# Appendix I – Acoustic Assessment

# Acoustic Assessment
# for the
# Ashley Wind Energy Project

McIntosh County, North Dakota

***Prepared for***

**CPV Ashley Renewable Energy Company, LLC**
50 Braintree Hill Office Park, Suite 300
Braintree, Massachusetts 02184

***Prepared by***

**Tetra Tech EC, Inc.**
160 Federal Street – 3rd Floor
Boston, Massachusetts 02110

**August 2010**

complex world CLEAR SOLUTIONS™

## TABLE OF CONTENTS



### TABLES

**FIGURES**

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AGL | above ground level |
| BLM | Bureau of Land Management |
| CadnaA | Computer-Aided Noise Abatement Program |
| CPV | CPV Ashley Renewable Energy Company, LLC |
| CFR | Code of Federal Regulations |
| dB | decibel |
| dBA | A-weighted decibel |
| dBL | unweighted decibel |
| EPA | United States Environmental Protection Agency |
| GE | General Electric |
| Hz | Hertz |
| HPD | hearing protection devices |
| IEC | International Electrotechnical Commission |
| ISO | Organization for International Standardization |
| kHz | kilohertz |
| kVA | kilovolt-ampere |
| $L_{dn}$ | day-night averaged sound level |
| $L_{eq}$ | equivalent sound level |
| LFN | low frequency noise |
| $L_{max}$ | maximum sound level |
| $L_p$ | sound pressure level |
| $L_w$ | sound power level |
| m/s | meters per second |
| mph | miles per hour |
| MVA | megavolt amperes |
| MW | megawatt |
| NEMA | National Electrical Manufacturers Association |
| OSHA | Occupational Safety and Health Administration |
| PEIS | Programmatic Environmental Impact Statement |
| Project | Ashley Wind Energy Project |
| pW | picowatt |
| rpm | rotations per minute |
| Siemens | Siemens Energy, Inc. |
| Tetra Tech | Tetra Tech EC, Inc. |
| $TWA_{8\text{-}hr}$ | time-weighted average eight-hour |
| μPa | microPascal |
| USGS | United States Geological Survey |
| UTM | Universal Transverse Mercator |
| W | watt |
| WTG | wind turbine generator |
| $z_0$ | roughness length coefficient |

## EXECUTIVE SUMMARY

Tetra Tech EC, Inc. (Tetra Tech) has completed the acoustic assessment for the proposed Ashley Wind Energy Project (Project) located in McIntosh County, North Dakota. A screening level acoustic analysis was developed to address sound levels resulting from wind turbine generator (WTG) operations, as well as the consideration of sound from the electrical substation and sound generated during Project construction and maintenance activities. The overall objectives of this study were to: (1) identify Project sound sources and estimate site-specific sound propagation characteristics incorporating terrain effects; (2) computer simulate WTG sound levels over a range of expected future Project operational and meteorological conditions using internationally accepted calculation standards; and (3) determine the feasibility of the Project to operate in compliance with applicable noise standards and guidelines.

Wind turbine sound source data was obtained from General Electric (GE) and Siemens Energy, Inc. (Siemens) for the two candidate wind turbine types. Sound propagation modeling was conducted using the Computer-Aided Noise Abatement (CadnaA) software program (version 4.0.136), a comprehensive 3-dimensional acoustic modeling computer simulation software specifically developed for the power generation industry, with calculations made in accordance with the Organization for International Standardization (ISO) 9613-2 "Attenuation of Sound during Propagation Outdoors." The industry standard CadnaA acoustic modeling software is widely used by sound engineers due to its adaptability to describe complex acoustic scenarios. The results of the acoustic modeling results were compared to United States Environmental Protection Agency (EPA) environmental noise guidelines and Occupational Safety and Health Administration (OSHA) regulatory limits for worker exposure and public safety.

Acoustic modeling results show that the Project has been adequately designed, inclusive of a number of conservative model input assumptions, to operate in compliance with EPA noise guidelines at all existing potentially occupied residences considered to be noise sensitive receptors. Operational sound generated from the Project will not approach OSHA noise exposure limits even in very close proximity to individual WTG locations Operation of the Project may result in periodically audible sound at noise sensitive receptors under certain operational and meteorological conditions. Specifically, the Project will be audible at the closest receptors relative to the Project, when background sound levels are low, and wind speeds high enough for WTG operation. Residents outside their houses and with a direct line of sight to an operating WTG may hear a gentle swooshing sound characteristic of wind energy projects. During meteorological conditions favorable to sound propagation and very quiet background ambient sound conditions, WTGs may be periodically audible at more distant receptor locations as well. Conversely, sometimes when wind turbines will be at full rotation corresponding to maximum sound output, the Project may be partially or fully masked by elevated ambient sound levels generated by the increased wind speed. The Ashley Wind Energy Project is expected to generate sound levels which will be below recommended guideline limits to avoid the potential for adverse noise impacts on public health and safety. As such, the Ashley Wind Energy Project is not expected to present an adverse noise impact on public health and safety.

## 1.0 INTRODUCTION

CPV Ashley Renewable Energy Company, LLC (CPV) is proposing to install up to 87 wind turbines as part of the Ashley Wind Energy Project (the Project) located in McIntosh County, North Dakota. CPV has identified two preferred wind turbine generator (WTG) manufacturers and models for use at the Project. The selected WTG may affect the number of turbines and configuration of the turbine layout; therefore, two Project layouts comprising of either 87 General Electric (GE) 2.5xl 2.5-megawatt (MW) WTGs or 87 Siemens Energy, Inc. (Siemens) SWT-2.3-101 2.3-MW WTGs are being considered in this assessment, resulting in a total power production output of up to approximately 200 MW. Both of these are three bladed, upwind variable speed-type WTGs with an active yaw and pitch regulated with power/torque control capability and an asynchronous generator. An electrical substation, which transforms the power generated from the WTGs to a higher voltage suitable for the local distribution system, will also be constructed. A screening level acoustic assessment was considering the following candidate wind turbine types and layout design options as provided by CPV on April 21, 2010:

- **87 GE 2.5xl** – 103-meter (338 feet) diameter rotor, with a hub height of 85 meters. The GE 2.5xl has a normal high rotor speed of 14 rotations per minute (rpm).
- **87 Siemens SWT-2.3-101** – 101-meter diameter rotor (331 feet), with a hub height of 80 meters (262.4 feet). The Siemens SWT-2.3-101 has a normal high rotor speed of 16 rpm.

In support of environmental permitting efforts, Tetra Tech EC, Inc. (Tetra Tech) was retained to perform the acoustic assessment. This document presents the findings of the assessment, including calculated future sound levels per the Organization for International Standardization (ISO) 9613-2 resulting from Project operation and provides an evaluation of the feasibility of the Project to operate in compliance with applicable noise regulations and guidelines. The acoustic assessment addresses sound associated with construction, substation, and operations and maintenance activities as well as the potential for reasonably foreseeable cumulative noise impacts.

### 1.1 Existing Acoustic Environment

McIntosh County would generally be characterized as a rural agricultural land use area. Existing ambient sound levels are expected to be relatively low, although sound levels may be sporadically elevated in localized areas due to roadway noise or periods of human activity. Background sound levels will vary both spatially and temporally depending on proximity to area sound sources, roadways and natural sounds. Principal contributors to the existing acoustic environment likely include motor vehicle traffic, mobile farming equipment, farming activities such as plowing and irrigation, all-terrain vehicles, local roadways, periodic aircraft flyovers, and natural sounds such as birds, insects, and leaf or vegetation rustle during elevated wind conditions in areas with established tree stands or established crops. Diurnal effects result in sound levels that are typically quieter during the night than during the daytime, except during periods when evening and nighttime insect noise may dominate the soundscape, in warmer seasons.

In areas with elevated background sound levels, sound may be obscured through a mechanism referred to as acoustic masking. Seasonal effects such as cricket chirping, certain farming activities, as well as wind-generated ambient noise as ground level airflow interacts with foliage and cropland, contribute to this masking effect. The latter is most prevalent in rural and suburban areas with established tree stands. Wintertime defoliate conditions generally have lower background sound levels due to lower wind masking effects and reduced outdoor activities in colder climates. During colder seasons, people typically exhibit lower sensitivities to outdoor sound levels, particularly in this geographical region of the United States, as windows are closed further enhancing outdoor to indoor transmission losses, and increasingly limited amount of time is spent outdoors.

Residences and abandoned farmsteads are widely scattered throughout the Project area. Patches of trees and shrubs exist in pockets and are found primarily between agricultural fields, in drainages, and as shelter belts around homesteads. A total of 15 receptor locations were identified within the designated acoustic study area using structure data provided by CPV on September 10, 2009 and updated by Tetra Tech for this assessment in June 2010. Figure 1 presents the McIntosh County acoustic study area, the locations of the proposed WTGs, and residential receptor locations.

## 1.2 Acoustic Terminology

All sounds originate with a source whether it is a human voice, motor vehicles on a roadway, or a wind turbine generator. Sound energy propagates through a medium where it is sensed and then interpreted by a receptor. A sound source is defined by a sound power level ($L_w$), which is independent of any external factors. By definition, sound power is the rate at which acoustical energy is radiated outward and is expressed in units of watts (W). Sound energy travels in the form of a wave, a rapid fluctuation or oscillation of air pressure above and below atmospheric pressure. A sound pressure level ($L_P$) is a measure of this fluctuation at a given receptor location and can be obtained through the use of a microphone or calculated from information about the source sound power level and the surrounding environment. Sound power, however, cannot be measured directly. It is calculated from measurements of sound intensity or sound pressure at a given distance from the source.

Sound levels are described on a logarithmic scale to account for the large range of pressure that the human ear can perceive, and is expressed in units of decibels (dB). A decibel is defined as the ratio between a measured value and a reference value usually corresponding to the lower threshold of human hearing defined as 20 micropascals ($\mu$Pa). Conversely, sound power is referenced to 1 picowatt (pW). As the human ear does not perceive every frequency with equal loudness, spectrally complex sounds are often adjusted with a weighting filter. The A-weighted filter is applied to compensate for the frequency response of the human auditory system and sound exposure in acoustic assessments is commonly reported in A-weighted decibels (dBA).

