Appendix G
Triple H Wind Project Acoustic Assessment

Acoustic Assessment for the Triple H Wind Energy Project
Hyde County, South Dakota

December 2018

PRESENTED TO

Triple H Wind Project, LLC

PRESENTED BY

Tetra Tech

EXECUTIVE SUMMARY

Tetra Tech, Inc. (Tetra Tech) has completed an acoustic assessment for the proposed Triple H Wind Energy Project (Project) under development in Hyde County, South Dakota. An analysis was completed to evaluate the expected sound levels resulting from the Project wind turbines and substation. The acoustic assessment evaluated 103 potential wind turbine locations from the November 16, 2018 Project layout; only 92 of the wind turbines will be constructed. Acoustic analyses for three different modeling scenarios were performed. Scenarios included wind turbine operation at cut-in wind speed, as well as maximum rotational speed under both moderate downwind and anomalous meteorological conditions. The overall objective of this study was to determine the feasibility of the Project to operate in compliance with the Hyde County Zoning Ordinance 45 dBA noise limit.

Wind turbine sound source data was obtained from GE for the GE 2.72-116 equipped with Low Noise Trailing Edge (LNTE) technology (GE 2018). Substation noise impacts were based on a projected 140 megavolt-ampere (MVA) transformer. It is expected that the wind turbines and substation equipment installed will have similar sound profiles to what was used in the acoustic modeling analysis; however, it is possible that the final warranty sound power levels may vary slightly.

Sound propagation modeling was conducted using the Computer-Aided Noise Abatement (CadnaA) program (version 2018 MR1), a comprehensive 3-dimensional acoustic modeling computer simulation software, with calculations made in accordance with the International Organization for Standardization (ISO) standard 9613-2 “Attenuation of Sound during Propagation Outdoors”. This acoustic modeling software is widely used by acoustical engineers due to its adaptability to evaluate complex acoustic scenarios. Several modeling assumptions inherent in the ISO 9613-2 calculation methodology, or selected as conditional inputs by the user, were implemented in the CadnaA model to ensure conservative results.

The results of the acoustic assessment show that the Project will comply with the Hyde County 45 dBA limit at all receptors, except for three participating landowner properties which may periodically experience sound levels above the noise threshold criteria. Triple H has obtained written waivers from those participating landowners. It is expected that received sound levels at noise-sensitive receptors will be consistent with sound generated at similar wind energy projects successfully sited throughout the state of South Dakota employing the same or similar criteria. However, while the acoustic assessment has demonstrated compliance with permitting requirements, the Project may result in periodically audible sound within adjacent areas under certain operational and meteorological conditions.

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
µPa	micropascal
dB	decibel
dBA	A-weighted decibel
dBL	unweighted (linear) decibel
Triple H	Triple H Wind Project, LLC
ft	foot
GE	General Electric Company
Hz	Hertz
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
kHz	kilohertz
Leq	equivalent sound level
Lp	sound pressure level
Lw	sound power level
LNTE	Low Noise Trailing Edge
m	meter
m/s	meters per second
MVA	megavolt ampere
MW	megawatt
NEMA	National Electric Manufacturers Association
NSR	noise-sensitive receptors
pW	picowatt
the Project	The Triple H Wind Energy Project
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

1.0 OVERVIEW

Triple H Wind Project, LLC (Triple H) is proposing to construct and operate the Triple H Wind Energy Project (the Project) located in Hyde County, South Dakota. The Project is expected to have an up to nominal 250 megawatt (MW) power output capacity. The acoustic assessment analyzed a total of 103 potential locations; only 92 of the wind turbines will be constructed. The proposed Project infrastructure includes General Electric (GE) model 2.72-116 wind turbines equipped with Low Noise Trailing Edge (LNTE) blade technology, collection lines and an onsite substation. The substation transformers are rated at 140 megavolt ampere (MVA) and located at the southwest corner of the intersection of 203rd Street and 330th Street.

This acoustic assessment included modeling analyses to predict future sound levels when the wind turbines are operational. Three different modeling scenarios were considered, one with wind turbines operating at cut-in wind rotational speed and two others at maximum rotational speed, under moderate downwind and anomalous meteorological conditions. Operational sounds levels resulting from the Project were analyzed at existing noise-sensitive receptors (NSRs; e.g., residential structures) and compliance was assessed relative to the Hyde County zoning ordinance requirements for siting large wind energy systems which sets numerical decibel limits.

1.1 STUDY AREA

The Project Study Area is entirely within Hyde County, South Dakota. County and township (section line) roads characterize the existing roadway system and the Study Area is accessible via US Highway 14, State Highway 47, and other local two-lane paved and gravel county roads. The land within the Study Area is primarily agricultural with scattered farmstead residences. The turbines will be located on privately-owned land in southwestern Hyde County. This region of South Dakota has topography that can be described as level to rolling plains. Gentle slopes characterize most of the Study Area and local relief ranges from less than 1,500 to over 2,200 feet. Current land use within the Study Area is primarily agricultural, supporting both crops and livestock grazing. Potential NSR locations within the Study Area and in the vicinity of proposed turbine locations were included in the acoustic analysis. Figures A-1 through A-3 (Appendix A) presents the proposed wind turbine locations, as well as the noise sensitive receptor locations.

1.2 EXISTING ACOUSTIC ENVIRONMENT

Hyde County would generally be considered a rural agricultural area. Existing ambient sound levels are expected to be relatively low, although sound levels would be higher near roadways such as US Highway 14 and State Highway 47. Other human activity such as agricultural operations would seasonally contribute to sound levels in the area associated with crop harvests. Background sound levels are expected to vary both spatially and temporally depending on natural sounds and proximity to area sound sources such as roadways. Typically, background sound levels are quieter during the night than during the daytime, except during periods when evening and nighttime insect noise may contribute to the soundscape, predominantly in the warmer seasons.

