COMMERCE DEPARTMENT

February 7, 2017
Mr. Daniel Wolf
Executive Secretary
Minnesota Public Utilities Commission
121 7th Place East, Suite 350
St. Paul, MN 55101-2147

RE: Bent Tree Wind Farm Noise Monitoring – Phase 2 Monitoring Report
Docket No. ET6657/WS-08-573

Dear Mr. Wolf:

The Department of Commerce's Energy Environmental Review and Analysis (EERA) staff submits the enclosed Bent Tree Wind Farm Phase 2 Post-Construction Noise Assessment Report (Report) pursuant to the Commission's August 24th, 2016 order requiring noise monitoring, noise study and further study to address noise-related complaints filed by three landowners regarding the Bent Tree project (E-dockets WS-08-573, Document ID 20168-124382-01).

Under the direction of EERA, DNV GL-Energy completed noise monitoring at the Bent Tree Wind Farm in June of 2017. The resulting Bent Tree Wind Farm Post-Construction Noise Assessment report was filed in the dockets on September 28, 2017 (E-dockets WS-08-573, Document ID 20179-135856-01. Due to exceedances documented during the June 2017 monitoring period, an "on/off" measurement campaign was recommended to properly isolate wind turbine sound from total measured sound, consistent with Appendix A of the Large Wind Energy Conversion System (LWECS) Noise Study Protocol and Report.

In consultation with Commission staff, EERA requested that DNV GL-Energy complete this "on/off" monitoring in order to fulfill the Commission's August 24th order. The study was conducted in late November of 2017. During this campaign, wind turbine sound was isolated from total measured sound by conducting measurements with all turbines operational and also conducting measurements with a subset of wind turbines in proximity to complaint receptors turned off across a range of wind and atmospheric conditions. Turbine contribution to overall sound level was derived by logarithmically subtracting the "turbine on" from the "turbine off" measurements.

The results of the "on/off" campaign are documented in the attached Report. As indicated in the Report, if wind turbine contribution to total sound exceeds a level of 50 dBA at certain wind speeds, it can be reasonably determined that the wind turbines are the main contributor to exceedances during those conditions. The analysis shows that turbine contribution in excess of 50 dBA can occur at the Langrud property when hub height wind speeds reach 11.5 m/s and higher, and extrapolated data in the report shows similar trends for the Hagen property.

We believe that completion of this “on/off” monitoring campaign fulfills the Commission’s August 24th order to conduct monitoring consistent with the guidance contained in the Large Wind Energy Conversion System Noise Study Protocol and Report. Because the report documents that there are periods during which Bent Tree Wind Farm turbines contribute significantly to total noise exceedances, EERA staff believes that noise standards indicated in Condition E. 3 of the Bent Tree Wind Farm LWECS site permit are not being met.

Please do not hesitate to contact me if you have any questions concerning this letter.

Sincerely,

s/ Louise I. Miltich

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enclosure: Report: Bent Tree Wind Farm Phase 2 Post-Construction Noise Assessment

BENT TREE WIND FARM

Phase 2 Post Construction Noise Assessment

Wisconsin Power and Light Company

Document No.: 10071686-HOU-R-01
Issue: B**, Status:** Final
Date: 1 February 2018

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Project name:	Bent Tree Wind Farm	DNV GL - Energy
Report title:	Phase 2 Post Construction Noise Assessment	Advisory Americas
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Task and objective:

This report presents the results of analysis conducted by DNV GL on behalf of Wisconsin Power and Light Company.

Prepared by:	Verified by:	Approved by:
Kristjan Varnik Project Engineer, Development and Engineering Services	Danny Schoborg Engineer, Development and Engineering Services	Shant Dokouzian, P.Eng. Principal Engineer, Development and Engineering Services

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B	1 February 2018	Final	K. Varnik	D. Schoborg	S. Dokouzian

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1 INTRODUCTION

The Department of Commerce, Energy, Environment Review and Analysis (EERA, formerly Energy Facilities Permitting) of the state of Minnesota has requested, on behalf of Wisconsin Power and Light Company ("WPL"), that Garrad Hassan America, Inc. (DNV GL) perform a second phase of post-construction noise assessment for the Bent Tree Wind Farm (the "Project"). The purpose of this Assessment is to determine the noise contribution of wind turbine generators on two nearby residences. The Project is in Freeborn County, MN, approximately 90 miles south of Minneapolis, consisting of 122 Vestas V82-1.65 MW wind turbine generators (WTG) with a hub height of 80 m and a rotor diameter of 82 m. The Project began operation in 2011.

1.1 Background

An audit was conducted in June 2017 by DNV GL [1], closely following the requirements under the "Guidance for Large Wind Energy Conversion System (LWECS) Noise Study Protocol and Report" ("Guidance") [2] issued by the EERA, in collaboration with the Minnesota Pollution Control Agency (MPCA) Noise standards [3]. More specifically, the audit was conducted, at the request of the EERA, due to on-going complaints at two receptors within the Project Area; the Langrud ("BT-M01") and Hagen ("BT-M02") receptors. The June 2017 audit, which measured the total noise experienced at the receptors, concluded that:

> *"(…) 16 total hours of non-compliance with the LWECS Guidance were identified at BT-M01 and BT-M02. During most of the exceedance periods, bird sounds and/or wind induced sound on vegetation and tree leaves appear to be the primary contributor to the exceedances. Wind turbine sound appears to be audible in the recordings during some of the exceedance periods. However, as stipulated in Appendix A of the LWECS Guidance, further detailed investigations would be necessary to assess the contribution of the wind turbines to the total sound levels experienced at the receptors.*
>
> *As such, it was recommended to perform an additional measurement campaign to properly isolate wind turbine sound from total measured sound. This can be achieved by conducting measurements where a subset of wind turbines in proximity of the complaint receptors are turned off and on under various wind and atmospheric conditions."*

As requested by the EERA, a second assessment (the "Phase 2 Assessment"), was undertaken with the primary goal of isolating the wind turbine sound from the total measured sound. The noise measurement protocol for this campaign was approved by EERA before measurements were undertaken [4].