An inherent property of the logarithmic decibel scale is that the sound pressure levels of two separate sources are not directly additive. For example, if a sound of 50 dBA is added to another sound of 50 dBA, the result is a 3-decibel increase (or 53 dBA), not an arithmetic doubling of 100 dBA. The human ear does not sense changes in the sound pressure level as equal changes in perceived loudness. Scientific research demonstrates that the following general relationships hold between sound level and human perception for two broadband sound levels with the same or similar frequency characteristics:

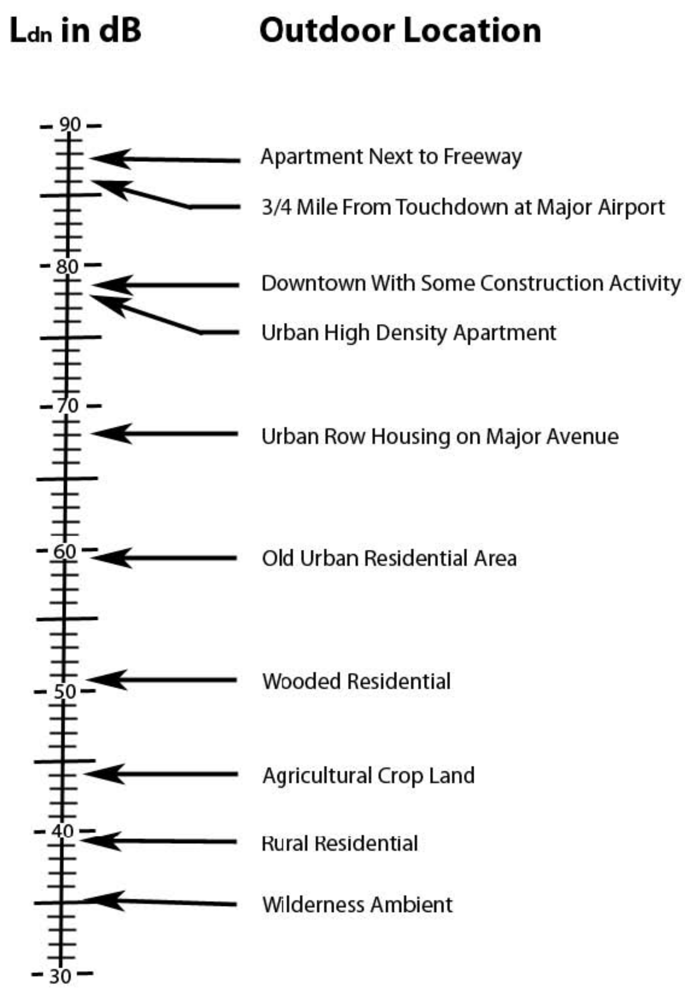
- 1 dBA is the practically achievable limit of the accuracy of sound measurement systems and corresponds to an approximate 10 percent variation in sound pressure. A 1 dBA increase or decrease is a non-perceptible change in sound.
- 3 dBA increase or decrease is a doubling (or halving) of acoustic energy and it corresponds to the threshold of perceptibility of change in a laboratory environment. In practice, the average person is not able to distinguish a 3 dBA difference in environmental sound outdoors.
- 5 dBA increase or decrease is described as a perceptible change in sound level and is a discernable change in an outdoor environment.
- 10 dBA increase or decrease is a tenfold increase or decrease in acoustic energy but is perceived as a doubling or halving in sound (i.e., the average person will judge a 10 dBA change in sound level to be twice or half as loud).

While the concept of sound is defined by the laws of physics, the term 'noise' has further qualities of being excessive or loud. The perception of sound as noise is influenced by technical factors as intensity, sound quality, tonality, duration, and the existing background levels. The effects of noise on people can be classified into three general categories: (1) subjective responses such as annoyance, nuisance, and dissatisfaction; (2) activity interference, e.g., speech, sleep, and learning; and (3) physiological effects such as anxiety or hearing loss. According to the United States Department of the Interior Bureau of Land Management (BLM), "Final Programmatic Environmental Impact Statement on Wind Energy Development on BLM-Administered Lands in the Western United States," the sound levels associated with environmental noise have been found to produce effects generally only in the first two categories (BLM 2005). At typically employed wind turbine setback distances, the comparatively low level sound generated by wind energy projects are expected to similarly fall principally within the subjective category, dependant on several technical and non-technical factors.

Sound can be measured, modeled, and presented in various formats, with the most common metric being the equivalent sound level ($L_{eq}$). The equivalent sound level has been shown to provide both an effective and uniform method for comparing time-varying sound levels and is widely used in acoustic assessments of wind energy projects. Community sound levels are also often described in terms of the day-night averaged sound level ($L_{dn}$), which accounts for the increased potential for annoyance that comes with elevated sound levels at night. In addition, the maximum sound level ($L_{max}$) can be used to quantify the maximum instantaneous sound pressure level generated by a source and is often used in establishing regulatory noise limits. Broadband sound includes sound energy summed across the frequency spectrum. In addition to broadband sound pressure levels, data may also include the analysis of the various frequency components of the sound spectrum to determine tonal characteristics. The unit of frequency is Hertz (Hz), measuring the cycles per second of the sound pressure waves, and typically the frequency analysis examines 11 octave (or 33 1/3 octave) bands ranging from 16 Hz (low) to 16,000 Hz (high), encompassing the entire human audible frequency range.

The United States Environmental Protection Agency (EPA) estimates of various outdoor sound pressure levels and acoustic environments are presented in the day-night averaged sound level ($L_{dn}$) in Table 1. Table 2 presents additional reference information on terminology used in the acoustic assessment.

**Table 1.** **Various Outdoor Sound Pressure ($L_P$) Levels**




Notes:
µPa - micropascals describe sound pressure levels (force/area)
dBA - A-weighted decibels describe sound pressure on a logarithmic scale referenced to 20 µPa
Reference: EPA 1978

**Table 2. Acoustic Terms and Definitions**

| Term | Definition |
|---|---|
| Noise | Unwanted sound dependant on level, character, frequency or pitch, time of day, and sensitivity and perception of the listener. This word adds the subjective response of humans to the physical phenomenon of sound. It s use is limited to when negative effects on people are known to occur. |
| Sound Pressure Level ($L_P$) | Pressure fluctuations in a medium. Sound pressure is measured in decibels referenced to 20 µPa, the approximate threshold of human perception to sound at 1,000 Hz. |
| Sound Power Level ($L_W$) | Sound power level is not the equivalent to a sound pressure level. While both are reported in decibels, the $L_W$ a noise source measured in decibels referenced to $10^{-12}$ W. Sound power is independent of the environment, for this reason wind turbine manufacturer noise specifications are provided in these terms.<br>A sound power level is a function of both the sound pressure level produced by a source with distance and the effective radiating area or physical size of the source. In general, the ostensible magnitude of a sound power level is always considerably higher than the received sound pressure level near a source because of the area term, which for a wind turbine is effectively the entire rotor swept area. |
| Frequency (Hz) | The rate of oscillation of a sound, measured in units of Hz or kilohertz (kHz). One hundred Hz is a rate of one hundred times per second. The frequency of a sound is the property perceived as pitch: a low-frequency sound (such as a bass note) oscillates at a relatively slow rate, and a high-frequency sound (such as a treble note) oscillates at a relatively high rate. For comparative purposes, the lowest note on a full range piano is approximately 32 Hz and middle C is 261 Hz. |
| A-Weighted Decibel (dBA) | Environmental sound is typically composed of acoustic energy across all frequencies (Hz). To compensate for the auditory frequency response of the human ear, an A-weighting filter is commonly used for describing environmental sound levels. Sound levels that are A-weighted are presented as dBA in this report. |
| Propagation and Attenuation | Propagation is the decrease in amplitude of an acoustic signal due to geometric spreading losses with increased distance from the source. Additional sound attenuation factors include air absorption, terrain effects, sound interaction with the ground, diffraction of sound around objects and topographical features, foliage, and meteorological conditions including wind velocity, temperature, humidity and atmospheric conditions. |
| Octave Bands | The audible range of humans spans from 20 to 20,000 Hz and is typically divided into octave band center frequencies (Hz) ranging from 31 to 8,000 Hz. |
| Broadband Sound | Noise which covers a wide range of frequencies within the audible spectrum, i.e., 200 to 2,000 Hz. |
| Masking | Interference in the perception of one sound by the presence of another sound. At elevated wind speeds, leaf rustle and noise made by the wind itself can mask wind turbine sound levels, which remain relatively constant. |
| Low Frequency Noise (LFN) | The frequency range of 20 to 200 Hz is typically defined as low frequency noise. Studies have shown that low frequency sound from modern wind turbines is generally below the threshold of human perception at standard setback distances. |
| Infrasound | The frequency range of infrasound is normally defined as below 20 Hz. Infrasound from wind turbines are significantly below recognized thresholds for both human perceptibility and standardized health. |

Note: Compiled by Tetra Tech from multiple technical and engineering resources.

## 2.0 NOISE REGULATIONS AND GUIDELINES

This section presents information on the criteria used to evaluate the effects of noise from the Project. With the exception of the EPA environmental noise guidelines and the United States Occupational Health and Safety Administration's (OSHA) regulations that describe health and safety limits for noise exposure, there are no overarching state, county, or federal noise requirements specific to this Project or wind energy facilities in the state of North Dakota. McIntosh County does not have an ordinance with numerical decibel limits.

### 2.1 Environmental Protection Agency Environmental Noise Guidelines

While the EPA has no regulation governing environmental noise, the agency has conducted several extensive studies to identify the effects of sound level on public health and welfare. In 1974, the EPA published a landmark document entitled "Information on Levels of Environmental Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety" (EPA 1974). This publication remains the authoritative study based on a large sampling of community reaction to noise. The EPA sound level guidelines do not provide an absolute measure of noise impact, but rather a consensus on potential activity interference, human health and welfare effects, and annoyance. For outdoor residential areas, the recommended EPA guideline is an $L_{dn}$ of 55 dBA (equivalent to an $L_{eq}$ (1-hour) of 48.6 dBA assuming continuous 24-hour operation). The EPA sound level guidelines also suggest an $L_{eq}$ of 70 dBA (24-hour) limit to avoid adverse effects on health and safety at publicly accessible property lines or work areas. Since these protective levels were derived without concern for technical or economic feasibility, and contain a margin of safety to ensure their protective value, they must not be viewed as standards, criteria, regulations, or goals. Rather, they should be viewed as levels below which there is no reason to suspect that the general population will be at risk from any of the identified effects of noise. The EPA criteria limits are summarized in Table 3.

