BADGER WIND FARM

Sound Assessment

Badger Wind, LLC

Document No.: 10455420-HOU-R-01
Issue: E, **Status:** Final
Date: 14 May 2024

BW Exhibit 5

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Project name:	Badger Wind Farm	
Report title:	Sound Assessment	
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Date of issue:	14 May 2024	
Project No.:	10455420	
Proposal Reference:	315673-HOU-P-01-B	
Document No.:	10455420-HOU-R-01	
Issue/Status:	E/Final	

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Task and objective:
This report presents the results of a sound analysis conducted by DNV on behalf of Badger Wind, LLC.

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Keywords:
Sound, Badger Wind, North Dakota

Issue	Date	Reason for Issue	Prepared by	Verified by	Approved by
E	14 May 2024	Modified Receptor Layout	K. Tassis	A. Nercessian	G. Constantin

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EXECUTIVE SUMMARY

DNV Energy USA Inc. ("DNV") has conducted a sound assessment for the Badger Wind Farm (the "Project") located in Logan County and McIntosh County, North Dakota. The Project application currently consists of 102 wind turbine generators (WTGs) and two step-up transformers within the proposed substation. There are no neighboring wind farms or solar farms near the Project. Only up to 93 of the 102 turbines and one substation are planned to be constructed.

54 sound receptors, representing inhabited residences or community buildings, within one mile of a WTG or substation transformer have been included in this report.

The sound pressure level (SPL) at each receptor for the aggregate of all WTGs and transformers was calculated based on the ISO 9613-2 method.

The calculated results include a +2 dB adjustment to the published wind turbine sound power level (PWL).

The loudest cumulative sound pressure level is 49.3 dBA at participant receptor 1064. There are 6 participant receptors with sound levels above 45.0 dBA and 3 non-participant receptors with sound levels above 45.0 dBA.

The three non-participant receptors have or are in the process of signing good neighbor agreements which allow for higher sound levels than the prescribed limit. All other non-participant receptors are compliant with sound levels below the 45.0 dBA limit.

Calculations were performed at the receptor location and at a distance of 100 feet from the respective noise sensitive building in the loudest direction as per North Dakota Administrative Code Section 69-06-08-01.

The total turbine count includes T73 and T73B, but only one of the two turbines will be constructed. A primary result and an alternative result were provided at the most affected receptor 492 in the case where T73B is selected as a turbine location instead of T73 or vice versa. Both layout options were compliant with the sound regulation.

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1 INTRODUCTION

Badger Wind, LLC ("Badger" or the "Customer") requested that DNV Energy USA Inc. ("DNV") perform a noise analysis for the Badger Wind Farm (the "Project") located in Logan County and McIntosh County, North Dakota.

The Project layout considered for the noise analysis includes 102 GE 2.8-127 wind turbine generators (WTGs) with a hub height of 292 ft (89 m) and two step-up transformers within the substation. Only up to 93 of the 102 turbine locations and one substation in this analysis are planned to be constructed.

The objective of this assessment was to predict the sound levels generated by the Project WTGs and substation transformers at all receptors within one mile of the Project's sound emitting equipment using the International Organization for Standardization (ISO) standard 9613-2 sound propagation model [1] and to compare the results with applicable regulations.

2 ENVIRONMENTAL SOUND BACKGROUND

Sound levels are expressed in the decibel unit and are quantified on a logarithmic scale to account for the large range of acoustic pressures to which the human ear is exposed. A decibel (dB) is used to quantify sound levels relative to a 0 dB reference. The reference level of 0 dB is defined as a sound pressure level of 20 micropascals (μPa), which is the typical lower threshold of hearing for humans.

Sound levels can be presented both in broadband (i.e., sound energy summed across the entire audible frequency spectrum) and in octave band spectra (i.e., audible frequency spectrum divided into bands). Frequency is expressed in the Hertz unit (Hz), measuring the cycles per second of the sound pressure waves. The human auditory range spans from 20 to 20,000 Hz. Since the human ear does not perceive every frequency with equal loudness, spectrally varying sounds are often adjusted with a weighting filter. The A-weighting filter is applied to closely approximate the human ear's response to sound. This scale is commonly used in environmental and industrial sound. Sound expressed in the A-weighted scale is denoted dBA. This is used as the weighting in this report.