1.3 ACOUSTIC TERMINOLOGY

Airborne sound is described as the rapid fluctuation or oscillation of air pressure above and below atmospheric pressure, creating a sound wave. Sound is characterized by properties of the sound waves, which are frequency, wavelength, period, amplitude, and velocity. Noise is defined as unwanted sound. A sound source is defined by a sound power level (Lw), which is independent of any external factors. The acoustic sound power is the rate at which acoustical energy is radiated outward and is expressed in units of watts. 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 (Lp) is a measure of this fluctuation and can be directly determined with a microphone or calculated from information about the source sound power level and the surrounding environment through predictive acoustic modeling. While the sound power of a source is strictly a function of the total amount of acoustic energy being radiated by the source, the sound pressure levels produced by a source are a function of the distance from the source and the effective radiating area or physical size of the source. In general, the magnitude of a source's sound power level is always considerably higher than the observed sound pressure level near a source since the acoustic energy is being radiated in various directions.

Sound levels are presented on a logarithmic scale to account for the large pressure response range of the human ear and are expressed in units of decibels (dB). A dB 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 (µPa). Conversely, sound power is commonly referenced to 1 picowatt (pW), which is one trillionth of a watt. Broadband sound includes sound energy summed across the frequency spectrum. In addition to broadband sound pressure levels, analysis of the various frequency components of the sound spectrum is often completed to determine tonal characteristics. The unit of frequency is Hertz (Hz), which corresponds to the rate in cycles per second that sound pressure waves are generated. Typically, a sound frequency analysis examines 11 octave bands (or 33 1/3 octave) ranging from 20 Hz (low) to 20,000 Hz (high). This range encompasses the entire human audible frequency range. Since the human ear does not perceive every frequency with equal loudness, spectrally varying 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. Sound exposure in acoustic assessments is commonly measured and calculated as A-weighted dB (dBA). Unweighted sound levels are referred to as linear. Linear dB (dBL) are used to determine a sound's tonality and to engineer solutions to reduce or control noise as techniques are different for low and high frequency noise.

Sound can be measured, modeled, and presented in various formats, with the most common metric being the equivalent sound level (Leq). 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 in the State of South Dakota. Estimates of noise sources and outdoor acoustic environments, and the comparison of relative loudness are presented in Table 1. Table 2 provides additional reference information on acoustic terminology.

Table 1. Sound Pressure Levels (Lp) and Relative Loudness of Typical Noise Sources and Soundscapes

Noise Source or Activity	Sound Level (dBA)	Subjective Impression	Relative Loudness (perception of different sound levels)
Jet aircraft takeoff from carrier (50 ft.)	140	Threshold of pain	64 times as loud
50-hp siren (100 ft.)	130		32 times as loud
Loud rock concert near stage or Jet takeoff (200 ft.)	120	Uncomfortably loud	16 times as loud
Float plane takeoff (100 ft.)	110		8 times as loud
Jet takeoff (2,000 ft.)	100	Very loud	4 times as loud
Heavy truck or motorcycle (25 ft.)	90		2 times as loud
Garbage disposal, food blender (2 ft.), or Pneumatic drill (50 ft.)	80	Loud	Reference loudness
Vacuum cleaner (10 ft.)	70	Moderate	1/2 as loud
Passenger car at 65 mph (25 ft.)	65		
Large store air-conditioning unit (20 ft.)	60		1/4 as loud

Noise Source or Activity	Sound Level (dBA)	Subjective Impression	Relative Loudness (perception of different sound levels)
Light auto traffic (100 ft.)	50	Quiet	1/8 as loud
Quiet rural residential area with no activity	45		
Bedroom or quiet living room or Bird calls	40	Faint	1/16 as loud
Typical wilderness area	35		
Quiet library, soft whisper (15 ft.)	30	Very quiet	1/32 as loud
Wilderness with no wind or animal activity	25	Extremely quiet	
High-quality recording studio	20		1/64 as loud
Acoustic test chamber	10	Just audible	
	0	Threshold of hearing	
Note: Adapted from: Beranek 1988; EPA 1971			

Table 2. Acoustic Terms and Definitions

Term	Definition
Noise	Typically defined as unwanted sound. This word adds the subjective response of humans to the physical phenomenon of sound. It is commonly used 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 microPascals, the approximate threshold of human perception to sound at 1,000 Hz.
Sound Power Level (L_W)	The total acoustic power of a noise source measured in decibels referenced to picowatts (one trillionth of a watt). Noise specifications are provided by equipment manufacturers as sound power as it is independent of the environment in which it is located. A sound level meter does not directly measure sound power.
A-Weighted Decibel (dBA)	Environmental sound is typically composed of acoustic energy across all frequencies. 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.
Unweighted Decibels (dBL)	Unweighted sound levels are referred to as linear. Linear decibels are used to determine a sound's tonality and to engineer solutions to reduce or control noise as techniques are different for low and high frequency noise. Sound levels that are linear are presented as dBL 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.

Term	Definition
Octave Bands	The audible range of humans spans from 20 to 20,000 Hz and is typically divided into center frequencies ranging from 31 to 8,000 Hz for noise modeling evaluations.
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.
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 (or cycles) 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.

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

2.0 NOISE REGULATIONS AND GUIDELINES

A review was conducted of noise regulations applicable to the Project at the federal, state, county, and local levels. There are no federal or state environmental noise requirements specific to this Project. At the county level, Hyde County has established regulations applicable to wind energy facilities.

Hyde County proposed regulations for wind energy facilities under Zoning Ordinance Section 9-104-A-18 as follows:

> *SECTION 9-104 Requirements for Siting Large Wind Energy Systems.*
>
> *A. Standards. A Large Wind Energy System shall be a Conditional Use in an Ag district subject to the following requirements:*
>
> *18. Noise. Noise level produced by the LWES shall not exceed forty-five (45) decibels of sound at the perimeter of occupied residences existing at the time the permit application is filed, unless a signed waiver or easement is obtained from the owner of the residence. The level, however may be exceeded during short-term events such as utility outages or wind storms.*

Sound levels resulting from the Project at all identified receptors located in the vicinity of the Project were assessed against the 45 dBA limit to determine whether compliance was achieved. The Hyde County Zoning Ordinance noise limit is absolute and independent of the existing acoustic environment; therefore, a baseline sound survey is not required to assess conformity.

