TO:	Antelope Hills Wind Project, LLC
FROM:	Tetra Tech, Inc.
DATE:	August 15, 2014
PROJECT:	Antelope Hills Wind Project
RE:	Acoustic Screening Level Analysis

Antelope Hill Wind Project, LLC (Antelope) is proposing to construct and operate the Antelope Hills Wind Project (Project) in Mercer County, North Dakota.

Tetra Tech has completed the following screening level acoustic assessment to determine the feasibility of the Project to operate within applicable noise criteria. Additionally, construction noise levels have been qualitatively assessed. The results of the acoustic analysis demonstrate that the Project would not exceed the State's regulatory noise limit for wind energy projects at any noise sensitive receptors (NSRs).

<u>Applicable Regulation</u>

Tetra Tech completed a review of regulations and at the federal and local regulatory levels there are no applicable noise regulations for the Project; however, the State provides regulatory limits that are applicable to the Project. North Dakota Chapter 69-06-08-01(4) provides for the State's noise requirements with respect to wind energy projects:

> *"Additional avoidance areas for wind energy conversion facilities. 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."*

<u>Facility Construction Sound Levels</u>

Project construction 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 1. No blasting or pile driving is anticipated during Project construction.

Table 1. 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

Table 1. 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)

Data compiled in part from the following sources:

Federal Highway Administration, "Roadway Construction Noise Model User's Guide," Report FHWA-HEP-05-054 / DOT-VNTSC-FHWA-05-01, January 2006.

Power Plant Construction Noise Guide, Bolt Beranek and Newman, Inc. 1977.

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

Construction activity would also generate traffic having potential noise effects, such as trucks travelling to and from the site on public roads.

Sound generated by construction activities is generally exempt from the state noise regulation. Construction would be limited to daytime hours between 7 a.m. and 7 p.m. to the extent practicable and reasonable efforts would be made to minimize the impact of noise resulting from construction activities.

Facility Operational Sound Levels

Sound power level data are used in acoustic models to predict received sound pressure levels at observer locations. The proposed Project has a nameplate (gross) generating capacity of 172 megawatts (MW). Table 2 provides the three turbine types under consideration to achieve the nameplate capacity and the broadband sound power level associated with each.

Because the final turbine locations have not been determined, all primary and alternative turbine locations were modeled in the Project layout. However, the actual number of turbines used for the final Project design would be less than that indicated in Table 2. For example, only 86 of the 92 Vestas V110 turbines modeled would be needed to achieve the 172MW nameplate capacity.

Table 2. Candidate Turbine Types and Layout Configurations

Model	Quantity	MW	Hub Height (m)	Rotor Diameter (m)	Sound Power Level (dBA)*
Siemens SWT 2.3-108	92	2.3	80	108	108.0
Vestas V100-2.0	104	2.8	80	100	105.0
Vestas V110-2.0	92	2.0	80	110	107.5

*K-factors (or uncertainty factor) of 1.5 and 2 dBA were applied to the overall A-weighted sound power level of the Siemens and Vestas WTGs, respectively.

Source: Siemens 2011, Vestas 2013, Vestas 2010

Turbine sound power levels are determined in accordance with IEC 61400-11, Wind Turbine Generator Systems—Part 11: "Wind turbine generator systems – Acoustic Noise Measurement Techniques". This methodology has been developed to allow for comparison between turbine manufacturers using consistent reporting and measurement techniques. The IEC test is an accepted standard providing a uniform methodology for measuring the noise emissions of a turbine from cut-in through full rotational wind speeds. The IEC testing standard defines deviation values σ_T, σ_R and σ_P for measured apparent sound power levels as described by IEC/TS 61400-14, where σ_T is the total standard deviation, σ_R is the standard deviation for test reproducibility, and σ_P is the standard deviation for product variation. To account for this inherent deviation associated with the IEC testing methodology, a confidence interval of $k = 1.5$ dBA and $K = 2$ dBA were applied to the broadband A-weighted turbine sound power level values for the Siemens and Vestas turbines, respectively. The combination of the modeling parameters used and the inclusion of the 1.5 or 2 dBA term are expected to result in a reasonable and conservative assessment of Project sound levels.

Sound power specifications and octave band frequency data were obtained from the manufacturers of the turbines under consideration. It is assumed that the turbines for the Project would have similar sound power profiles as those used in the acoustic modeling analysis; however, it is possible that the final manufacturer warranty values may vary slightly. Table 3 provides a summary of the sound power data correlated by wind speed for each turbine model at reference rotor hub height assuming a roughness length[1] coefficient of 0.05 meters. As shown in Table 3, generally wind speeds lower than those corresponding to full rated power also result in lower sound levels.

Table 3. Turbine Broadband Sound Power Levels (dBA) Correlated with Wind Speed

Sound Power Level at Reference Wind Speed											
Wind Speed (m/s)	3	4	5 m/s	6 m/s	7 m/s	8 m/s	9 m/s	10	11	12	13
Siemens SWT 2.3-	-	94.8	99.4	104.6	108.0	108.0	108.0	108.0	108.0	108.0	108.0
Vestas V100-2.0	93.8	96.0	100.1	103.9	105.0	105.0	105.0	105.0	105.0	105.0	105.0
Vestas V110-2.0	97.3	99.6	103.8	107.5	106.1	106.1	106.1	106.3	106.5	106.7	107.0

Source: Siemens 2011, Vestas 2013, Vestas 2010

The Project collector substation was not included in the acoustic analysis because setback distances to the nearest NSR are relatively large at approximately one mile and it is assumed that received sound levels would attenuate to low levels at the nearest NSRs. The Project substation would connect to a new 345kV transmission line which is evaluated in a separate acoustic technical memo that Tetra Tech has prepared for Antelope.

