APPENDIX S

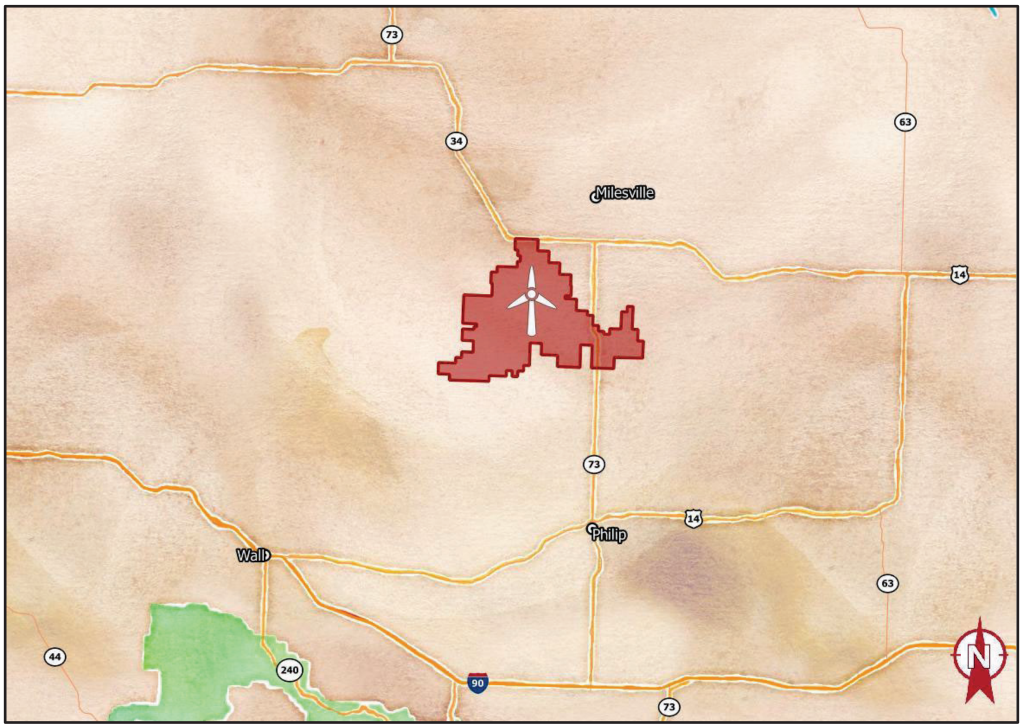
Pre-construction Noise Analysis

Pre-Construction Noise Analysis

for the proposed

Philip Wind Energy Center

December 11, 2024



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HANKARD ENVIRONMENTAL
ACOUSTICS AND VIBRATION CONSULTING

Contents

Figures

Tables

Appendices

1. Introduction

This report describes a pre-construction noise analysis conducted by Hankard Environmental for the proposed Philip Wind Energy Center (Project, Facility) in support of its application to the South Dakota Public Utilities Commission (PUC) for an energy facility permit. Philip Wind Partners LLC (Philip Wind), an affiliate of Invenergy LLC (Invenergy), is developing the up to 300-megawatt (MW) Project located in Haakon County, South Dakota. Figure 1-1 shows the general location of the Project.

This report describes the methods and results of a noise analysis that demonstrates that the Project is designed to conform with the South Dakota PUC's precedence of a 45 dBA noise goal at non-participating residences and a 50 dBA noise goal at participating residences. Described herein are the applicable noise standards, the Project and its environs, the methods and data used to predict noise levels, the results of the noise level predictions, and demonstration of compliance with the Project noise goals.