3.0 ACOUSTIC MODELING METHODOLOGY AND RESULTS

Sound generated by an operating wind turbine is comprised of both aerodynamic and mechanical sound with the dominant sound component from modern utility scale wind turbines being aerodynamic. Aerodynamic noise results from air flowing across and around each blade of the turbine. Secondarily, mechanical sound generated by machinery located inside the nacelle of the turbine, such as gearboxes, motors, cooling systems, and pumps. Due to the improved design of wind turbine 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 minimized.

Wind energy facilities, in comparison to other energy-related facilities, are somewhat unique in that the sound generated by each individual wind turbine will increase as the wind speed increases. The sound emitted by a wind turbine is strongly dependent on the speed of the tip of the blade, the design of the blade, and on atmospheric conditions such as the degree of turbulence. Blade noise increases with increasing wind speed until full rated electrical power is achieved due to the interaction between the incident turbulence eddies and the blade surface. The prevalence of this inflow turbulence noise will vary depending on site-specific and variable atmospheric conditions. The second mechanism is the shedding of vortices that form at the tip of each blade. This depends on the strength of the vortex and the design of the blade tip. Finally, noise may be generated by turbulent flow over the trailing edge of the blade. As air flows over the face of the blade, a turbulent boundary layer develops, but remains attached to the trailing edge. Eddies extending past the trailing edge causes sound emission scattering, resulting in the characteristic wind turbine broadband swooshing sound. This turbulent boundary layer noise (trailing edge noise) usually defines the upper limit of wind turbine noise levels and is considered the greatest contributor to aerodynamic noise.

One of the primary blade design features effecting noise emissions is the shape of the trailing edge of the blades. Sound reduction elements have been incorporated into the Project design including the use of LNTE blades designed to minimize noise generation. The addition of blade serrations has been demonstrated to reduce noise levels by 2 to 3 dBA below standard blades. The wind turbine analyzed on this Project, the GE 2.72-116, is equipped with LNTE blade technology as an optional noise mitigative feature to reduce audible noise.

It is important to recognize as wind speeds increase, the background ambient sound level will generally increase as well, resulting in acoustic masking effects; however, this trend is also affected by local contributing sound sources. The net result is that during periods of elevated wind speeds when higher wind turbine sound emissions occur, the sound produced from a wind turbine operating at maximum rotational speed may be largely or fully masked due to wind generated sound in foliage or vegetation. In practical terms, this means a nearby receptor would tend to hear leaves or vegetation rustling rather than wind turbine noise. This relationship is expected to further minimize the potential for any adverse noise effects of the Project. Conversely, these acoustic masking effects may be limited during periods of unusually high wind shear or at receiver locations that are sheltered from the prevailing wind direction.

3.1 ACOUSTIC MODELING SOFTWARE AND CALCULATION METHODS

To assess the noise emissions of a wind energy facility prior to construction, it is necessary to have prediction models with which a noise emission source level measured at a given reference point can be certified. A generally accepted approach for modeling a wind turbine as an idealized point source is described in International Organization for Standardization (ISO) 9613-2, "Attenuation of Sound during Propagation Outdoors". The standard specifies methods to enable noise levels in the community to be predicted from sources of known sound emission and provides a summary of existing knowledge on outdoor sound propagation as published by ISO, a worldwide federation of national standards bodies. The calculation methodologies described are relied on by professionals in the field of acoustics.

Standard acoustic engineering methods that conform to ISO 9613-2 were used in this noise analysis using DataKustic GmbH's CadnaA, the computer-aided noise abatement program (version 2018 MR1). The engineering methods specified in this standard consist of full (1/1) octave band algorithms that incorporate geometric spreading due to wave divergence, reflection from surfaces, atmospheric absorption, screening by topography and obstacles, ground effects, source directivity, heights of both sources and receptors, seasonal foliage effects, and meteorological conditions. For compliance assessment purposes, operational broadband sound pressure levels were calculated assuming that all wind turbines are operating continuously and concurrently at the maximum manufacturer-rated sound level. The sound energy was then summed to determine the equivalent continuous A-weighted downwind sound pressure level at a given point of reception.

The effects of topography were incorporated into the noise prediction model using ground contour data from the official U.S. 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. The ISO 9613-2 standard accounts for ground absorption rates by assigning a numerical coefficient of G=0 for acoustically hard, reflective surfaces and G=1 for absorptive surfaces and soft ground. If the ground is hard-packed dirt, typically found in industrial complexes, pavement, bare rock or for sound traveling over water, the absorption coefficient is defined as G=0 to account for reduced sound attenuation and higher reflectivity. In contrast, ground covered in vegetation, including suburban lawns, livestock and agricultural fields (both fallow with bare soil and planted with crops), will be acoustically absorptive and aid in sound attenuation (i.e., G=1.0). For the purposes of this modeling analysis, a semi-reflective ground absorption factor was applied throughout the Project area. In addition to geometrical divergence, attenuation factors include topographical features, terrain coverage, and/or other natural or anthropogenic obstacles that can affect sound attenuation and result in acoustical screening. To be conservative, sound attenuation through foliage and diffraction around and over existing anthropogenic structures such as buildings was not included in the model. Sound attenuation by the atmosphere is not strongly dependent on temperature and humidity; however, a temperature of 10°C (50°F) and 70 percent relative humidity parameters were selected as reasonably representative of conditions favorable to sound propagation.