2 METHODLOGY

2.1 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 (sound energy summed across the entire audible frequency spectrum) and in octave band spectra (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 audible range of humans 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. All values in this report are presented in A-weighted scales, unless explicitly stated otherwise.

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.

In order to determine the sound contribution from the wind turbine on the receptor, it is necessary to quantify the ambient background sound level, and then subtract it logarithmically from the total measured sound level. Background sound levels may be highly variable in rural areas and may be dependent on atmospheric conditions including wind speed and wind direction.

2.2 Minnesota Noise Limits

The regulations applicable to the Project are the Minnesota Noise Standards [3].

Minnesota Pollution Control Agency (MPCA) 7030.0040 Noise Standards state the following:

> **7030.0040 Noise Standards**.
>
> **Subpart 1. Scope**. These standards describe the limiting levels of sound established on the basis of present knowledge for the preservation of public health and welfare. These standards are consistent with speech, sleep, annoyance, and hearing conservation requirements for receivers within areas grouped according to land activities by the noise area classification (NAC) system established in part 7030.005. However, these standards do not, by themselves, identify the limiting levels of impulsive

noise needed for the preservation of public health and welfare. Noise standards in subpart 2 apply to all sources.

Subpart. 2. Noise Standards.

Table 2-1 Minnesota Noise Standards

	Daytime		Nighttime	
Noise Area Classification	L_{50}	L_{10}	L_{50}	L_{10}
1	***60***	***65***	***50***	***55***
2	*65*	*70*	*65*	*70*
3	*75*	*80*	*75*	*80*

The Project is considered under noise area classification 1, which includes homes, other residential uses, religious activities, and educational services. Therefore, the applicable nighttime L50 limit is 50 dBA and the nighttime L10 limit is 55 dBA at each receptor. Daytime L50 and L10 limits are 60 dBA and 65 dBA, respectively.

Sound pressure levels can be reported in a variety of ways. L50 and L10 represent noise levels that are exceeded 50% and 10% of the time, respectively. Leq represents the average sound over a period of time. L50, L10, and Leq sound pressure levels can be reported in dB, or weighted units such as dBA or dBC. The A-weighted curve (i.e. dBA) is used to duplicate the sensitivity of the human ear to sound. In other terms, dBA is the most accurate unit to replicate how a human ear translates sound pressure waves, originating from ambient sound and wind turbine sound, into sound levels. The Minnesota Noise Standards are expressed in dBA, as are the sound levels within this document. The noise standard applies to one hour survey periods, meaning that for any given one-hour period, the L50 and L10 levels shall not exceed Table 2-1.

The above sound limits are for "total" sound, or in other terms, the contribution of the Project combined with the ambient sound. As discussed in Section 1.1, if "total" sound exceedances are measured, further detailed investigations are necessary to isolate the contribution of the wind turbines to the total sound levels experienced at the receptors. The focus of this assessment is to determine the wind turbine contribution.

It should be noted that acoustic specifications for wind turbines are provided in terms of Leq, as well as measurements and results to determine the wind turbine contribution. Due to the generally constant nature of wind turbine sound, when reported over long periods, the Leq results are a reasonable approximator of L50, however careful consideration should be applied when comparing the two metrics.

It should be noted that the Minnesota wind turbine guidance [2] does not state what level of turbine only contribution is acceptable, i.e. compliant, but suggests investigating if the wind turbines are the main contributor to the total sound during exceedances. If the contribution of the wind turbines exceeds an Leq level of 50 dBA at certain wind speeds, it can be reasonably determined that the wind turbines are the main contributor to L50 total noise exceedances during those conditions. Lower wind turbine contribution levels, but close to this threshold, could be viewed as impactful as well, but determining which level is impactful is outside the scope of this present study.

2.3 Instrumentation

The instrumentation used for the post-construction noise monitoring included the following:

- Larson Davis sound meters model 831 Class I;
- FreeField ½ inch microphone model 377B02;
- Preamplifier model PRM831;
- Vaisala Weather Transmitter model SEN-031;
- Larson Davis Precision Acoustic on-site Calibrator model CAL200; and
- Complete kit for outside sound measurement (including large tripods, 7" wind and rain screen, protective Pelican case, solar panels, and long range batteries).

The sound meters meet the IEC 61672 Class 1 specifications. All instruments had a valid calibration, and calibration sheets are included in Appendix C of this document. Based on the above descriptions, the instrumentation complies with the requirements of the Guidance and Minnesota regulations [3]. The weather sensor was appropriately heated with an autonomous power supply in order to ensure accurate data was gathered during low temperatures. Pictures of the monitoring set-ups are including in Appendix B.

Table 2-2 provides the serial numbers of the equipment used at each monitoring location.

