Oliver III Wind Energy Center
Acoustic Assessment
Morton and Oliver Counties, North Dakota

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Prepared for

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ACRONYMS AND ABBREVIATIONS

AGL	above ground level
CadnaA	Computer-Aided Noise Abatement Program
dB	decibel
dBA	A-weighted decibel
dBL	unweighted decibel
GE	General Electric
HH	hub height
Hz	Hertz
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
kHz	kilohertz
L_{eq}	equivalent sound level
L_{max}	maximum sound level
L_p	sound pressure level
L_w	sound power level
LLJ	low level jet
m/s	meters per second
mph	miles per hour
MVA	megavolt ampere
MW	megawatt
NEER	NextEra Energy Resources, LLC
NEMA	National Electrical Manufacturers Association
Project	Oliver III Wind Energy Center
PSC	Public Service Commission
pW	picowatt
RD	rotor diameter
Tetra Tech	Tetra Tech, Inc.
µPa	microPascal
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
W	watt
WTG	wind turbine generator

EXECUTIVE SUMMARY

Tetra Tech, Inc. (Tetra Tech) has completed an acoustic assessment for the proposed Oliver III Wind Energy Center located in Morton and Oliver Counties, North Dakota. A screening-level analysis was completed to evaluate the expected sound levels resulting from the Project wind turbine generators (WTGs) and substation. Although the Project would consist of up to 48 WTGs, two alternate WTG locations are included in the layout. Two scenarios were analyzed, one referred to as the "With Alternates" scenario and the other referred to as the "No Alternates" scenario. Analysis of the "With Alternates" scenario should be considered conservative, since all 50 WTGs were modeled but only 48 WTGs will be built as part of the Project. The overall objective of this study was to determine the feasibility of the Project to operate in compliance with the applicable North Dakota Public Service Commission (PSC) 50 dBA noise limit.

Wind turbine sound source data was obtained from General Electric (GE), the manufacturer of the GE 2.1-116 (2.1 MW) and GE 1.79-100 (1.79 MW) as documented in the turbine noise specification section (GE 2015). Substation data were obtained Oliver III, LLC (Oliver III) based on a 170 megavolt ampere (MVA) transformer. It is expected that the GE WTGs 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 4.6.153), 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.

The results of the acoustic modeling analysis were compared to the North Dakota PSC 50 dBA noise limit within 100 feet of an inhabited residence. Acoustic modeling results showed that the Project will comply with the PSC noise limit at the majority of occupied NSRs with the exception of NSR ID 810021. However, NSR ID 810021 is a Project participant and has signed a waiver that would no longer require the Project to comply with the PSC 50 dBA noise limit at that receptor.

1.0 INTRODUCTION

Oliver Wind III, LLC (Oliver III), a wholly-owned, indirect subsidiary of NextEra Resources, LLC (NEER), proposes to construct and operate the Oliver III Wind Energy Center (Project) in Oliver and Morton Counties, North Dakota. Oliver III is proposing to construct up to 48 wind turbine generators (WTGs). The site layout dated June 13, 2016, includes 43 GE 2.1-116 WTGs, 5 GE 1.79-100 WTGs, and 2 alternate GE 2.1-116 WTG locations. While no more than 48 WTGs will be built, one or more of the alternate WTG locations could be activated in the event that any of the primary WTG locations were eliminated. The rotor diameter of the GE 2.1-116 is 381 feet (116 meters) and it has a hub height (HH) of 262 feet (80 meters). The GE 1.79-100 has a rotor diameter of 328 feet (100 meters) and a hub height of 262 feet (80 meters). The proposed Project infrastructure also includes a collection substation to enable interconnection to the Minnkota Power Cooperative, Inc. Center to Mandan 230 kilovolt (kV) overhead transmission line located in the northeast quarter of Section 23, Township 141 North, Range 83 West. This site is located approximately 14 miles south, southeast of the City of Center, North Dakota. Substation data were obtained from Oliver III based on a 170 megavolt ampere (MVA) transformer similar to the HICO 170 MVA transformer in use at other NEER energy facilities.

An acoustic modeling analysis was completed for the Project, evaluating two scenarios, one referred to as the “With Alternates” scenario and the other referred to as the “No Alternates” scenario. Analysis of the “With Alternates” scenario should be considered conservative since only 48 WTGs will be built as part of the Project. Operational sounds levels resulting from the Project were analyzed at existing noise-sensitive receptors (e.g., residential structures) and compliance was assessed relative to the North Dakota Public Service Commission (PSC) noise limit.

1.1 Project Area

The Oliver III Project Area encompasses approximately 21,878 acres (34 square miles) in northern Morton County and southern Oliver County. One turbine is located in Oliver County and the rest are located in Morton County. County and township (section line) roads characterize the existing roadway infrastructure in and around the Project Area. The Project Area is accessed via I-94, State Highway 25, State Highway 31, and other local two-lane paved and gravel county roads. The land within the Project Area is primarily agricultural with scattered farmstead residences. The turbines will be located on privately-owned land in northern Morton County, approximately 12 miles northwest of Bismarck. This region of North Dakota has topography that can be described as level to rolling plains. Gentle slopes characterize most of the Project Area and local relief ranges from less than 2018 ft to 2278 ft. Current land use within the Project Area is primarily agricultural, supporting both crops and livestock grazing.

Occupied and unoccupied structures are scattered throughout the Project Area. Potential noise sensitive receptor locations within the Project Area and in the vicinity of proposed turbine locations were included in the acoustical analysis. Of these 92 receptors identified, 64 are occupied structures and 28 are unoccupied. Oliver III designed the Project using a minimum turbine setback of 2,000 feet from occupied residences, which exceeds Morton County’s setback requirement of

1,320 feet. Figure 1 in the Appendix presents the proposed Oliver III WTGs, as well as the noise sensitive receptor locations.

1.2 Existing Acoustic Environment

Northern Morton County and Southern Oliver County would generally be considered rural agricultural areas. Existing ambient sound levels are expected to be relatively low, although sound levels would be higher near roadways such as I-94, State Highway 25, and State Highway 31. Additional noise is likely a result of equipment and trucks associated with oil exploration in the area. 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 proximity to area sound sources such as roadways and natural sounds. 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 (L_W), 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 (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 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 due to the fact that 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 (or 33 1/3 octave) bands 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 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 in this report are presented as dBL.

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 in the State of North 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 (L_P) 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		1/2 as loud
Passenger car at 65 mph (25 ft)	65	Moderate	
Large store air-conditioning unit (20 ft)	60		1/4 as loud
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	
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.
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 environmental noise requirements specific to this Project. At the state level, the PSC has established regulations applicable to wind energy facilities. Morton and Oliver Counties do not provide noise limits applicable to the Project via their land use regulations. The controlling regulation for the Project is the PSC's noise limit.

2.1 State of North Dakota Public Service Commission Noise Regulations

North Dakota adopted noise regulations for wind energy facilities under the PSC Chapter 69-06-08-01(4) as follows:

> *A wind energy conversion facility site must not include a geographic area where, due to operation of the facility, the sound levels within one hundred feet of an inhabited residence or a community building will exceed fifty dBA. The sound level avoidance area criteria may be waived in writing by the owner of the occupied residence or the community building.*

Sound levels resulting from the Project within 100 feet of all identified receptors located in the vicinity of the Project were assessed against the 50 dBA limit to determine whether compliance was achieved. The PSC 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 WTG is comprised of both aerodynamic and mechanical sound with the dominant sound component from modern utility scale WTGs being largely aerodynamic. Aerodynamic sound refers to the sound produced from air flow and the interaction with the WTG tower structure and moving rotor blades. 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 minimized. Sound reduction elements designed as a part of the WTGs include impact noise insulation of the gearbox and generator, sound reduced gearbox, sound reduced nacelle, and rotor blades designed to minimize noise generation.

Wind energy facilities, in comparison to other energy-related facilities, are somewhat unique in that the sound generated by each individual WTG will increase as the wind speed across the site increases. 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 maximum rotational speed are achieved. Under this condition, the WTG maximum sound power level will be reached at approximately 7 meters per second [m/s], according to the GE specifications. 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 WTG sound emissions occur, the sound produced from a WTG 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 WTG 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

The operational acoustic assessment was performed using the proposed Project WTG layout dated June 13, 2016, which includes 43 GE 2.1-116 WTGs, 5 GE 1.79-100 WTGs, and 2 alternate GE 2.1-116 WTG locations. Two scenarios were modeled, a “With Alternates” scenario consisting of 50 WTG locations (48 planned WTG locations and an additional 2 alternate locations), and a “No Alternates” scenario consisting of 48 WTG locations. The Project would use the GE 2.1-116 WTG model, which has a rotor diameter of 381 feet (116 meters) and a hub height of 262 feet (80 meters) and the GE 1.79-100 WTG model, which has a rotor diameter of 328 feet (100 meters) and a hub height of 262 feet (80 meters). The Project would also include a collection substation with a 170 MVA transformer. WTG sound source data were obtained from GE (GE 2013 and 2015) and substation transformer data were obtained from Oliver Wind III.

The acoustic modeling analysis was conducted using the most recent version of DataKustic GmbH's computer-aided noise abatement program or CadnaA (v 4.6.153). CadnaA is a comprehensive 3-dimensional acoustic software model that conforms to the International Organization for Standardization (ISO) standard ISO 9613-2 "Attenuation of Sound during Propagation Outdoors." 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. 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. 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). A mixed (semi-reflective) ground factor of G=0.5 was used in the Project acoustic modeling analysis. 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, the temperature of 10ºCelsius (50ºFahrenheit) and 70 percent relative humidity parameters were selected as reasonably representative of conditions favorable to sound propagation. Atmospheric absorption depends on temperature and humidity and is most important at higher frequencies. Over short distances, the effects of atmospheric absorption are minimal. The ISO 9613-2 standard calculates attenuation for meteorological conditions favorable to propagation, i.e., downwind sound propagation or what might occur typically during a moderate atmospheric ground level inversion. Though a physical impracticality, the ISO 9613-2 standard simulates omnidirectional downwind propagation. For receivers located between discrete WTG locations or WTG groupings, the acoustic model may result in over-prediction. 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 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 and Low Level Jets (LLJs). While the North Dakota PSC does not specifically require or suggest that these meteorological conditions be explicitly addressed in modeling assessments, ISO 9613-2 includes a methodology to account for effects produced under these conditions and so they were addressed to ensure a conservative assessment.