Since it is not possible to account for all factors that affect sound propagation and attenuation, acoustic modeling followed the methodologies as described in the ISO 9613-2 standard, which have been accepted as reasonably conservative, to serve as regulatory worst case. Inherent to the ISO 9613-2 standard is the assumption of downwind sound propagation conditions. That is, the wind turbine sound power levels and modeling methods are representative of when the wind is blowing from the wind turbine to the receptor. In fact, the ISO 9613-2 modeling method unrealistically assumes that downwind conditions exist in all directions, between each wind turbine and each receptor simultaneously, even though this is physically impossible. Therefore, lower levels are expected in the upwind direction. In addition, 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 variations 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 may aid in the long range propagation of sound. These anomalous meteorological conditions may include wind gradients that bend sound downwards, which principally affects long range sound attenuation. Received sound levels during anomalous meteorological conditions were also estimated using a range dependent correction factor.

3.2 ACOUSTIC MODELING INPUT PARAMETERS

The operational acoustic assessment was performed using the proposed November 16, 2018 layout with 103 potential wind turbine locations. The following wind turbine model was evaluated in this analysis:

- **GE 2.72-116 with LNTE –** Wind turbine equipped with LNTE blade technology, a rotor diameter of 381 feet (ft) (116 meters [m]) and a hub height of 295 ft. (90 m).

To assist project developers and acoustical engineers, wind turbine manufacturers report wind turbine sound power data at integer wind speeds referenced to the effective hub height, ranging from cut-in to full rated power. This accepted International Electrotechnical Commission (IEC) standard was developed to ensure consistent and comparable sound emission data of utility-scale wind turbines between manufacturers. The IEC test is an accepted standard providing a uniform methodology for measuring the noise emissions of a wind turbine from cut-in through full rotational wind speeds. The IEC testing standard defines deviation values σ_T, σ_R and σ_P for measured apparent sound power levels as described by IEC/TS 61400-14, where σ_T is the total standard deviation, σ_R is the standard deviation for test reproducibility, and σ_P is the standard deviation for product variation. To account for this inherent deviation associated with the IEC testing methodology, a confidence interval of k = 2 dBA was applied. The combination of the modeling parameters used and the inclusion of the 2-dBA term are expected to result in a reasonable and conservative assessment of Project sound levels since it is unlikely that all wind turbines would be operating concurrently 2 dB above the mean.

Tables 3 provides a summary of the sound power data correlated by wind speed at reference rotor hub height assuming a roughness length coefficient of 0.05 meters. The roughness length describes the change in wind speed at increased elevation and may vary based on site specific terrain conditions. It is assumed that the wind turbine models for the Project will have similar sound power profiles as those used in the acoustic modeling analysis; however, it is possible that the final manufacturer warranty values may vary slightly. A summary of sound power data for the GE 2.72-116 with LNTE by octave band center frequency during maximum rotational speed is presented in Table 4.

Table 3. GE 2.72-116 LNTE Wind Turbine Broadband Sound Power Levels Correlated with Wind Speed

Hub Height (m)	Sound Power Level (dBA) at Reference Hub Height Wind Speed (m/s)						
	4	5	6	7	8	9	10
90.0	94.8	94.8	98.0	101.4	104.4	106.8	107.5
Source: GE 2018.							

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, it is assumed that wind turbine directivity and sound generating efficiencies are inherently incorporated in the sound source data and used in acoustic model development. A summary of sound power data by octave band center frequency for both wind turbines operating at maximum rotation are presented in Table 4 (1/1 octave band frequency data provided with stated intended use limited for informational purposes only).

Table 4. GE 2.72-116 LNTE Wind Turbine Broadband Sound Power Level by Octave Band Frequency (10 m/s)

K-Factor	Octave Band Sound Power Level (dBA) by Frequency (Hz)									Broadband (dBA)
	31.5	63	125	250	500	1000	2000	4000	8000	
2.0	79.7	89.3	94.0	97.1	100.5	103.3	101.1	93.4	75.2	107.5
Source: GE 2018.										

3.3 ACOUSTIC MODELING RESULTS

Acoustic modeling was completed for wind turbine operation for the following conditions thereby describing the full range of expected receive sound levels at receiver locations: (1) initial cut-in wind speeds; (2) maximum rotation; and (3) maximum rotation during anomalous meteorological conditions. Sound contour plots displaying Project operational sound levels in color-coded isopleths are provided in Figures A-1, A-2, and A-3, in Attachment A. The sound contours are graphical representations of the cumulative noise associated with the Project substation and all project wind turbines operating concurrently at the given operating condition and show how operational noise would be distributed over the surrounding area. The contour lines presented are analogous to elevation contours on a topographic map, i.e., the sound contours are continuous lines of equal noise level. Figure A-1 displays broadband operational sound levels at the wind speeds during initial cut-in, which is when the turbines engage and start producing power. Figure A-2 displays broadband operational sound levels at wind speeds sufficient to sustain wind turbine operation at maximum rotational speeds during moderate downwind propagation. Figure A-3 displays broadband operational sound levels at wind speeds sufficient to sustain wind turbine operation at maximum rotational speeds during anomalous meteorological conditions. 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 5 presents the results of the Project acoustic modeling analysis and includes the NSR ID, Universal Transverse Mercator (UTM) coordinates, NSR status and the received sound levels at each NSR. Received sound levels are rounded to the nearest whole decimal for consistency with the Hyde County Zoning Ordinance noise limit absolute value of 45 dBA.

Acoustic modeling results show that there are three occupied NSRs (NSR IDs 11, 18, and 81) with received sound levels greater than 45 dBA. All these residences are owned by landowners that are participating in the Project. Received sound levels at all non-participating NSRs were determined to be below the Hyde County Zoning Ordinance 45 dBA noise limit.