Table 2-2 Monitoring Equipment Serial Numbers by Monitoring Location

Monitoring location	Sound Level Meter	Preamplifier	Microphone
Langrud (M01)	3172	019221	159539
Hagen (M02)	2661	10895	158436

2.4 Measurement Locations

On-site monitoring was conducted at the two receptors, identified as BT-M01 and BT-M02. Table 2-3 summarizes the selected monitoring locations, which were at the same properties as the initial audit in June 2017. Since the foliage had changed between November and June, BT-M01 was repositioned on the same property to avoid potential noise issues from a nearby evergreen tree. The new location was 135 ft (41 meters) north of the old location but approximately the same distance to the nearest wind turbine. Although the new location was placed in an area more commonly traversed by the landowner, this location was not preferable for monitoring during the June 2017 period due to deciduous foliage and avian wildlife. Table 2-3 provides the coordinates of the monitoring locations.

Figure 2-1 presents a general overview map of the measurement locations in relation to the Project. Figure 2-2 provide locations for the equipment on the properties. Pictures of the monitoring locations are included in Appendix B.

Table 2-3 Final Measurement Point Locations

Final Measurement Point	Receptor Address	Easting	Northing	Distance to nearest turbine, ft	Notes
Langrud (BT-M01)	25887 – 705th Avenue, Alden, MN 56009	463000	4841960	350 m (1150 ft) from Turbine 362	Closest wind turbine is West
Hagen (BT-M02)	70286 – 290th Street, Hartland, MN 56042	462949	4847019	465 m (1525 ft) from Turbine 132	Closest wind turbines are NE and SE