Operational Acoustic Modeling Methodology

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

Standard acoustic engineering methods conforming to ISO 9613-2 were incorporated into the Project acoustic modeling analysis using DataKustic GmbH's CadnaA, the computer-aided noise abatement program (v 4.4.145). The engineering methods specified in this standard consist of full 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 sources and receptors, seasonal foliage effects, and meteorological conditions. Operational broadband sound pressure levels were calculated assuming that all WTGs inclusive of the alternates are operating continuously and concurrently at the maximum manufacturer-rated sound level. The sound energy was then summed to determine the equivalent continuous A-weighted downwind sound pressure level at a given point of reception such as a NSR.

Topographical information was imported into the acoustic model using the official U.S. Geological Survey (USGS) digital elevation dataset to accurately represent terrain in three dimensions. Terrain conditions, vegetation type, ground cover, and the density and height of foliage can also influence the absorption that takes place when sound waves travel over land. The ISO 9613-2 standard accounts for ground absorption rates by assigning a numerical coefficient of G=0 for acoustically hard, reflective surfaces and G=1 for absorptive surfaces and soft ground. In this case, the Project area agricultural lands

[1] The roughness length describes the change in wind speed at increased elevation and may vary based on site specific terrain conditions.

used for cultivation are assumed to be moderately reflective and therefore a ground absorption factor of G=0.5 was applied. Sound attenuation through foliage and diffraction around and over existing structures such as buildings was ignored under all acoustic modeling scenarios. Sound attenuation by the atmosphere is not strongly dependent on temperature and humidity; however, a temperature of 10°C (50°F) and a relative humidity of 70 percent were selected as reasonably representative of conditions favorable to sound propagation.

Inherent to the ISO 9613-2 and IEC61400-11 standards are downwind conditions. That is, the turbine sound power levels and modeling methods are representative of when the wind is blowing from the turbine to the receptor. In fact, the ISO 9613-2 modeling method unrealistically assumes that downwind conditions exist in all directions, between each turbine and each receptor simultaneously, even though that is physically impossible. Therefore, lower levels are expected in the upwind direction. Conversely, there may be meteorological conditions from time to time that may aid in the long range propagation of sound. These anomalous meteorological conditions may include wind gradients that bend sound downwards, which principally affect long range sound propagation. Received sound levels during anomalous meteorological conditions were also estimated using a range dependent correction factor.

Sound power levels were modeled at each NSR within the Project Area and a one-mile buffer area. Potential NSRs were identified based on the North Dakota standard quoted above as occupied residences or community buildings. Within the Project Area 38 potential NSRs were identified. All were residences, and included those known to be occupied and those whose status as occupied or unoccupied was not known.

Operational Acoustic Modeling Results

To determine compliance with the State's noise regulation acoustic modeling was completed for Project operation for two cases: (1) highest specified operational sound level according to the turbine manufacturer's specifications under typical downwind propagation conditions; and (2) highest specified operational sound level according to the turbine manufacturer's specifications under anomalous meteorological conditions. Noise was modeled at a distance of 100 feet from each residential structure in consideration of the North Dakota noise standard quoted above.

The acoustic modeling results were compared to the State's numerical limits of 50 dBA. Table 4 summarizes the number of NSRs within selected sound pressure level ranges (in dBA) under each of the modeled operational conditions. The tabulated results are independent of the existing acoustic environment (i.e. are representative of expected Project-generated sound levels only). Table A-1 (Attachment 1) presents the received sound levels at each of the 38 individual NSRs for each turbine type by receptor ID and UTM coordinates. The assessment included prediction and plotting of sound level contours from the Project. Sound contour maps displaying the corresponding typical downwind and anomalous meteorological operational sound levels in color-coded isopleths are presented in Figures 1 to 6 (Attachment 1). Isopleths are projected onto scaled aerial photographs at a height of 1.52 meters (5 feet) above grade i.e., at the approximate height of a person's ears while standing. In conclusion, modeling results, as shown in Tables 4 and A-1, indicate that the Project would not exceed the applicable State noise limits for wind energy projects at any NSRs.

Table 4. Number of NSRs by Sound Level Range and Exceedance Condition for each Turbine Layout

Sound Level Range (dBA)	Siemens SWT 2.3-108		Vestas V100-2.0		Vestas V110-2.0	
	Typical Downwind	Anomalous Meteorological	Typical Downwind	Anomalous Meteorological	Typical Downwind	Anomalous Meteorological
Less than 35	11	6	11	6	11	5
35 - 40	10	10	10	10	10	11
40 - 45	7	10	7	10	7	10
45-50	10	12	10	12	10	12
50-55+	0	0	0	0	0	0
>50 (North Dakota Limit)	0	0	0	0	0	0