**Table 3. Summary of EPA Cause and Effect Noise Levels**

| Location | Level | Effect |
|---|---|---|
| All public accessible areas with prolonged exposure | 70 dBA $L_{eq(24)}$ | Safety / hearing loss concerns |
| Outdoor at residential structure and other noise sensitive receptors where a large amount of time is spent | 55 dBA $L_{dn}$ | Protection against annoyance and activity interference |
| Outdoor areas where limited amounts of time are spent, e.g., park areas, school yards, golf courses, etc. | 55 dBA $L_{eq(24)}$ | |
| Indoor residential | 45 dBA $L_{dn}$ | |
| Indoor non-residential | 55 dBA $L_{eq(24)}$ | |

The EPA sound level guidelines state that the levels identified are low enough to be protective with an adequate margin of safety. The EPA sound level guidelines do not impose arbitrary federal decisions about the appropriateness of noise environments upon any level of government, nor are they a source of instructions for solving local noise problems, but best viewed as a technical aid for local decision makers who seek to balance scientific information about effects of noise on people, and to reconcile local economic and political realities such as cost and technical feasibility. The relationship between physical acoustic relationships and human response is not linear and depends on factors and cannot be precisely predicted. In any environment, a small portion of the general population may be somewhat annoyed depending on the person's subjective response due to the presence of any level of recurring audible sound, regardless of the actual or perceived loudness.

### 2.2 Bureau of Land Management Guidance

In June 2005, the BLM published the Final Programmatic Environmental Impact Statement (PEIS) to address the potential impacts of wind energy projects on BLM Lands in the Western United States. One of the issues identified was the siting of wind energy projects in areas that do not have applicable noise standards. Section 4.5.4 of that document states: "The EPA guideline recommends an $L_{dn}$ of 55 dBA to protect the public from the effects of broadband environmental noise in typically quiet outdoor and residential areas. The EPA limit is not a regulatory limit but "intentionally conservative to protect the most sensitive portion of the American population" with "an additional margin of safety." The BLM PEIS findings are not directly applicable to the Project as it will be entirely sited on private land; however, the BLM restatement of the EPA guideline provides insight on how one governmental agency is addressing the potential for noise impacts produced by wind energy projects in areas with no state or local noise regulation.

### 2.3 Occupational Safety and Health Administration Noise Safety Standards

The federal government has long recognized the potential hazards caused by noise to work health and safety. Onsite noise levels are regulated by the Occupational Safety and Health of 1970 (29 Code of Federal Regulations [CFR] 1910.95). This regulation establishes standards for permissible noise exposure in the workplace to guard against the risk of hearing loss. The standards shown in Table 4 establish a sliding scale of permissible noise levels by duration of exposure. The exposure level is raised 5 dB for every halving of exposure duration. OSHA permits noise levels up to 90 dBA, over a time-weighted average eight-hour shift ($TWA_{8\text{-}hr}$), measured on the A-scale of a sound level meter set at slow response. If there are workers exposed to a $TWA_{8\text{-}hr}$ above 85 dBA, then the regulations call for a worker hearing protection program that includes baseline and periodic hearing testing, availability of hearing protection devices, and training in hearing damage protection.

**Table 4. OSHA Permissible Daily Noise Exposure Limits**

| Duration of Exposure Per Day (Hours) | Sound Level (dBA) |
|---|---|
| 8 | 90 |
| 6 | 92 |
| 4 | 95 |
| 3 | 97 |
| 2 | 100 |
| 1 ½ | 102 |
| 1 | 105 |
| ½ | 110 |
| ¼ or less | 115 |

When employees are subjected to noise doses exceeding those shown in Table 4, feasible administrative or engineering controls will be identified and implemented to lower employee noise exposure. If controls fail to reduce sound to these acceptable levels, personal protective equipment must be provided and used to reduce noise exposure. In compliance with OSHA, Project contractors will be required to readily provide construction workers with OSHA-approved hearing protection devices (HPD) and to identify high noise areas and activities where hearing protection Operational sound generated from the Project will not approach OSHA noise exposure limits even in very close proximity to individual WTG locations.

### 2.4 Summary of Acoustic Criteria

A summary of the pertinent acoustic criteria used to assess sound levels at existing receptors during Project operation is provided below:

- EPA 70 dBA $L_{eq\ (24)}$ at publicly accessible project property lines or extents of work areas where extended public exposure is possible;
- EPA 55 dBA $L_{eq\ (24)}$ in outdoor areas where limited time is spent;
- 55 dBA $L_{dn\ (24)}$ outdoors at all residential receptor locations where extended periods of time are spent outdoors, residential structures and areas in close proximity to the residential structure, e.g., yards; and
- OSHA regulatory limits for the protection of worker exposure and public safety.

The application of the EPA noise guidelines is a common noise assessment compliance approach used to ensure adequate protection of human health and welfare. While the EPA criteria limits cannot be used to infer audibility thresholds, compliance with EPA guidelines would likely result in the reduced probability of dissatisfaction. Inaudibility under all future operating conditions is an unrealistic expectation, and one that is not required for any other permitted industrial, commercial, or agricultural activity within the state of North Dakota or elsewhere in the United States. OSHA noise safety standards are mandatory requirements at all times. Guideline limits identified are absolute and independent of the existing acoustic environment; therefore, a baseline sound survey is not required to assess conformity.

Wind turbines operate intermittently depending on wind conditions at hub height. Assuming the wind turbine is operating as a continuous steady state sound source and is the dominant contributor of environmental sound level at the receptor location, the $L_{dn}$ is approximately 6.4 dB above the measured $L_{eq}$. Consequently, an $L_{dn}$ of 55 dBA corresponds to a $L_{eq}$ of 48.6 dBA.

## 3.0 ACOUSTIC MODELING METHODOLOGY

With the construction of wind energy projects in North Dakota and throughout the United States, a better understanding of the generation, propagation and attenuation of WTG sound in the natural environment has been gained. While sound generated by an operating WTG is comprised of both aerodynamic and mechanical sound, the dominant sound component from utility scale WTGs is largely aerodynamic. Aerodynamic sound refers to the sound produced from air flow and its interaction with the WTG's tower structure and rotor blades when they are in motion. Mechanical sound is generated at the gearbox, generator, and cooling fan, and is radiated from the surfaces of the nacelle and machinery enclosure and by openings in the nacelle casing. Due to the improved design of WTG mechanical components and the use of improved noise damping materials within the nacelle, including elastomeric elements supporting the generator and gearbox, mechanical noise emissions have been further minimized. The GE 2.5xl and Siemens SWT-2.3-101 are upwind variable speed-type WTGs with an active yaw and pitch regulated with power/torque control capability and an asynchronous generator. Sound reduction elements designed into these WTGs include impact noise insulation of the gearbox and generator, sound reduced gearbox, noise reduced nacelle, and rotor blades with minimized noise level.

Wind energy projects, in comparison to conventional energy projects, are somewhat unique in that the sound generated by each individual WTG will increase as the wind speed across the site increases, up to a certain maximum sound level under elevated wind conditions (i.e., greater than approximately 9 meters per second [m/s]) as per manufacturer's specifications. Wind turbine sound is negligible when the rotor is at rest, increases as the rotor tip speed increases, and is generally constant once rated power output and full rotational speed is achieved. As an offset, as wind speeds increase, the background ambient sound levels likely will continue to increase, resulting in acoustic masking effects. The net result is that during periods of elevated wind when higher wind turbine sound emissions would occur (the sound produced from a wind turbine operating at full rated speed) in areas with established tree stands, a masking effect due to wind generated sound in foliage and as it moves around objects is expected to further minimize the potential for adverse noise effects. Conversely, acoustic masking effects may be limited during periods of unusually high wind shear or at receptor locations that are particularly sheltered from prevailing winds.

### 3.1 Acoustic Modeling Software and Setup Parameters

The operational acoustic assessment was performed using the Project WTG layout dated April 21, 2010. The acoustic modeling analysis employed the most recent version of DataKustic GmbH's (2010) Computer-Aided Noise Abatement Program (CadnaA) version 4.0.136. CadnaA is a comprehensive 3-dimensional acoustic software model that conforms to the ISO standard 9613-2 "Attenuation of Sound during Propagation Outdoors." The engineering methods specified in this standard consist of 1/1 octave band algorithms that incorporate the following:

- Geometric spreading wave divergence
- Reflection from surfaces
- Atmospheric absorption
- Screening by topography and obstacles
- Terrain complexity and ground effects
- Sound power at multiple frequencies
- Source directivity factors
- Multiple noise sources, and source type (point, area, and/or line)
- Height of both sources and receptors
- Seasonal foliage effects
- Averaging predicted sound levels over a given time period
- Meteorological conditions including the effects of downwind sound propagation and anomalous meteorological conditions

Topographical information was imported into the acoustic model using the official United States Geological Survey (USGS) digital elevation dataset to accurately represent terrain in three dimensions. Terrain conditions, vegetation type, ground cover, and the density and height of foliage can also influence the absorption that takes place when sound waves travel over land. Calculations were completed for meteorological conditions corresponding to downwind propagation, or equivalently, propagation under a well-developed moderate ground-based temperature inversion. Though somewhat infrequent according the ISO 9613-2 procedures, Project sound levels resulting from operation during periodic anomalous meteorological conditions were also considered in the modeling analysis. Sound attenuation through foliage and diffraction around and over existing anthropogenic structures such as buildings were ignored under all acoustic modeling scenarios. The results are therefore more representative of defoliate wintertime conditions. The acoustic model assumes that all WTGs are operating continuously and concurrently at the maximum rated sound level per manufacturer specifications at the given operational condition.