Table 5. Acoustic Modeling Results Summary

NSR ID	NSR Status	UTM Coordinates (meters)		GE 2.72-116 LNTE		
		Easting	Northing	Cut-in	Maximum Rotational	Anomalous Meteorological
1	Non-Participant	442456	4925508	9	22	24
2	Non-Participant	451309	4925851	28	40	42
3	Participant	459033	4925620	31	44	44
4	Participant	459719	4925668	26	38	40
5	Participant	452062	4924182	30	43	44
6	Participant	452075	4924501	30	43	44
7	Participant	451447	4924097	30	43	44
8	Participant	441895	4923973	9	21	24
9	Participant	444984	4923741	17	30	32
10	Non-Participant	464696	4924005	26	39	40
11	Participant	455990	4922426	36	49	49
12	Participant	446141	4922203	20	33	35
13	Participant	466431	4921923	22	34	36
14	Participant	468148	4921891	16	29	31
15	Participant	471362	4920960	6	18	21
16	Participant	467845	4920175	15	28	30
17	Participant	448828	4920034	21	34	36
18	Participant	452048	4919694	32	45	46
19	Participant	464884	4919863	29	41	42

NSR ID	NSR Status	UTM Coordinates (meters)		GE 2.72-116 LNTE		
		Easting	Northing	Cut-in	Maximum Rotational	Anomalous Meteorological
20	Participant	464748	4919035	24	37	39
21	Participant	464203	4919234	28	40	41
22	Non-Participant	463391	4919194	29	41	42
23	Participant	461381	4919347	28	41	42
24	Non-Participant	463004	4919118	27	40	41
25	Non-Participant	445619	4918666	15	27	30
26	Participant	443100	4918874	10	23	26
27	Participant	440534	4919290	3	15	18
28	Participant	440696	4922014	6	18	21
29	Non-Participant	442687	4922261	11	23	26
30	Non-Participant	440889	4923289	7	19	22
31	Non-Participant	440819	4926574	6	18	21
32	Non-Participant	440290	4924271	6	18	21
33	Non-Participant	440237	4924430	5	18	21
34	Non-Participant	442458	4928172	8	20	23
35	Non-Participant	449221	4927448	20	33	35
36	Non-Participant	460325	4926929	21	33	36
37	Non-Participant	461603	4926472	21	34	36
38	Non-Participant	462994	4927231	18	31	33
39	Non-Participant	461400	4927437	19	31	34
40	Non-Participant	461242	4927391	19	32	34
41	Non-Participant	464857	4925441	20	33	35
42	Non-Participant	463829	4927184	18	30	33
43	Non-Participant	464803	4927722	15	28	31
44	Non-Participant	464851	4927459	16	29	31
45	Non-Participant	465002	4927396	16	29	31
46	Non-Participant	468316	4927007	12	24	27
47	Non-Participant	471332	4926983	6	18	21
48	Non-Participant	471209	4924768	8	21	24
49	Non-Participant	471206	4924735	8	21	24
50	Non-Participant	440238	4928577	2	15	17
51	Non-Participant	438694	4928202	<1	<1	<1
52	Non-Participant	435698	4928234	<1	<1	<1

NSR ID	NSR Status	UTM Coordinates (meters)		GE 2.72-116 LNTE		
		Easting	Northing	Cut-in	Maximum Rotational	Anomalous Meteorological
53	Non-Participant	438710	4926367	<1	12	15
54	Non-Participant	437503	4925640	<1	<1	<1
55	Non-Participant	438592	4919467	<1	7	10
56	Participant	437526	4918519	<1	<1	<1
57	Participant	437554	4918480	<1	<1	<1
58	Non-Participant	435779	4916792	<1	<1	<1
59	Non-Participant	436640	4914868	<1	<1	<1
60	Non-Participant	435784	4915280	<1	<1	<1
61	Non-Participant	440462	4914035	<1	<1	<1
62	Non-Participant	435967	4912462	<1	<1	<1
63	Non-Participant	435919	4912203	<1	<1	<1
64	Non-Participant	435242	4912250	<1	<1	<1
65	Non-Participant	435423	4912001	<1	<1	<1
66	Non-Participant	435331	4912501	<1	<1	<1
67	Non-Participant	434868	4912262	<1	<1	<1
68	Non-Participant	442662	4914507	2	15	18
69	Non-Participant	442582	4914367	4	17	20
70	Non-Participant	444337	4912679	7	19	22
71	Non-Participant	445435	4912474	5	17	20
72	Participant	445330	4915443	11	24	26
73	Participant	445448	4917655	14	27	29
74	Participant	448546	4915132	19	32	34
75	Participant	450196	4915008	24	36	38
76	Non-Participant	452106	4916110	29	42	43
77	Non-Participant	452006	4912597	16	29	31
78	Participant	453410	4917626	30	42	44
79	Participant	453397	4917705	30	42	44
80	Participant	456381	4914352	20	32	35
81	Participant	456315	4918412	33	46	47
82	Non-Participant	459068	4914217	18	30	33
83	Non-Participant	461526	4915309	15	28	31
84	Non-Participant	461567	4915598	18	31	33
85	Non-Participant	461490	4915880	17	30	33

NSR ID	NSR Status	UTM Coordinates (meters)		GE 2.72-116 LNTE		
		Easting	Northing	Cut-in	Maximum Rotational	Anomalous Meteorological
86	Non-Participant	461668	4915110	17	30	32
87	Non-Participant	463153	4913889	14	27	29
88	Non-Participant	464660	4916997	18	30	33
89	Non-Participant	464996	4914979	14	27	29
90	Non-Participant	466480	4914752	11	24	27
91	Non-Participant	466495	4914819	10	23	25
92	Participant	467931	4916490	12	25	28
93	Non-Participant	467980	4918031	14	27	29
94	Non-Participant	468070	4914826	9	21	24
95	Non-Participant	468886	4917101	7	20	22
96	Non-Participant	470985	4912972	<1	<1	<1
97	Non-Participant	472613	4917854	<1	11	14
98	Non-Participant	472969	4917714	<1	13	16
99	Participant	472739	4924006	4	17	20
100	Participant	473852	4920692	<1	13	16
101	Non-Participant	473795	4925678	<1	<1	<1
102	Non-Participant	475241	4920717	<1	<1	<1
103	Non-Participant	474504	4919960	<1	<1	<1
104	Non-Participant	477592	4926817	<1	<1	<1
105	Non-Participant	445356	4911624	7	20	22
106	Non-Participant	442769	4911898	2	15	17
107	Non-Participant	443050	4911873	2	15	18
108	Participant	440574	4919273	3	15	18
109	Non-Participant	442257	4914401	<1	12	15
110	Non-Participant	442602	4922219	10	23	26
111	Non-Participant	448944	4911212	11	24	26
112	Non-Participant	461642	4915097	17	30	32
113	Non-Participant	471201	4924811	8	21	24
114	Participant	472755	4924016	4	17	20
115	Non-Participant	473177	4921096	<1	12	15
116	Participant	470358	4924798	10	23	25
117	Participant	466407	4918894	19	31	34

Note: Predicted sound levels greater than the 45 dBA threshold criteria are identified in red.