ATTACHMENT 1

Tabulated Results and Sound Contour Figures

Table A-1. Tabulated Acoustic Modeling Results

NSR ID	UTM Coordinates (m)		Sound Levels (dBA L_{eq}) Siemens SWT 2.3-108		Sound Levels (dBA L_{eq}) Vestas V100-2.0		Sound Levels (dBA L_{eq}) Vestas V110-2.0	
	Easting	Northing	Typical Downwind	Anomalous Meteorological	Typical Downwind	Anomalous Meteorological	Typical Downwind	Anomalous Meteorological
1	731437	5255350	45	46	42	43	45	46
2	731508	5251629	39	41	37	38	39	41
3	731684	5252901	43	44	40	41	43	44
4	727710	5252234	43	44	40	41	43	44
5	728422	5255087	49	50	47	47	49	50
6	727193	5251180	37	39	35	37	38	40
7	725499	5254654	48	48	45	45	48	48
8	724089	5255508	50	50	46	47	50	50
9	721931	5254703	43	44	43	44	43	44
10	722548	5253758	46	46	43	44	46	46
11	721603	5258460	43	44	39	40	43	44
12	721875	5260187	35	37	31	34	35	38
13	721768	5260539	32	34	28	30	33	35
14	719590	5259774	39	41	35	37	40	41
15	718419	5260217	39	41	35	37	39	41
16	717332	5254867	40	41	37	38	40	41
17	716563	5259406	48	48	46	46	48	48
18	716778	5260862	40	41	38	39	40	41
19	714673	5259316	49	49	46	46	49	49
20	714980	5253990	36	38	33	35	36	38
21	713395	5256469	38	40	35	37	39	40
22	721131	5255792	49	50	46	46	49	50
23	728353	5256210	47	47	43	44	47	47
24	727751	5256373	45	46	41	42	45	46
25	731064	5256591	36	37	32	34	36	37
26	726863	5258471	36	38	32	35	36	38
27	728259	5258682	35	37	32	34	35	38
28	728358	5259438	33	36	31	33	35	37
29	729774	5258950	30	32	26	29	30	32
30	731342	5257954	34	36	31	33	35	37
31	736027	5252884	21	23	18	21	22	24
32	735517	5249601	22	24	20	23	23	26
33	734475	5249461	23	25	21	23	24	26
34	731806	5253536	44	44	43	44	44	45
35	729522	5251697	47	48	46	46	47	48

Table A-1. Tabulated Acoustic Modeling Results

NSR ID	UTM Coordinates (m)		Sound Levels (dBA L_{eq}) Siemens SWT 2.3-108		Sound Levels (dBA L_{eq}) Vestas V100-2.0		Sound Levels (dBA L_{eq}) Vestas V110-2.0	
	Easting	Northing	Typical Downwind	Anomalous Meteorological	Typical Downwind	Anomalous Meteorological	Typical Downwind	Anomalous Meteorological
36	732207	5250969	34	37	32	34	35	37
37	733070	5251261	32	35	30	33	33	36
38	727161	5256975	47	47	43	43	47	47