### 3.2 Acoustic Modeling Input Parameters

In order to assist project developers and acoustical engineers, wind turbine manufacturers report WTG sound power data at integer wind speeds referenced to the effective hub height, ranging from cut-in to full rated power per International Standard IEC 61400-11:2006 Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques. This internationally accepted International Electrotechnical Commission (IEC) standard was developed to ensure consistent and comparable sound emission data of utility-scale WTGs between manufacturers. Table 5 presents a summary of sound power data during normal mode as opposed to noise restricted operation. Sound data is correlated by integer wind speeds, referenced at WTG hub height with a stated roughness length of 0.03 to 0.05 meters which is representative of level, grass covered terrain. The roughness length describes the vertical wind profile per IEC specification with a neutral atmosphere with the wind profile following a logarithmic curve. Sound power data presented are inclusive of both mechanical and aerodynamic source components. The GE and Siemens specification present an expected warranty confidence interval of k=2 dB and k=1.5 dB, respectively, which was included in all acoustic modeling calculations. This confidence interval incorporates the uncertainty in independent sound power level measurements conducted, the applied probability level and standard deviation for test measurement reproducibility, and product variability. It is expected that the GE and Siemens turbines version installed will be similar to the sound data that was used in the acoustic modeling. However, it is possible that the warranty sound data could vary slightly.

**Table 5. Broadband Sound Power Levels (dBA) Reported in Accordance with IEC 61400-11**

| | WTG Lmax Sound Power Level ($L_W$) at Reference Wind Speed | | | | | | |
|---|---|---|---|---|---|---|---|
| 80-m Wind Speed AGL | 7 mph (3 m/s) | 9 mph (4 m/s) | 11.2 mph (5 m/s) | 13.4 mph (6 m/s) | 15.9 mph (7 m/s) | 17.9 mph (8 m/s) | 20.1 mph (9 m/s) |
| GE 2.5xl | ≤97.0 | ≤99.0 | ≤101.0 | ≤104.0 | ≤106.0 | ≤106.0 | ≤106.0 |
| SWT-2.3-101 | - | 95.1 | 99.8 | 105.1 | 107.0 | ≤107.0 | ≤107.0 |

AGL – above ground level
mph – miles per hour
Reference: Siemens 2009 and GE Company 2010

A summary of sound power data during maximum rotational by octave band center frequency is presented in Table 6. Wind turbines can be somewhat directional, radiating more sound in some directions than others. The IEC test measurement protocol requires that sound measurements are made for the maximum downwind directional location when reporting apparent sound power levels. Thus, worst-case WTG directivity and sound generating efficiencies are reported in the sound source data and used in the acoustic model calibration.

**Table 6. Sound Power Level by Octave Band 1/1 Center Frequencies at Full Rotational**

| Frequency (Hz) | Octave Band Sound Power Level (dBA)[1] | | | | | | | | Broadband (dBA) |
|---|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| GE 2.5xl | 87.7 | 94.2 | 100.4 | 101.0 | 99.3 | 96.0 | 88.2 | 71.8 | 106.0 |
| SWT-2.3-101 | 83.5 | 94.4 | 98.1 | 102.1 | 102.1 | 98.4 | 91.2 | 87.2 | 107.0 |

[1] Octave band sound power level data derived from available manufacturer specification for GE 2.5xl – 60 Hz (GE Company 2009) and SWT-2.3 (Siemens 2009) is provided by the manufacturer for informational purposes only.

## 4.0 ACOUSTIC MODELING RESULTS

Operational broadband (dBA) sound pressure levels were calculated throughout the Project area. Acoustic modeling results and the overall analysis conclusions are given in the following sections.

### 4.1 Acoustic Modeling Results

Acoustic modeling for the Project layout was completed for WTG cut-in and full rotational operating conditions, thereby describing sound pressure levels over the entire range of future Project operational conditions. A list of receptors, unique number identifier, Universal Transverse Mercator (UTM) coordinates, and received sound levels are provided in Table 7. Sound contour plots displaying Project operational sound levels in color-coded isopleths are provided in Figures 2 through 4. Figures 2a and 2b show broadband (dBA) operational sound levels under low-level wind speeds sufficient for WTGs to operate at initial cut-in rotational speeds for the GE 2.5xl and Siemens 2.3-101, respectively. Figures 3a (GE 2.5xl) and 3b (Siemens SWT-2.3-101) show broadband (dBA) received sound levels during wind speeds sufficient to sustain WTG operation at maximum rotational speeds and omnidirectional downwind sound propagation. The acoustic modeling was completed for all WTGs operating concurrently. The resultant sound contour plots are independent of the existing acoustic environment, i.e., the plots and tabulated results represent Project-generated sound levels only.

**Table 7. Summary of WTG Acoustic Model Output at Receptors (dBA)**

| Receptor ID | UTM Coordinates (meters) | | GE 2.5xl | | SWT-2.3-101 | |
|---|---|---|---|---|---|---|
| | Easting | Northing | Cut-In | Maximum Rotation | Cut-In | Maximum Rotation |
| 1 | 468053 | 5117786 | 31 | 40 | 28 | 40 |
| 2 | 471340 | 5117655 | 36 | 45 | 33 | 45 |
| 3 | 472283 | 5117330 | 39 | 48 | 36 | 48 |
| 4 | 472726 | 5114975 | 35 | 44 | 32 | 44 |
| 5 | 468197 | 5112620 | 31 | 40 | 28 | 40 |
| 6 | 468774 | 5112459 | 33 | 42 | 30 | 42 |
| 7 | 469464 | 5114104 | 35 | 44 | 32 | 44 |
| 8 | 472736 | 5114758 | 35 | 44 | 32 | 44 |
| 9 | 470185 | 5110761 | 31 | 40 | 28 | 40 |
| 10 | 468947 | 5110096 | 29 | 38 | 26 | 38 |
| 11 | 472869 | 5110093 | 35 | 44 | 32 | 44 |
| 12 | 477860 | 5114700 | 34 | 43 | 31 | 43 |
| 13 | 475569 | 5110104 | 36 | 45 | 33 | 45 |
| 14 | 472585 | 5118769 | 24 | 33 | 21 | 32 |
| 15 | 470966 | 5109911 | 28 | 37 | 25 | 37 |

Reported sound pressure levels are representative of receptors located downwind of the WTGs; lower sound levels are expected in other directions dependent on wind velocities, speed, direction, and gustiness. The acoustic modeling results were compared to the broadband (dBA) guideline criteria as described in Section 2.0 of this report, specifically the EPA broadband guideline of 55 dBA $L_{dn}$ (equivalent to a $L_{eq\ (1\text{-hour})}$ of 48.6 dBA assuming continuous 24-hour operation, 365 days a year), which was used as a Project acoustic design goal.

The EPA guideline limits presented in Section 2.1 are based on the yearly $L_{dn}$. To calculate the yearly $L_{dn}$, knowledge of future atmospheric conditions across the entire site over an extended time period are required to determine the long term sound exposure. The approach employed in this Project acoustic assessment assumed a sustained wind speed at WTG hub height sufficient to result in full rotation wind turbine operation over a continuous one year period. Actual wind speeds and directions over the course of a year will vary.

The yearly $L_{dn}$ is calculated using the following equation per the EPA guidance document:

$$Yearly\ L_{dn}(exterior) = 10 \cdot \log_{10}\left[\frac{\left(15 \cdot 10^{\left(Leq(1-hour)/10\right)} + 9 \cdot 10^{\left((Leq(1-hour)+10)/10\right)}\right)}{24}\right] dBA$$

To calculate yearly $L_{dn}$, the $L_{eq\ (1\text{-hour})}$ in the above equation was assigned the value of the Project-generated sound level for the WTG operating condition under analysis (cut-in or at full rotational speed). Under real world meteorological conditions wind speed and direction will be variable. Over the course of a year, the actual received sound pressure levels as a result of Project operations will fluctuate from periods of calm or low level wind speeds, to wind speeds ranging from cut-in up to maximum rotational. During periods of calm and low level wind speeds below the rated cut-in wind speeds when WTGs will not operate, the Project will generate negligible sound. For time-varying sources, including wind energy projects, assessing sound levels generated during maximum rotational will ensure compliance during all other WTG operational conditions. Though this worst-case continuous operating scenario is not a realistic scenario, the intention of employing this calculation methodology is to provide a further level of conservatism in the acoustic assessment approach.

## 5.0 OTHER SOUND CONSIDERATIONS

### 5.1 Cumulative Effects

An assessment of cumulative environmental impacts considers the potential impact of the proposed Project in the context of existing or known future developments to ensure that any potential environmental impacts are not considered in isolation. The cumulative effects can result from individually minor, but collectively more significant actions taking place over a given period of time. Cumulative impacts are impacts that result from the incremental consequences of a project when added to other existing and/or proposed wind energy developments. An existing wind energy development would need to be located within approximately 2 to 3 kilometers (2 miles) of the proposed wind farm in order to present a possible cumulative influence on sound. There are no existing or proposed projects within these distance constraints from the Ashley Wind Energy Project.

### 5.2 Electrical Substation

The substation is an integral part of the Project as it collects and increases the voltage produced by the WTGs to the higher voltage needed for transmission by the local grid system. Sound from the Project electrical substations was examined as part of the Acoustic Assessment. Substations have switching, protection and control equipment and one or more transformers, which generate the sound generally described as a low humming. There are three main sound sources associated with a transformer: core noise, load noise and noise generated by the operation of the cooling equipment. The core is the principal noise source, dominating in the intermediate frequency range between 100 and 600 Hz. The relative magnitudes of the noise at these different frequency components is dependent on the design of the transformer (i.e., core material, core geometry) and does not vary significantly with the load on the transformer, meaning that the noise generated is largely independent of the transformer load. The load noise is primarily caused by the load current in the transformer's conducting coils (or windings) and consequently the main frequency of this sound is twice the supply frequency; 100 Hz for 50 Hz transformers and 120 Hz for 60 Hz transformers. The cooling equipment (fans and pumps) noise typically dominates the very low and very high frequency ends of the sound spectrum; however, cooling equipment sound is comparatively lower and considered secondary to the sound produced by the core and load.

Transformers are designed and catalogued by kilovolt-ampere (kVA) ratings. Just as horsepower ratings designate the power capacity of an electric motor, a transformer's kVA rating indicates its maximum power output capacity. The transformer industry uses the National Electrical Manufacturers Association (NEMA) sound level rating to designate the sound emitted from a transformer. This rating system requires the determination of the average A-weighted sound level at a distance of 0.3 meter (1 foot) from the wall surfaces of the transformer and is specified by the equipment manufacturer. The sound power radiated is a function of the NEMA rating and the total surface area of the four side walls.