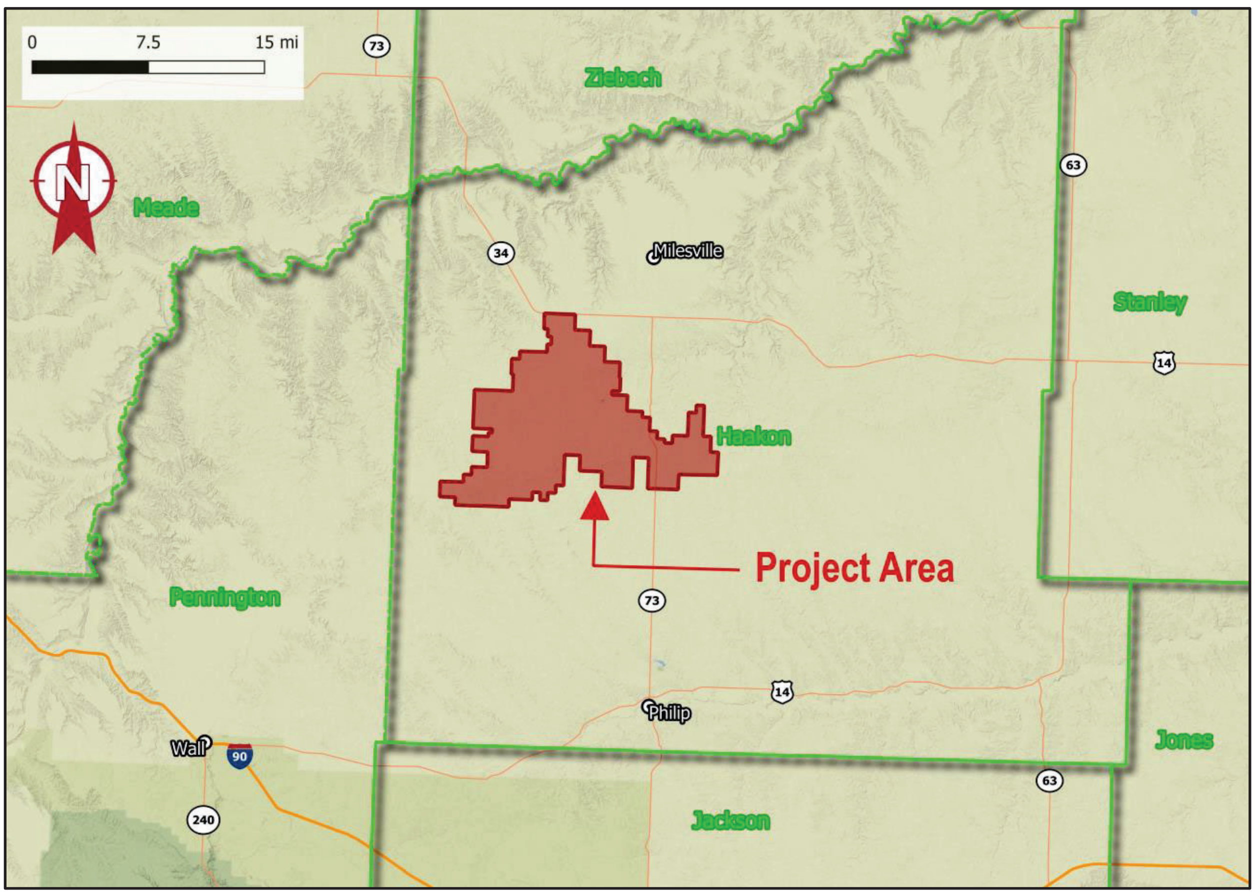

Figure 1-1. General Location of the Proposed Philip Wind Energy Center

2. Applicable Noise Standards

There are no noise-related federal, county, or local regulations that apply to the Project.

At the state level, South Dakota Administrative Rule 20:10:22:33.02 requires that an application for an Energy Facility Permit include "Anticipated noise levels during construction and operation." The noise levels reported herein are those expected during operation. Construction noise levels will be typical of those produced by standard construction equipment.

The South Dakota PUC does not have a specific noise limit that applies to wind turbine projects. In lieu of this, Hankard Environmental reviewed the South Dakota PUC's Wind Energy Siting Dockets to determine what noise limits have been applied to recent projects. Out of 14 dockets we reviewed covering the period 2017 to 2024, eight had county limits of 45 dBA at non-participating residences and six had local limits of 50 dBA at non-participating residences.

This range of 45 to 50 dBA is consistent with the limits that are typically applied to wind turbine projects nationally. To be conservative, this Project has been designed to meet the more stringent 45 dBA limit at non-participating residences.

The noise levels predicted in this analysis are in the form of the energy equivalent average noise level (L_{eq}) over a short duration of time (one hour), which is a practical and widely utilized duration for assessing both industrial and community noise levels.

3. Project Description

The Project is located in West Haakon and East Haakon Townships in Haakon County, South Dakota. Land use in the area is predominantly agricultural. The proposed wind turbines and associated facilities are sited on agricultural lands.

Three different turbine models were included in the analysis of the proposed Project layout, which contains up to 91 wind turbine pad locations, delivering up to 300 MW of electrical power. Associated facilities include gravel access roads and underground cabling to collect and transmit the power to the Project collector substation and its two step-up transformers.

Table 3-1 lists the turbine types that were analyzed for this Project, which include:

- Vestas model V163-4.5 wind turbines with a hub-height of 98 meters, utilizing all 91 pad locations.
- Nordex model N163-4.5 wind turbines with a hub-height of 108 meters, utilizing all 91 pad locations.
- General Electric (GE) Sierra model 3.8-154 wind turbines with Low Noise Trailing Edge (LNTE) blades and a hub-height of 98 meters, utilizing all 91 pad locations.

Turbine locations are shown graphically in Figure A-1 in Appendix A. Also shown in this figure are the locations of all 10 non-participating and seven participating residences in the vicinity of the Project. The geographic coordinates of each of the 17 receptor locations are provided in Appendix B. The geographic coordinates of each Project noise source are provided in Appendix C.

Table 3-1. Wind Turbine Models Analyzed

Turbine Model	Blade Type	Rotor Diameter (m)	Hub Height (m)	Number of Turbines
Vestas V163-4.5	Standard	163	98	91
Nordex N163-4.5	Standard	163	108	91
GE Sierra 3.8-154	LNTE	154	98	91

4. Noise Modeling Method

Noise levels from the Project were predicted using the modeling method set forth in the International Organization for Standardization (ISO) Standard 9613-2:2024: *Attenuation of Sound During Propagation Outdoors*. The method was implemented using the SoundPLAN (v9.0) acoustical modeling program. A sample three-dimensional view of the SoundPLAN model is shown in Figure 4-1. The selection of ISO 9613-2:2024 modeling parameters and input data used in the analysis are described below.