UTM NAD83 zone 15

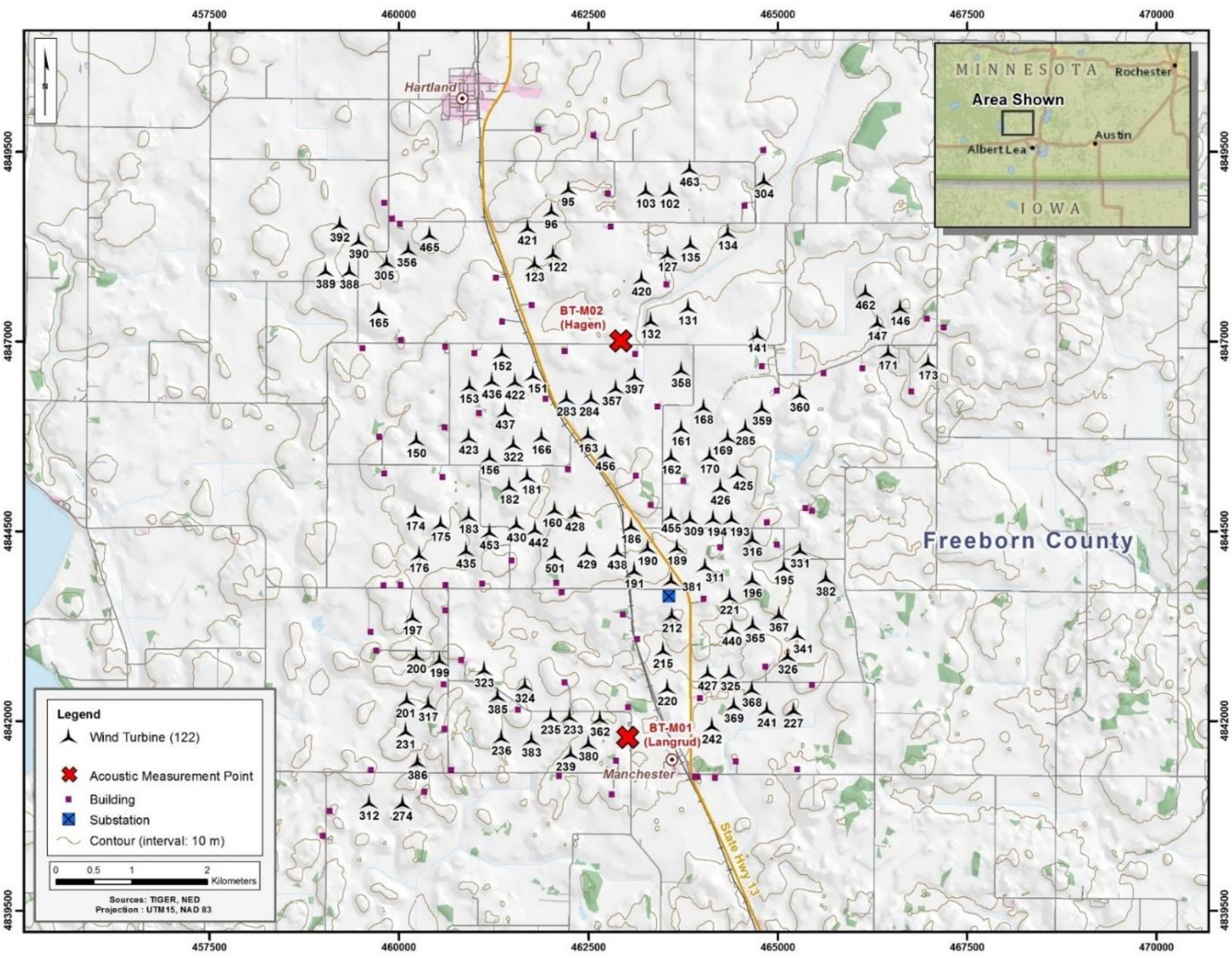

Figure 2-1 Map of Project and Monitoring Locations

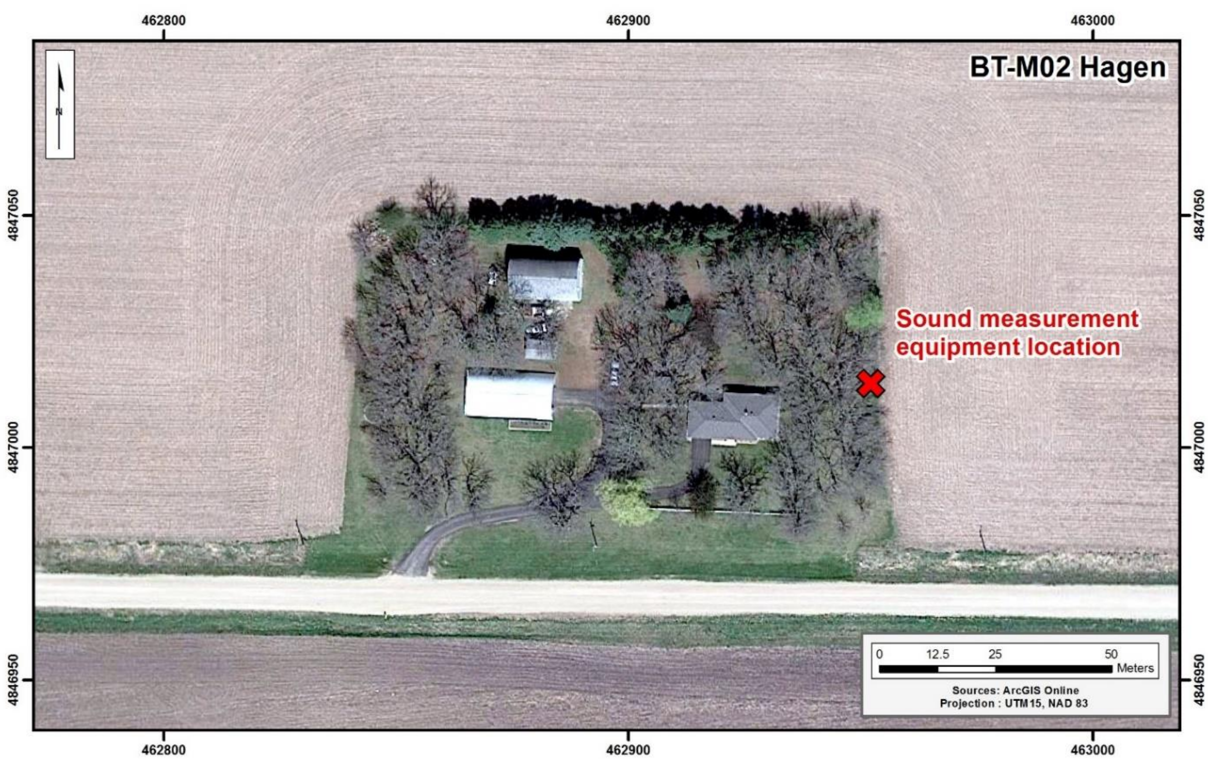

Figure 2-2 Equipment Locations on Properties

2.5 Data Collection

Just over one week (9 days) of data was collected from 21 November 2017 to 30 November 2017. For two nighttime periods during the monitoring period, as defined in Table 2-4, all wind turbines within a 2.4 km (1.5 mile) radius were parked under medium to high wind conditions to allow collection of ambient noise conditions. This represents 73 out of the 122 operational turbines.

Only nighttime data was used throughout the assessment as detailed in further Sections below, since it is typically at night that domestic and traffic activities are at its lowest. As such, this allows for less interference or intrusive sounds that require filtering, and a better “signal-to-noise” ratio, i.e. a stronger level of total noise vs ambient level which can provide a more accurate understanding of turbine only contribution. Sound contribution from wind turbines vary primarily with hub height wind speed and not with time of day; the sound contribution from the turbines estimated with nighttime data, applies to daytime as well.

Each day, wind speed forecasts were reviewed to select the best opportunities to measure ambient sound levels, i.e. with the wind turbines parked, during relevant wind speeds. As such, wind turbines were parked from November 23rd 10 p.m. to November 24th 4 a.m. and on November 25th from 12 a.m. to 7 am. There were other periods when wind turbines were not operational due to hub height wind speeds below the cut-in level. Measurements during these periods were excluded in the analysis. Operational logs provided by EERA from the Project operator confirm the shutdown periods occurred [5]. Aside from the forced curtailment periods, all wind turbines within 2.4 km (1.5 miles) were operational during the measurement campaign.

Table 2-4 Shutdown Schedule

Wind Turbine Forced Curtailment Window	
Start Time	End Time
23 November 2017, 10 p.m.	24 November 2017, 4 a.m.
25 November 2017, 12 a.m.	25 November 2017, 7 a.m.

2.6 Wind Speed Data

The Minnesota LWECS Guidance does not have a defined method for determining the wind turbine contribution at the receptors, including the wind speed range relevant for data analysis.

Wind turbine sound changes with respect to hub height wind speeds. Wind turbine manufacturers provide sound data sorted in separate bins based on the wind speed (i.e. when the hub height wind speed is x, the sound power level of the turbine is y). A wind speed bin is a narrow range of wind speeds to group data in a more meaningful way for further analysis; for example, data acquired under hub height wind speeds ranging from 9.6 m/s to 10.5 m/s would be grouped under the 10 m/s wind speed *bin*, and so forth.