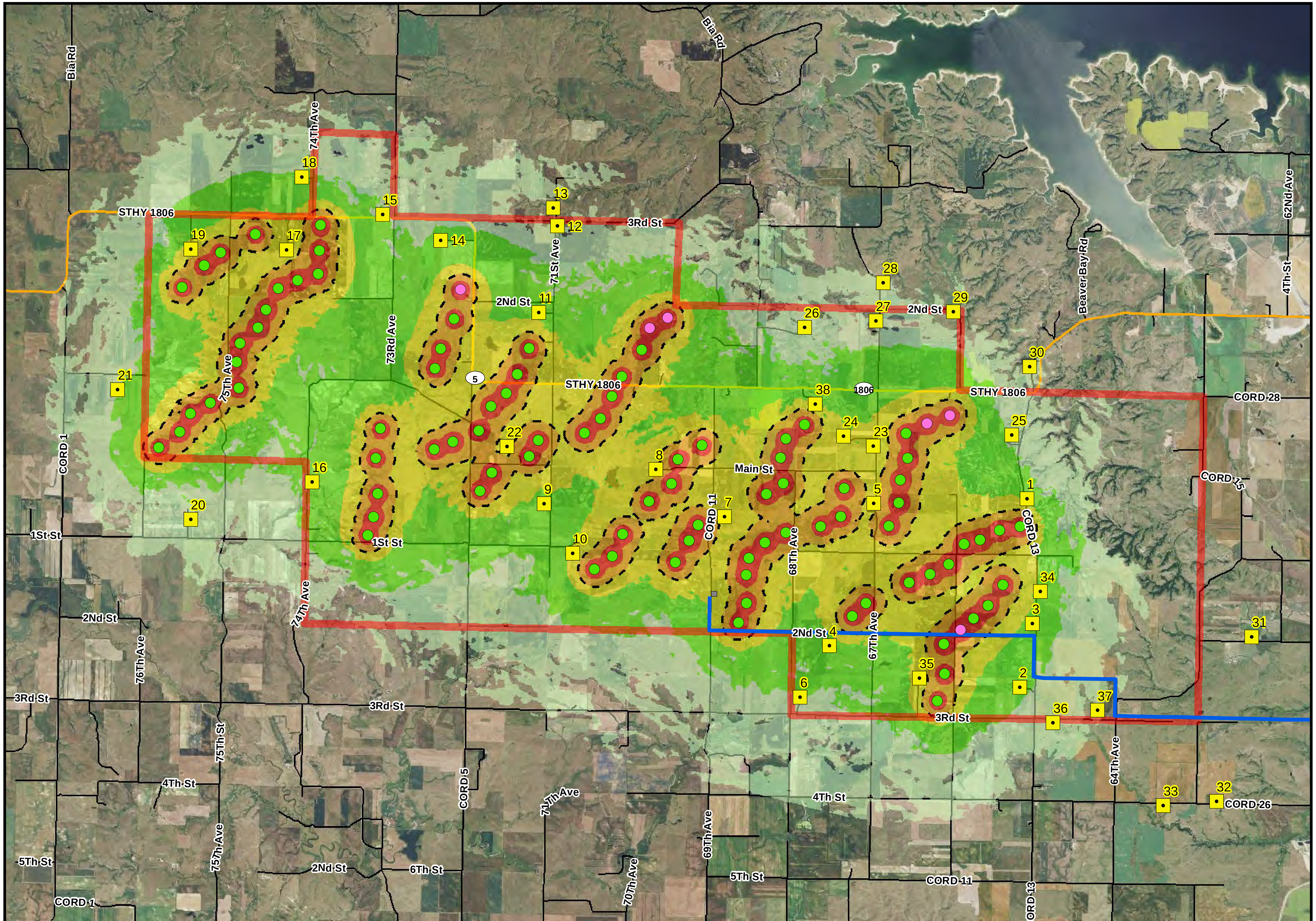

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Figure 6 Operational Leq Sound Levels under Anomalous Meteorological Conditions – Vestas V110-2.0

Mercer County, ND
August 2014

- State Highway
- Minor Road
- Project Area
- Turbine Location*
- Alternate Turbine Location*
- Interconnection Line
- Proposed Substation
- Residences
- North Dakota Limit 50 dBA

Sound Isopleths (dBA)

- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60 or greater

*The Project would utilize up to 86 Vestas V110 Turbines; however, 92 potential Vestas turbine locations are included on this figure to account for alternate locations that may be used.

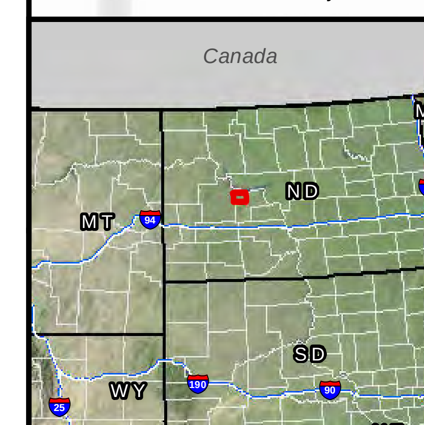

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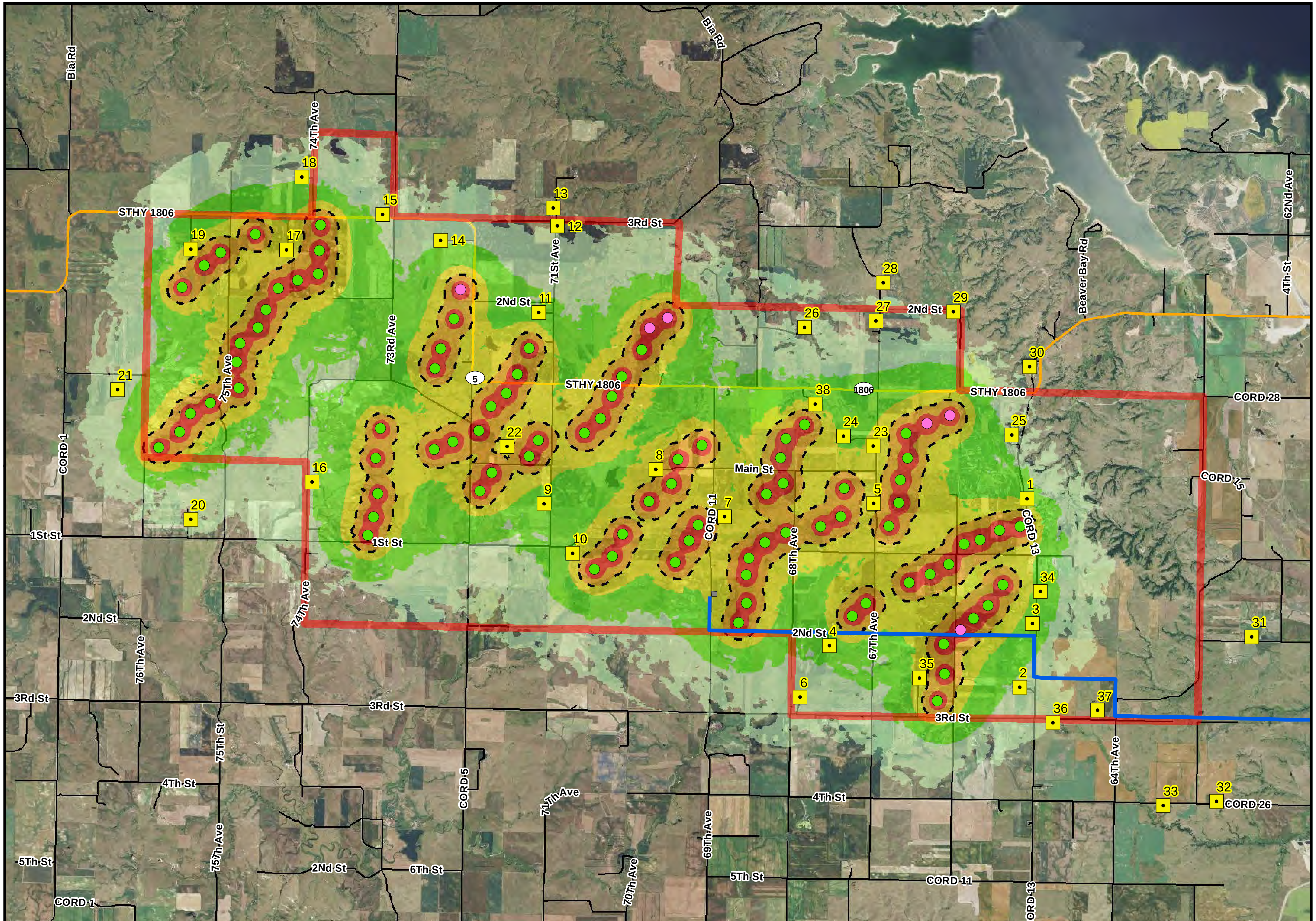
Figure 5
Operational Leq Sound Levels under Typical Downwind Conditions – Vestas V110-2.0