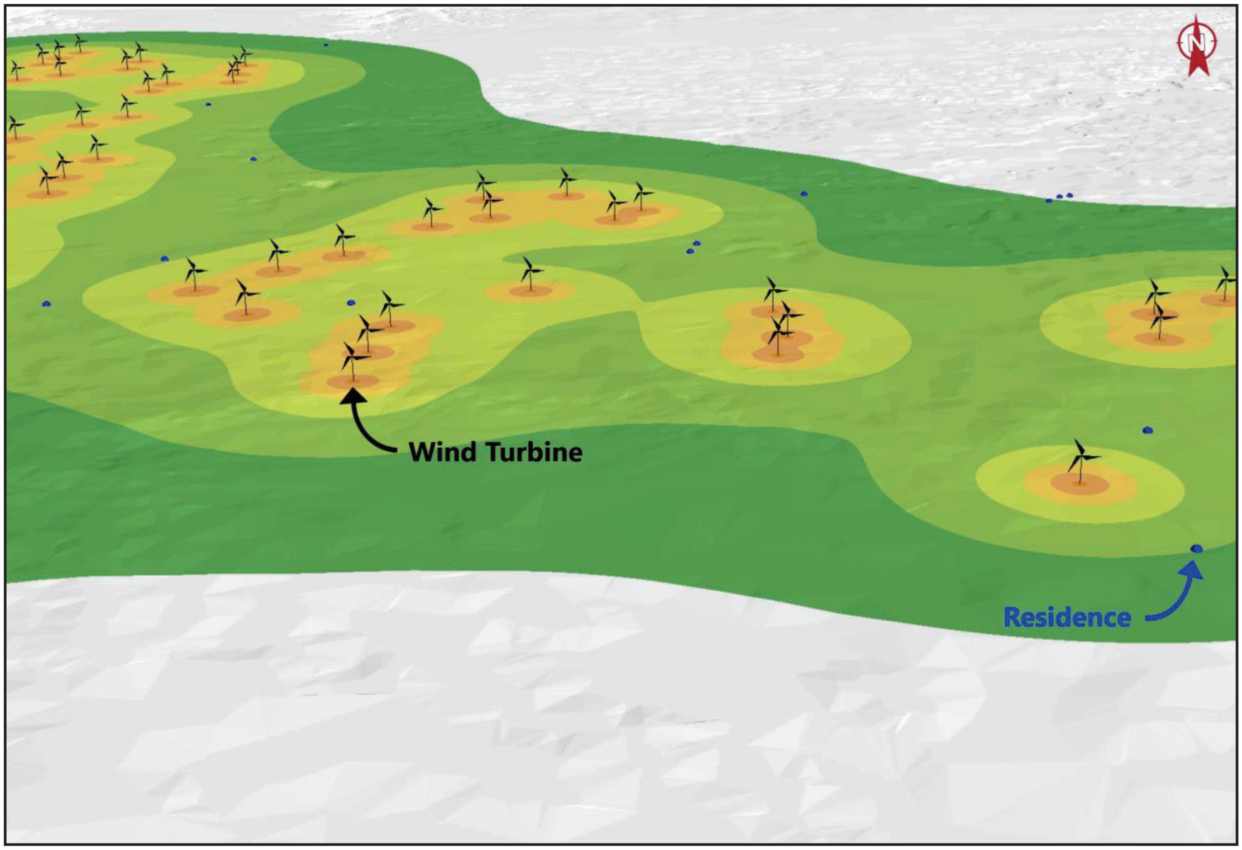

Figure 4-1. Three-Dimensional View of the SoundPLAN Noise Model

Noise Sources

In the SoundPLAN model, each turbine was represented as an acoustical point source located at its hub height, which is 98 meters above the ground for the V163-4.5 and GE 3.8-154 units, and 108 meters for the N163-4.5 units. Transformers were modeled at a height of three meters above the ground. No directivity was applied to any noise source, thus assuming maximum acoustic output in all directions. All turbines were assumed to be operating in full, continuous, and normal mode (versus noise-reduction mode). Similarly, the collector substation transformers were assumed to be operating fully. The locations of the turbines and transformers were provided by Philip Wind. The ground elevation for each source location was determined using Digital Elevation Model (DEM) data from the USGS National Elevation Dataset.

Table 4-1 lists the octave band sound power levels for all modeled noise sources in the Project. The levels are expressed in terms of A-weighted decibels (dB) for both overall levels and levels in each of the nine frequency bands defined by the American National Standards Institute (ANSI) Standard S1.11: *Specification for Octave-Band and Fractional Octave-Band Analog and Digital Filters*. The noise level data for each turbine model under consideration was provided by the manufacturer and was determined according to International Electrotechnical Commission standard 61400-11. This standard requires wind turbine sound power levels to be reported for a number of wind speed bins across the operating range of the turbine. In general, sound levels increase with increasing wind speeds, up to approximately 10 m/s at hub height. Noise levels do not further increase above this wind speed because the turbines reach a maximum rotational speed. This relationship between wind speed and noise level holds true for each octave band. This analysis used octave band noise levels provided by the manufacturer for the 10 m/s wind speed at hub height.

The Project's collector substation will contain two 140 megavolt-ampere (MVA) step-up transformers, switch gear, electrical control and communication systems, and other equipment required to increase the electrical collection system voltage to that of the transmission system at the point of interconnection. The only significant noise-producing equipment is the step-up transformers. The sound power levels of the transformers are listed in Table 4-1. The sound level spectrum of the transformers was estimated using the methodology published in the Edison Electric Institute, "Electric Power Plant Environmental Noise Guide," 2nd Edition, BBN, 1984.

Table 4-1. Source Sound Power Levels

Source Type	No. of Units	Octave Band Level (dBA)									Overall Level (dBA)
		31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	
Vestas V163-4.5	91	72.8	87.4	97.6	102.8	103.6	102.1	97.5	89.7	78.2	108.4
Nordex N163-4.5	91	78.3	89.6	96.5	99.6	103.1	104.6	102.3	93.3	84.3	109.2
GE Sierra 3.8-154 LNTE	91	82.6	92.7	97.4	99.2	101.3	104.2	103.3	95.7	78.7	109.0
140 MVA Transformer	2	57.4	76.6	88.7	91.2	96.6	93.8	90.0	84.8	75.7	100.2

Noise Level Metric

The noise levels predicted using this method are in the form of the energy equivalent average noise level (L_{eq}) over a one-hour period of maximum acoustic emissions from the turbines and the transformers at the collector substation.

Receptors

In the SoundPLAN model, receptors were located at each of the non-participating and participating residences located in the vicinity of the Project. The location of each receptor is shown in Figure A-1 in Appendix A. The geographic coordinates of each receptor are listed in

Appendix B. In accordance with ANSI ACP 111-1 (2022) and ISO 9613-2:2024, each receptor's height was set to 4 meters (13 feet) above the ground.