3.4 SUBSTATION ACOUSTIC ANALYSIS

Substations have switching, protection and control equipment, and typically 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 vibrational noise is the principal noise source and does not vary significantly with electrical load. Transformers are designed and catalogued by MVA ratings. Just as horsepower ratings designate the power capacity of an electric motor, a transformer's MVA rating indicates its maximum power output capacity. The National Electrical Manufacturers Association (NEMA) published NEMA Standards TR1-1993 (R2000), which establish the maximum noise level allowed for transformers, voltage regulators, and shunt reactors based on the equipment's method of cooling its dielectric fluid (air-cooled vs. oil-cooled) and the electric power rating.

Transformer noise is generated and will attenuate with distance at different rates depending on the transformer dimensions, voltage rating, and design. The noise produced by substation transformers 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. The characteristic humming sound consists of tonal components generated at harmonics of 120 Hz. Most of the acoustical energy resides in the fundamental tone (120 Hz) and the first 3 or 4 harmonics (240, 360, 480, 600 Hz). In addition to core vibration noise, transformer cooling fans may generate broadband noise, limited to periods when high heat loads require additional cooling capacity. The resulting audible sound is a combination of core noise and the broadband fan noise. Circuit-breaker operations may also cause audible noise, particularly the operation of air-blast breakers which is characterized as an impulsive sound event of very short duration. This is expected to occur only a few times throughout the year and was therefore not considered in this analysis.

The Project collector substation was also reviewed as part of the acoustic analysis. The proposed substation would be located along at the intersection of 203rd Street and 330th Street, approximately 6 miles (9.7 kilometers) south of US Highway 14 and 6 miles (9.7 kilometers) west of State Highway 47, with the closest residence approximately 1.1 miles (1.75 kilometers) to the northeast. Sound source levels for the future transformers were calculated for the Project substation, which will consist of two 140-MVA rating transformers. The transformers are expected to have a NEMA sound rating of less than or equal to 80 dBA during maximum load and forced air cooling operation. The transformers were modeled using the latest version of CadnaA implementing ISO 9613-2. Table 6 presents the transformer sound source data by octave band center frequency calculated based on the specified transformer NEMA and MVA ratings using standardized engineering guidelines.

Table 6. 140 MVA Transformer Sound Power Level

Octave Band Sound Power Level (dBA) by Frequency (Hz)									Broadband (dBA)
31.5	63	125	250	500	1000	2000	4000	8000	
57.2	76.4	88.5	91.0	96.4	96.6	89.8	84.6	75.5	100.0

Transformers the size of the one proposed for the Project can present a noise concern if the separation distance is less than a few hundred feet between the transformer and NSRs. The proposed transformer location is approximately 6,000 ft (1,800 m) from the nearest NSR and poses little concern from a noise perspective. Nevertheless, transformer noise may be periodically audible at nearby NSRs on occasions when background sound levels are very low.

3.5 CONSTRUCTION NOISE

The development of the Project will involve construction to establish access roads, excavate and form wind turbine foundations, prepare the site for crane-lifting and assemble and commission the wind turbines. Work on large-scale wind projects such as the Project 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. *Grading*: This phase would begin with the grading 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 Generator 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 wind turbines will be erected in small groupings. Each grouping may undergo periodic testing and commissioning prior to commencement of full commercial operation. Other construction activities include those for the supporting infrastructure such as the substation, operations and maintenance building, and the overhead transmission line.

The construction of the Project may cause short-term but unavoidable noise impacts. 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. The list of construction equipment that may be used on the Project and estimates of near and far sound source levels are presented in Table 7.

Table 7. Estimated Maximum Sound Pressure Levels from Construction Equipment

Equipment	Estimated Sound Pressure Level at 50 feet (dBA)	Estimated Sound Pressure Level at 2000 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
Concrete Batch Plant	83	51
Source: FHWA 2006; Bolt et al. 1977		

Sounds generated by construction activities are typically exempt from state and local noise oversight if they occur within weekday, daytime periods as may be specified under local zoning or legal codes. All reasonable efforts will be made to minimize the impact of noise resulting from construction activities. As the design of the Project progresses and construction scheduling is finalized, the construction engineer normally notifies the community, via public notice or alternative method, of the expected Project construction commencement and duration to help minimize the effects of construction noise. In addition, the location of stationary equipment and the siting of construction laydown areas will be carefully selected to be as far removed from existing NSRs as is practical. Candidate construction noise mitigation measures include scheduling louder construction activities during daytime hours and equipping internal combustion engines with appropriate sized muffler systems to minimize noise excessive emissions.

Construction activity will generate traffic having potential noise effects, such as trucks travelling 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.

4.0 CONCLUSIONS

Project operational sound has been calculated and compared to the 45 dBA Hyde County Zoning Ordinance noise requirements. Acoustic modeling analyses per ISO 9613-2 and inclusive of a number of conservative assumptions demonstrate the Project will operate in compliance with the 45 dBA noise limit at all NSRs, except at three participating landowner properties which may periodically experience sound levels above the criteria threshold. Triple H has obtained written waivers of the 45 dBA noise limit from participating landowners. It is expected that received sound levels at noise-sensitive receptors will be consistent with sound generated at similar wind energy projects successfully sited throughout the state of South Dakota employing the same or similar criteria.