A sound source has a certain sound power level rating, which describes the amount of sound energy per unit of time. This is a basic measure of how much acoustical energy it can produce and is independent of its surroundings. Sound pressure is created as sound energy flows away from the source. The measured sound pressure level (SPL) at a given point depends not only on the power rating of the source and the distance between the source and the measurement point (geometric divergence), but also on the amount of sound energy absorbed by environmental elements between the source and the measurement point (attenuation). Sound attenuation factors include meteorological conditions such as wind direction, temperature, and humidity, sound interaction with the ground, atmospheric absorption, terrain effects, diffraction of sound around objects and topographical features, and foliage.

3 APPLICABLE REGULATIONS

Sound emanating from the Project is subject to the *North Dakota Administrative Code Section 69-06-08-01* [2]. The regulations state:

> *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 forty-five dBA. The sound level avoidance area criteria may be waived in writing by the owner of the occupied residence or the community building.*

The applicable sound regulation is therefore 45 dBA within 100 feet of an inhabited residence or a community building that is not subject to a waiver.

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4 DESCRIPTION OF THE PROJECT SITE

4.1 Site description

The Project is situated in relatively simple terrain, consisting of flat farmland, with project equipment base elevations ranging from approximately 2,000 to 2,200 feet above sea level. The ground cover on and near the site is primarily composed of farmland or open fields. Dwellings are interspersed throughout the Project site.

The Project is located in Logan County and McIntosh County, west of the town of Wishek, North Dakota.

4.2 Project layout

The Project layout included in this assessment consists of 102 GE2.8-127 WTGs with a hub height of 292 ft (89 m). Two step-up transformers were included in the Project substation. Only up to 93 of the 102 turbines and one substation included in this analysis are planned to be constructed.

The coordinates of the Project equipment included in the modeling are presented in Appendix A. The turbine layout and substation transformer locations were provided by the Customer [3] and later modified as requested by the Customer.

4.3 Neighboring wind farms

There are no neighboring operational wind or solar farms near the Project.

4.4 Receptor locations

A list of receptors was provided by the Customer [4], most of which were clustered in the nearby town of Wishek over 1 mile from the nearest turbine. Of the total number of identified receptors, results for 54 field verified receptors within one mile of the Project equipment were included in this assessment. Coordinates of each receptor point are presented in Appendix B.

5 SOUND ASSESSMENT

5.1 Description of the sound sources

The sources of sound considered in this analysis are the WTGs and substation transformers. Sound associated with other sources in the vicinity of the Project, such as construction activities, have not been considered in this report.

5.1.1 Project turbines

Project specific total broadband and octave band sound power levels for the General Electric GE 2.8-127 WTG at a hub height of 292 ft (89 m) are contained in the manufacturer documentation [5]. The maximum sound power level for the GE 2.8-127 turbine model is 108.5 dBA. A +2 dB adjustment was applied to ensure conservatism in the assessment for a total modeled sound power level of 110.5 dBA. The sound power levels used in the analysis were at hub height wind speeds of 10-15 m/s, which were reported to have the same octave band sound levels for each wind speed within that range. Low Noise Trailing Edge Technology (LNTE) is included in this model as per the manufacturer documentation [5].

Table 5-1 shows the octave band sound power levels associated with the turbines used in this analysis.

Table 5-1 WTG sound power levels [dBA]

WTG Model	Frequency [Hz]									Broadband
	31.5	63	125	250	500	1000	2000	4000	8000	
GE2.8-127 (+2dB)	84.8	94.6	99.2	100.2	102.4	105.8	104.7	97.0	78.9	110.5

5.1.2 Substation transformers

There are two transformers planned at the Project substation. Two Hyundai 167 MVA 230 kV transformers were modeled at the MISO substation.

The total broadband sound power levels were estimated for each transformer according to the Institute of Electrical and Electronics Engineers Standards Association (IEEE) standard C57.12.90-2015 [6]. A tonality penalty of 5 dB is included in this value in accordance with ISO-1996-2 [7].

A typical transformer octave band distribution [8] was used. The octave band sound power levels of the Project transformers are shown in Table 5-2.