Terrain and Ground Effect

Terrain in the Project area was modeled by importing DEM data from the USGS National Elevation Dataset into SoundPLAN. The acoustical effect of the ground was modeled using the ISO 9613-2:2024 General Method. This requires the selection of ground absorption factors for the ground near the source, near the receiver, and in between. Ground factors range from 0.0 to 1.0 and represent the proportion of sound that is reflected or absorbed when sound waves interact with the ground. A value of 0.0 represents completely reflective ground material such as pavement or flat water, and results in a higher level of sound reaching a receptor. A value of 1.0 represents absorptive material such as thick grass, crops, or fresh snow, and results in a lower level of sound reaching a receptor. For this noise analysis, we conservatively assumed a ground factor of 0.0 (completely reflective) in accordance with ANSI standards, as described below.

Atmospheric Conditions

The air temperature, relative humidity, and atmospheric pressure were set to 10°C, 70%, and 1 atmosphere, respectively. Per ISO 9613-2:2024, these values result in the least amount of atmospheric sound absorption and the highest levels of sound reaching the receivers.

Validation of Noise Prediction Method

The noise level prediction method employed in this noise analysis is consistent with that described by ANSI/ACP Standard 111-1 (2022): *Wind Turbine Sound Modeling* (Option 1). The noise level prediction method specified by ANSI/ACP 111-1 (2022) has been validated by Hankard Environmental and other researchers by comparing predicted noise levels to actual measured levels at operating wind farms. Hankard Environmental analyzed the long-term noise data it collected at 10 operating wind farms consisting of 50 individual measurement locations. The loudest turbine-only noise levels measured at each location, which occur for only a few hours/nights at each site over the course of many weeks of data collection, were compared to the levels predicted at those locations using the methodology employed in this noise analysis. The results show that when the ISO 9613-2:2024 method is used as it is here (with a 0.0 ground factor), the model consistently overpredicts noise levels by approximately 1 to 2 dBA. That is, actual noise levels are expected to be less than those described herein.

5. Predicted Noise Levels

Noise levels from the full, normal, and continuous operation of 91 turbines and two 140 MVA transformers were predicted at each non-participating and participating residence in the vicinity of the Project. Table 5-1 lists the predicted noise levels, for each turbine model, at all 10 non-participating residences. All levels are less than the Project noise goal of 45 dBA for non-participating residences. In summary:

- Vestas V163-4.5: levels range from 45 dBA to 32 dBA, with an average of 39 dBA,
- Nordex N163-4.5: levels range from 44 dBA to 30 dBA, with an average of 37 dBA,
- GE Sierra 3.8-154: levels range from 44 dBA to 31 dBA, with an average of 38 dBA.

Predicted noise levels are illustrated graphically in the form of noise level contours in Figures D-1 through D-3 in Appendix D. The 45 dBA contours are shown for each turbine model. The area between the source and a contour has a predicted noise level greater than 45 dBA. The area outside of the 45 dBA contour has a predicted level less than 45 dBA. As can be seen, no non-participating residences under any turbine scenario are located inside the 45 dBA contours.

At participating residences, predicted noise levels range from 48 dBA to 33 dBA, with an average of 41 dBA across all three turbine models. All levels are less than the Project noise goal of 50 dBA for participating residences.

Predicted noise levels and locations of all participating and non-participating residences are listed in Appendix B.

Table 5-1. Predicted Noise Levels at Non-Participating Residences

Receptor	Predicted Noise Level (L_{eq} dBA)		
	Vestas V163-4.5	Nordex N163-4.5	GE 3.8-154 LNTE
R-001	37	35	35
R-005	45	44	44
R-007	44	43	43
R-009	37	36	36
R-012	34	32	33
R-013	32	30	31
R-018	40	38	38
R-020	37	36	36
R-022	41	41	40
R-025	40	39	39

6. Construction Noise

Construction of a wind energy facility includes construction of the wind turbine sites, collector substation, access roads, and underground collector circuits. Construction will generate temporary noise from a variety of equipment and noise levels at nearby residences will vary greatly depending on the phase of construction, proximity of construction activities, and other factors.

Table 6-1 provides a list of potential construction equipment for each type, phase, and sub-phase for construction of a wind energy facility.

Construction noise at receptors will usually be dependent on the loudest one or two pieces of equipment in operation at a particular time. Noise levels from diesel-powered equipment at 50 feet generally range from 70 dBA to 90 dBA. Noise from construction equipment is often limited in duration as construction activities often only occur for short periods of time. Table 6-2 provides a list of common construction equipment, the maximum noise level expected at 50 feet, the typical duration a particular piece of equipment is used in any one-hour period, and the resulting hourly equivalent noise level ($L_{eq\ (1\ Hr)}$) for the piece of equipment.

Table 6-1. Potential Construction Equipment to be Employed on a Wind Energy Facility

Type	Phase	Sub-Phase	Equipment
Turbines	Site Preparation	Clearing	Chainsaw, Feller Buncher, Grapple Loader, Log Truck
		Road/Site	Dozer, Excavator, Grader, Roller, Dump Truck
		Foundation	Drill Rig, Track Hoe, Dozer, RT Crane, Concrete Truck
	Installation	Delivery	Forklift, RT Crane, Tractor Trailer
		Components	Crawler Crane
	Site Finishing	---	Dozer, Moto Grader, Skid Steer, Seed Drill
Collector Substation	Site Preparation	Clearing	Chainsaw, Feller Buncher, Grapple Loader, Log Truck
		Road/Site	Dozer, Excavator, Grader, Roller, Dump Truck
		Foundation	Drill Rig, Track Hoe, Dozer, RT Crane, Concrete Truck
	Construction	Delivery	Forklift, RT Crane, Tractor Trailer
		Components	Forklift, Bucket Truck, Truck Crane
	Site Finishing	---	Dozer, Moto Grader, Skid Steer, Seed Drill
Roadways	Site Preparation	---	Chainsaws, Feller Buncher, Grapple Loader, Log Truck
	Construction	---	Dozer, Moto Grader, Backhoe, Dump Truck, Roller
	Site Finishing	---	Dozer, Moto Grader, Skid Steer, Seed Drill
Underground Electrical Collections	Trenching	---	Trencher, Track Hoe, HDD machine
	Installation	---	Cable Layer
	Site Finishing	---	Track Hoe, Skid Steer, Seed Drill