The IEC-61400-11 Edition 3 standard [6] is the internationally recognized standard for determining the wind turbine sound power level. Its method for determining the relevant hub height wind speed range is specific to the wind turbine. It is defined as the hub height wind speeds ranging from 0.8 to 1.3 times the wind speed occurring at 85% of the rated wind turbine power. The rated power for the Vestas V82 is 1650 kW, and 85% rated power is approximately 1400 kW which occurs at approximately a 10 m/s hub height wind speed, or wind speed *bin*. To account for the 0.8 and 1.3 range, the relevant range for acoustic testing would equate to hub height wind speed bins from 8 m/s (17.9 mph) to 13 m/s (29.0 mph). Therefore, the current analysis aimed at acquiring data samples within this range, but also at a hub height wind speed bin of 7 m/s (15 mph), to help identify acoustic trends at slightly lower wind speeds. It should be noted that measuring wind turbine sound at higher hub height wind speeds can be difficult due to increased wind-induced sound on the microphone at ground level, and the less-frequent occurrence of those elevated winds speeds.

Hub height wind speed data was collected from operational logs obtained by EERA from the plant operator [5]. The logs were provided for the two closest wind turbine generators at each location. Two anemometers on each wind turbine nacelle provided measured wind speeds at hub height. The electrical output of the wind turbine as well as the turbine power curve, which relates electric power output to hub height wind speeds, was also provided as another means to extract hub height wind speed. DNV GL used the nacelle anemometers that were in best agreement with wind speeds derived by the electrical output and power curve. These were anemometers #2 on turbines #362 (BT-M01) and #132 (BT-M02).

Wind speed data at the microphone level was collected from an in-situ weather station. This is described as the microphone wind speed and is different from the hub height wind speed. The Vaisala units monitor wind speed and wind direction, temperature, relative humidity, and precipitation. Precipitation data obtained on-site was compared to the nearest NOAA station, and on-site data broadly concurred. Due to the benefit of the in-situ weather stations, the local data was used for initial data filtering, in lieu of data from a distant NOAA station, as it is more accurate for data filtering at the microphone level. Wind speed measurements at the microphone and at hub height are inherently related, but not directly correlated. Wind speed can vary significantly at different elevations depending on atmospheric conditions, and the influence of nearby structures and landscape.

It should be noted that units in this report are generally provided in metric units, to suit the international standards that govern certification. However, Table 2-5 provides a comparison between wind speed in miles per hour and meters per second to suit English units.

Table 2-5 Wind Speed Units Comparison

Miles per hour (mph)	Meters per second (m/s)
1	0.4
2	0.9
3	1.3
4	1.8
5	2.2
6	2.7
7	3.1
8	3.6
9	4.0
10	4.5
11	4.9
12	5.4
13	5.8
14	6.3

Miles per hour (mph)	Meters per second (m/s)
15	6.7
16	7.2
17	7.6
18	8.0
19	8.5
20	8.9

2.7 Noise Emission Data

Free field microphones connected to sound level meters were installed on tripods approximately 1.8 m (6 feet) above ground, and site calibration was performed before and after each monitoring period. The differential calibration was not greater than 0.5 dBA as per Table 2-6. Photos of sound equipment stations at each point are included in Appendix B.

Table 2-6 Site Calibration Log

Monitoring location	End-of-campaign site calibration	
	Date	Differential (dBA)
Langrud (BT-M01)	30 November 2017	0.10
Hagen (BT-M02)	30 November 2017	-0.09

Sound measurements were made continuously using a FAST response setting and were averaged and stored every 10 seconds, along with the relevant statistics for that period. Sound events louder than 60 dBA were recorded as an audio file as well for further analysis. Periods with intruding intermittent background noise (as from aircraft) were omitted.

Because environmental sound measurements are greatly influenced by wind-induced sound, the measurement stations included an oversized 175 mm (7 in) foam wind screen, as per industry standards. This enabled the measurement of sound (without significant wind-induced sound effects on the microphone) in microphone winds up to 5 m/s (i.e. 11 mph) at the measurement level. The LWECS Guidance states that measurements taken during winds higher than 11 miles per hour at microphone height should not be used in a measurement campaign.

Hub height wind speed binning of the sound level data was the primary method of analysis, and binning based on microphone wind speed was used as a supplemental data set to confirm wind turbine noise contribution trends. Hub height binning of data is the preferred method since wind turbine sound is directly related to hub height wind speed. Microphone hub height wind speed binning more accurately reflects ambient sound on the ground. It is worth noting, as described in sections below, that sorting data based on the microphone wind speeds showed similar sound levels during the turbine parked periods, similar increasing noise levels as wind speeds increased and similar turbine contributions levels.

3 DATA ANALYSIS AND RESULTS

3.1 Measurement Point BT-M01 - Langrud

BT-M01 is in the southern-central region of the Project area. The property is characterized by a series of small buildings including a residence, garage and workshop with a gravel dirt driveway connecting them. A series of evergreen trees on the western side serves as a windbreak. The deciduous trees scattered across the property had lost their foliage prior to the measurement period.

Measurement results are presented per hub height wind speed bins below. The data presented is a subset of the overall dataset, filtered for nighttime and downwind from the nearest wind turbine (#362) to the west. The applied downwind filter is +/- 45 degree from the wind turbine (winds coming from the 225° to 315° True North direction) to include all western wind directions. This also consists of the direction range that is not shielded by the buildings on the property. The downwind filter is used as it provides a clearer and more accurate representation of turbine noise contribution on this property. Excluded data also includes microphone height wind speeds greater than 11 mph, intruding intermittent background noise, and the beginning and end of the curtailment periods. There were no periods of precipitation during the nighttime periods.