Table 5-2 Transformer sound power levels [dBA]

Transformer	Frequency [Hz]									Broadband
	31.5	63	125	250	500	1000	2000	4000	8000	
Hyundai 167 MVA - 230 kV	65.9	85.1	97.2	99.7	105.1	102.3	98.5	93.3	84.2	108.7

5.2 Assessment methodology

The sound pressure level at each receptor for the aggregate of all WTGs and transformers associated with the Project was calculated using CadnaA acoustic modeling software based on the ISO 9613-2 method [1]. The simulation was performed using the maximum sound power level of the turbines and transformers, including upward corrections or safety margins. The Project's turbines were modeled with a 292 ft (89 m) hub height. Substation transformers were modeled at a height of 3.7 m (12.1 ft).

The ISO 9613-2 standard provides a prediction of the equivalent continuous SPL at a distance from one or more point sources. The method consists of octave-band algorithms (i.e., with nominal mid band frequencies from 31.5 Hz to 8 kHz) for calculating the attenuation of the emitted sound. The algorithm takes into account the following physical effects:

- Geometrical divergence – attenuation due to spherical spreading from the sound source
- Atmospheric absorption – attenuation due to absorption by the atmosphere
- Ground absorption – attenuation due to the acoustical properties of the ground

The ISO 9613-2 standard calculates attenuation "under meteorological conditions favorable to propagation from sources of sound emission." These meteorological conditions are for "downwind propagation or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night". In other words, though a physical impracticality, the ISO 9613-2 standard treats every receptor as being downwind from every source of sound emission (i.e., transformers and turbines).

The ISO 9613-2 standard accounts for ground absorption by assigning a numerical coefficient (G) with a value ranging from 0 to 1. A value of G = 0 represents hard ground (e.g., paving, water, ice, concrete, tamped ground, and other ground surfaces with a low porosity), while a G = 1 value represents porous ground (e.g., ground covered by grass, trees, or other vegetation, and other ground surfaces suitable for the growth of vegetation such as farming land). Though the ground use on and around the site is farming, a mixed (i.e., semi-reflective) global ground factor of G = 0.5 was used in this assessment.

Additionally, temperature, barometric pressure, and humidity parameters were selected to represent typical local annual averages, and topographical information to accurately represent terrain in three-dimensions was included in this assessment.

Specifically, the ISO 9613-2 parameters were set as follows:

- Ambient air temperature: 50° F (10° C)
- Ambient barometric pressure: 101.32 kPa
- Humidity: 70%
- Overall ground factor: 0.5
- Topography included (10 m elevation intervals)

Additional attenuation from foliage was not considered in this assessment, implying that lower sound levels are expected in areas where there is foliage present in the line of sight between any turbine and a sound receptor. Similarly, because the model assumes every receptor is downwind of every sound source at all times, lower sound levels are expected at times when a receptor is upwind of any sound source.

6 RESULTS

A detailed map illustrating predicted sound pressure levels at receptors located in the vicinity of the Project is presented in Figure 6-1, at 4 m height. This figure illustrates the scenario with turbine 73 included. An alternate scenario with 73B replacing 73 would be quieter at the nearest receptors and compliant.

The predicted sound levels at each of the receptors located within 1 mile of the Project equipment are presented in Appendix B.

For each receptor, the following information is provided:

- ID
- Coordinates in UTM projection and NAD83 Datum
- Closest noise generating equipment
- Distance to the closest noise generating equipment
- Sound pressure levels (SPL) in dBA for each receptor

Two sets of results were calculated for each receptor:

1. At a distance of 100 feet from the receptor in the loudest direction, at a height of 5 ft (1.5 m)
2. At the building location at a height of 13 ft (4 m).

The greater of the two sound levels was reported in the results in Appendix B for each receptor and compared to the prescribed sound level limits in accordance with North Dakota Administrative Code Section 69-06-08-01.

The highest modelled sound level throughout the Project area is is 49.3 dBA at participant receptor 1064. There are 6 participant receptors with sound levels above 45.0 dBA and 3 non-participant receptors with sound levels above 45.0 dBA.

The three non-participant receptors have or are in the process of signing good neighbor agreements which allow for higher sound levels than the prescribed limit. All other non-participant receptors are compliant with sound levels below the 45.0 dBA limit.