The proposed Project electrical substation was included in the acoustic assessment and modeled cumulatively with WTG operational scenarios. Transformer sound source levels were estimated at a NEMA sound rating of 82 dBA and are presented in Table 8. The octave band center frequencies were calculated linearly based on the estimate transformer NEMA rating using standard engineering technical guidelines.

Table 8. Transformer Sound Power Level (NEMA 82 dBA)

| | Unweighted Octave Band Sound Power Data (dBL) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| NEMA Rating 82 dBA | 100 | 106 | 108 | 103 | 103 | 97 | 92 | 87 | 80 |

Few complaints from nearby residents are expected regarding substations with transformers less than 10 megavolt amperes (MVA) capacities, except in urban areas with little or no buffer distance attenuation between source and receptor locations. Complaints are more likely at substations with transformer sizes of 10 to 150 MVA with separation distances of 500 to 600 feet or less. In very quiet rural areas where the nighttime ambient acoustic environment can reach levels of 20 to 25 dBA under calm wind conditions, the sound generated from transformers of this size may be periodically audible at distances of half a mile or greater.

### 5.3 Construction Noise

The development of the Ashley Wind Energy Project will involve construction to establish access roads, excavate and form WTG foundations, works associated with preparing the site for crane-lifting and actual WTG assembly and commissioning. Work on large-scale wind projects is generally divided into four phases consisting of the following:

1. *Site Clearing*: The initial site mobilization phase includes the establishment of temporary site offices, workshops, stores, and other on-site facilities. Installation of erosion and sedimentation control measures will be completed as well as the preparation of initial haulage routes.
2. *Excavation*: This phase would begin with the excavation and formation of access roads and preparation of laydown areas. Excavation for the concrete turbine foundations would also be completed.
3. *Foundation Work*: Construction of the reinforced concrete turbine foundations would take place in addition to installation of the internal transmission network.
4. *Wind Turbine Installation*: Delivery of the turbine components would occur followed by their installation and commissioning.

Work on these construction activities is expected to overlap. It is likely that the WTGs will be erected in small groupings. Each grouping may undergo testing and commissioning prior to commencement of full commercial operation. Other construction activities include those for the supporting infrastructure such as the substation.

The construction of the Project may cause short-term but unavoidable noise impacts depending on the construction activity being performed and the distance to the receptor. The sound levels resulting from construction activities vary significantly depending on several factors such as the type and age of equipment, the specific equipment manufacturer and model, the operations being performed, and the overall condition of the equipment and exhaust system mufflers. A list of representative construction equipment that may be used on the Project and estimates of near and far sound source levels are presented in Table 9.

Sounds generated by construction activities are typically exempt from state and local noise oversight provided that they occur within weekday, daytime periods as may be further stipulated under local zoning or legal codes. As the design of the Project progresses and construction scheduling is finalized, the construction engineer should notify the community via public notice or alternative method of expected Project construction commencement and duration to help minimize the effects of construction noise. CPV will proactively work with the community and attempt to resolve any complaints or concerns due to noise from construction by coordinating activities and informing the community of the timing of the expected construction noise to avoid conflicts, i.e. if blasting for foundation or other noisy activities are required during the construction period, nearby residents shall be notified in advance.

**Table 9. Estimated $L_{max}$ Sound Pressure Levels from Construction Equipment**

| Equipment* | Estimated Sound Pressure Level at 50 feet (dBA) | Estimated Sound Pressure Level at 2,000 feet (dBA) |
|---|---|---|
| Crane | 85 | 53 |
| Forklift | 80 | 48 |
| Backhoe | 80 | 48 |
| Grader | 85 | 53 |
| Man basket | 85 | 53 |
| Dozer | 83 - 88 | 51 - 56 |
| Loader | 83 - 88 | 51 - 56 |
| Scissor Lift | 85 | 53 |
| Truck | 84 | 52 |
| Welder | 73 | 41 |
| Compressor | 80 | 48 |
| Concrete Pump | 77 | 45 |

Data compiled in part from the following references:
Federal Highway Administration 2006
Bolt, Beranek and Newman, Inc. 1977
Federal Highway Administration 1992

Construction activity will generate traffic having potential noise effects, such as trucks traveling to and from the site on public roads. At the early stage of the construction phase, equipment and materials will be delivered to the site, such as hydraulic excavators and associated spreading and compacting equipment needed to form access roads and foundation platforms for each turbine. Once the access roads are constructed, equipment for lifting the towers and turbine components will arrive. Traffic noise is categorized into two categories: (1) the noise that will occur during the initial temporary traffic movements related to turbine delivery, haulage of components and remaining construction; and (2) maintenance and ongoing traffic from staff and contractors, which is expected to be minor.

Federal laws prohibit state and local governments from regulating off-site sound levels generated by trucks and automobiles operating on a private site or public roadways. This federal regulatory preemption is specified in the Federal Noise Control Act of 1972 and in the Surface Transportation Assistance Act of 1982, both of which prohibit states and local authorities from regulating the noise emitted by trucks engaged in interstate commerce, i.e., truck deliveries. A federal OSHA preemption also prohibits local and state governments from regulating safety signals on trucks and construction equipment. CPV will coordinate with individual landowners regarding the operation of trucks, cars and other vehicles on private site access roadways as necessary to prevent the occurrences of unexpected noise resulting from construction and transport related vehicle movements.

### 5.4 Effects of Anomalous Weather Conditions and Wind Shear

The ISO 9613-2 standard calculates received sound pressure levels for meteorological conditions favorable to propagation, i.e., downwind sound propagation or what might occur typically during a moderate atmospheric ground level inversion (ISO 1989). The acoustic modeling algorithms essentially assume laminar atmospheric conditions, in which neighboring layers of air do not mix. This conservative assumption does not take into consideration turbulent eddies and micrometeorological inhomogeneities that may form when winds change speed or direction, which can interfere with the sound wave propagation path and increase attenuation effects.

Conversely, there may be meteorological conditions from time to time that will aid in the long range propagation of sound. These anomalous meteorological conditions may include well-developed moderate ground-based temperature inversions, such as commonly occurs at nighttime and during early morning hours, and wind gradients which can bend sound downwards, which may occur at anytime depending on predominant weather conditions. Per ISO 9613-2, the effects of meteorological conditions on sound propagation are small for short distances, and for longer distances at greater source and receptor heights. Over extended distances when the influences of wind or temperature gradients are most prevalent, atmospheric effects may cause fluctuations in received sound levels over long distances, but will typically attenuate noise to levels below those predicted. Levels significantly above those predicted are defined as exceptional events under the ISO 9613-2 standard. Project operational sound levels resulting from periodic anomalous meteorological conditions were also considered in the modeling analysis and are visually presented in Figures 4a and 4b. Figures 4a and 4b shows broadband (dBA) operational sound levels at wind speeds sufficient to sustain WTG operation at maximum rotational speeds under anomalous meteorological conditions, for the GE 2.5xl and Siemens SWT-2.3-101, respectively. Propagation for anomalous meteorological conditions are presented to show, that for relatively short periods of time, received sound levels may be higher than the mean.

In addition to sound propagation, meteorological factors may also affect wind turbine source levels. The roughness length coefficient ($z_0$) describes the rate of change of wind speed with elevation and is used to take into account the effect of friction at the ground and obstacles such as trees, resulting in lower wind speeds near the ground than at higher elevations. The vertical wind profile depends mainly on the terrain relief and the terrain roughness, but will also vary by month depending on ground cover and vegetation and will vary from place to place. Roughness length values reported per the IEC 61400-11 standard requires WTG manufacturers to report WTG source levels to a reference height of 10 meters using a standardized roughness length of $z_0$ = 0.05 meter that allows WTGs to be comparable on a uniform basis.

A wind energy project sited in an area with a higher roughness length coefficient has both positive and negative implications. As the value of the roughness length coefficient increases so does the available wind resource at WTG tower height, which is favorable from a power production standpoint. Conversely, higher wind shear levels impose greater levels of mechanical strain on a WTG's blades and drive train. This effect is taken into account when assessing the suitability of different WTG models for a specific site. Overall, the Project site is expected to have a low to moderate roughness length and wind shear. This means that from time to time WTG near maximum sound power output may occur, even when low level wind conditions are occurring closer to the ground, which may temporarily increase the overall perceptibility of the Project.

## 6.0 CONCLUSIONS

Project operational sound has been calculated and compared to relevant environmental noise guidelines as established by the EPA and OSHA. Acoustic modeling analysis per ISO 9613-2 indicates no exceedances of the 55 dBA $L_{dn}$ EPA noise guideline with and without including sound contribution from the substation (indicating the substation is not the chief sound source contribution). Results further indicate that the Project has been adequately designed to operate in compliance with EPA noise guidelines at all existing occupied residences considered to be noise sensitive receptors, while allowing for an additional 3 dBA margin of safety between the ISO 9613-2 calculated received sound levels and the EPA guideline limits.

The EPA guideline limits identified are not legally enforceable requirements, but serve as useful guidelines to determine the likelihood of adverse community noise impacts. The EPA guidelines do not require inaudibility of a sound source. In fact, even if a Project-generated received sound level is below ambient conditions, the spectral and temporal characteristics of the new sound may result in perceptibility. The results of the acoustic modeling analysis indicate that operation of the Project may result in periodically audible sound within the adjacent areas under certain operational and meteorological conditions. Individual response to low-level WTG sound is largely subjective and therefore not easily predictable and may depend on several technical and non-technical factors, including predetermined perceptions of the Project and wind energy in general, individual and community economic incentives, existing background sound levels, the proximity of the listener to a single or grouping of WTGs, among several others. Due to their support of Project development, Project participants have been found to be less likely to become annoyed by low-level WTG sound than non-participants. Non-participants that consider the development of renewable energy sources, and wind energy projects specifically, as beneficial will also be more likely to deem the low-level environmental noise as generally acceptable Nonetheless, complaints about noise from wind energy projects may still occur, even when fixed standards or limits relative to existing ambient conditions are proposed and met.