Mercer County, ND
August 2014

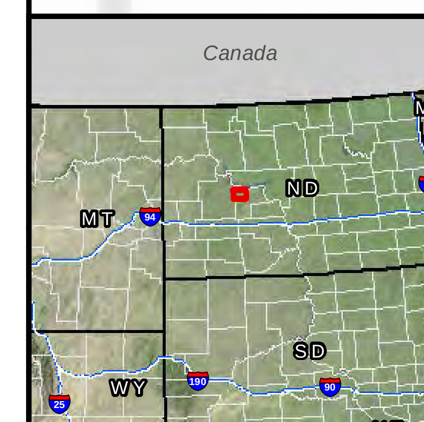


- State Highway
- Minor Road
- Project Area
- Turbine Location*
- Alternate Turbine Location*
- Interconnection Line
- Proposed Substation
- Residences
- North Dakota Limit 50 dBA

Sound Isopleths (dBA)

- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60 or greater

*The Project would utilize up to 86 Vestas V110 Turbines; however, 92 potential Vestas turbine locations are included on this figure to account for alternate locations that may be used.



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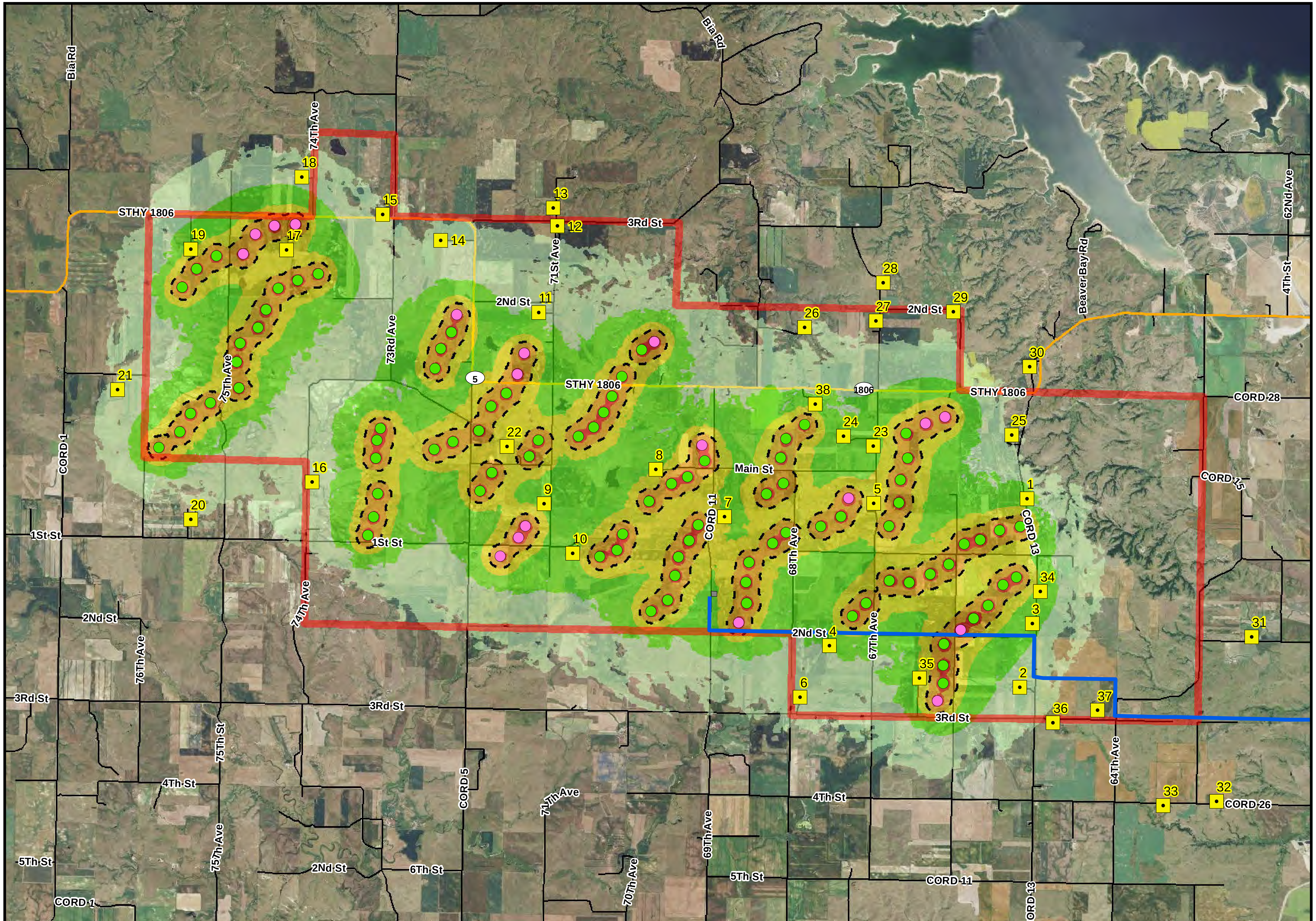