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 Electrotechnical Commission (IEC) standard IEC 61400-11:2006 Wind Turbine Generator Systems—Part 11: Acoustic Noise Measurement Techniques. This accepted IEC standard was developed to ensure consistent and comparable sound emission data of utility-scale WTGs between manufacturers. Tables 3 and 4 present a summary of sound power data for the GE 1.79-100 and GE 2.1-116 WTGs during normal operations correlated to 10 meter height integer wind speeds 10 meter above ground level (AGL) with a stated roughness length[1] of 0.05 meters, which is representative of level grass-covered terrain (GE 2015). The sound power data for the GE 2.1-116 WTG is not yet available, so data for the GE 2.3-116 WTG was used. GE stated that the sound power profile for the GE 2.3-116 WTG is effectively the same as the profile for the GE 2.1-116 WTG, and therefore this data substitution should not impact results.

The specification for the WTGs includes an expected warranty confidence interval, or k-factor, of 2 dB, which was added to the nominal sound power level in the acoustic model. 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.

Table 3. Broadband Sound Power Levels (dBA) Correlated with Wind Speed (GE 1.79-100)

	WTG L_{max} Sound Power Level (L_W) at Reference Wind Speed							
10-meter AGL Wind Speed	11.2 mph (5 m/s)	12.3 mph (5.5 m/s)	13.4 mph (6 m/s)	14.5 mph (6.5 m/s)	15.7 mph (7 m/s)	17.9 mph (8 m/s)	20.1 mph (9 m/s)	22.4 mph (10 m/s)
GE 1.79-100	98.6	101.0	103.2	105.5	107.2	107.5	107.5	107.5

[1] The roughness length describes the vertical wind profile per IEC specification in a neutral atmosphere with the wind profile following a logarithmic curve.

Table 4. Broadband Sound Power Levels (dBA) Correlated with Wind Speed (GE 2.3-116)

	WTG L_{max} Sound Power Level (L_W) at Reference Wind Speed									
Wind Speed	8.9 mph (4.0 m/s)	11.2 mph (5.0 m/s)	13.4 mph (6.0 m/s)	15.7 mph (7.0 m/s)	17.9 mph (8.0 m/s)	20.1 mph (9.0 m/s)	22.4 mph (10.0 m/s)	24.6 mph (11.0 m/s)	26.8 mph (12.0 m/s)	29.1 mph (13.0 m/s)
GE 2.3-116	95.0	95.8	98.2	101.6	104.5	105.8	107.5	107.5	107.5	107.5

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 WTG 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 WTG models operating at maximum rotation are presented in Table 5 (1/1 octave band frequency data provided with stated intended use limited for informational purposes only).

Table 5. Sound Power Level by Octave Band Center Frequency

Frequency (Hz)	Octave Band Sound Power Level (dBA)								Broadband (dBA)
	63	125	250	500	1000	2000	4000	8000	
GE 1.79-100	91.0	96.1	98.0	100.8	103.3	100.0	90.3	70.6	107.5
GE 2.3-116	89.0	95.1	99.6	102.8	102.5	97.6	87.4	66.8	107.5

3.3 Acoustic Modeling Results

Acoustic modeling was completed for WTG cut-in and maximum rotational operating conditions, thereby describing resultant sound pressure levels over the entire operational range of the Project for both the “With Alternates” and “No Alternates” scenarios. In addition, sound energy contribution from the Project substation was included in the acoustic modeling analysis. When calculating received sound levels, it was assumed that the Project substation and all WTGs were operating concurrently at the given operating condition. Sound contour plots displaying Project operational sound levels in color-coded isopleths are provided in Figures 2 through 8 in the Appendix. Figures 2 and display the broadband operational sound levels under low-level wind speeds sufficient for the WTGs to operate at initial cut-in rotational speeds. Figures 4 and 5 display broadband operational sound levels at wind speeds sufficient to sustain WTG operation at maximum rotational speeds for moderate downwind propagation. Figures 6 and 7 display broadband operational sound levels at wind speeds sufficient to sustain WTG operation at maximum rotational speeds under anomalous meteorological conditions.

Table 6 presents the results of the Oliver III Wind Energy Center acoustic modeling analysis and includes the ID, Universal Transverse Mercator (UTM) coordinates, receptor status and the received sound levels at each receptor for both scenarios. Received sound levels are rounded to the nearest whole decimal for consistency with the State of North Dakota noise limit, which is an absolute value of 50 dBA. In addition, a 100-foot buffer was included around the receptors, corresponding to the point of compliance identified in the PSC 50 dBA noise limit.

The acoustic modeling results shown in Table 6 demonstrate that received sound levels are all below the PSC 50 dBA noise limit with the exception of two receptors, NSR IDs 30008 and 810021. NSR ID 30008 was identified as an unoccupied structure; therefore, it is not considered noise sensitive and demonstrating compliance with the limit is not required. NSR ID 810021 was identified as an occupied structure; however, NSR ID 810021 is a Project participant and has signed a waiver that would no longer require the Project to comply with the PSC 50 dBA noise limit at that receptor.

Table 6. Oliver III Wind Energy Center – Acoustic Modeling Results

NSR ID	NSR Status	UTM Coordinates (NAD83 UTM Zone 14 meters)		No Alternates			With Alternates		
		Easting (m)	Northing (m)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)
107	Occupied	328318	5199223	15	27	30	15	27	30
111	Occupied	332294	5197910	18	31	33	18	31	33
113	Occupied	333315	5198704	22	34	36	22	34	36
117	Unoccupied	334380	5197276	15	28	30	16	28	30
120	Unoccupied	339638	5195765	20	32	34	20	33	35
123	Unoccupied	340219	5195497	19	32	34	20	32	34
125	Unoccupied	342224	5195776	16	28	31	17	29	31
130	Occupied	342338	5201598	17	29	32	18	30	32
131	Occupied	342481	5201792	16	29	31	17	29	32
134	Occupied	342502	5201888	17	29	32	18	30	33
138	Occupied	342586	5201880	18	29	32	18	30	33
170	Unoccupied	327196	5203001	15	28	30	15	28	30
172	Occupied	326573	5203121	18	30	33	18	30	33
173	Unoccupied	326614	5203107	18	30	33	18	30	33
175	Occupied	336480	5210588	10	20	23	10	20	23
5013	Occupied	331662	5210195	16	27	30	16	27	30
5015	Occupied	335015	5210254	11	22	24	11	22	24
5016	Occupied	335270	5210159	15	26	28	15	26	28
5017	Occupied	335141	5210664	10	21	23	10	21	23
5018	Occupied	334958	5209903	16	27	29	16	27	29
5020	Occupied	334149	5206673	24	35	37	24	35	37
5021	Occupied	334144	5206664	24	35	37	24	35	37

Table 6. Oliver III Wind Energy Center – Acoustic Modeling Results

NSR ID	NSR Status	UTM Coordinates (NAD83 UTM Zone 14 meters)		No Alternates			With Alternates		
		Easting (m)	Northing (m)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)
5026	Occupied	331919	5207710	19	31	33	19	31	33
6002	Unoccupied	335368	5206778	26	36	38	26	36	38
6003	Unoccupied	335435	5204641	33	43	44	33	43	44
6004	Occupied	334582	5203847	33	45	46	33	45	46
6005	Occupied	335894	5202102	32	45	46	32	45	46
6006	Occupied	335875	5202206	33	45	47	33	45	47
6008	Occupied	338714	5201739	27	39	41	28	40	42
6009	Unoccupied	338753	5201759	27	39	41	28	40	42
6010	Occupied	335722	5198836	26	39	41	27	39	41
6011	Occupied	336821	5199125	30	43	44	30	43	44
6012	Unoccupied	335789	5197882	24	36	38	24	36	39
6013	Occupied	336785	5196966	24	37	38	25	37	39
6014	Unoccupied	337857	5198463	34	46	46	34	46	47
7002	Occupied	339472	5200083	30	43	43	32	45	45
7004	Unoccupied	339106	5200837	28	40	41	34	47	47
7007	Occupied	338286	5203461	28	39	41	28	39	41
7010	Occupied	338391	5204385	27	37	39	27	38	40
7016	Occupied	337949	5204464	29	39	40	29	39	41
7020	Occupied	341032	5200597	21	33	36	22	35	37
7023	Occupied	342191	5197153	20	33	35	21	33	35
7027	Occupied	342126	5197130	21	33	35	21	34	36
7029	Occupied	341907	5197106	21	34	36	22	34	36
30008	Unoccupied	337240	5201768	39	52	52	39	52	52
500009	Occupied	336405	5207685	23	32	34	23	32	34

Table 6. Oliver III Wind Energy Center – Acoustic Modeling Results

NSR ID	NSR Status	UTM Coordinates (NAD83 UTM Zone 14 meters)		No Alternates			With Alternates		
		Easting (m)	Northing (m)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)
500013	Unoccupied	330397	5207060	22	34	37	22	34	37
500015	Occupied	329972	5208020	19	31	34	19	31	34
500016	Unoccupied	330022	5206923	21	34	36	21	34	36
500023	Unoccupied	328917	5203693	32	44	44	32	44	44
500034	Occupied	337954	5210133	15	25	28	15	25	28
500038	Occupied	337720	5211843	6	16	19	6	16	19
500042	Occupied	335296	5211142	9	20	22	9	20	22
500046	Occupied	335293	5211109	9	20	22	9	20	22
500048	Occupied	335435	5209595	12	23	26	12	23	26
810006	Occupied	339698	5209012	13	24	27	14	24	27
810009	Unoccupied	336106	5208385	21	31	34	21	31	34
810013	Occupied	336115	5209049	19	30	32	19	30	32
810021	Occupied	331249	5204371	38	51	51	38	51	51
810023	Unoccupied	330451	5204493	34	46	47	34	46	47
810029	Unoccupied	330511	5205949	29	41	42	29	41	42
810036	Occupied	341396	5194840	13	25	27	13	25	28
810040	Occupied	340215	5195314	18	30	33	19	31	34
810043	Occupied	338198	5195469	19	32	34	20	32	34
810044	Occupied	338224	5195477	21	33	35	21	34	36
810048	Occupied	337653	5195304	21	33	35	21	34	36
810051	Occupied	337439	5194605	18	31	33	19	31	33
810054	Occupied	337303	5194404	15	28	30	15	28	31
810058	Occupied	337338	5196332	24	36	37	24	36	37
810063	Occupied	337149	5195323	20	32	35	20	33	35