Table 6-2. Noise Source Characteristics of Construction Equipment

Equipment	L_{max} Noise Level at 50 ft (dBA)	Usage Factor (%)	$L_{eq\ (1\ Hr)}$ Noise Level at 50 ft (dBA)
Backhoe	82	40	78
Bucket Truck	82	20	75
Cable Layer	70	50	67
Chain Saw	91	20	84
Concrete Truck	88	20	81
Crawler Crane	89	16	81
Dozer	86	40	82
Drill Rig	86	20	79
Dump Truck	81	40	77
Excavator	85	40	81
Feller Buncher	89	40	85
Forklift	69	40	65
Grapple Loader	83	40	79
Horizontal Drill	88	25	82
Log Truck	78	40	74
Moto Grader	89	40	85
Roller	84	40	80
RT Crane	89	16	81
Seed Drill	83	50	80
Skid Steer	83	40	79
Track Hoe	82	40	78
Tractor Trailer	78	40	74
Trencher	83	50	80
Truck Crane	87	16	81

Construction noise from the Project is not expected to create any significant impact. That said, the following steps should be considered by the Project to minimize the impact of construction noise:

- Limit nighttime work to the degree practicable,
- Maintain equipment to manufacturers' specifications, particularly mufflers,
- Minimize backing up of trucks on site to the degree practicable,
- Provide a 24-hour telephone complaint number for residents to use if needed,
- Attempt to resolve complaints in a prompt manner,
- Notify residents of expected construction schedule.

7. Conclusions

- Noise levels from the full, normal, and continuous operation of the Project were predicted at each non-participating and participating residence located in the vicinity of the Project.
- Noise levels are predicted to be less than the Project's 45 dBA noise goal at all 10 non-participating residences, and less than the 50 dBA noise goal at all seven participating residences.
- Additionally, the noise level prediction method employed for this analysis has been validated by ANSI/ACP, Hankard Environmental, and other acoustic professionals by comparing predicted noise levels to those measured at operating wind farms. The results show that the modeling approach employed here is conservative and the model consistently overpredicts measured noise levels. That is, actual noise levels from the Project are expected to be less than those reported herein.
- The noise levels reported herein are the highest expected. A majority of the time noise levels will be lower when the turbines are not producing full acoustic output due to low winds, and/or atmospheric conditions are not as conducive to sound propagation as assumed in this analysis.
- During very windy periods, the noise of the wind blowing through vegetation will be louder than that from the turbines and can in many cases render noise from the turbines inaudible.
- The results described herein are valid for the receptor locations provided, the turbine and collector substation layouts analyzed, and the wind turbine sound power levels as provided by the manufacturers.