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Figure 4 Operational Leq Sound Levels under Anomalous Meteorological Conditions – Vestas V100-2.0

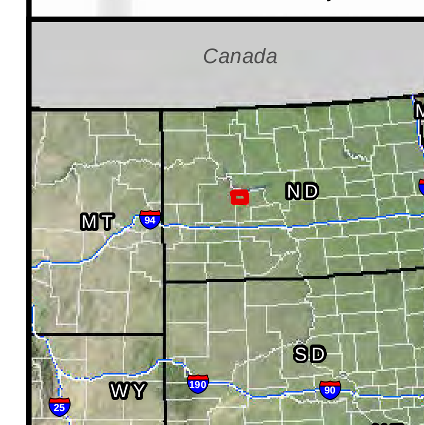
Mercer County, ND
August 2014

- State Highway
- Minor Road
- Project Area
- Turbine Location*
- Alternate Turbine Location*
- Interconnection Line
- Proposed Substation
- Residences
- North Dakota Limit 50 dBA

Sound Isopleths (dBA)

- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60 or greater

*The Project would utilize up to 86 Vestas V100 Turbines; however, 105 potential Vestas turbine locations are included on this figure to account for alternate locations that may be used.



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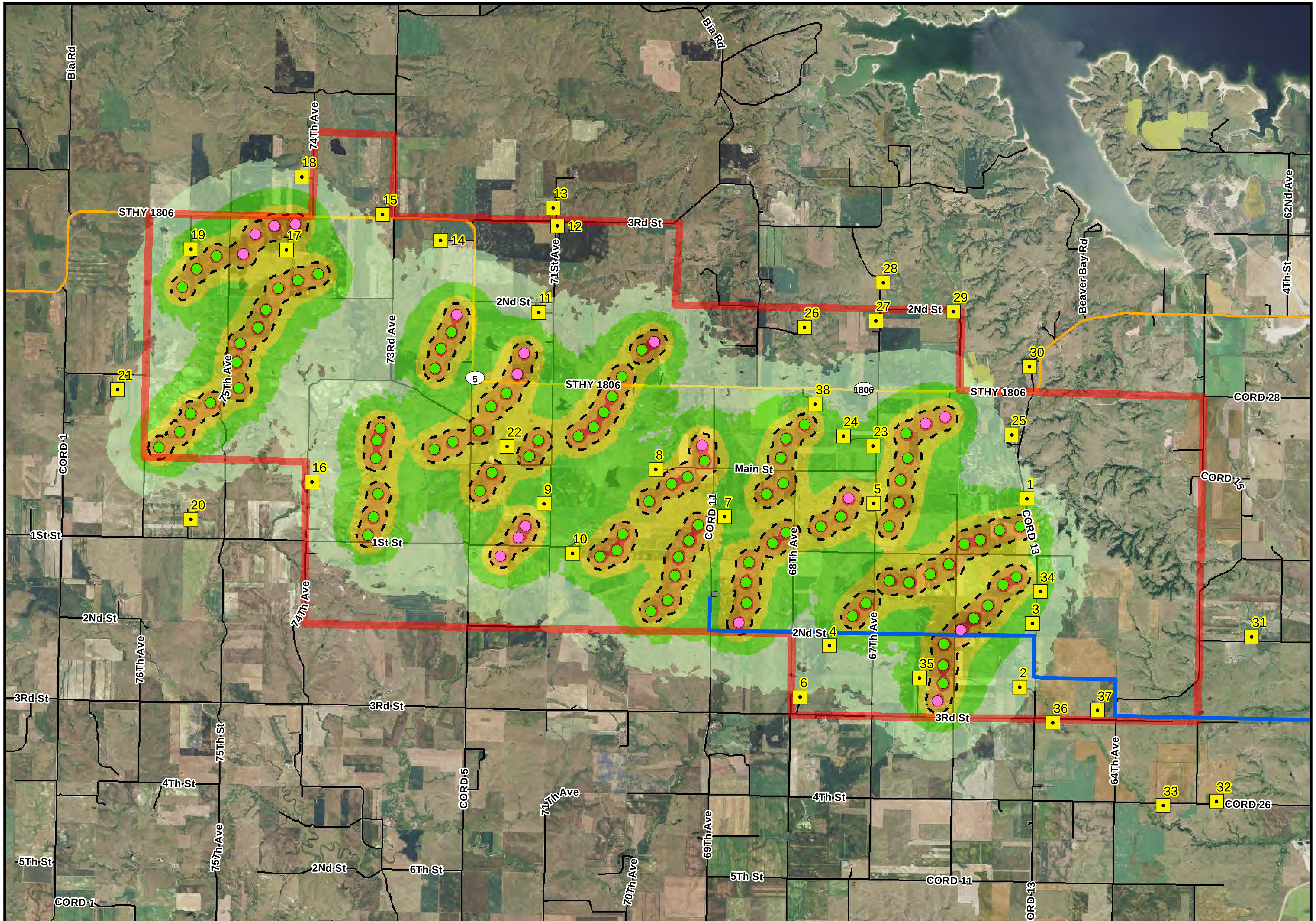