Table 6. Oliver III Wind Energy Center – Acoustic Modeling Results

NSR ID	NSR Status	UTM Coordinates (NAD83 UTM Zone 14 meters)		No Alternates			With Alternates		
		Easting (m)	Northing (m)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)
810068	Occupied	336713	5195341	19	31	34	19	32	34
810070	Occupied	336646	5195342	19	31	33	19	32	33
810074	Occupied	336623	5195344	18	31	33	19	31	33
810079	Occupied	336099	5195320	17	30	32	18	30	33
810083	Occupied	335553	5195486	17	30	32	17	30	32
810087	Occupied	335690	5195807	19	31	34	19	32	34
810094	Occupied	335659	5196501	20	32	35	20	33	35
810101	Occupied	333216	5199405	24	36	39	24	36	39
810102	Occupied	333166	5199373	23	36	38	23	36	38
810109	Occupied	332567	5199511	24	37	39	24	37	39
810110	Unoccupied	332347	5200690	29	41	43	29	41	43
810116	Occupied	336094	5195437	19	31	33	19	31	34
810118	Occupied	327470	5200229	14	27	29	14	27	29
810126	Unoccupied	329809	5200210	22	34	37	22	34	37
810132	Unoccupied	338217	5201930	30	42	43	30	42	44
810144	Unoccupied	337177	5202967	36	49	49	36	49	49
810242	Occupied	340658	5196713	25	38	39	25	38	39
810365	Unoccupied	329428	5201283	23	36	38	23	36	38
810366	Unoccupied	329219	5201020	23	35	37	23	35	37
810614	Unoccupied	338133	5200625	36	48	49	37	49	49
810628	Unoccupied	338043	5195338	20	33	35	21	33	35
810634	Unoccupied	327032	5203541	19	32	34	19	32	34

4.0 OTHER SOUND CONSIDERATIONS

4.1 Substation Noise

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 proposed Oliver III electrical substation would be located near the center of the Project Area along 32nd Street near the intersection of 32nd Street and 33rd Avenue. The transformer at this substation location was modeled using the latest version of CadnaA implementing ISO 9613-2. Transformer sound source levels for the Oliver III substation were provided based on a 170 MVA transformer similar to the HICO 170 MVA transformer in use at other NEER energy facilities. Table 9 presents the transformer sound source data by octave band center frequency calculated based on the estimated transformer NEMA and MVA ratings using standardized engineering guidelines.

Table 7. Transformer Sound Power Level

	Octave Band Sound Power Level (dB)								Broadband (dBA)
Frequency (Hz)	63	125	250	500	1000	2000	4000	8000	
170 MVA Transformer	93	99	101	94	90	85	80	73	97

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 noise-sensitive receptors. The proposed Oliver III transformer location is approximately 1,683 feet (513 meters) from the nearest noise sensitive receptor and poses little concern from a noise perspective. That being said, transformer noise may be periodically audible at nearby receptors on occasions when background sound levels are very low.

4.2 Construction Noise

The development of Oliver III Wind Energy Center will involve construction to establish access roads, excavate and form WTG foundations, prepare the site for crane-lifting and assemble and commission the WTGs. Work on large-scale wind projects such as Oliver III Wind Energy Center 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. *WTG 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 periodic testing and commissioning prior to commencement of full commercial operation. Other construction activities include those for the supporting infrastructure such as the substation, 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 8.

Table 8. Estimated L_{max} 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

Source: FHWA 2006; Bolt et al. 1977

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 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 noise-sensitive receptors 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.

5.0 CONCLUSIONS

Project operational sound has been calculated and compared to the 50 dBA PSC noise limit. Acoustic modeling analysis per ISO 9613-2 and inclusive of a number of conservative assumptions under operational conditions demonstrates the Project will comply with the PSC noise limit at the majority of occupied NSRs with the exception of NSR ID 810021. However, NSR ID 810021 is a Project participant and has signed a waiver that would no longer require the Project to comply with the PSC 50 dBA noise limit at that receptor. 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 North Dakota employing the same or similar criteria.

6.0 TECHNICAL REFERENCES

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APPENDIX

Figures

Figure 1. Project Layout

Figure 2. With Alternates: Received Sound Levels—Wind Turbines at Cut-In Wind Speed

Figure 3. No Alternates: Received Sound Levels—Wind Turbines at Cut-In Wind Speed

Figure 4. With Alternates: Received Sound Levels—Wind Turbines at Maximum Rotational Wind Speed

Figure 5. No Alternates: Received Sound Levels—Wind Turbines at Maximum Rotational Wind Speed

Figure 6. With Alternates: Received Sound Levels—Wind Turbines at Maximum Rotational Wind Speed, Anomalous Meteorological Conditions

Figure 7. No Alternates: Received Sound Levels—Wind Turbines at Maximum Rotational Wind Speed, Anomalous Meteorological Conditions

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ACRONYMS AND ABBREVIATIONS

AGL	above ground level
CadnaA	Computer-Aided Noise Abatement Program
dB	decibel
dBA	A-weighted decibel
dBL	unweighted decibel
GE	General Electric
HH	hub height
Hz	Hertz
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
kHz	kilohertz
L_{eq}	equivalent sound level
L_{max}	maximum sound level
L_p	sound pressure level
L_w	sound power level
LLJ	low level jet
m/s	meters per second
mph	miles per hour
MVA	megavolt ampere
MW	megawatt
NEER	NextEra Energy Resources, LLC
NEMA	National Electrical Manufacturers Association
Project	Oliver III Wind Energy Center
PSC	Public Service Commission
pW	picowatt
RD	rotor diameter
Tetra Tech	Tetra Tech, Inc.
µPa	microPascal
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
W	watt
WTG	wind turbine generator

EXECUTIVE SUMMARY

Tetra Tech, Inc. (Tetra Tech) has completed an acoustic assessment for the proposed Oliver III Wind Energy Center located in Morton and Oliver Counties, North Dakota. A screening-level analysis was completed to evaluate the expected sound levels resulting from the Project wind turbine generators (WTGs) and substation. Although the Project would consist of up to 48 WTGs, two alternate WTG locations are included in the layout. Two scenarios were analyzed, one referred to as the "With Alternates" scenario and the other referred to as the "No Alternates" scenario. Analysis of the "With Alternates" scenario should be considered conservative, since all 50 WTGs were modeled but only 48 WTGs will be built as part of the Project. The overall objective of this study was to determine the feasibility of the Project to operate in compliance with the applicable North Dakota Public Service Commission (PSC) 50 dBA noise limit.

Wind turbine sound source data was obtained from General Electric (GE), the manufacturer of the GE 2.1-116 (2.1 MW) and GE 1.79-100 (1.79 MW) as documented in the turbine noise specification section (GE 2015). Substation data were obtained Oliver III, LLC (Oliver III) based on a 170 megavolt ampere (MVA) transformer. It is expected that the GE WTGs 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 4.6.153), 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.

The results of the acoustic modeling analysis were compared to the North Dakota PSC 50 dBA noise limit within 100 feet of an inhabited residence. Acoustic modeling results showed that the Project will comply with the PSC noise limit at the majority of occupied NSRs with the exception of NSR ID 810021. However, NSR ID 810021 is a Project participant and has signed a waiver that would no longer require the Project to comply with the PSC 50 dBA noise limit at that receptor.

1.0 INTRODUCTION

Oliver Wind III, LLC (Oliver III), a wholly-owned, indirect subsidiary of NextEra Resources, LLC (NEER), proposes to construct and operate the Oliver III Wind Energy Center (Project) in Oliver and Morton Counties, North Dakota. Oliver III is proposing to construct up to 48 wind turbine generators (WTGs). The site layout dated June 13, 2016, includes 43 GE 2.1-116 WTGs, 5 GE 1.79-100 WTGs, and 2 alternate GE 2.1-116 WTG locations. While no more than 48 WTGs will be built, one or more of the alternate WTG locations could be activated in the event that any of the primary WTG locations were eliminated. The rotor diameter of the GE 2.1-116 is 381 feet (116 meters) and it has a hub height (HH) of 262 feet (80 meters). The GE 1.79-100 has a rotor diameter of 328 feet (100 meters) and a hub height of 262 feet (80 meters). The proposed Project infrastructure also includes a collection substation to enable interconnection to the Minnkota Power Cooperative, Inc. Center to Mandan 230 kilovolt (kV) overhead transmission line located in the northeast quarter of Section 23, Township 141 North, Range 83 West. This site is located approximately 14 miles south, southeast of the City of Center, North Dakota. Substation data were obtained from Oliver III based on a 170 megavolt ampere (MVA) transformer similar to the HICO 170 MVA transformer in use at other NEER energy facilities.

An acoustic modeling analysis was completed for the Project, evaluating two scenarios, one referred to as the “With Alternates” scenario and the other referred to as the “No Alternates” scenario. Analysis of the “With Alternates” scenario should be considered conservative since only 48 WTGs will be built as part of the Project. Operational sounds levels resulting from the Project were analyzed at existing noise-sensitive receptors (e.g., residential structures) and compliance was assessed relative to the North Dakota Public Service Commission (PSC) noise limit.

1.1 Project Area

The Oliver III Project Area encompasses approximately 21,878 acres (34 square miles) in northern Morton County and southern Oliver County. One turbine is located in Oliver County and the rest are located in Morton County. County and township (section line) roads characterize the existing roadway infrastructure in and around the Project Area. The Project Area is accessed via I-94, State Highway 25, State Highway 31, and other local two-lane paved and gravel county roads. The land within the Project Area is primarily agricultural with scattered farmstead residences. The turbines will be located on privately-owned land in northern Morton County, approximately 12 miles northwest of Bismarck. This region of North Dakota has topography that can be described as level to rolling plains. Gentle slopes characterize most of the Project Area and local relief ranges from less than 2018 ft to 2278 ft. Current land use within the Project Area is primarily agricultural, supporting both crops and livestock grazing.