The number of 10 second samples is presented for periods with the turbines on (i.e. “total” noise) and off (i.e. ambient background sound during forced curtailment). The acoustic average and standard deviation of the turbine on periods and turbine off periods is also provided. It can be observed that the turbine off data remains fairly constant, due to the significant shielding at the Langrud property. The data shows a slight upward trend at hub height wind speeds above 10 m/s. The turbine contribution is determined by logarithmically subtracting the average noise level for the turbine on periods from the turbine off periods. This is presented visually in Figure 3-1 and as a data table in Table 3-1. The bold line represents the average noise level, while the dotted line represents the standard deviation.

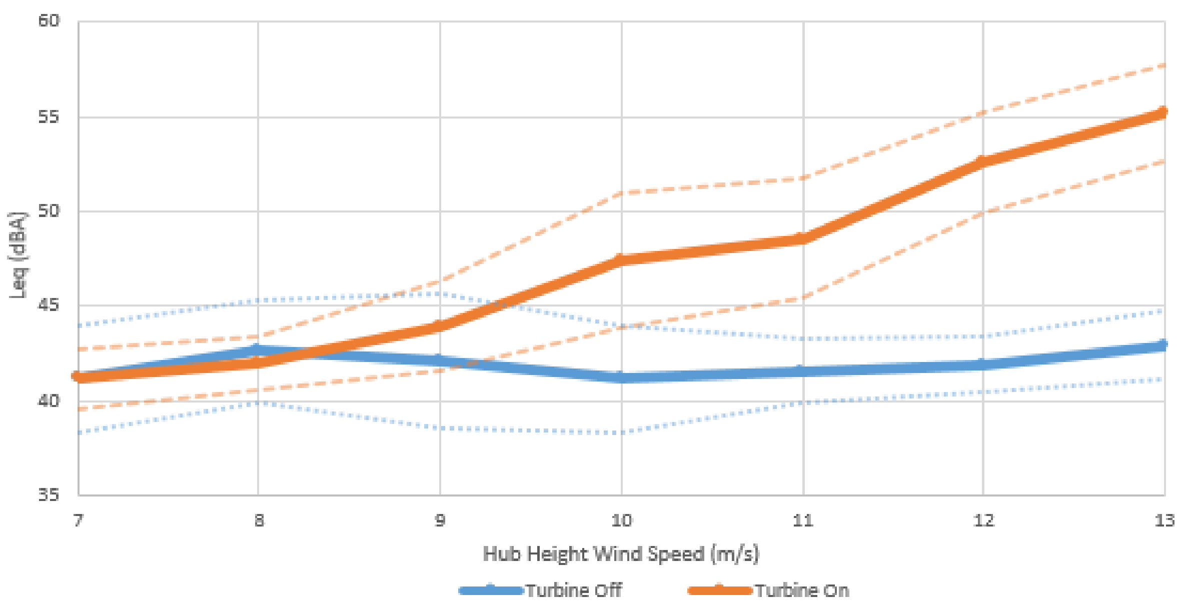

Figure 3-1 BT-M01 Leq Sound Levels per Hub Height Wind Speed

Table 3-1 BT-M01 Leq Sound Levels per Hub Height Wind Speed

	Turbine Off			Turbine On			
Hub Height Wind Speed (m/s)	**Average Level (dBA)**	**Number of Samples**	**Standard Deviation (dBA)**	**Average Level (dBA)**	**Number of Samples**	**Standard Deviation (dBA)**	**Turbine Contribution (dBA)**
7	41	530	2.8	41	2524	1.5	-
8	43	1124	2.6	42	1068	1.4	-
9	42	781	3.4	44	2075	2.4	**39**
10	41	349	2.7	48	1554	3.7	**47**
11	42	464	1.7	49	1545	3.1	**48**
12	42	189	1.4	53	1042	2.7	**52**
13	43	42	1.5	55	564	2.5	**55**

From the results, the turbine contribution at the property would be in excess of 50 dBA at hub height wind speeds equal and above the 12 m/s wind speed bin at hub height, and the turbine contribution is considered a main contributor to exceedances under the assumptions of this report.

A supplemental evaluation is provided under Appendix C, where the same filtered data is binned per microphone wind speed. Similar trends and turbine contribution values were calculated. A more pronounced upward trend in turbine off sound was measured, as expected.

Figure 3-2 presents the 1/3 octave band 10 second Leq for all nights, filtered similarly by wind direction and for the 10 and 13 m/s hub height wind speed bins. The A-weighted data presents a notable difference between the turbine on (solid) and turbine off (dotted) levels for frequencies under 8000 Hertz.