In conclusion, the acoustic modeling analysis, inclusive of a number of conservative assumptions has been shown to be adequately designed to operate in compliance with EPA guideline limits. As the Project is using a minimum turbine siting setback requirement of 1,400 feet (427 meters to any residence), potential noise impacts on sensitive receptors (occupied residences) have been minimized. Sound from the Project when audible will likely not be deemed excessive or unusually loud at the setback distance in place and will be consistent with sound generated at similar wind energy projects successfully sited throughout the state of North Dakota employing similar criteria and WTG setbacks.

## 7.0 TECHNICAL REFERENCES

ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers). 1989. ASHRAE Handbook—Fundamentals, Atlanta, Georgia.

BLM (Bureau of Land Management). 2005. "Final Programmatic Environmental Impact Statement on Wind Energy Development on BLM-Administered Lands in the Western United States," FES 05-11, June 2005.

Bolt, Beranek and Newman, Inc. 1977. Power Plant Construction Noise Guide, prepared for the Empire State Electric Energy Research Corporation, Report No. 3321, 1977.

Commercial Documentation Wind Turbine Generator Systems. 2010. GE 2.5xl – 103 m rotor – 50 Hz & 60 Hz, Product Acoustic Specifications, Normal Operation according to IEC 61400-11, GE Company, 2010.

Commercial Documentation Wind Turbine Generator Systems.2009. GE 2.5xl – 60 Hz, Product Acoustic Specifications, Canada Specific – Normal Operation according to IEC 61400-11, GE Company, 2009.

David Bies and Collin Hansen. 2003. "Engineering Noise Control: Theory and Practice", Pages 554-555, Published by Taylor & Francis, 2003.

DataKustik GmbH. 2010. Computer-Aided Noise Abatement Model CadnaA, Version 4.0.136 Munich, Germany.

Elliott, T. et al. 1998. Standard handbook of powerplant engineering. McGraw-Hill: 1998, New York.

EPA (United States Environmental Protection Agency). 1974. Information on Levels of Environmental Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety, Publication EPA-550/9-74-004, March.

EPA. 1978. Protective Noise Levels. Condensed Version of EPA Levels Document. Publication EPA-550/9-79-100, November.

Federal Highway Administration. 2006. FHWA Roadway Construction Noise Model User's Guide, FHWA-HEP-05-054, January 2006.

Federal Highway Administration. 1992. "Procedures for Abatement of Highway Traffic Noise and Construction Noise". Code of Federal Regulations, Title 23, Part 772, 1992.

GE Company. 2009. Commercial Documentation Wind Turbine Generator Systems. GE 2.5xl – 60 Hz, Product Acoustic Specifications, Canada Specific – Normal Operation according to IEC 61400-11, GE Company, 2009.

GE Company. 2010. Commercial Documentation Wind Turbine Generator Systems. GE 2.5xl - 103 m rotor 50 Hz & 60 Hz, 2010

International Electrotechnical Commission (IEC) 61400-11:2006 Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques, Edition 2.1 2006-11.

ISO (Organization for International Standardization). 1989. Standard ISO 9613-2 Acoustics – Attenuation of Sound During Propagation Outdoors. Part 2 General Method of Calculation. Geneva, Switzerland.

Rogers, Anthony, James Manwell, Sally Wright. 2006. "Wind Turbine Noise – A White Paper," Renewable Energy Research Laboratory, University of Massachusetts at Amherst, June 2002, Amended January 2006.

Siemens. 2009. SWT-2.3-101 Acoustic Emission, Proprietary Data, Siemens Wind Power A/S, 2009.

Wagner, S., Bareib, R. and Guidati, G. 1996. Wind Turbine Noise, Springer, Berlin.

# FIGURES

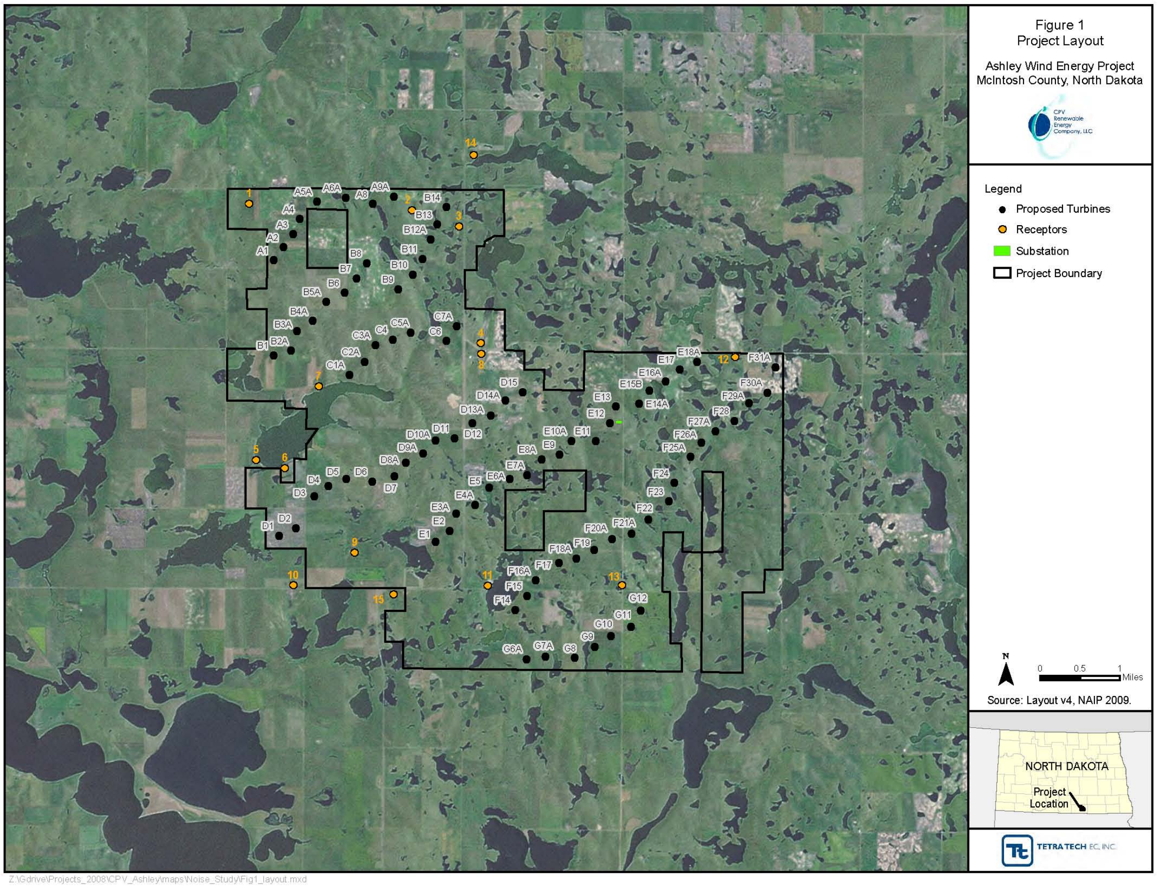


Figure 1
Project Layout
Ashley Wind Energy Project
McIntosh County, North Dakota
Legend
Proposed Turbines
Receptors
Substation
Project Boundary
Miles
Source: Layout v4, NAIP 2009.
NORTH DAKOTA
Project Location
TETRA TECH EC, INC.

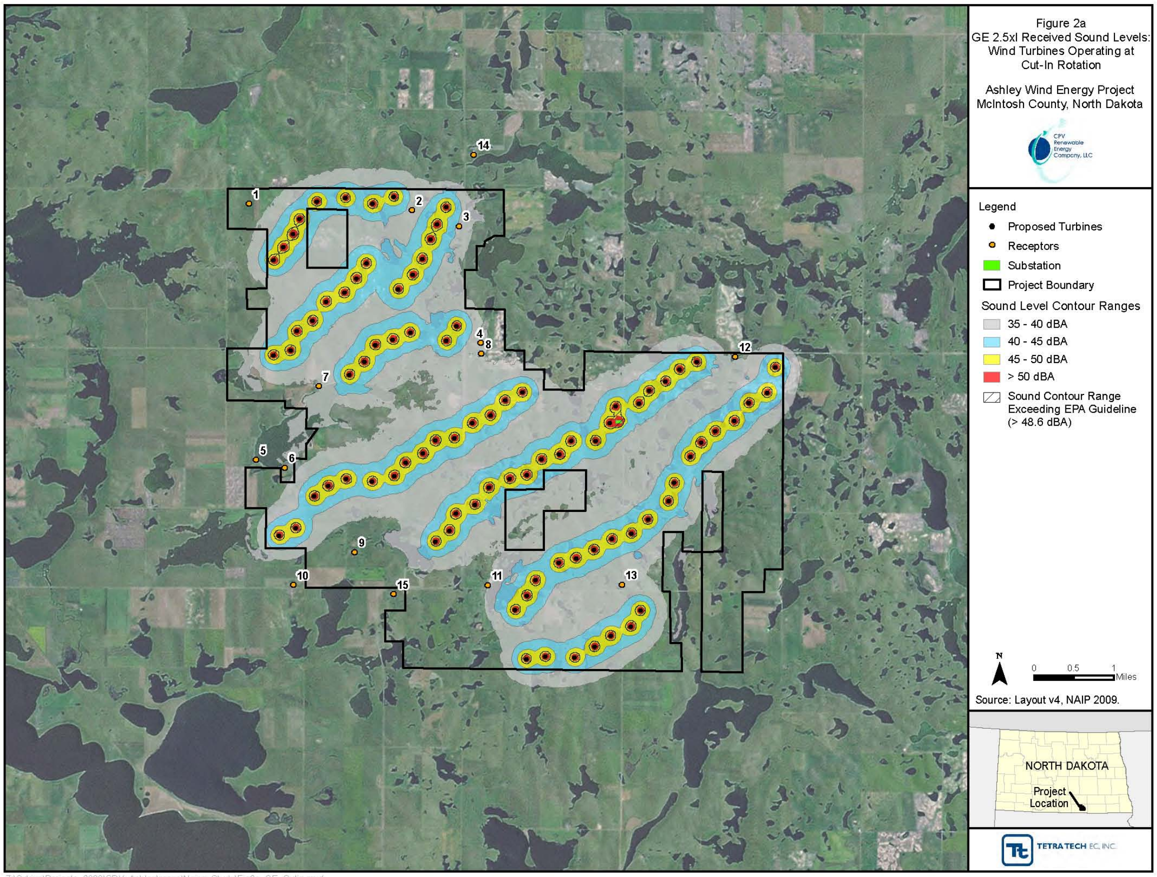


Figure 2a
GE 2.5xl Received Sound Levels:
Wind Turbines Operating at
Cut-In Rotation
Ashley Wind Energy Project
McIntosh County, North Dakota
Legend
Proposed Turbines
Receptors
Substation
Project Boundary
Sound Level Contour Ranges
35 - 40 dBA
40 - 45 dBA
45 - 50 dBA
> 50 dBA
Sound Contour Range
Exceeding EPA Guideline
(> 48.6 dBA)
N
0
0.5
1
Miles
Source: Layout v4, NAIP 2009.
NORTH DAKOTA
Project
Location
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