Occupied and unoccupied structures are scattered throughout the Project Area. Potential noise sensitive receptor locations within the Project Area and in the vicinity of proposed turbine locations were included in the acoustical analysis. Of these 92 receptors identified, 64 are occupied structures and 28 are unoccupied. Oliver III designed the Project using a minimum turbine setback of 2,000 feet from occupied residences, which exceeds Morton County’s setback requirement of

1,320 feet. Figure 1 in the Appendix presents the proposed Oliver III WTGs, as well as the noise sensitive receptor locations.

1.2 Existing Acoustic Environment

Northern Morton County and Southern Oliver County would generally be considered rural agricultural areas. Existing ambient sound levels are expected to be relatively low, although sound levels would be higher near roadways such as I-94, State Highway 25, and State Highway 31. Additional noise is likely a result of equipment and trucks associated with oil exploration in the area. 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 proximity to area sound sources such as roadways and natural sounds. 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 (L_W), 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 (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 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 due to the fact that 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 (or 33 1/3 octave) bands 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 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 in this report are presented as dBL.

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 in the State of North 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 (L_P) 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
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	

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.
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 environmental noise requirements specific to this Project. At the state level, the PSC has established regulations applicable to wind energy facilities. Morton and Oliver Counties do not provide noise limits applicable to the Project via their land use regulations. The controlling regulation for the Project is the PSC's noise limit.

2.1 State of North Dakota Public Service Commission Noise Regulations

North Dakota adopted noise regulations for wind energy facilities under the PSC Chapter 69-06-08-01(4) as follows:

> *A wind energy conversion facility site must not include a geographic area where, due to operation of the facility, the sound levels within one hundred feet of an inhabited residence or a community building will exceed fifty dBA. The sound level avoidance area criteria may be waived in writing by the owner of the occupied residence or the community building.*

Sound levels resulting from the Project within 100 feet of all identified receptors located in the vicinity of the Project were assessed against the 50 dBA limit to determine whether compliance was achieved. The PSC 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 WTG is comprised of both aerodynamic and mechanical sound with the dominant sound component from modern utility scale WTGs being largely aerodynamic. Aerodynamic sound refers to the sound produced from air flow and the interaction with the WTG tower structure and moving rotor blades. 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 minimized. Sound reduction elements designed as a part of the WTGs include impact noise insulation of the gearbox and generator, sound reduced gearbox, sound reduced nacelle, and rotor blades designed to minimize noise generation.

Wind energy facilities, in comparison to other energy-related facilities, are somewhat unique in that the sound generated by each individual WTG will increase as the wind speed across the site increases. 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 maximum rotational speed are achieved. Under this condition, the WTG maximum sound power level will be reached at approximately 7 meters per second [m/s], according to the GE specifications. 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 WTG sound emissions occur, the sound produced from a WTG 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 WTG 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

The operational acoustic assessment was performed using the proposed Project WTG layout dated June 13, 2016, which includes 43 GE 2.1-116 WTGs, 5 GE 1.79-100 WTGs, and 2 alternate GE 2.1-116 WTG locations. Two scenarios were modeled, a “With Alternates” scenario consisting of 50 WTG locations (48 planned WTG locations and an additional 2 alternate locations), and a “No Alternates” scenario consisting of 48 WTG locations. The Project would use the GE 2.1-116 WTG model, which has a rotor diameter of 381 feet (116 meters) and a hub height of 262 feet (80 meters) and the GE 1.79-100 WTG model, which has a rotor diameter of 328 feet (100 meters) and a hub height of 262 feet (80 meters). The Project would also include a collection substation with a 170 MVA transformer. WTG sound source data were obtained from GE (GE 2013 and 2015) and substation transformer data were obtained from Oliver Wind III.

The acoustic modeling analysis was conducted using the most recent version of DataKustic GmbH's computer-aided noise abatement program or CadnaA (v 4.6.153). CadnaA is a comprehensive 3-dimensional acoustic software model that conforms to the International Organization for Standardization (ISO) standard ISO 9613-2 "Attenuation of Sound during Propagation Outdoors." 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. 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. 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). A mixed (semi-reflective) ground factor of G=0.5 was used in the Project acoustic modeling analysis. 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, the temperature of 10ºCelsius (50ºFahrenheit) and 70 percent relative humidity parameters were selected as reasonably representative of conditions favorable to sound propagation. Atmospheric absorption depends on temperature and humidity and is most important at higher frequencies. Over short distances, the effects of atmospheric absorption are minimal. The ISO 9613-2 standard calculates attenuation for meteorological conditions favorable to propagation, i.e., downwind sound propagation or what might occur typically during a moderate atmospheric ground level inversion. Though a physical impracticality, the ISO 9613-2 standard simulates omnidirectional downwind propagation. For receivers located between discrete WTG locations or WTG groupings, the acoustic model may result in over-prediction. 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 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 and Low Level Jets (LLJs). While the North Dakota PSC does not specifically require or suggest that these meteorological conditions be explicitly addressed in modeling assessments, ISO 9613-2 includes a methodology to account for effects produced under these conditions and so they were addressed to ensure a conservative assessment.

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 Electrotechnical Commission (IEC) standard IEC 61400-11:2006 Wind Turbine Generator Systems—Part 11: Acoustic Noise Measurement Techniques. This accepted IEC standard was developed to ensure consistent and comparable sound emission data of utility-scale WTGs between manufacturers. Tables 3 and 4 present a summary of sound power data for the GE 1.79-100 and GE 2.1-116 WTGs during normal operations correlated to 10 meter height integer wind speeds 10 meter above ground level (AGL) with a stated roughness length[1] of 0.05 meters, which is representative of level grass-covered terrain (GE 2015). The sound power data for the GE 2.1-116 WTG is not yet available, so data for the GE 2.3-116 WTG was used. GE stated that the sound power profile for the GE 2.3-116 WTG is effectively the same as the profile for the GE 2.1-116 WTG, and therefore this data substitution should not impact results.

The specification for the WTGs includes an expected warranty confidence interval, or k-factor, of 2 dB, which was added to the nominal sound power level in the acoustic model. 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.

Table 3. Broadband Sound Power Levels (dBA) Correlated with Wind Speed (GE 1.79-100)

	WTG L_{max} Sound Power Level (L_W) at Reference Wind Speed							
10-meter AGL Wind Speed	11.2 mph (5 m/s)	12.3 mph (5.5 m/s)	13.4 mph (6 m/s)	14.5 mph (6.5 m/s)	15.7 mph (7 m/s)	17.9 mph (8 m/s)	20.1 mph (9 m/s)	22.4 mph (10 m/s)
GE 1.79-100	98.6	101.0	103.2	105.5	107.2	107.5	107.5	107.5

[1] The roughness length describes the vertical wind profile per IEC specification in a neutral atmosphere with the wind profile following a logarithmic curve.

Table 4. Broadband Sound Power Levels (dBA) Correlated with Wind Speed (GE 2.3-116)

	WTG L_{max} Sound Power Level (L_W) at Reference Wind Speed									
Wind Speed	8.9 mph (4.0 m/s)	11.2 mph (5.0 m/s)	13.4 mph (6.0 m/s)	15.7 mph (7.0 m/s)	17.9 mph (8.0 m/s)	20.1 mph (9.0 m/s)	22.4 mph (10.0 m/s)	24.6 mph (11.0 m/s)	26.8 mph (12.0 m/s)	29.1 mph (13.0 m/s)
GE 2.3-116	95.0	95.8	98.2	101.6	104.5	105.8	107.5	107.5	107.5	107.5

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 WTG 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 WTG models operating at maximum rotation are presented in Table 5 (1/1 octave band frequency data provided with stated intended use limited for informational purposes only).

Table 5. Sound Power Level by Octave Band Center Frequency

Frequency (Hz)	Octave Band Sound Power Level (dBA)								Broadband (dBA)
	63	125	250	500	1000	2000	4000	8000	
GE 1.79-100	91.0	96.1	98.0	100.8	103.3	100.0	90.3	70.6	107.5
GE 2.3-116	89.0	95.1	99.6	102.8	102.5	97.6	87.4	66.8	107.5

3.3 Acoustic Modeling Results

Acoustic modeling was completed for WTG cut-in and maximum rotational operating conditions, thereby describing resultant sound pressure levels over the entire operational range of the Project for both the “With Alternates” and “No Alternates” scenarios. In addition, sound energy contribution from the Project substation was included in the acoustic modeling analysis. When calculating received sound levels, it was assumed that the Project substation and all WTGs were operating concurrently at the given operating condition. Sound contour plots displaying Project operational sound levels in color-coded isopleths are provided in Figures 2 through 8 in the Appendix. Figures 2 and display the broadband operational sound levels under low-level wind speeds sufficient for the WTGs to operate at initial cut-in rotational speeds. Figures 4 and 5 display broadband operational sound levels at wind speeds sufficient to sustain WTG operation at maximum rotational speeds for moderate downwind propagation. Figures 6 and 7 display broadband operational sound levels at wind speeds sufficient to sustain WTG operation at maximum rotational speeds under anomalous meteorological conditions.

Table 6 presents the results of the Oliver III Wind Energy Center acoustic modeling analysis and includes the ID, Universal Transverse Mercator (UTM) coordinates, receptor status and the received sound levels at each receptor for both scenarios. Received sound levels are rounded to the nearest whole decimal for consistency with the State of North Dakota noise limit, which is an absolute value of 50 dBA. In addition, a 100-foot buffer was included around the receptors, corresponding to the point of compliance identified in the PSC 50 dBA noise limit.

The acoustic modeling results shown in Table 6 demonstrate that received sound levels are all below the PSC 50 dBA noise limit with the exception of two receptors, NSR IDs 30008 and 810021. NSR ID 30008 was identified as an unoccupied structure; therefore, it is not considered noise sensitive and demonstrating compliance with the limit is not required. NSR ID 810021 was identified as an occupied structure; however, NSR ID 810021 is a Project participant and has signed a waiver that would no longer require the Project to comply with the PSC 50 dBA noise limit at that receptor.