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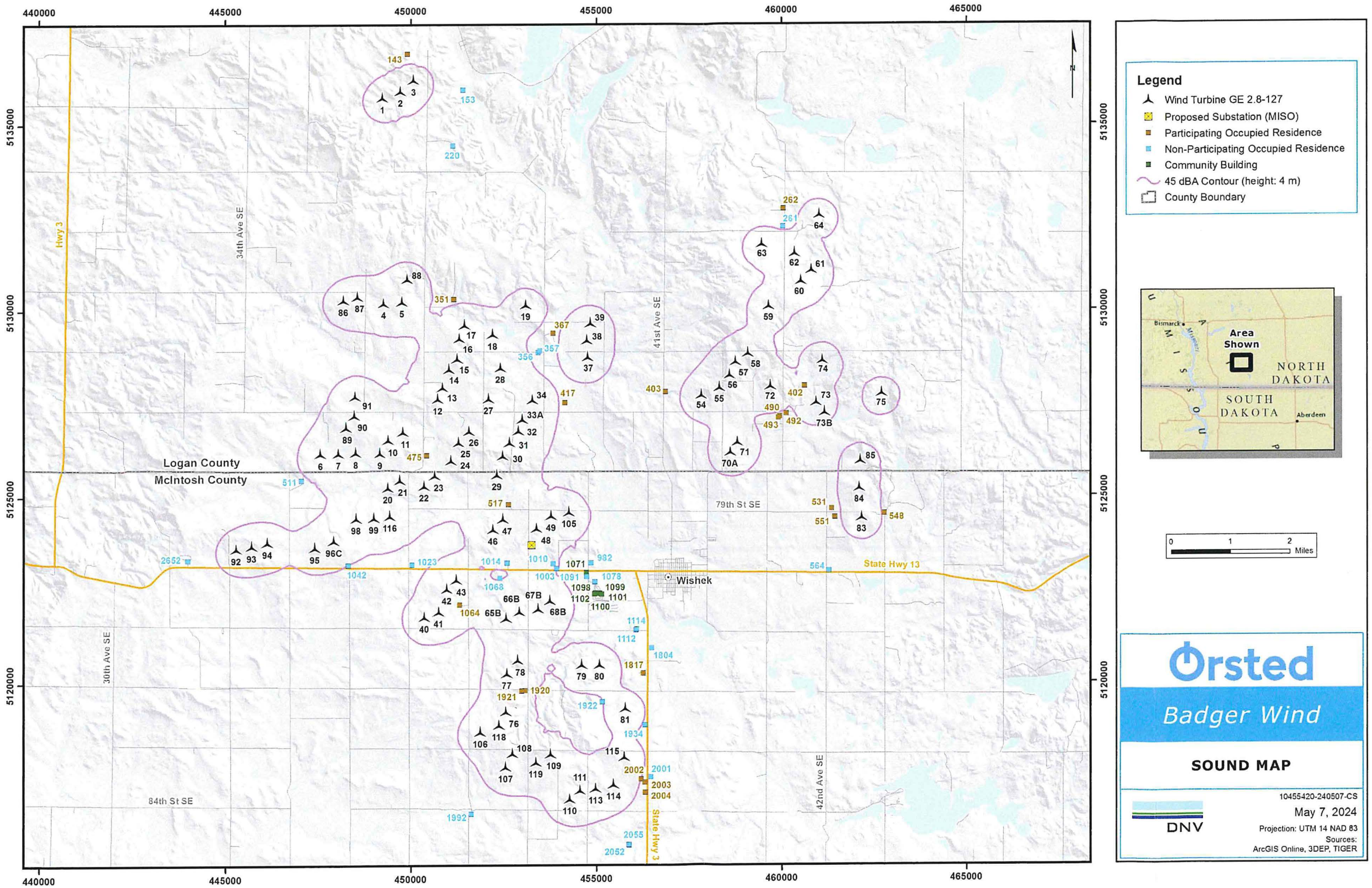

Figure 6-1 Modeled sound levels at the Badger Wind Farm

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7 CONCLUSION

DNV has conducted an analysis to determine the maximum predicted sound levels at receptors in the vicinity of the Badger Wind Farm in Logan County and McIntosh County, North Dakota. The Project equipment considered in the analysis were 102 GE 2.8-127 WTGs with a hub height of 292 ft (89 m) and two step-up transformers at the substation. Only up to 93 of the 102 turbine locations and one substation in this analysis are planned to be constructed. Sound levels in this report may be overestimated in areas where no turbines will eventually be built.