APPENDIX A

Receptor and Turbine Location Figure

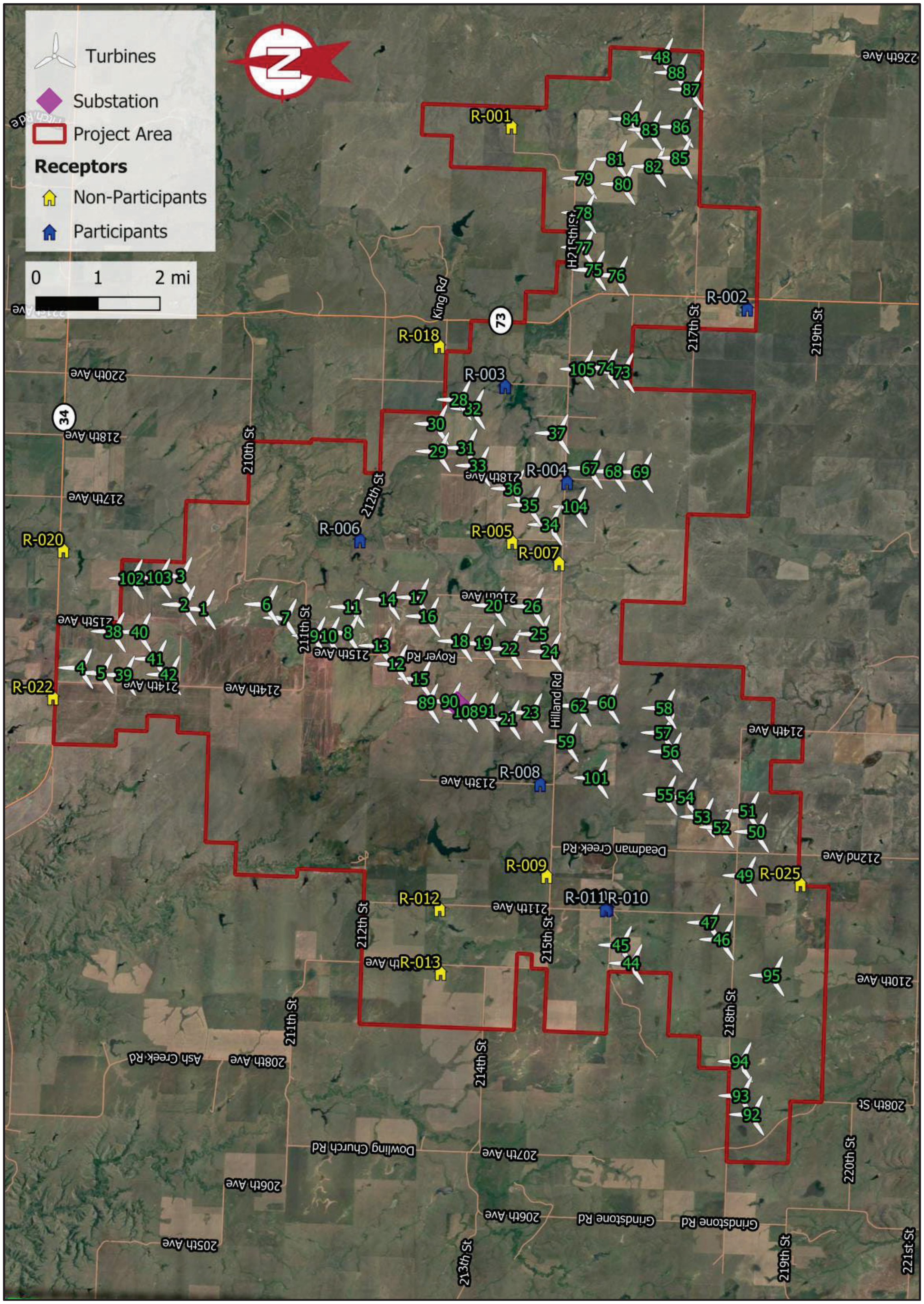

Figure A-1. Turbine and Receptor Locations

APPENDIX B

Receptor Locations and Predicted Noise Levels

Table B-1. Receptor Locations and Predicted Noise Levels

Receptor	Status	UTM 14N NAD83		Ground Elevation (m asl)	Predicted Noise Level (L_{eq} dBA)		
		Easting (m)	Northing (m)		Vestas V163-4.5	Nordex N163-4.5	GE 3.8-154 LNTE
R-001	Non-Participating	291512	4908428	762	37	35	35
R-002	Participating	286782	4902300	764	35	33	34
R-003	Participating	284772	4908591	760	43	42	42
R-004	Participating	282281	4906984	786	48	47	47
R-005	Non-Participating	280731	4908411	770	45	44	44
R-006	Participating	280769	4912366	743	41	40	40
R-007	Non-Participating	280173	4907190	771	44	43	43
R-008	Participating	274442	4907683	784	42	41	41
R-009	Non-Participating	272058	4907513	791	37	36	36
R-010	Participating	271214	4905926	802	41	40	40
R-011	Participating	271191	4905981	802	41	40	40
R-012	Non-Participating	271201	4910294	770	34	32	33
R-013	Non-Participating	269542	4910270	771	32	30	31
R-018	Non-Participating	285815	4910305	760	40	38	38
R-020	Non-Participating	280511	4920074	750	37	36	36
R-022	Non-Participating	276690	4920342	762	41	41	40
R-025	Non-Participating	271847	4900917	801	40	39	39

APPENDIX C

Noise Source Locations and Types

Table C-1. Source Locations and Type

Source ID	UTM 14N NAD83		Ground Elevation (m asl)
	Easting (m)	Northing (m)	
1	278952	4916433	760
2	279061	4916934	760
3	279805	4917016	759
4	277420	4919622	765
5	277289	4919089	770
6	279070	4914794	752
7	278715	4914302	758
8	278330	4912681	760
9	278252	4913554	760
10	278250	4913184	760
11	279003	4912569	760
12	277524	4911422	785
13	277996	4911820	770
14	279200	4911644	760
15	277133	4910805	790
16	278759	4910603	770
17	279249	4910862	770
18	278114	4909769	783
19	278058	4909163	790
20	279041	4908888	780
21	276093	4908512	799
22	277917	4908477	785
23	276259	4907924	800
24	277844	4907429	790
25	278298	4907714	790
26	279017	4907881	780
28	284381	4909787	768
29	283040	4910336	764
30	283754	4910385	770
31	283130	4909607	770
32	284150	4909434	770
33	282670	4909299	777
34	281137	4907426	778
35	281644	4907959	780

Source ID	UTM 14N NAD83		Ground Elevation (m asl)
	Easting (m)	Northing (m)	
36	282071	4908389	780
37	283511	4907242	780
38	278366	4918775	763
39	277237	4918509	780
40	278350	4918094	770
41	277653	4917680	770
42	277246	4917335	774
44	269752	4905320	802
45	270224	4905591	797
46	270367	4902964	830
47	270807	4903284	830
48	293273	4904521	770
49	272028	4902363	813
50	273165	4902059	801
51	273707	4902285	806
52	273282	4902972	830
53	273551	4903467	829
54	274060	4903901	810
55	274130	4904440	810
56	275246	4904295	810
57	275736	4904482	810
58	276376	4904465	820
59	275509	4907005	797
60	276515	4905941	810
62	276438	4906675	810
67	282605	4906387	791
68	282522	4905776	800
69	282504	4905066	820
73	285095	4905552	781
74	285208	4905963	776
75	287752	4906292	773
76	287611	4905697	777
77	288334	4906566	780
78	289233	4906553	780
79	290126	4906526	775

Source ID	UTM 14N NAD83		Ground Elevation (m asl)
	Easting (m)	Northing (m)	
80	289977	4905535	776
81	290624	4905716	780
82	290436	4904736	770
83	291391	4904825	771
84	291666	4905329	770
85	290654	4904054	768
86	291461	4904026	760
87	292435	4903763	770
88	292871	4904139	772
89	276517	4910626	790
90	276549	4910032	790
91	276300	4909052	797
92	265823	4902187	840
93	266312	4902468	847
94	267201	4902486	840
95	269436	4901663	820
101	274565	4906231	794
102	279742	4918306	764
103	279764	4917587	763
104	281602	4906781	783
105	285175	4906596	770
108	276287	4909619	796
Transformer 1	276491	4909841	791
Transformer 2	276480	4909841	791