Table 6. Oliver III Wind Energy Center – Acoustic Modeling Results

NSR ID	NSR Status	UTM Coordinates (NAD83 UTM Zone 14 meters)		No Alternates			With Alternates		
		Easting (m)	Northing (m)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)
107	Occupied	328318	5199223	15	27	30	15	27	30
111	Occupied	332294	5197910	18	31	33	18	31	33
113	Occupied	333315	5198704	22	34	36	22	34	36
117	Unoccupied	334380	5197276	15	28	30	16	28	30
120	Unoccupied	339638	5195765	20	32	34	20	33	35
123	Unoccupied	340219	5195497	19	32	34	20	32	34
125	Unoccupied	342224	5195776	16	28	31	17	29	31
130	Occupied	342338	5201598	17	29	32	18	30	32
131	Occupied	342481	5201792	16	29	31	17	29	32
134	Occupied	342502	5201888	17	29	32	18	30	33
138	Occupied	342586	5201880	18	29	32	18	30	33
170	Unoccupied	327196	5203001	15	28	30	15	28	30
172	Occupied	326573	5203121	18	30	33	18	30	33
173	Unoccupied	326614	5203107	18	30	33	18	30	33
175	Occupied	336480	5210588	10	20	23	10	20	23
5013	Occupied	331662	5210195	16	27	30	16	27	30
5015	Occupied	335015	5210254	11	22	24	11	22	24
5016	Occupied	335270	5210159	15	26	28	15	26	28
5017	Occupied	335141	5210664	10	21	23	10	21	23
5018	Occupied	334958	5209903	16	27	29	16	27	29
5020	Occupied	334149	5206673	24	35	37	24	35	37
5021	Occupied	334144	5206664	24	35	37	24	35	37

Table 6. Oliver III Wind Energy Center – Acoustic Modeling Results

NSR ID	NSR Status	UTM Coordinates (NAD83 UTM Zone 14 meters)		No Alternates			With Alternates		
		Easting (m)	Northing (m)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)
5026	Occupied	331919	5207710	19	31	33	19	31	33
6002	Unoccupied	335368	5206778	26	36	38	26	36	38
6003	Unoccupied	335435	5204641	33	43	44	33	43	44
6004	Occupied	334582	5203847	33	45	46	33	45	46
6005	Occupied	335894	5202102	32	45	46	32	45	46
6006	Occupied	335875	5202206	33	45	47	33	45	47
6008	Occupied	338714	5201739	27	39	41	28	40	42
6009	Unoccupied	338753	5201759	27	39	41	28	40	42
6010	Occupied	335722	5198836	26	39	41	27	39	41
6011	Occupied	336821	5199125	30	43	44	30	43	44
6012	Unoccupied	335789	5197882	24	36	38	24	36	39
6013	Occupied	336785	5196966	24	37	38	25	37	39
6014	Unoccupied	337857	5198463	34	46	46	34	46	47
7002	Occupied	339472	5200083	30	43	43	32	45	45
7004	Unoccupied	339106	5200837	28	40	41	34	47	47
7007	Occupied	338286	5203461	28	39	41	28	39	41
7010	Occupied	338391	5204385	27	37	39	27	38	40
7016	Occupied	337949	5204464	29	39	40	29	39	41
7020	Occupied	341032	5200597	21	33	36	22	35	37
7023	Occupied	342191	5197153	20	33	35	21	33	35
7027	Occupied	342126	5197130	21	33	35	21	34	36
7029	Occupied	341907	5197106	21	34	36	22	34	36
30008	Unoccupied	337240	5201768	39	52	52	39	52	52
500009	Occupied	336405	5207685	23	32	34	23	32	34

Table 6. Oliver III Wind Energy Center – Acoustic Modeling Results

NSR ID	NSR Status	UTM Coordinates (NAD83 UTM Zone 14 meters)		No Alternates			With Alternates		
		Easting (m)	Northing (m)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)
500013	Unoccupied	330397	5207060	22	34	37	22	34	37
500015	Occupied	329972	5208020	19	31	34	19	31	34
500016	Unoccupied	330022	5206923	21	34	36	21	34	36
500023	Unoccupied	328917	5203693	32	44	44	32	44	44
500034	Occupied	337954	5210133	15	25	28	15	25	28
500038	Occupied	337720	5211843	6	16	19	6	16	19
500042	Occupied	335296	5211142	9	20	22	9	20	22
500046	Occupied	335293	5211109	9	20	22	9	20	22
500048	Occupied	335435	5209595	12	23	26	12	23	26
810006	Occupied	339698	5209012	13	24	27	14	24	27
810009	Unoccupied	336106	5208385	21	31	34	21	31	34
810013	Occupied	336115	5209049	19	30	32	19	30	32
810021	Occupied	331249	5204371	38	51	51	38	51	51
810023	Unoccupied	330451	5204493	34	46	47	34	46	47
810029	Unoccupied	330511	5205949	29	41	42	29	41	42
810036	Occupied	341396	5194840	13	25	27	13	25	28
810040	Occupied	340215	5195314	18	30	33	19	31	34
810043	Occupied	338198	5195469	19	32	34	20	32	34
810044	Occupied	338224	5195477	21	33	35	21	34	36
810048	Occupied	337653	5195304	21	33	35	21	34	36
810051	Occupied	337439	5194605	18	31	33	19	31	33
810054	Occupied	337303	5194404	15	28	30	15	28	31
810058	Occupied	337338	5196332	24	36	37	24	36	37
810063	Occupied	337149	5195323	20	32	35	20	33	35

Table 6. Oliver III Wind Energy Center – Acoustic Modeling Results

NSR ID	NSR Status	UTM Coordinates (NAD83 UTM Zone 14 meters)		No Alternates			With Alternates		
		Easting (m)	Northing (m)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)	Cut-in Rotation (dBA)	Maximum Rotation (dBA)	Maximum Rotation under Anomalous (dBA)
810068	Occupied	336713	5195341	19	31	34	19	32	34
810070	Occupied	336646	5195342	19	31	33	19	32	33
810074	Occupied	336623	5195344	18	31	33	19	31	33
810079	Occupied	336099	5195320	17	30	32	18	30	33
810083	Occupied	335553	5195486	17	30	32	17	30	32
810087	Occupied	335690	5195807	19	31	34	19	32	34
810094	Occupied	335659	5196501	20	32	35	20	33	35
810101	Occupied	333216	5199405	24	36	39	24	36	39
810102	Occupied	333166	5199373	23	36	38	23	36	38
810109	Occupied	332567	5199511	24	37	39	24	37	39
810110	Unoccupied	332347	5200690	29	41	43	29	41	43
810116	Occupied	336094	5195437	19	31	33	19	31	34
810118	Occupied	327470	5200229	14	27	29	14	27	29
810126	Unoccupied	329809	5200210	22	34	37	22	34	37
810132	Unoccupied	338217	5201930	30	42	43	30	42	44
810144	Unoccupied	337177	5202967	36	49	49	36	49	49
810242	Occupied	340658	5196713	25	38	39	25	38	39
810365	Unoccupied	329428	5201283	23	36	38	23	36	38
810366	Unoccupied	329219	5201020	23	35	37	23	35	37
810614	Unoccupied	338133	5200625	36	48	49	37	49	49
810628	Unoccupied	338043	5195338	20	33	35	21	33	35
810634	Unoccupied	327032	5203541	19	32	34	19	32	34

4.0 OTHER SOUND CONSIDERATIONS

4.1 Substation Noise

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 proposed Oliver III electrical substation would be located near the center of the Project Area along 32nd Street near the intersection of 32nd Street and 33rd Avenue. The transformer at this substation location was modeled using the latest version of CadnaA implementing ISO 9613-2. Transformer sound source levels for the Oliver III substation were provided based on a 170 MVA transformer similar to the HICO 170 MVA transformer in use at other NEER energy facilities. Table 9 presents the transformer sound source data by octave band center frequency calculated based on the estimated transformer NEMA and MVA ratings using standardized engineering guidelines.

Table 7. Transformer Sound Power Level

	Octave Band Sound Power Level (dB)								Broadband (dBA)
Frequency (Hz)	63	125	250	500	1000	2000	4000	8000	
170 MVA Transformer	93	99	101	94	90	85	80	73	97

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 noise-sensitive receptors. The proposed Oliver III transformer location is approximately 1,683 feet (513 meters) from the nearest noise sensitive receptor and poses little concern from a noise perspective. That being said, transformer noise may be periodically audible at nearby receptors on occasions when background sound levels are very low.

4.2 Construction Noise

The development of Oliver III Wind Energy Center will involve construction to establish access roads, excavate and form WTG foundations, prepare the site for crane-lifting and assemble and commission the WTGs. Work on large-scale wind projects such as Oliver III Wind Energy Center 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. *WTG 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 periodic testing and commissioning prior to commencement of full commercial operation. Other construction activities include those for the supporting infrastructure such as the substation, 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 8.

Table 8. Estimated L_{max} 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

Source: FHWA 2006; Bolt et al. 1977

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 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 noise-sensitive receptors 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.

5.0 CONCLUSIONS

Project operational sound has been calculated and compared to the 50 dBA PSC noise limit. Acoustic modeling analysis per ISO 9613-2 and inclusive of a number of conservative assumptions under operational conditions demonstrates the Project will comply with the PSC noise limit at the majority of occupied NSRs with the exception of NSR ID 810021. However, NSR ID 810021 is a Project participant and has signed a waiver that would no longer require the Project to comply with the PSC 50 dBA noise limit at that receptor. 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 North Dakota employing the same or similar criteria.