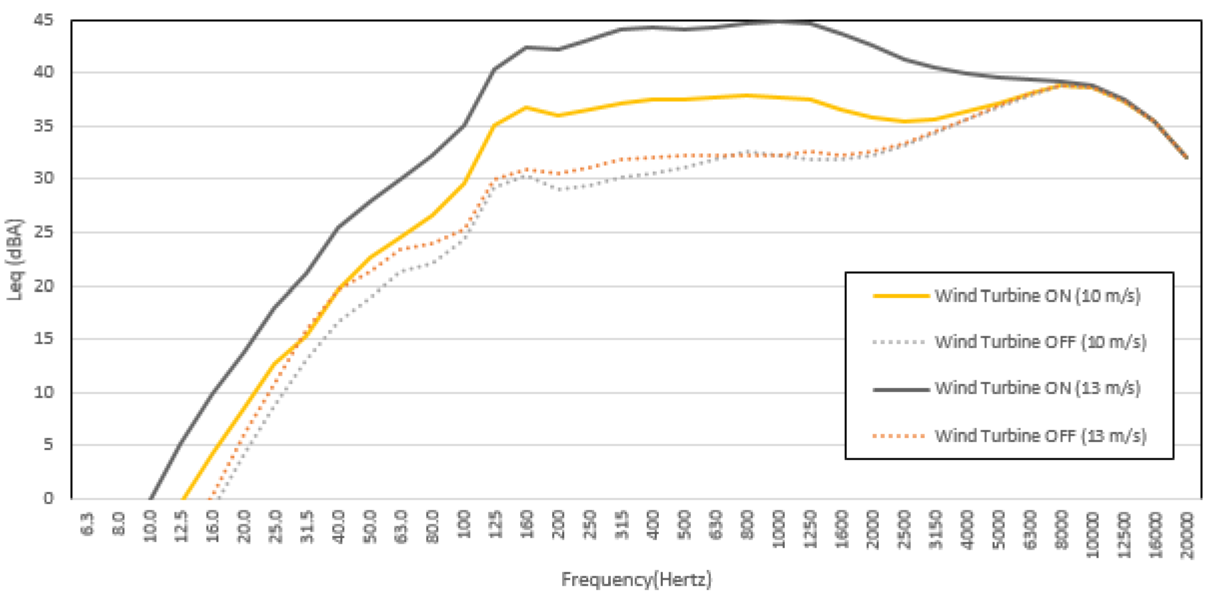

Figure 3-2 BT-M01 Leq Frequency Content per Hub Height Wind Speed

3.2 Measurement Point BT-M02 - Hagen

BT-M02 is located in the central region of the project area. An evergreen windbreak is located on the northern side of the property. There are many mature deciduous trees on the property, but the trees had lost their foliage prior to the measurement period.

During the first night of forced curtailment ("turbines off"), the winds were primarily from the south-southwest direction and the noise levels between periods with the turbines on and turbines off were very similar. Under these conditions, the turbine contribution could not be determined. The 10 second A-weighted sound Leq were measured in a range between 46 dBA and 58 dBA. Figure 3-3 presents the 1/3 octave band 10 second Leq from the first night of operation for the 10, 11 and 12 m/s hub height wind speed bins. The A-weighted data demonstrates a concentration of acoustic energy between 100-200 Hz regardless of whether the turbines were operational or not, which resulted in high measured sound levels. There were minor differences between the turbine on and turbine off levels for this night, with some turbine off binned data being louder than turbine on data. This indicates that the turbines were not the significant contributor for the night, and indicates a possibility that when winds are from the south-southwest, there is a strong predominance of low frequency sound on the property which does not originate from the wind turbines.

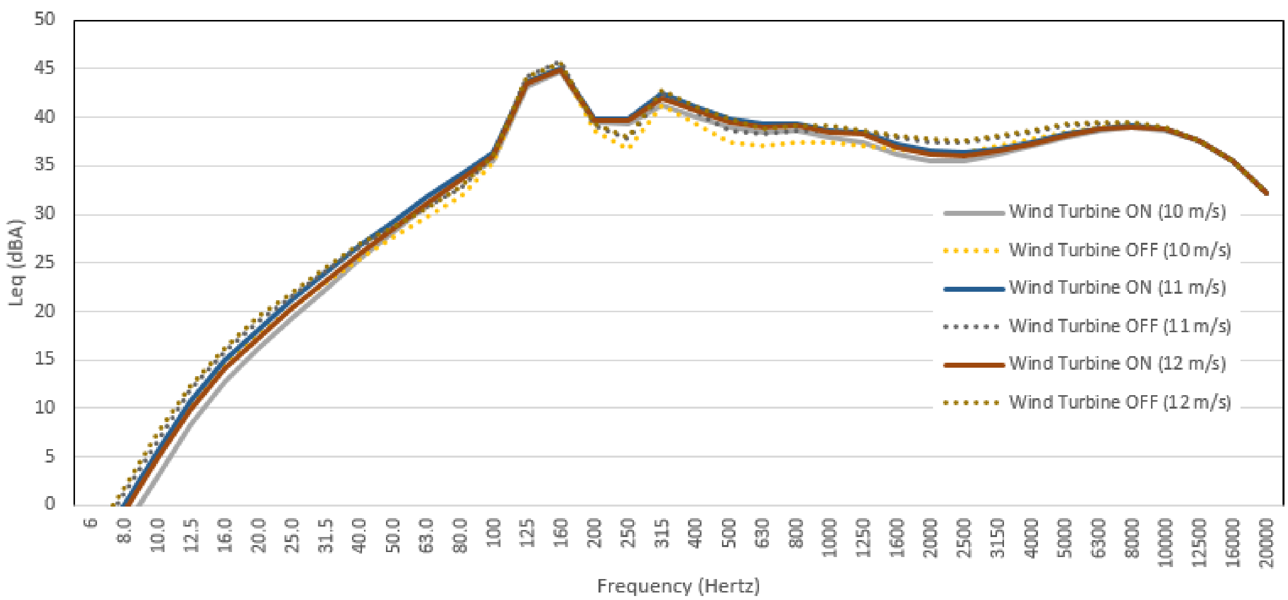

Figure 3-3 BT-M02 Leq Frequency Content per Hub Height Wind Speed (Nighttime 11/23-11/24)

As such, Figure 3-3 presents measurement results per hub height wind speed bins, but exclude turbine off data from the first night of forced curtailment (23 to 24 November). The data presented is a subset of the overall dataset, filtered to improve signal-to-noise ratio by only including western and northwestern wind directions between 250 and 350 degrees, with turbine off data and turbine on data coming from similar directions. These measurements were screened by the trees and the house, but still present the most consistent results at this property. The 10 second measured sound levels at the Hagen residence were highly variable, with 10 second A-weighted Leqs between 28 dBA and 58 dBA during periods of parked turbines.