APPENDIX D

Noise Level Contours

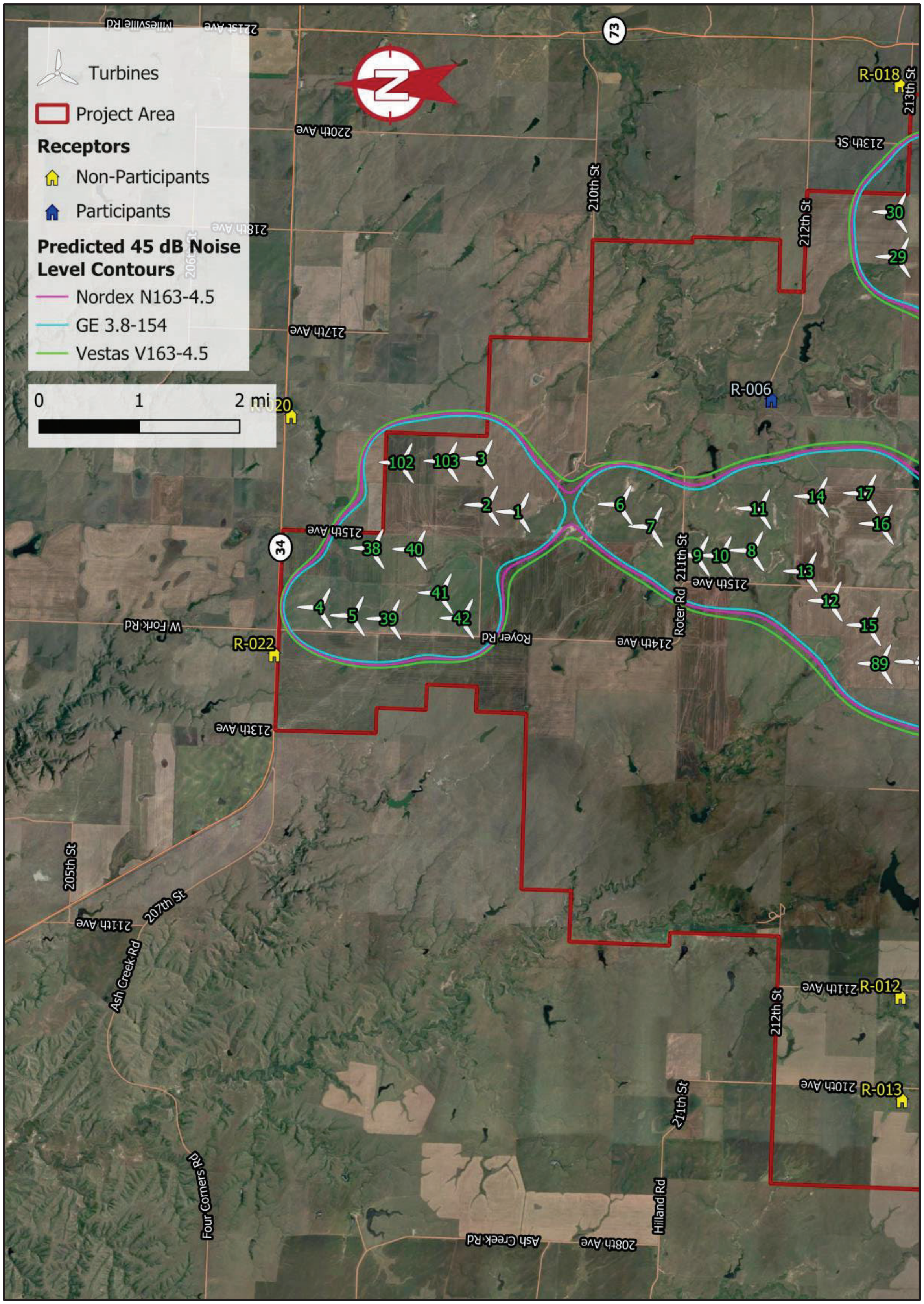

Figure D-1. Noise Level Contours – Northern Area

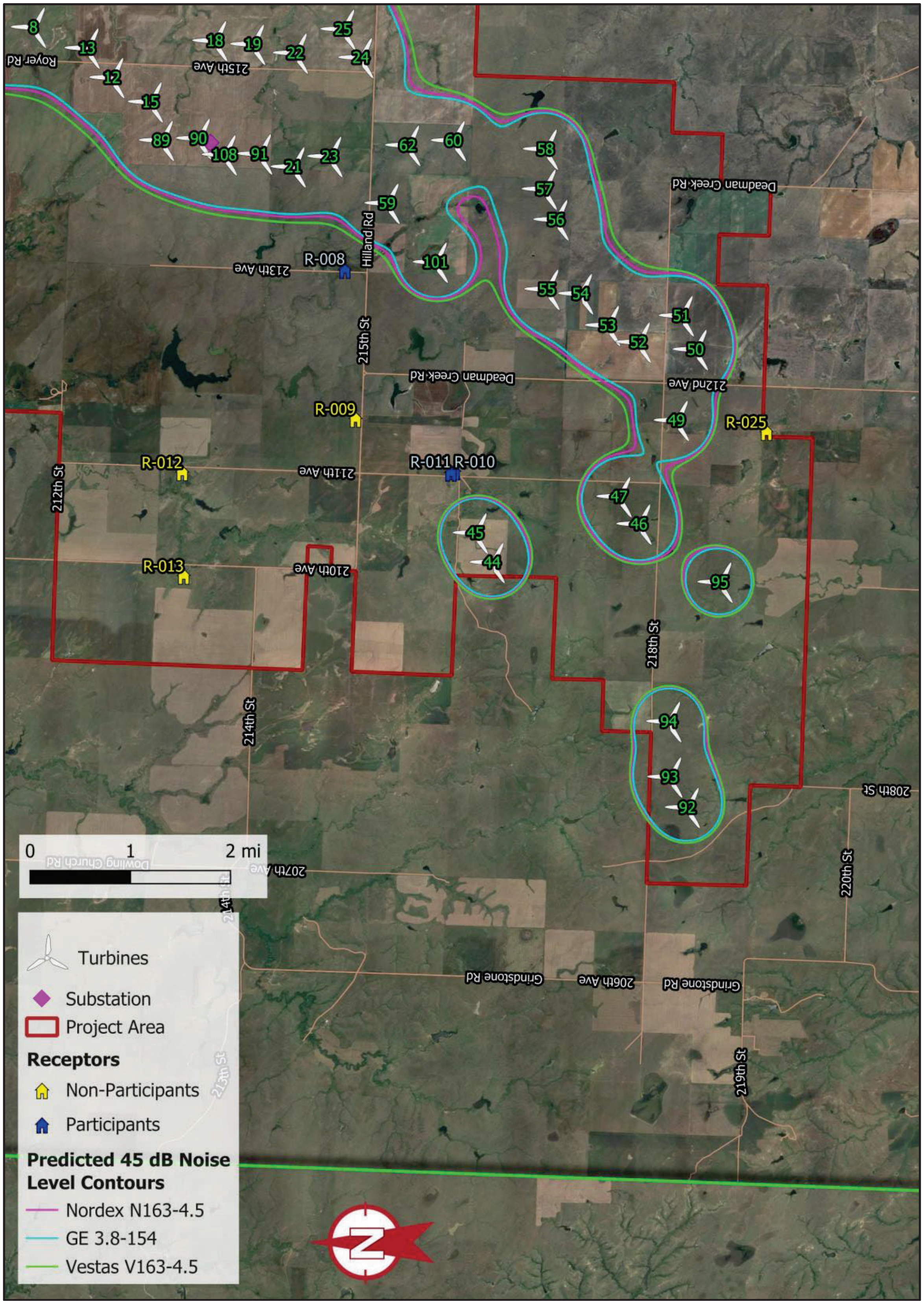