6.0 TECHNICAL REFERENCES

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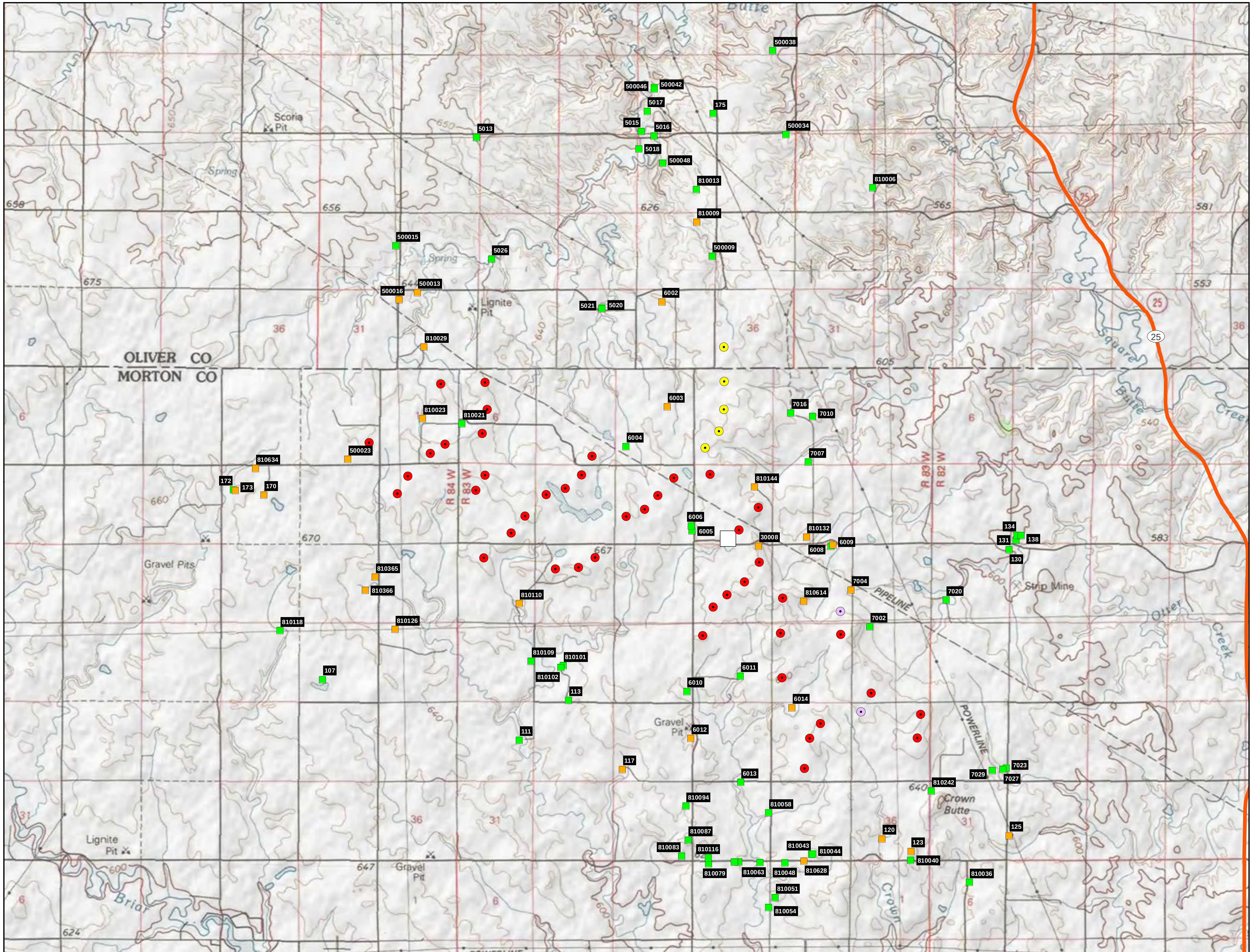
APPENDIX

Figures

NEXTERA ENERGY RESOURCES, LLC
OLIVER III WIND PROJECT
OLIVER AND MORTON COUNTIES, NORTH DAKOTA

FIGURE 1
PROJECT LAYOUT

JUNE 2016



Proposed Turbine Array (6/13/2016)

- GE 2.1 MW Turbine
- GE 2.1 MW Turbine (Alt)
- GE 1.79 MW Turbine

Receptors

- Occupied
- Unoccupied
- Substation
- Major Road

N

0 0.5 1 1.5 2 MILES

REFERENCE MAP

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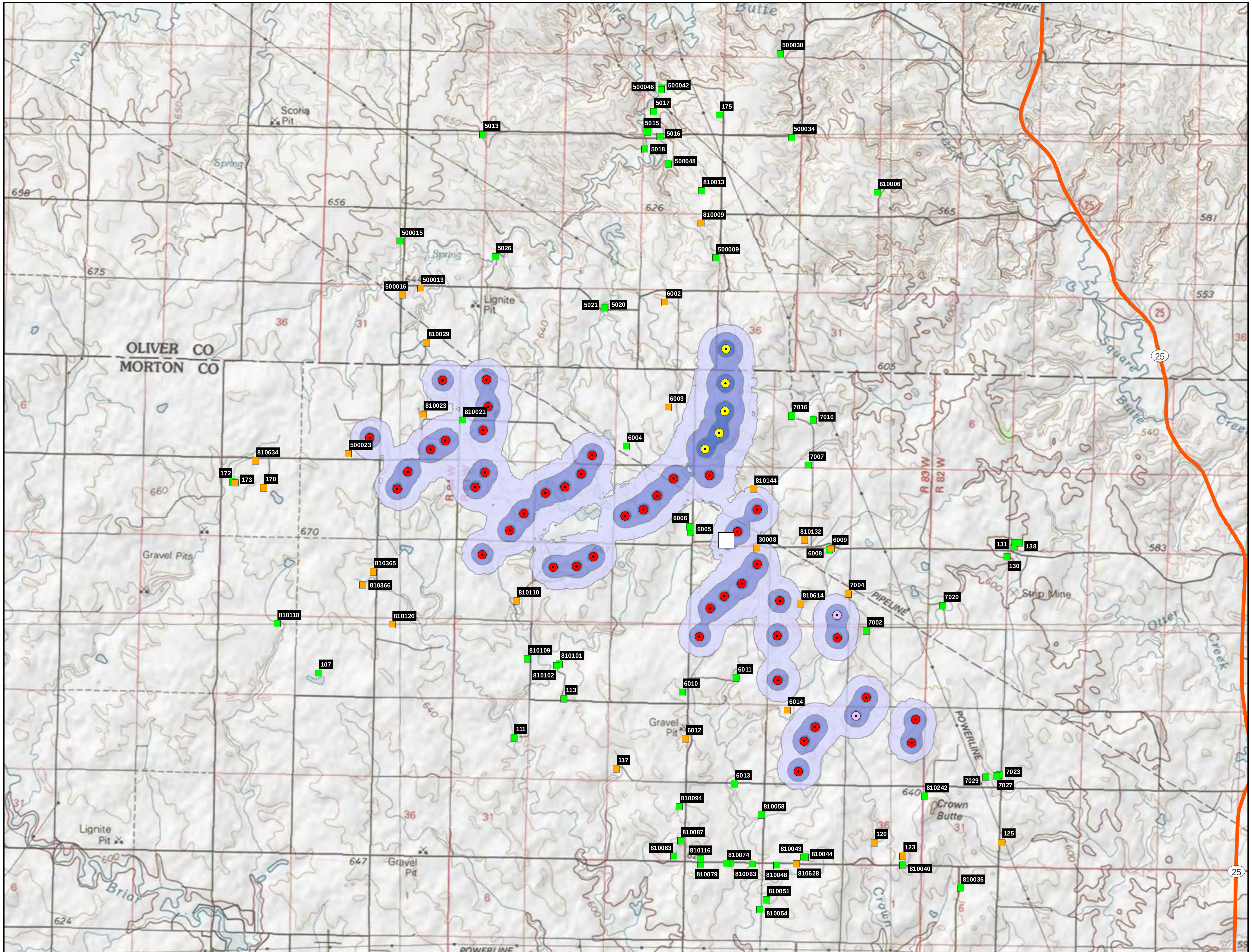

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OLIVER III WIND PROJECT
OLIVER AND MORTON COUNTIES, NORTH DAKOTA

FIGURE 2
WITH ALTERNATES:
RECEIVED SOUND LEVELS - WIND TURBINES AT CUT-IN WIND SPEED

JUNE 2016

Proposed Turbine Array (6/13/2016)
- GE 2.1 MW Turbine
- GE 2.1 MW Turbine (Alt)
- GE 1.79 MW Turbine

Receptors
- Occupied
- Unoccupied
- Substation

Sound Level Contour Ranges (dBA)
- 35-40
- >40-45
- >45-50
- >50
- Major Road

N

0 0.5 1 1.5 2 MILES

REFERENCE MAP

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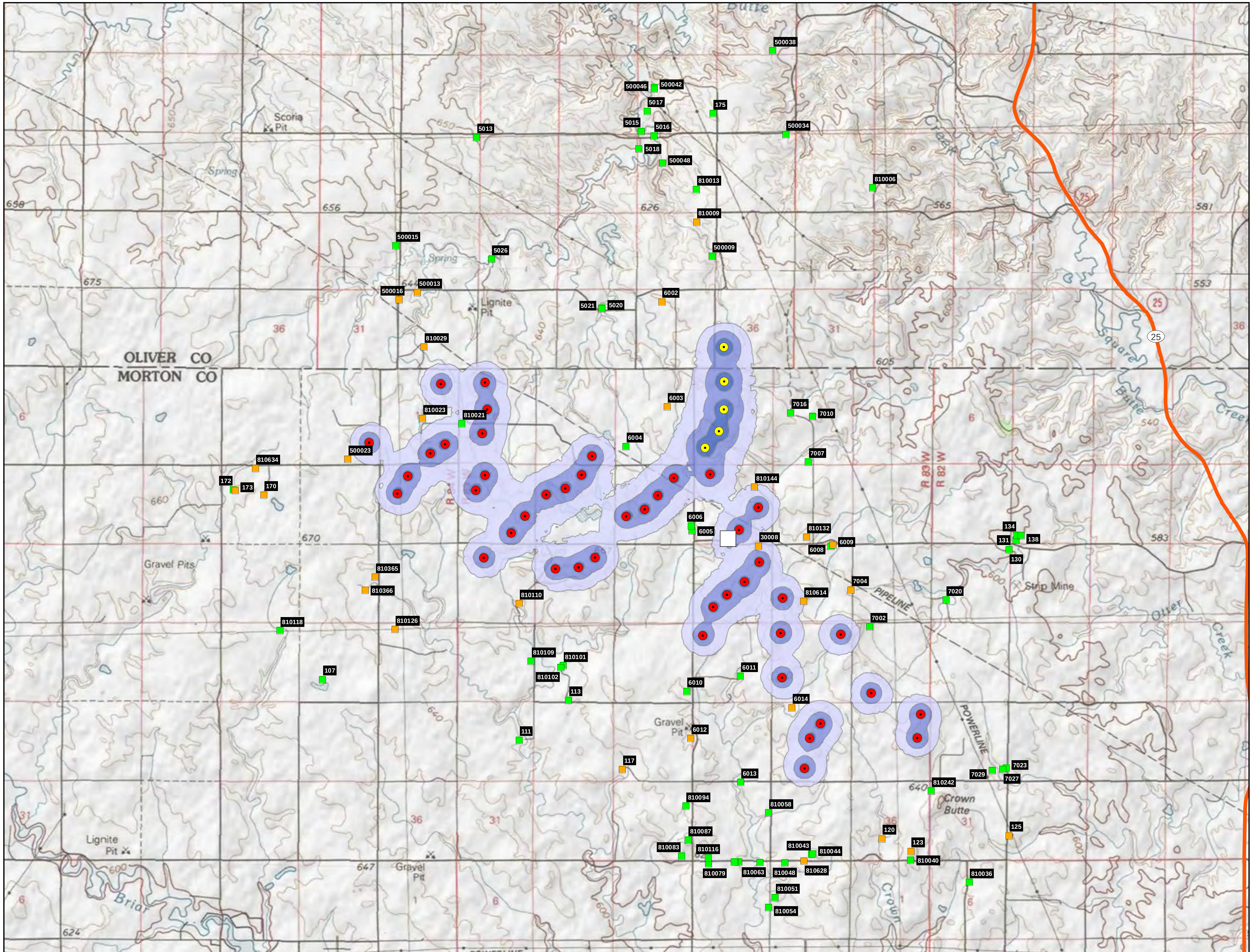