5.0 REFERENCES

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APPENDIX A. FIGURES

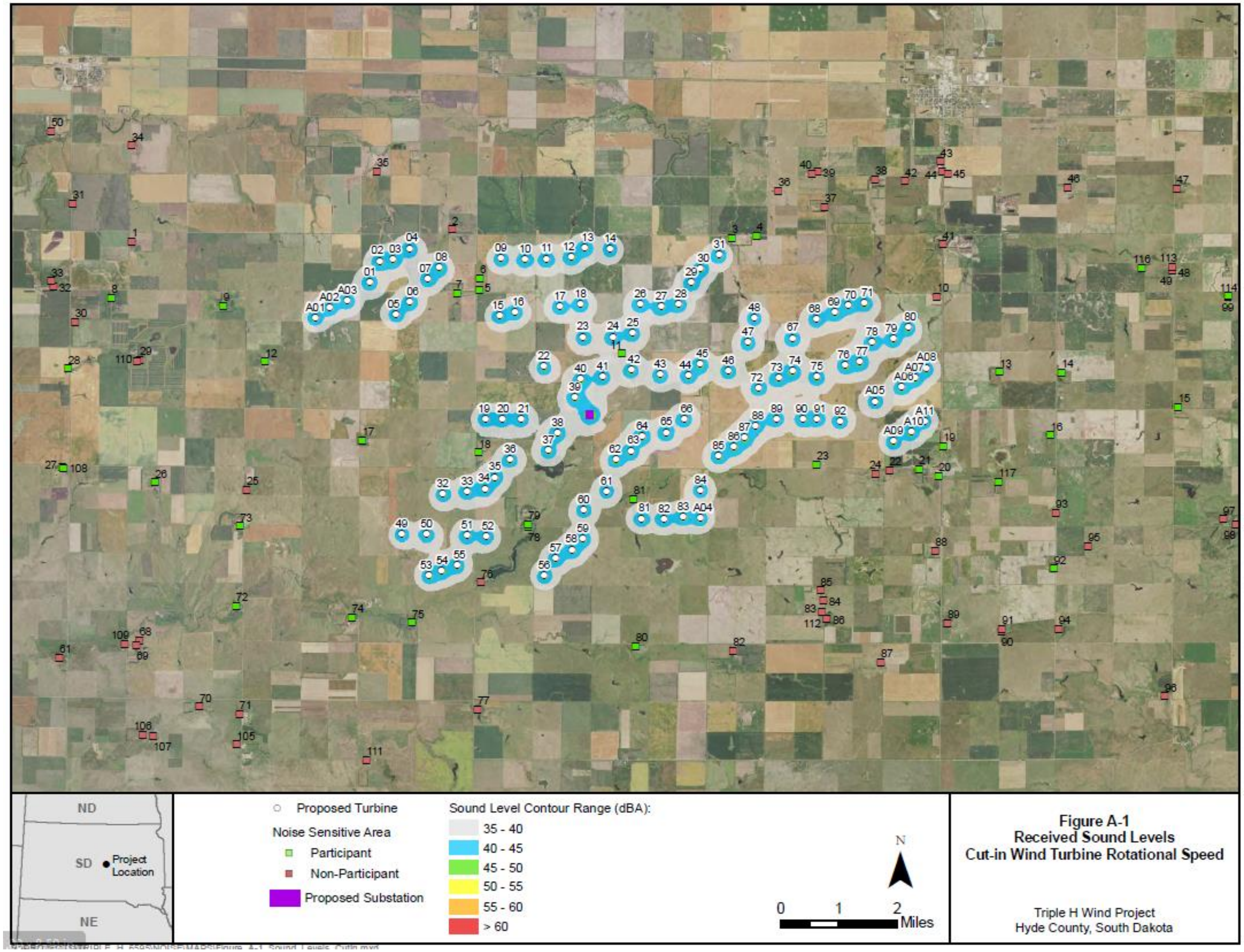

Figure A-1. Received Sound Levels – Cut-in Wind Turbine Rotational Speed

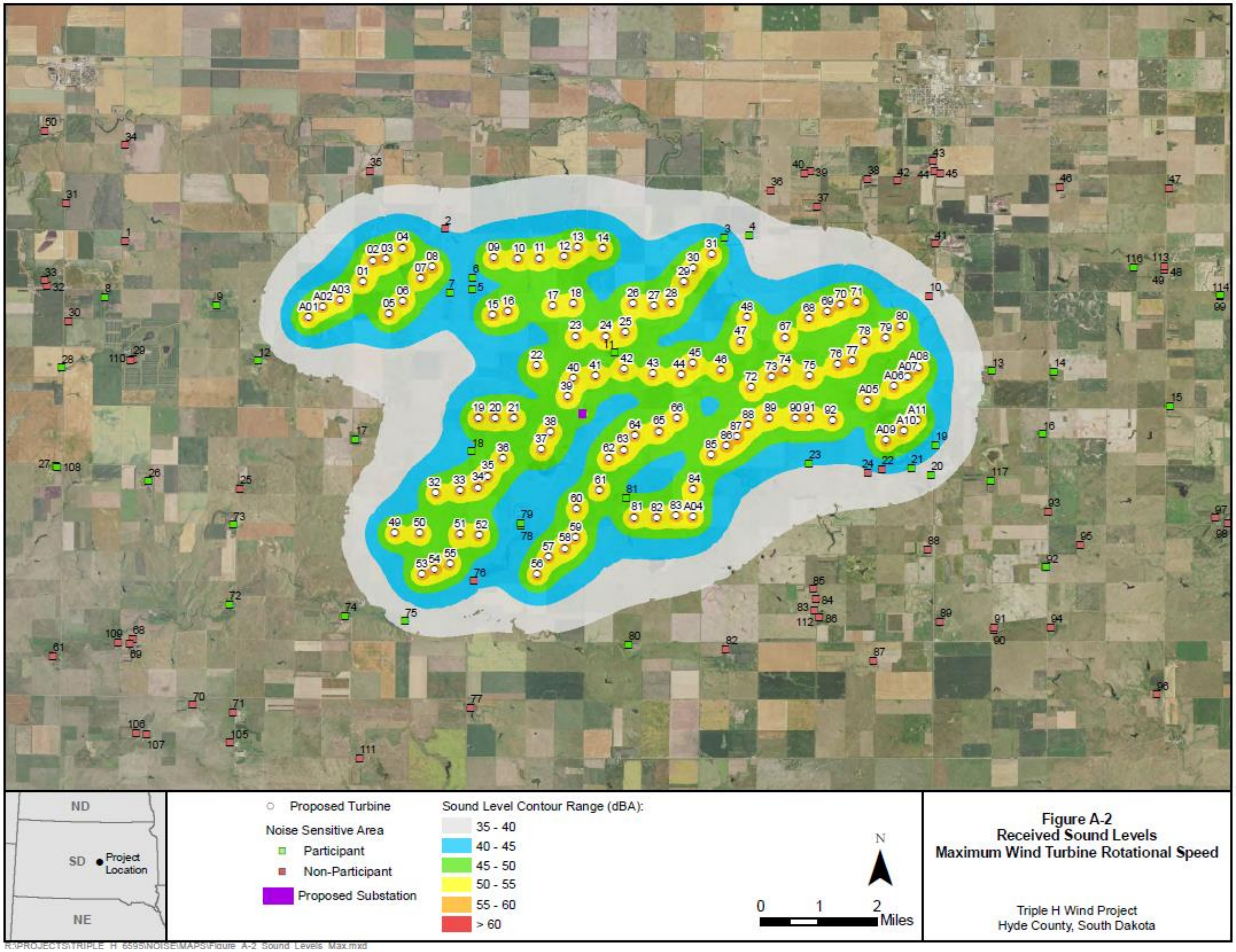