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Figure 3
Operational Leq Sound Levels under Typical Downwind Conditions – Vestas V100-2.0

Mercer County, ND
August 2014

- State Highway
- Minor Road
- Project Area
- Turbine Location*
- Alternate Turbine Location*
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- Proposed Substation
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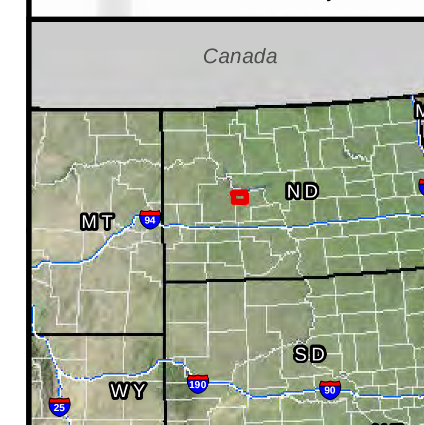

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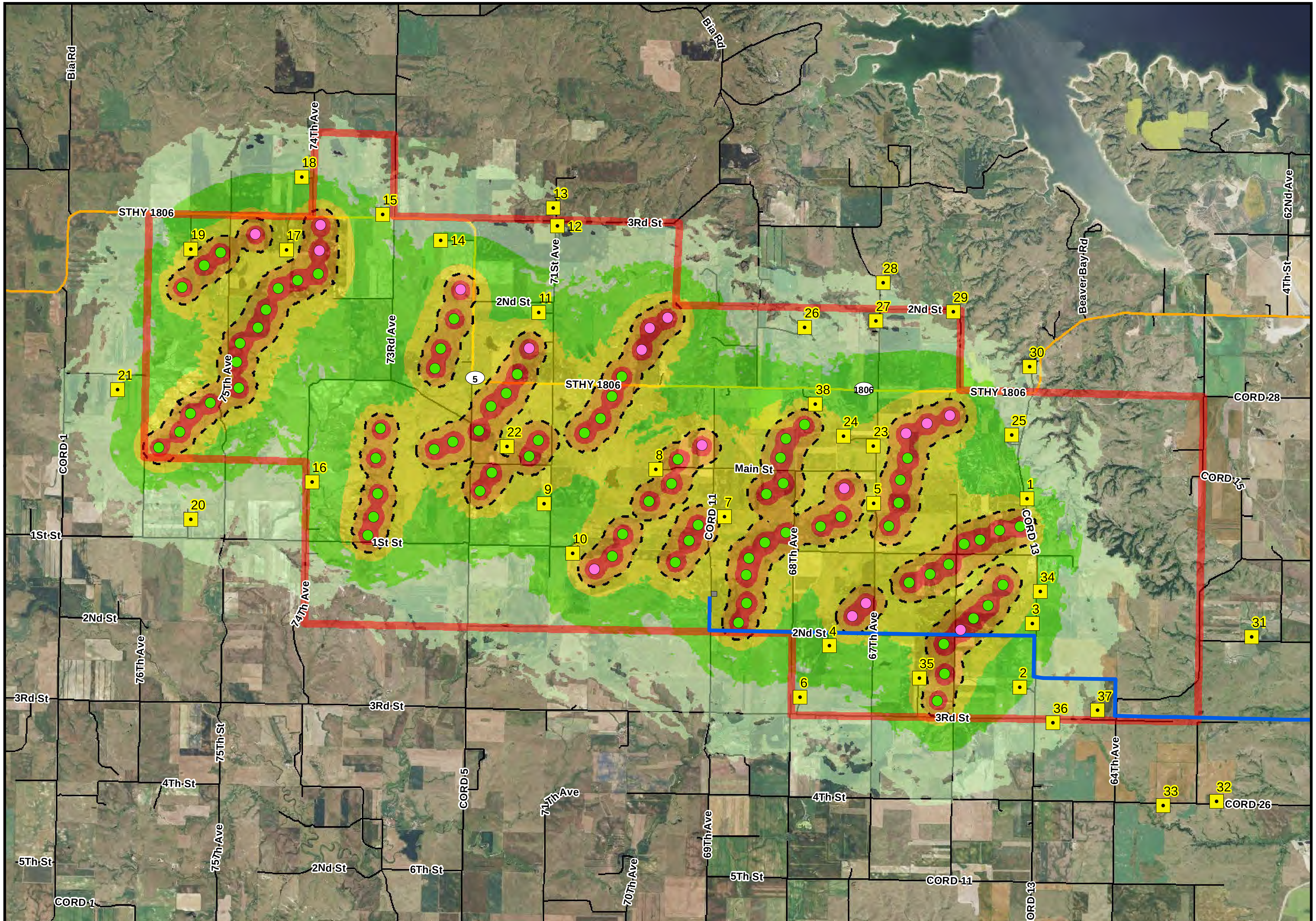

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Figure 2
Operational Leq Sound Levels under Anomalous Meteorological Conditions – Siemens SWT 2.3-108

Mercer County, ND
August 2014

- State Highway
- Minor Road
- Project Area
- Turbine Location*
- Alternate Turbine Location*
- Interconnection Line
- Proposed Substation
- Residences
- North Dakota Limit 50 dBA

Sound Isopleths (dBA)

- 35-40
- 40-45
- 45-50
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- 55-60
- 60 or greater

*The Project would utilize up to 75 Siemens SWT Turbines; however, 92 potential Siemens turbine locations are included on this figure to account for alternate locations that may be used.