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OLIVER AND MORTON COUNTIES, NORTH DAKOTA

FIGURE 3
NO ALTERNATES:
RECEIVED SOUND LEVELS - WIND TURBINES AT CUT-IN WIND SPEED

JUNE 2016

Proposed Turbine Array (6/13/2016)
- GE 2.1 MW Turbine
- GE 1.79 MW Turbine

Receptors
- Occupied
- Unoccupied
- Substation

Sound Level Contour Ranges (dBA)
- 35-40
- >40-45
- >45-50
- >50
- Major Road

N

0 0.5 1 1.5 2 MILES

REFERENCE MAP

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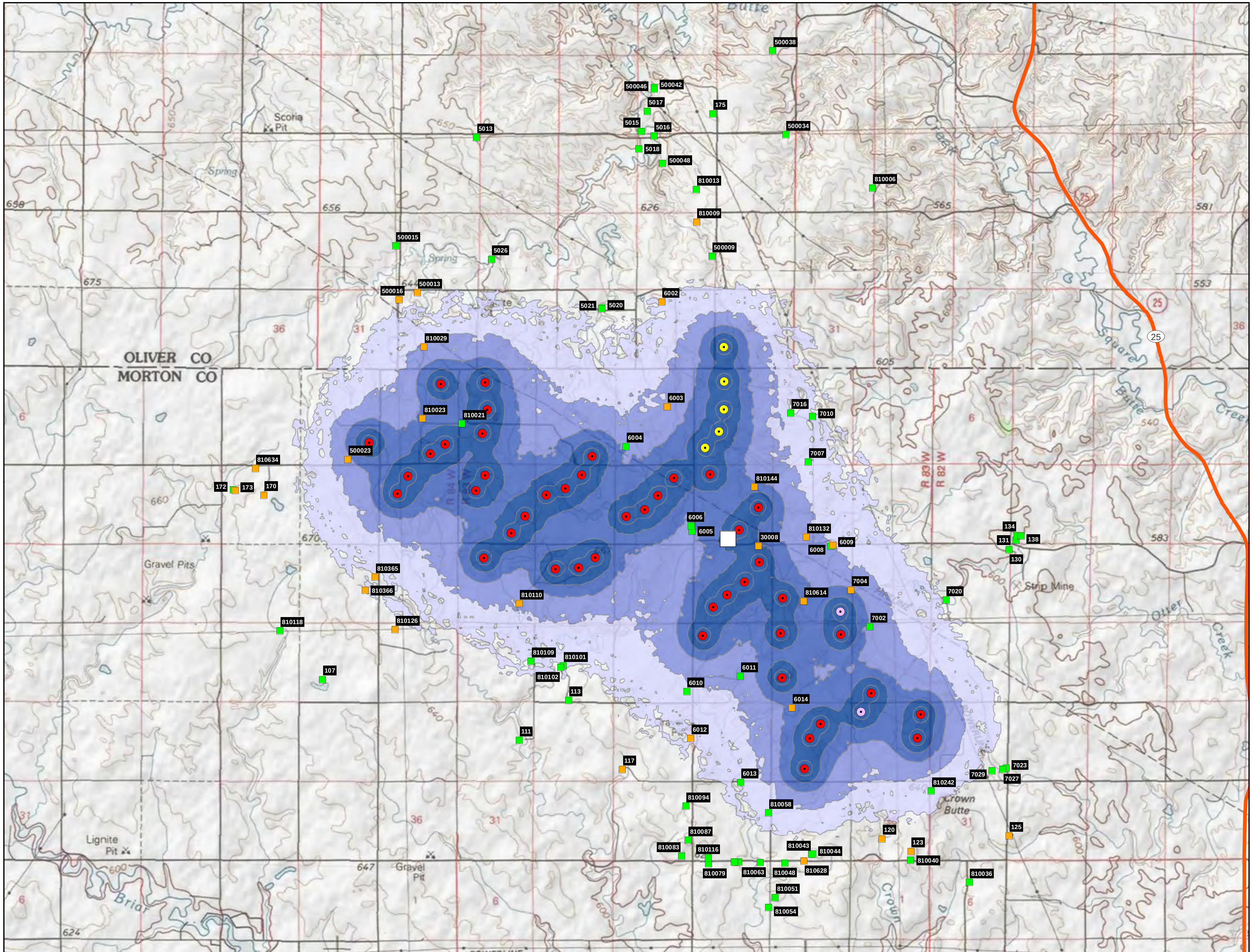
OLIVER III WIND PROJECT
OLIVER AND MORTON COUNTIES, NORTH DAKOTA

FIGURE 4
WITH ALTERNATES:
RECEIVED SOUND LEVELS - WIND TURBINES AT MAXIMUM ROTATIONAL WIND SPEED

JUNE 2016



Proposed Turbine Array (6/13/2016)
- GE 2.1 MW Turbine
- GE 2.1 MW Turbine (Alt)
- GE 1.79 MW Turbine