Results are presented for receptors within approximately one mile of a sound source. The loudest cumulative sound pressure level is 49.3 dBA at participant receptor 1064. There are 6 participant receptors with sound levels above 45.0 dBA and 3 non-participant receptors with sound levels above 45.0 dBA.

The three non-participant receptors have or are in the process of signing good neighbor agreements which allow for higher sound levels than the prescribed limit. All other non-participant receptors are compliant with sound levels below the 45.0 dBA limit.

Calculations were performed at the receptor location and at a distance of 100 feet from the building in the loudest direction as per North Dakota Administrative Code Section 69-06-08-01. Badger Wind has obtained or is in the process of obtaining waivers from the owners of receptors modeled above the 45 dBA sound limit.

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8 REFERENCES

[1] International Organization for Standardization. *ISO 9613-2: Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General Method of Calculation*. 15 December 1996.

[2] North Dakota Administrative Code Section 69-06-08-01 Energy Conversion Facility Siting Criteria item 4 Additional Avoidance Areas for Wind Energy Conversion Facilities

[3] Turbine locations provided by Badger Wind on 9 November 2023, filename "2023-11-3 Badger Wind 30% Civil Design.kmz"

[4] Receptor locations sent by Orsted to DNV, "*Receptors_Badger_230724.shp*" with some subsequent minor updates based on field verifications performed in August 2023. November 2023.

[5] GE "2.3 - Noise_Emission-NO_2.x-DFIG-127-60Hz_1-2MW_LNTE_EN_r05.pdf""18 Sep 2022

[6] C57.12.90-2015 IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers. 11 March 2016.

[7] International Organization for Standardization. *ISO 1996-2: Acoustics – Description, measurement and assessment of environmental noise -Part 2: Determination of sound pressure levels*. July 2017

[8] *Handbook of Acoustics*. Edited by Malcolm J. Crocker. John Wiley & Sons. 1998.

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APPENDIX A – SOUND SOURCE LOCATIONS

ID	UTM Zone 14, NAD 83 Datum	
	Easting [m]	Northing [m]
TR1	453233	5123739
TR2	453259	5123740
T1	449232	5135638
T2	449714	5135812
T3	450071	5136111
T4	449260	5130118
T5	449758	5130152
T6	447550	5126069
T7	448035	5126080
T8	448497	5126098
T9	449154	5126084
T10	449386	5126438
T11	449781	5126652
T12	450728	5127537
T13	450860	5127853
T14	451041	5128333
T15	451256	5128620
T16	451315	5129160
T17	451460	5129521
T18	452210	5129270
T19	453099	5130065
T20	449376	5125160
T21	449699	5125356
T22	450359	5125200
T23	450646	5125478
T24	451091	5125879
T25	451295	5126363
T26	451577	5126666
T27	452097	5127541
T28	452421	5128376
T29	452323	5125495
T30	452479	5126004
T31	452664	5126361
T32	452894	5126680
T33-A	453003	5126987

ID	UTM Zone 14, NAD 83 Datum	
	Easting [m]	Northing [m]
T34	453276	5127510
T37	454764	5128664
T38	454742	5129112
T39	454835	5129566
T40	450370	5121682
T41	450760	5121822
T42	450982	5122434
T43	451235	5122676
T46	452216	5124027
T47	452481	5124306
T48	453381	5124054
T49	453778	5124395
T54	457834	5127638
T55	458325	5127835
T56	458601	5128175
T57	458765	5128525
T58	459094	5128759
T59	459656	5130026
T60	460523	5130695
T61	460803	5130994
T62	460359	5131441
T63	459474	5131693
T64	461020	5132473
T65	452574	5121646
T66	452928	5121822
T67B	453431	5121899
T68B	453743	5122114
T70-A	458619	5126099
T71	458816	5126367
T72	459697	5127871
T73	460934	5127435
T73B	461159	5127167
T74	461104	5128566
T75	462699	5127679
T76	452565	5119147

ID	UTM Zone 14, NAD 83 Datum	
	Easting [m]	Northing [m]
T77	452596	5120163
T78	452882	5120526
T79	454604	5120400
T80	455082	5120401
T81	455774	5119232
T83	462165	5124334
T84	462095	5125131
T85	462125	5125862
T86	448174	5130196
T87	448552	5130291
T88	449901	5130762
T89	448243	5126773
T90	448461	5127094
T91	448482	5127610
T92	445292	5123520
T93	445705	5123590
T94	446125	5123690
T95	447398	5123549
T96C	447909	5123734
T98	448512	5124333
T99	448991	5124344
T105	454252	5124496
T106	451880	5118601
T107	452555	5117661
T108	452740	5118025
T109	453762	5118008
T110	454279	5116798
T111	454557	5117036
T113	454981	5117083
T114	455457	5117189
T115	455748	5117927
T116	449433	5124398
T118	452384	5118784
T119	453366	5117786

Transformer IDs (TR1 and TR2) have been added for the purpose of this report.