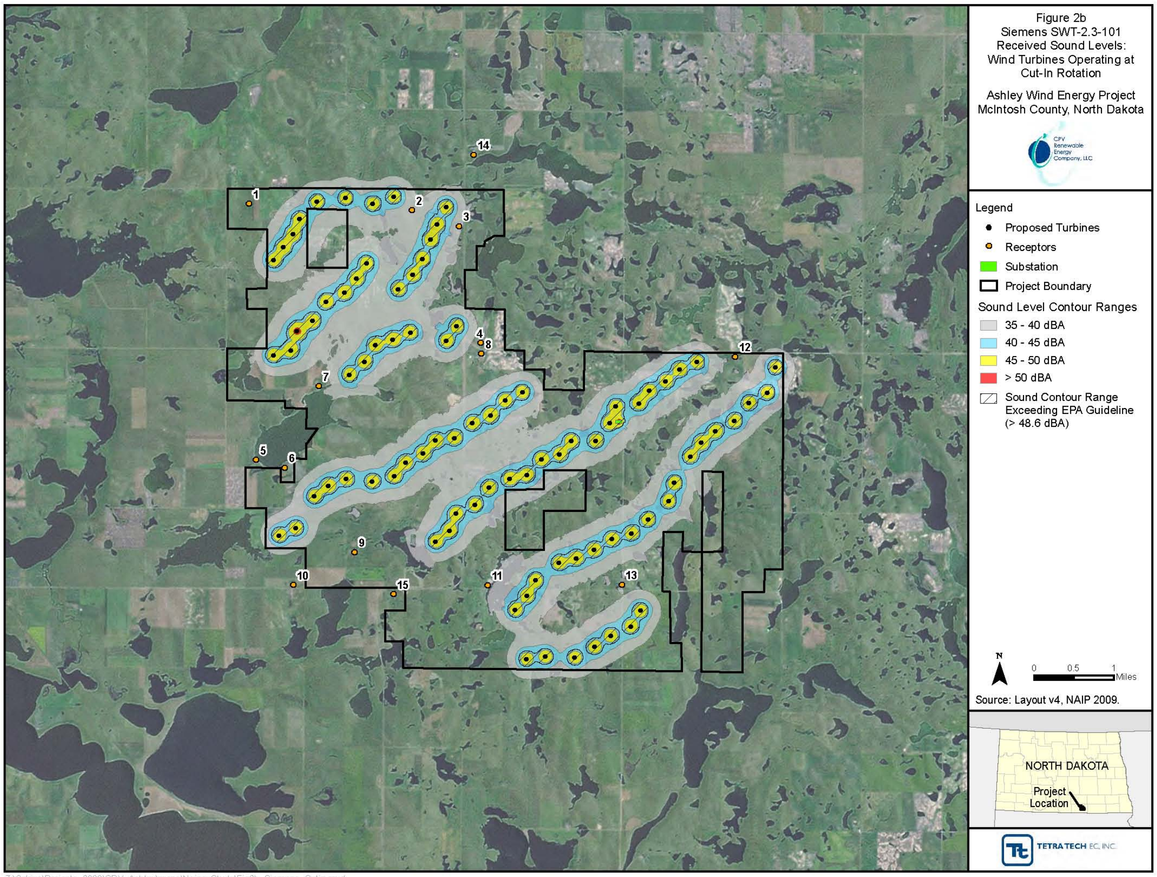


Figure 2b
Siemens SWT-2.3-101
Received Sound Levels:
Wind Turbines Operating at
Cut-In Rotation
Ashley Wind Energy Project
McIntosh County, North Dakota
Legend
Proposed Turbines
Receptors
Substation
Project Boundary
Sound Level Contour Ranges
35 - 40 dBA
40 - 45 dBA
45 - 50 dBA
> 50 dBA
Sound Contour Range
Exceeding EPA Guideline
(> 48.6 dBA)
0 0.5 1 Miles
Source: Layout v4, NAIP 2009.
NORTH DAKOTA
Project
Location
TETRA TECH EC, INC.

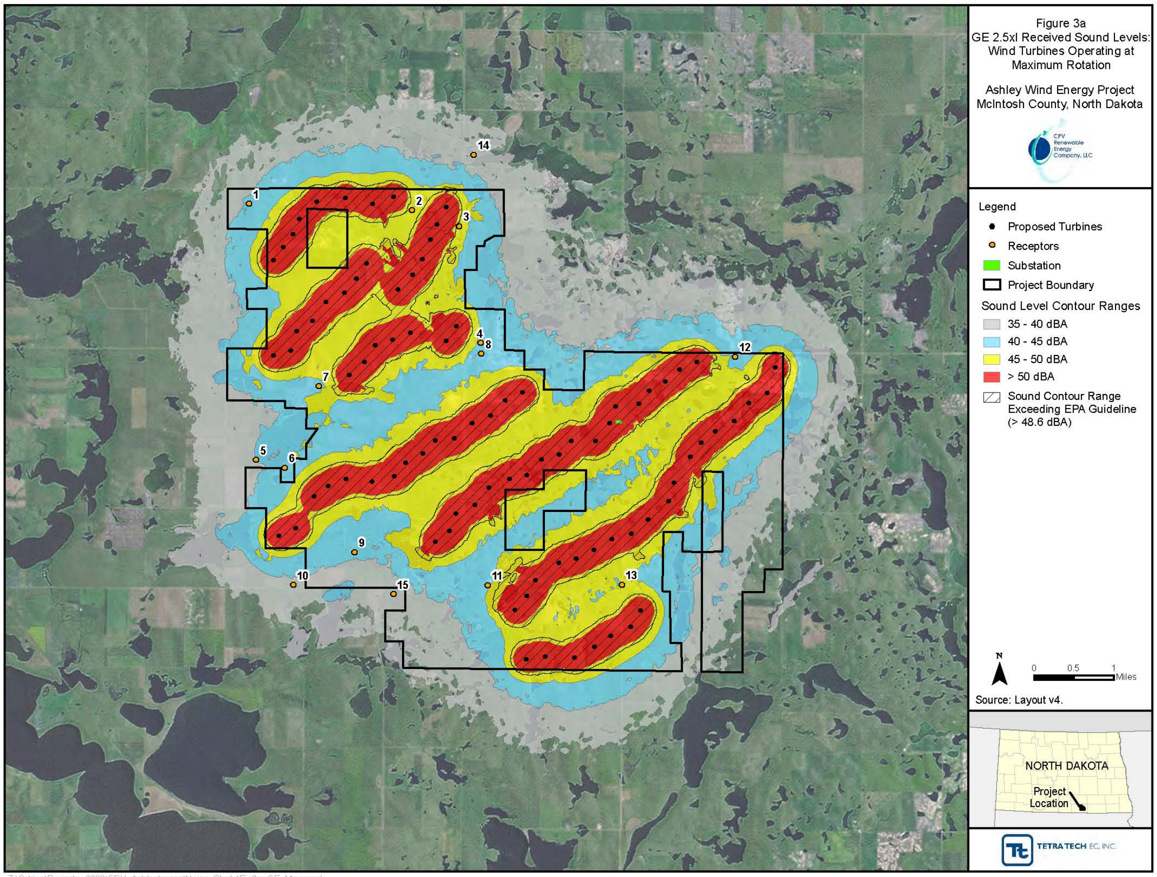


Figure 3a
GE 2.5xl Received Sound Levels:
Wind Turbines Operating at
Maximum Rotation
Ashley Wind Energy Project
McIntosh County, North Dakota
Legend
Proposed Turbines
Receptors
Substation
Project Boundary
Sound Level Contour Ranges
35 - 40 dBA
40 - 45 dBA
45 - 50 dBA
> 50 dBA
Sound Contour Range
Exceeding EPA Guideline
(> 48.6 dBA)
Source: Layout v4.
NORTH DAKOTA
Project
Location
TETRA TECH EC, INC.