Receptors
- Occupied
- Unoccupied
- Substation

Sound Level Contour Ranges (dBA)
- 35-40
- >40-45
- >45-50
- >50
- Major Road

N

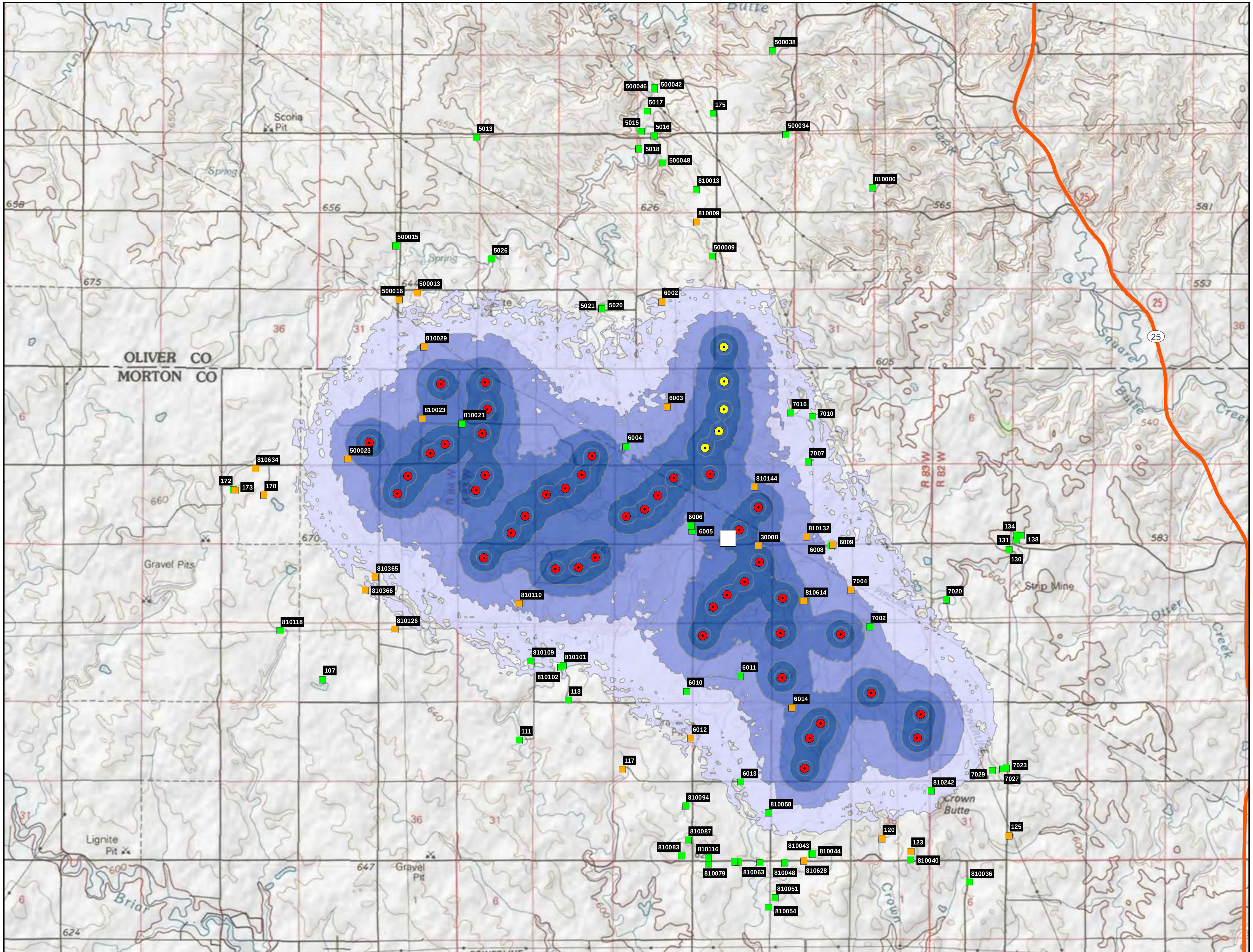
0 0.5 1 1.5 2 MILES

REFERENCE MAP

NEXTERA ENERGY RESOURCES, LLC
OLIVER III WIND PROJECT
OLIVER AND MORTON COUNTIES, NORTH DAKOTA

FIGURE 5
NO ALTERNATES:
RECEIVED SOUND LEVELS - WIND TURBINES AT MAXIMUM ROTATIONAL WIND SPEED

JUNE 2016



Proposed Turbine Array (6/13/2016)
- GE 2.1 MW Turbine
- GE 1.79 MW Turbine

Receptors
- Occupied
- Unoccupied
- Substation

Sound Level Contour Ranges (dBA)
- 35-40
- >40-45
- >45-50
- >50
- Major Road

N

0 0.5 1 1.5 2 MILES

REFERENCE MAP

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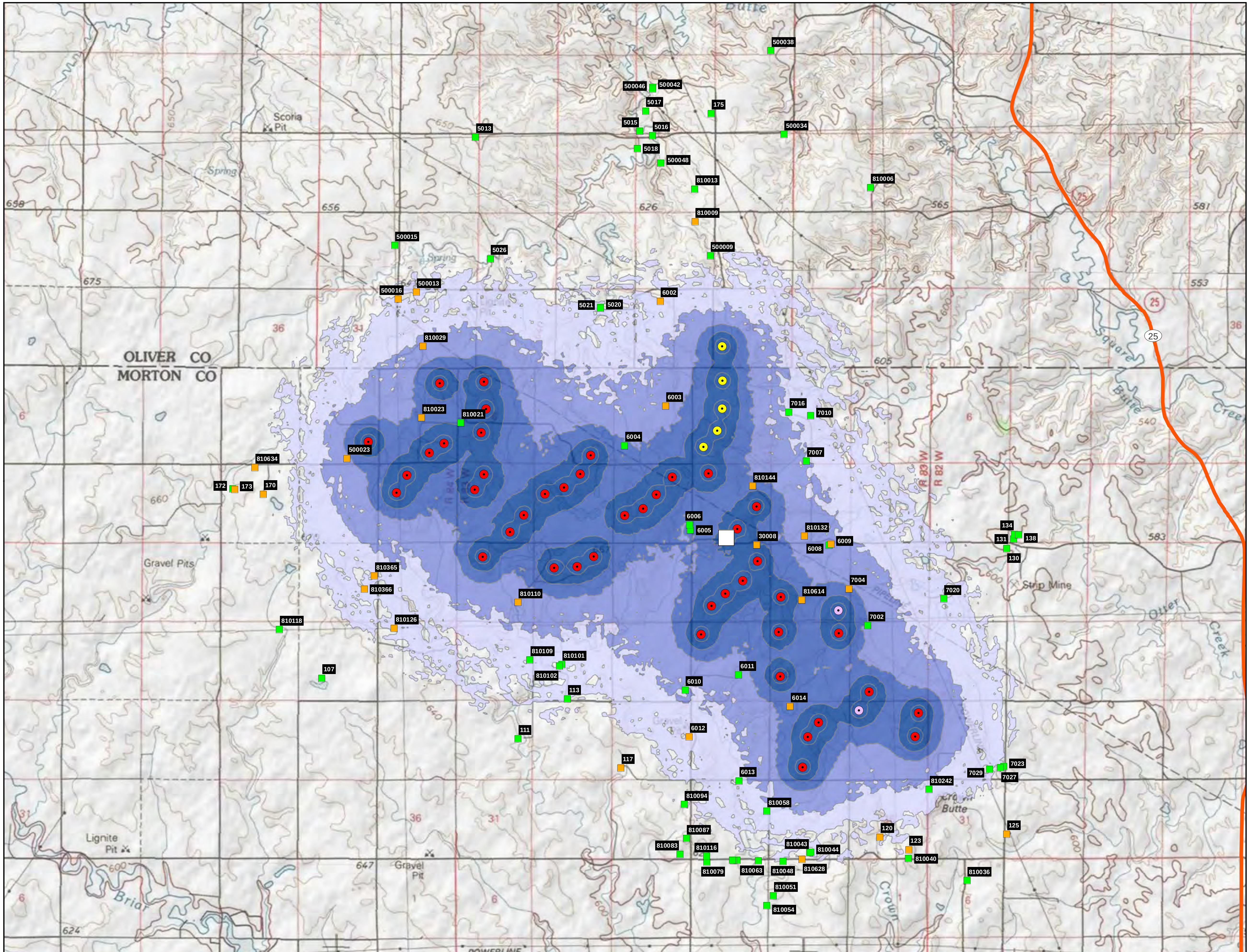

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OLIVER III WIND PROJECT

OLIVER AND MORTON COUNTIES, NORTH DAKOTA

FIGURE 6
WITH ALTERNATES:
RECEIVED SOUND LEVELS - WIND TURBINES AT MAXIMUM ROTATIONAL WIND SPEED ANOMALOUS METEOROLOGICAL CONDITIONS

JUNE 2016

Proposed Turbine Array (6/13/2016)

- GE 2.1 MW Turbine
- GE 2.1 MW Turbine (Alt)
- GE 1.79 MW Turbine

Receptors

- Occupied
- Unoccupied
- Substation

Sound Level Contour Ranges (dBA)

- 35-40
- >40-45
- >45-50
- >50
- Major Road

N

0 0.5 1 1.5 2 MILES

REFERENCE MAP

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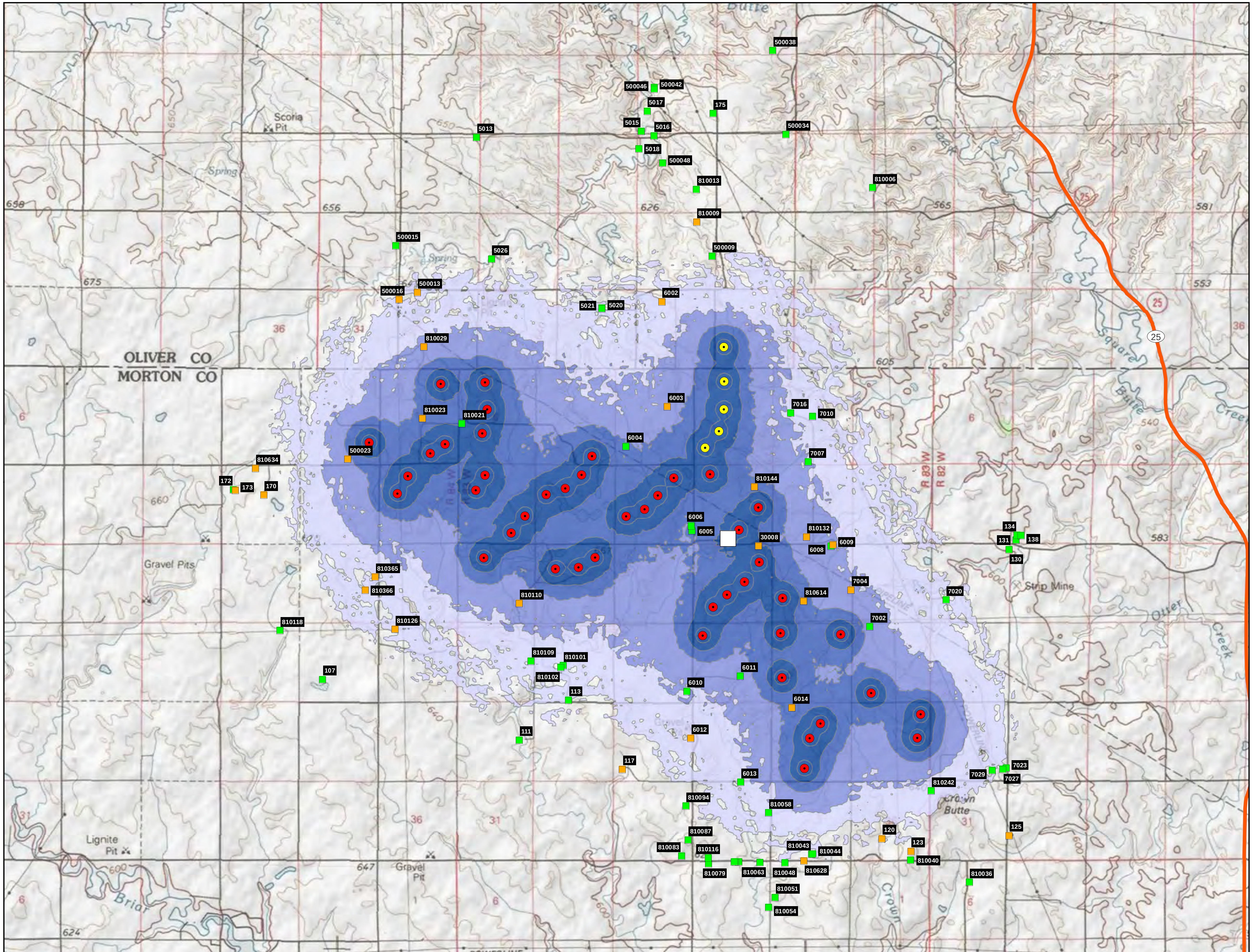

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OLIVER III WIND PROJECT

OLIVER AND MORTON COUNTIES, NORTH DAKOTA

FIGURE 7
NO ALTERNATES:
RECEIVED SOUND LEVELS - WIND TURBINES AT MAXIMUM ROTATIONAL WIND SPEED ANOMALOUS METEOROLOGICAL CONDITIONS

JUNE 2016

Proposed Turbine Array (6/13/2016)

- GE 2.1 MW Turbine
- GE 1.79 MW Turbine

Receptors

- Occupied
- Unoccupied
- Substation

Sound Level Contour Ranges (dBA)

- 35-40
- >40-45
- >45-50
- >50
- Major Road

N

0 0.5 1 1.5 2 MILES

REFERENCE MAP

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