Figure D-2. Noise Level Contours – Southwest Area

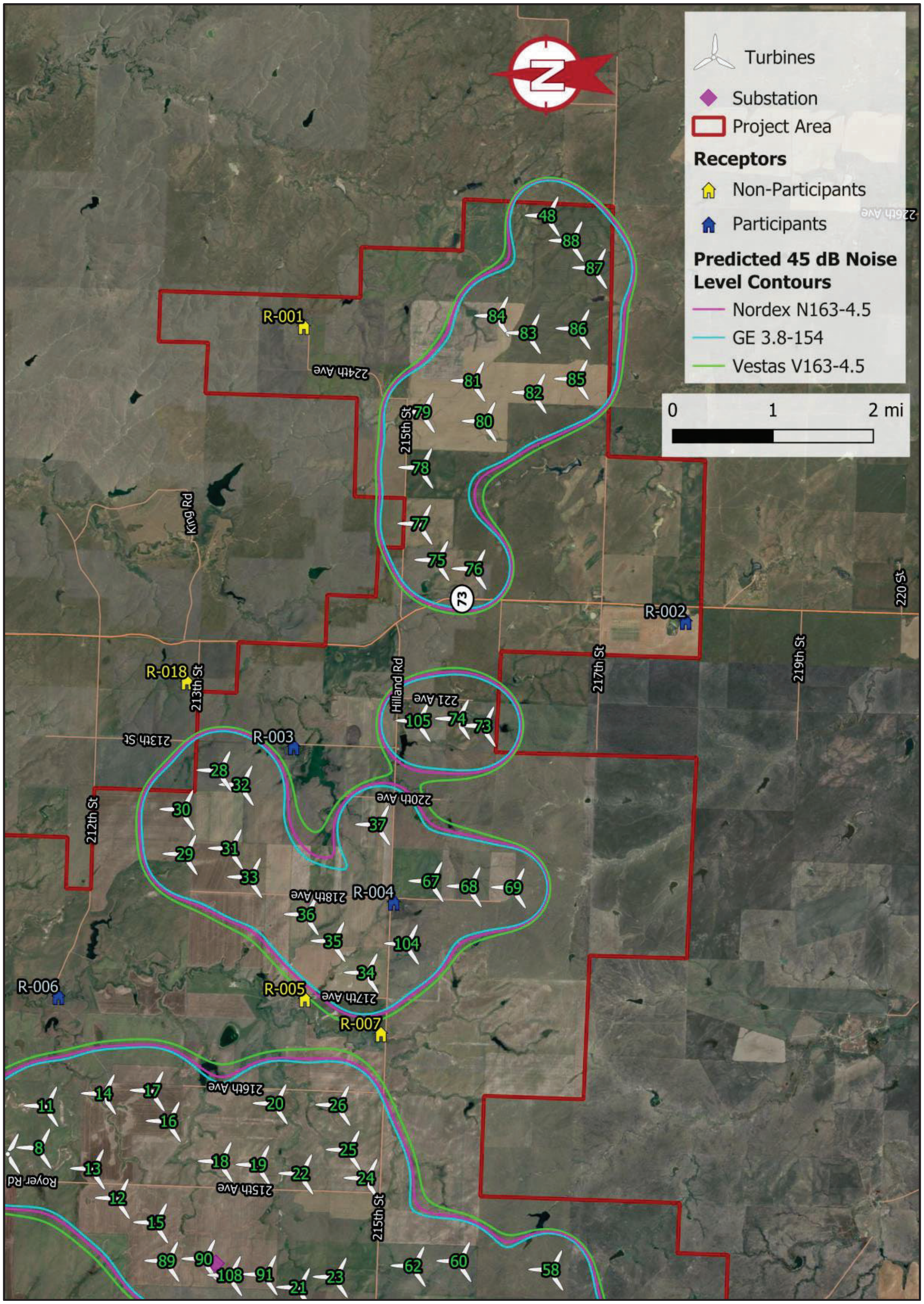

Figure D-3. Noise Level Contours – Southeast Area