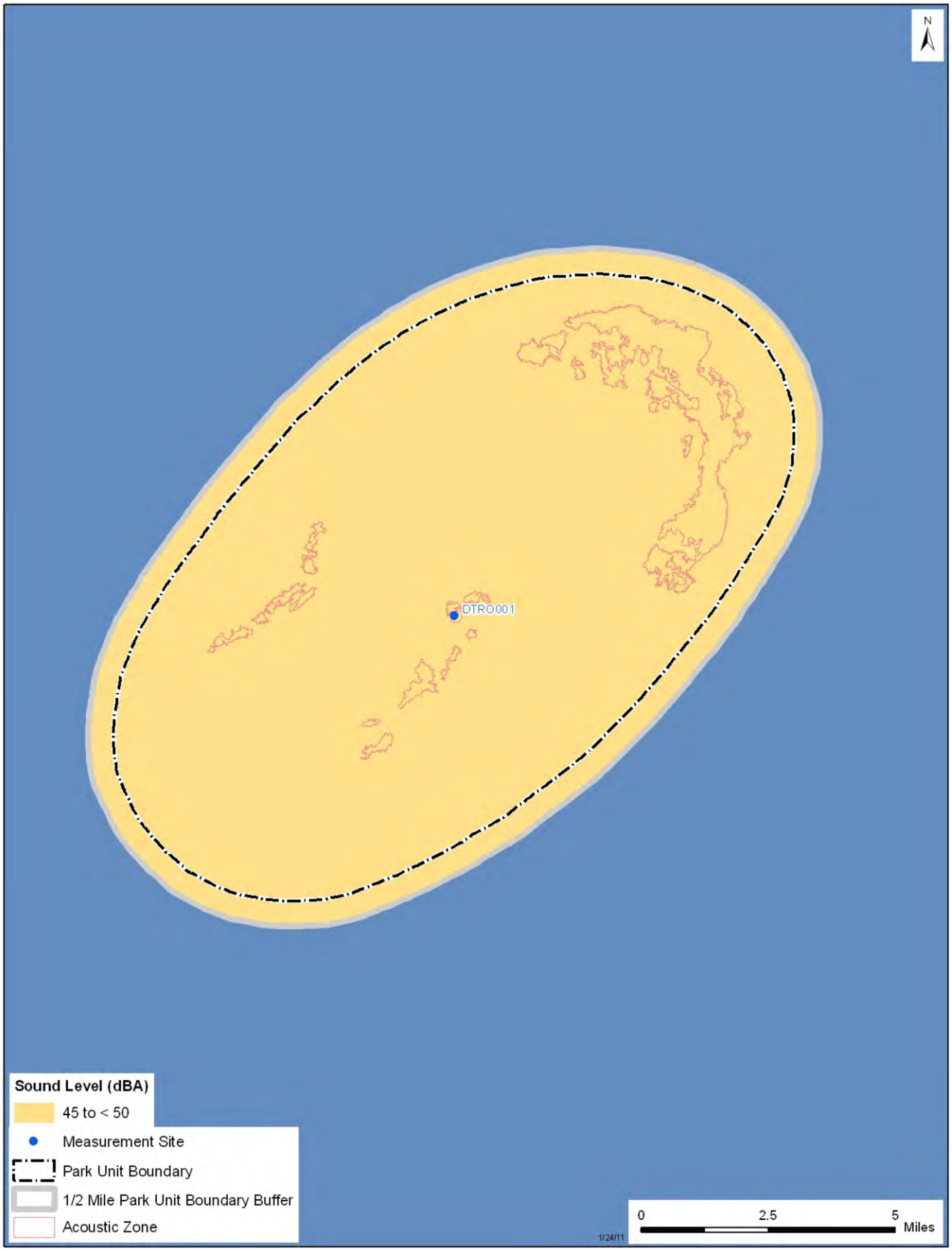

Figure 34. Baseline ambient map: Existing Ambient Without Air Tours (L_{50}) for the winter season.