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APPENDIX B – RECEPTOR RESULTS

Receptor ID	UTM Coordinates Zone 14, NAD 83 Datum		Nearest Sound Source [ID]	Distance to Nearest Sound Source [feet]	Sound Pressure Level at Receptor [dBA]	Participant Status / Waiver Status
	Easting [m]	Northing [m]				
143	449910	5136911	T3	2675	41.3	P
153	451414	5135938	T3	4440	36.2	NP
220	451142	5134435	T2	6515	33.9	NP
261	460040	5132243	T63	2587	44.2	NP
262	460052	5132724	T64	3281	41.3	P
351	451171	5130311	T17	2760	44.1	P
356	453428	5128874	T28	3686	44.1	NP
357	453463	5128918	T28	3854	44.1	NP
367	453827	5129394	T38	3140	43.6	P
402	460620	5127961	T73	2007	46.1	P
403	456860	5127809	T54	3246	41.3	P
417	454147	5127522	T34	2858	43.7	P
475	450426	5126113	T23	2204	49.0	P
490	459950	5127152	T72	2501	44.2	P
492[1]	460131	5127219	T72	2568	44.5	P
493	459917	5127112	T72	2592	44.0	P
511	447037	5125452	T6	2635	44.1	NP
517	452631	5124788	T47	1652	48.5	P
531	461350	5124665	T84	2884	42.6	P
548	462767	5124527	T83	2073	44.0	P
551	461444	5124433	T83	2389	43.1	P
564	461281	5123004	T83	5239	34.3	NP
982	454849	5123219	T105	4628	40.7	NP
1003	453922	5123072	TR2	3086	45.5	NP Waiver pending
1010	453837	5123201	TR2	2590	46.7	NP Waiver pending
1014	452598	5123225	TR1	2681	45.5	NP Waiver obtained
1023	450024	5123180	T42	3984	43.7	NP
1042	448303	5123172	T96C	2250	44.9	NP
1064	451329	5122110	T42	1558	49.3	P
1068	452406	5122819	T66	3692	44.9	NP
1071	454729	5122962	T68B	4263	41.2	NP
1078	454738	5122856	T68B	4070	41.2	NP
1091	454957	5122712	T68B	4436	40.3	NP
1098	454969	5122422	T68B	4145	40.6	NP
1099	455092	5122408	T68B	4528	40.0	NP
1100	455124	5122382	T68B	4612	39.9	NP
1101	455138	5122382	T68B	4658	39.9	NP
1102	454951	5122389	T68B	4063	40.7	NP
1112	456064	5121418	T80	4635	38.4	NP
1114	456081	5121438	T80	4721	38.2	NP
1804	456482	5120937	T80	4917	37.7	NP
1817	456265	5120265	T81	3750	40.5	P
1920	453076	5119807	T77	1960	47.2	P
1921	452989	5119794	T77	1768	47.7	P
1922	455159	5119498	T81	2200	44.9	NP
1934	456308	5118878	T81	2101	44.0	NP
1992	451637	5116504	T107	4848	38.2	NP
2001	456463	5117481	T115	2764	42.6	NP
2002	456205	5117426	T115	2224	44.9	P
2003	456305	5117334	T115	2670	43.6	P
2004	456317	5117069	T114	2848	42.6	P
2052	455875	5115654	T114	5219	38.0	NP
2055	455871	5115671	T114	5162	38.1	NP
2652	443993	5123311	T92	4317	37.0	NP

[1] The sound pressure level in the case where T73B (461159.00, 5127167.00) is used in place of T73 is 44.0 dBA.

[2] Receptor 220 has been included in the Sound Assessment, however it falls outside of 1 mile radius of the nearest noise source.

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