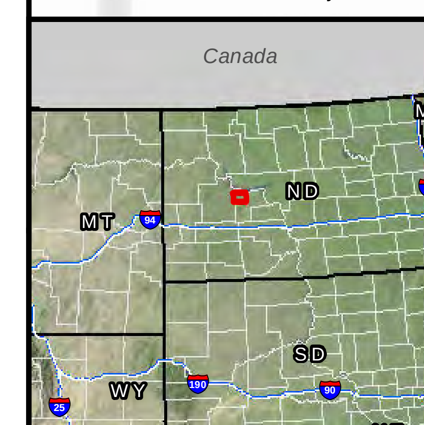

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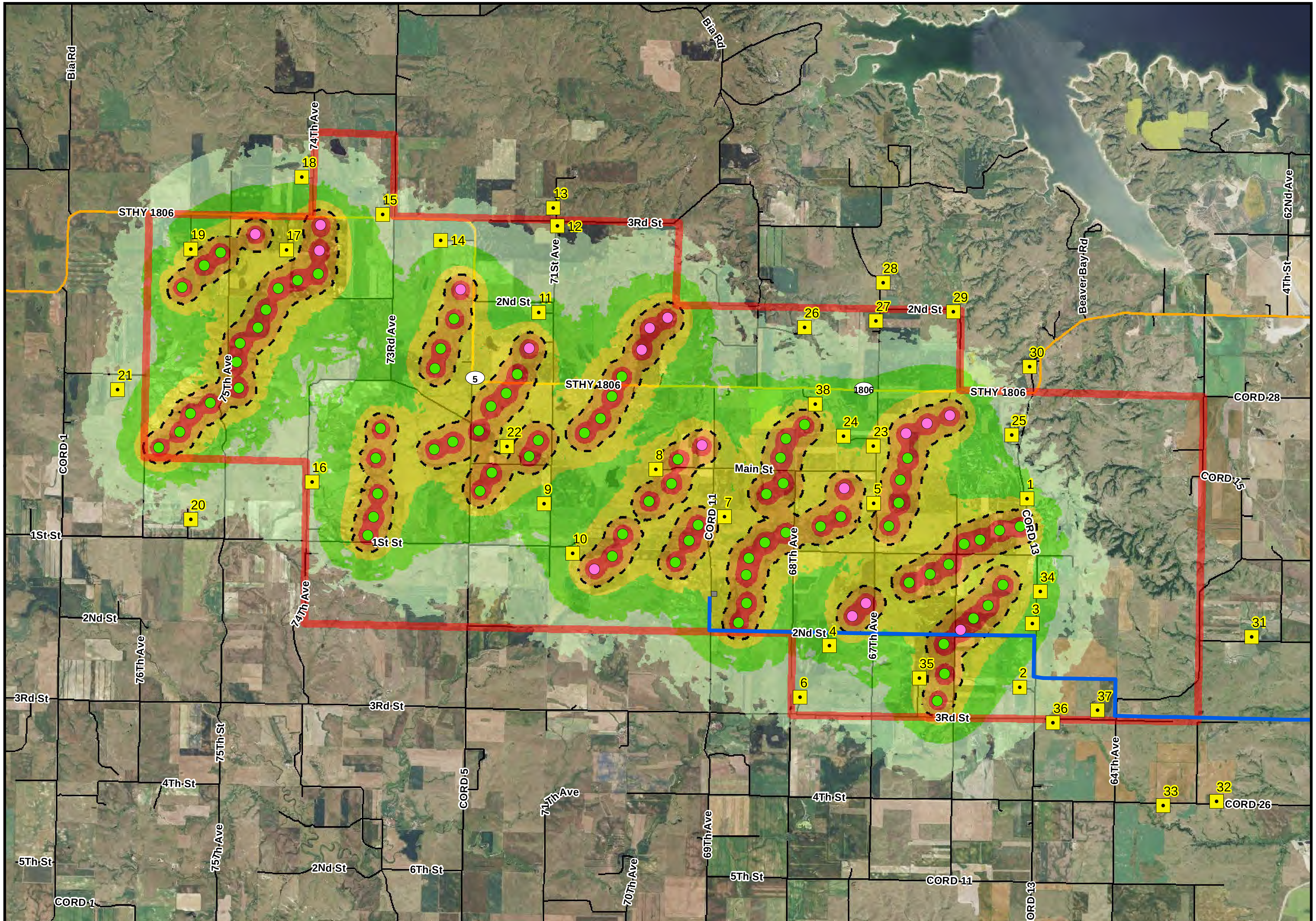
Figure 1
Operational Leq Sound Levels under Typical Downwind Conditions – Siemens SWT 2.3-108

Mercer County, ND
August 2014



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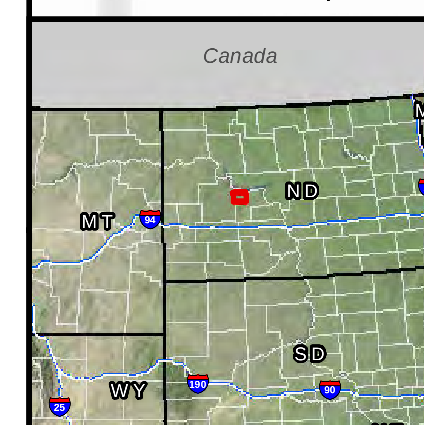

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