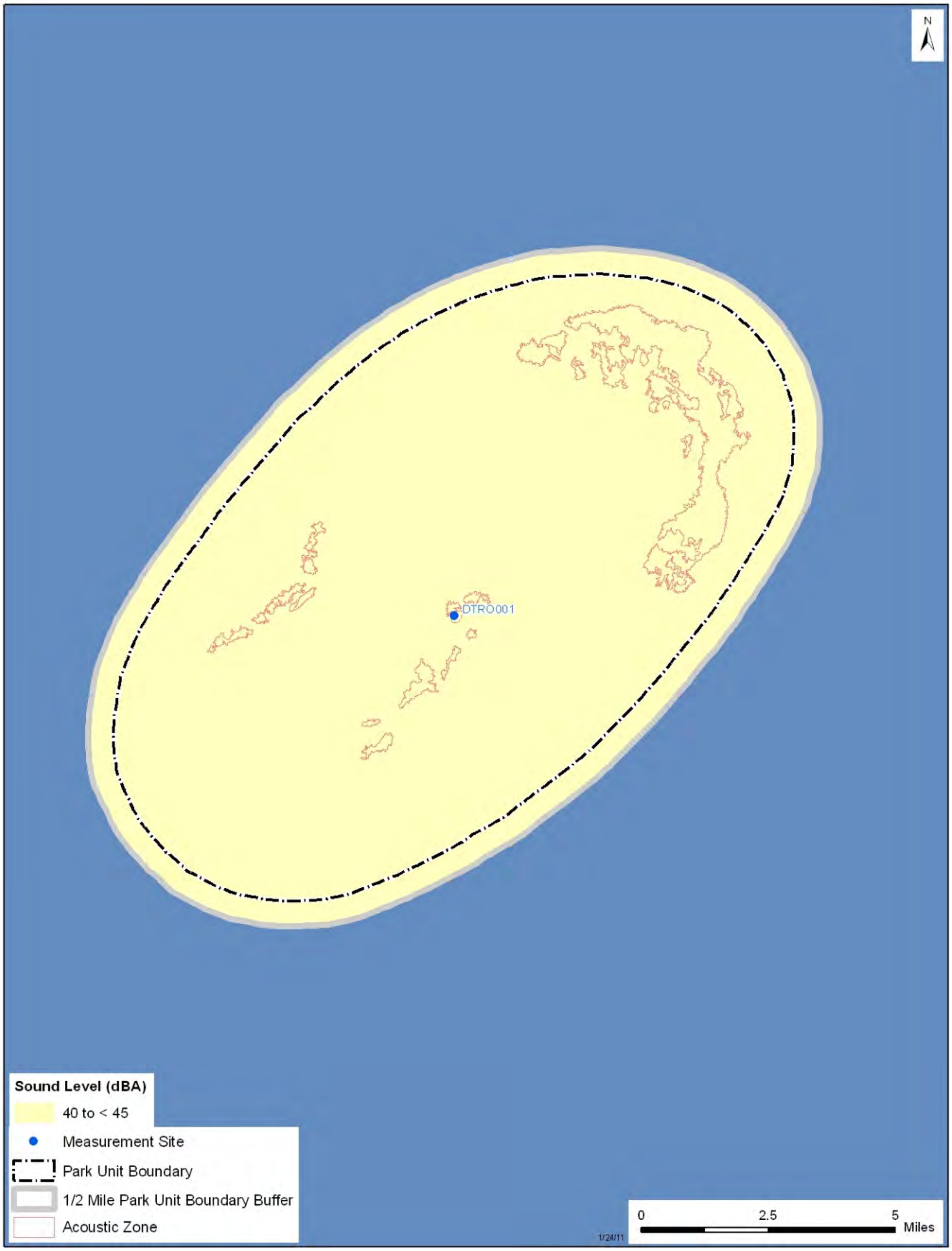

Figure 35. Baseline ambient map : Natural Ambient (L_{50}) for the winter season.

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 25 through 29.

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

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

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

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

ANNOYANCE - Any bothersome or irritating occurrence.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

L_{AE} (see Sound Exposure Level)

L_{Aeq} (see Equivalent Sound Level)

L_{ASmx} (see Maximum Sound Level)

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

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

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

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

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

NATURAL AMBIENT (see Ambient)

NATURAL QUIET - The natural sound conditions found in a study area. Natural quiet is a subset of ambient noise. Traditionally, it is characterized by the total absence of human or mechanical sounds, but includes all sounds of nature, such as wind, streams, and wildlife. In a park environment, the National Park Service (NPS) on Page 74 of its Report to Congress[29] 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. [30]

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

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

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

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

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

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

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

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

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

SOUND EXPOSURE LEVEL (SEL, denoted by the symbol L_{AE}) –
Over a stated time interval, T (where $T=t_2-t_1$, in seconds), ten times the base-10 logarithm of a given time integral of squared instantaneous A-weighted sound pressure, divided by the product of the squared reference sound pressure of 20 μPa, the threshold of human hearing, and the reference duration of 1 sec. The time interval, T, must be long enough to include a majority of the sound source's acoustic energy. As a minimum, this interval should encompass the 10-dB down points (see Figure 36).

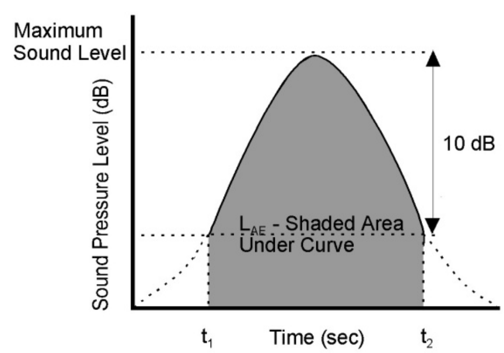

Figure 36. Graphical representation of L_{AE}.

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

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

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

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

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

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

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

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

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

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

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

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

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

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