Figure A-2. Received Sound Levels – Maximum Wind Turbine Rotational Speed

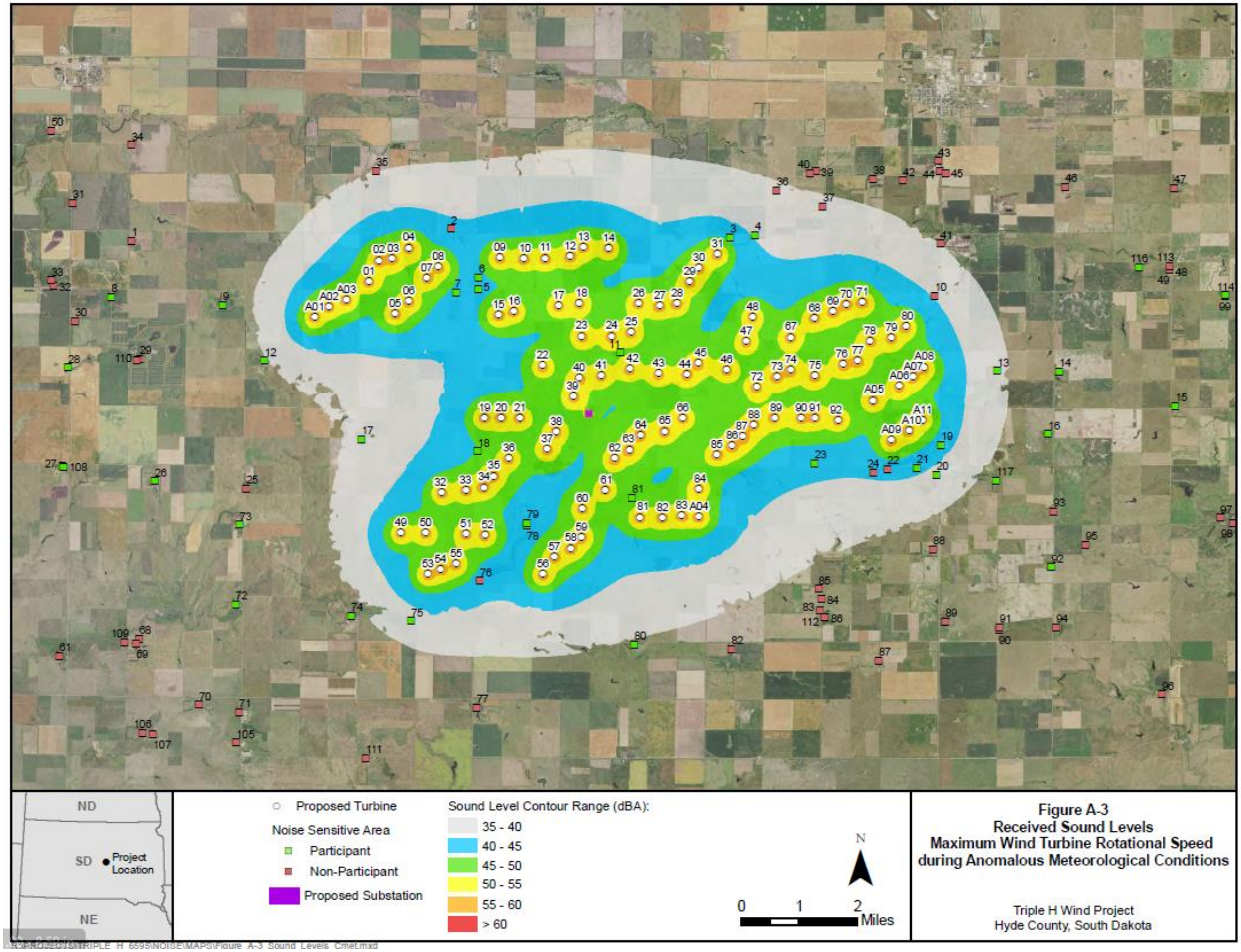

Figure A-3. Received Sound Levels – Maximum Wind Turbine Rotational Speed during Anomalous Meteorological Conditions