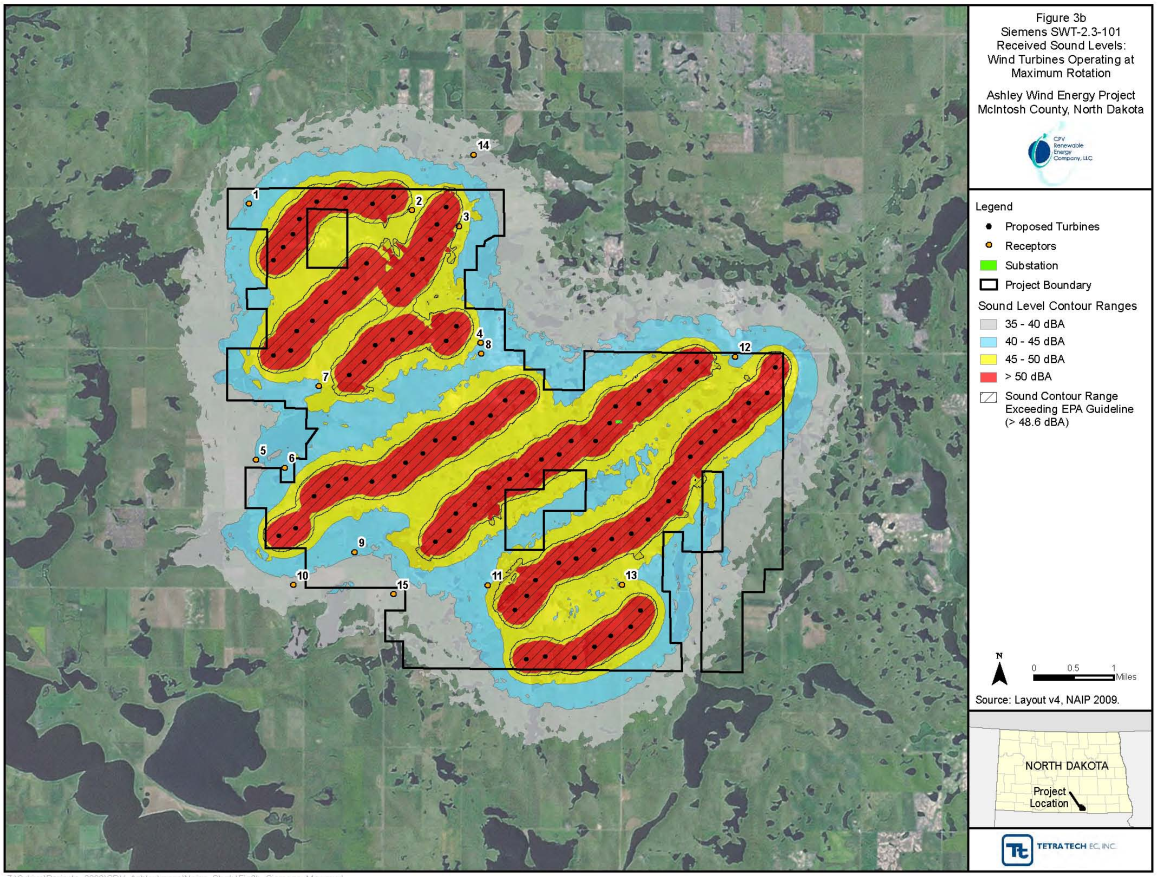


Figure 3b
Siemens SWT-2.3-101
Received Sound Levels:
Wind Turbines Operating at
Maximum Rotation
Ashley Wind Energy Project
McIntosh County, North Dakota
Legend
Proposed Turbines
Receptors
Substation
Project Boundary
Sound Level Contour Ranges
35 - 40 dBA
40 - 45 dBA
45 - 50 dBA
> 50 dBA
Sound Contour Range Exceeding EPA Guideline (> 48.6 dBA)
N
0 0.5 1 Miles
Source: Layout v4, NAIP 2009.
NORTH DAKOTA
Project Location
TETRA TECH EC, INC.

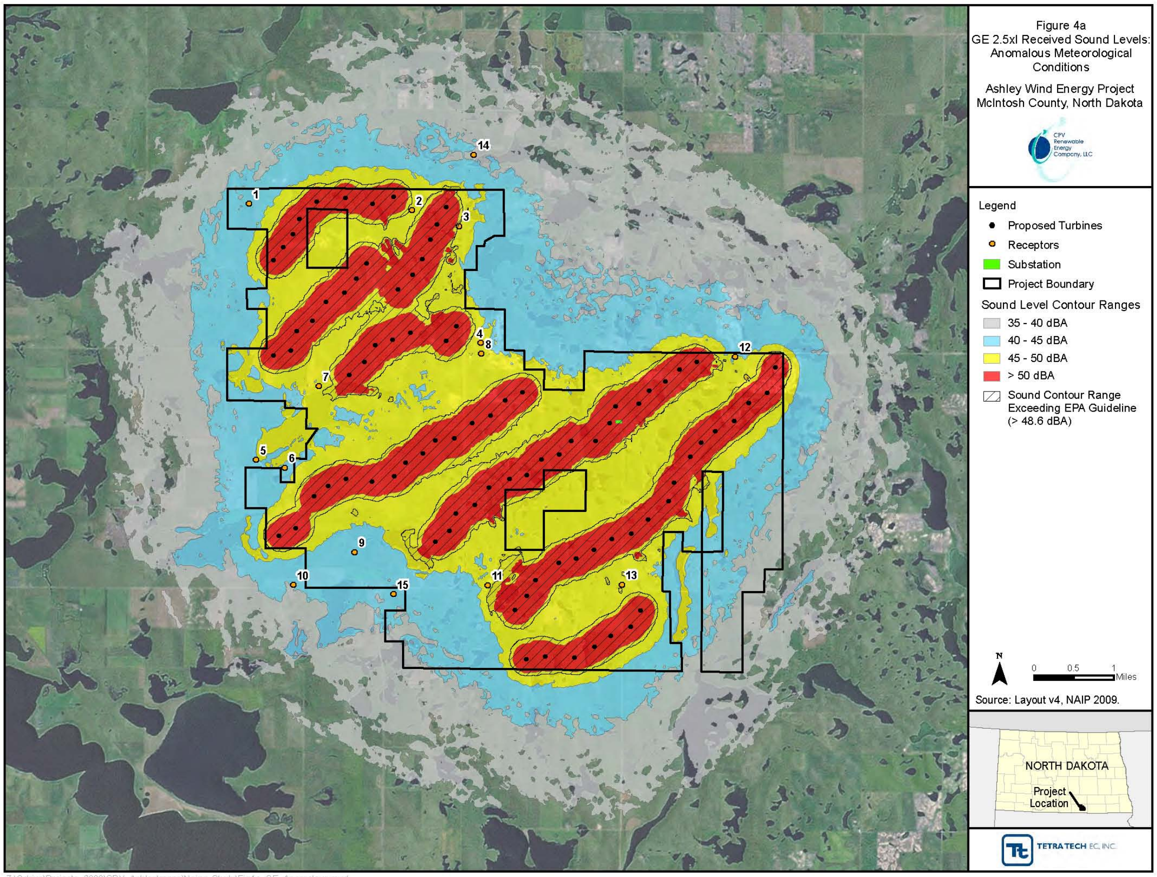


Figure 4a
GE 2.5xl Received Sound Levels: Anomalous Meteorological Conditions
Ashley Wind Energy Project
McIntosh County, North Dakota
CPV Renewable Energy Company, LLC
Legend
Proposed Turbines
Receptors
Substation
Project Boundary
Sound Level Contour Ranges
35 - 40 dBA
40 - 45 dBA
45 - 50 dBA
> 50 dBA
Sound Contour Range Exceeding EPA Guideline (> 48.6 dBA)
N
0 0.5 1 Miles
Source: Layout v4, NAIP 2009.
NORTH DAKOTA
Project Location
TETRA TECH EC, INC.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

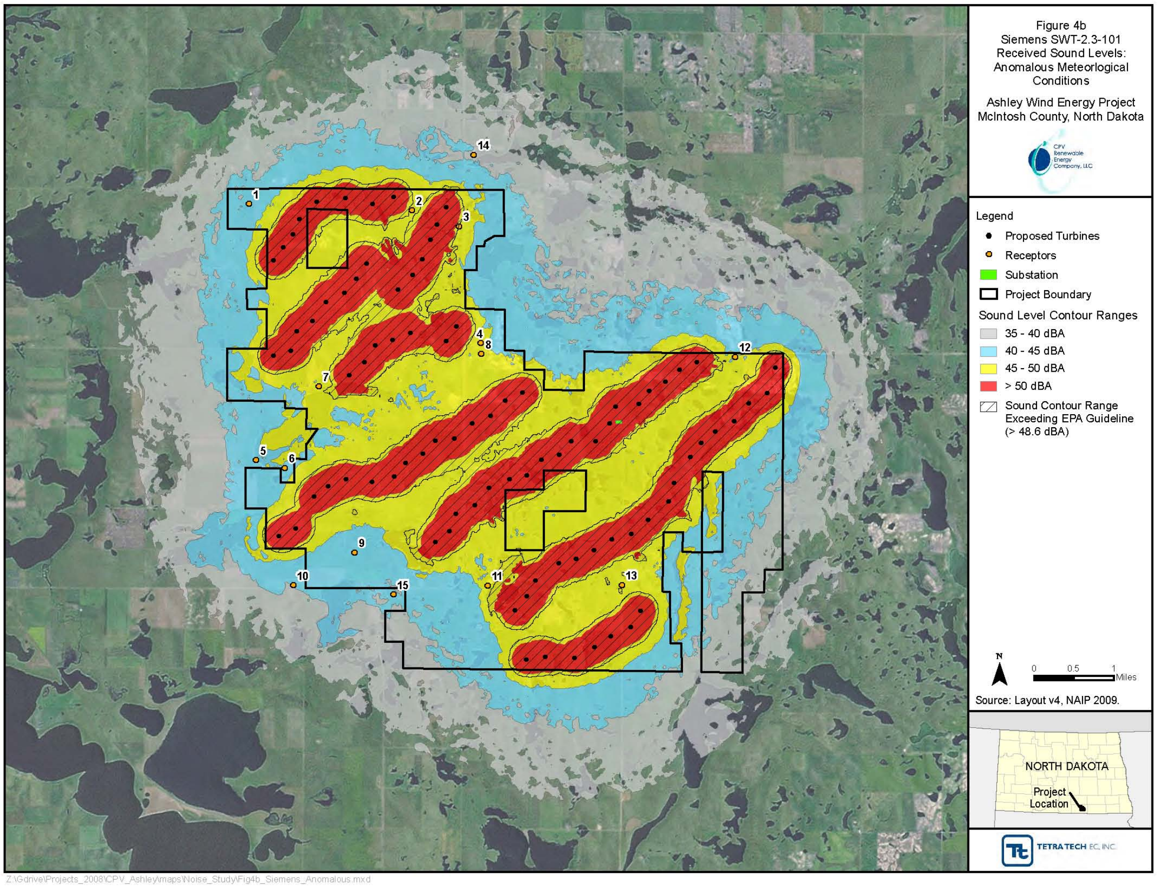


Figure 4b
Siemens SWT-2.3-101
Received Sound Levels:
Anomalous Meteorlogical
Conditions
Ashley Wind Energy Project
McIntosh County, North Dakota
CPV Renewable Energy Company, LLC
Legend
Proposed Turbines
Receptors
Substation
Project Boundary
Sound Level Contour Ranges
35 - 40 dBA
40 - 45 dBA
45 - 50 dBA
> 50 dBA
Sound Contour Range Exceeding EPA Guideline (> 48.6 dBA)
N
0 0.5 1 Miles
Source: Layout v4, NAIP 2009.
NORTH DAKOTA
Project Location
TETRA TECH EC, INC.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15