The downwind filter also effectively filtered away data from the first night of turbine off measurements. Excluded data also includes microphone height wind speeds greater than 11 mph, intruding intermittent background noise, and the beginning and end of the curtailment periods. There were no periods of precipitation for the whole period.

Turbine off noise levels at wind speeds above 10 m/s at hub height were not captured on the second night of forced curtailment (25 November), therefore a preliminary extrapolation was used to estimate turbine on sound levels, and estimate turbine contribution. Standard polynomial curves were not an acceptable fit to the observed wind speed and noise measurement data relationship, so a linear trend line was applied and used to estimate the noise levels at hub wind speeds up to 13 m/s.

The number of 10 second samples is presented for periods with the turbines on (i.e. "total noise") and off (i.e. ambient sound during forced curtailment). The acoustic average and standard deviation of the turbine on periods and turbine off periods is provided. The turbine contribution is determined by logarithmically subtracting the average noise level for the turbine on periods from the turbine off periods. This is presented visually in Figure 3-4 and as a data table in Table 3-2. The bold line represents the average noise level, while the dotted line represents the standard deviation.

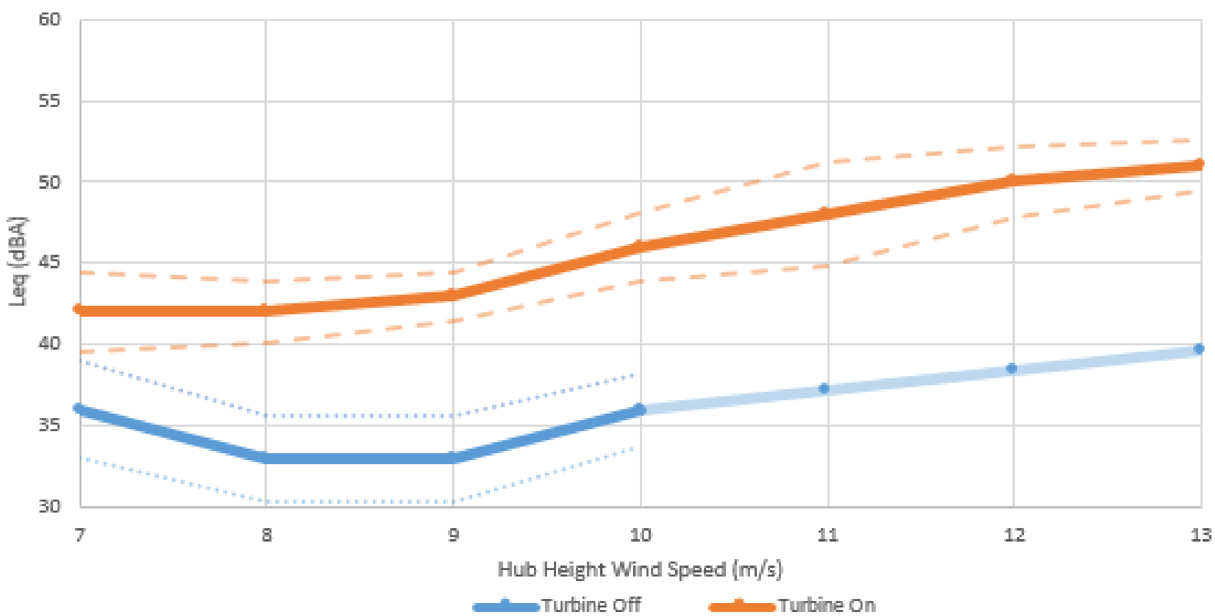

Figure 3-4 BT-M02 Leq Sound Levels per Hub Height Wind Speed

Table 3-2 BT-M02 Leq Sound Levels per Hub Height Wind Speed

	Turbine Off			Turbine On			
Hub Height Wind Speed (m/s)	**Average Level (dBA)**	**Number of Samples**	**Standard Deviation (dBA)**	**Average Level (dBA)**	**Number of Samples**	**Standard Deviation (dBA)**	**Turbine Contribution (dBA)**
7	36	231	3.0	42	2539	2.5	**41**
8	33	993	2.7	42	1568	1.8	**41**
9	33	432	2.7	43	1235	1.5	**43**
10	36	584	2.2	46	1114	2.2	**46**
11	37*	0	-	48	1059	3.2	48*
12	38*	0	-	50	653	2.2	50*
13	40*	0	-	51	550	1.6	51*

* Represents theoretical results from extrapolated values

Preliminary analysis indicates that the turbine contribution may exceed 50 dBA at higher hub height wind speeds, and be considered a significant contributor to exceedances under the assumptions of this report. However, this was not specifically measured. The extrapolated results show the turbine is a significant contributor above 12 m/s, but there is increased uncertainty in the extrapolation process when compared to noise measurements.

A supplemental evaluation is provided under Appendix C, where the same filtered data was binned per microphone wind speed. Turbine off data were not extrapolated for the supplemental analysis, but similar trends and turbine contribution values were calculated for the measured data. A more pronounced upward trend in turbine off sound was measured, as expected.

Figure 3-5 presents the A-weighted third octave band for the 10 m/s hub height wind speed bin, filtered for wind direction between 250 and 350 degrees for the second night of curtailment, to improve the signal-to-noise ratio. The A-weighted data presents a notable difference between the turbine on (solid) and turbine off (dotted) levels for frequencies under 2000 Hertz.

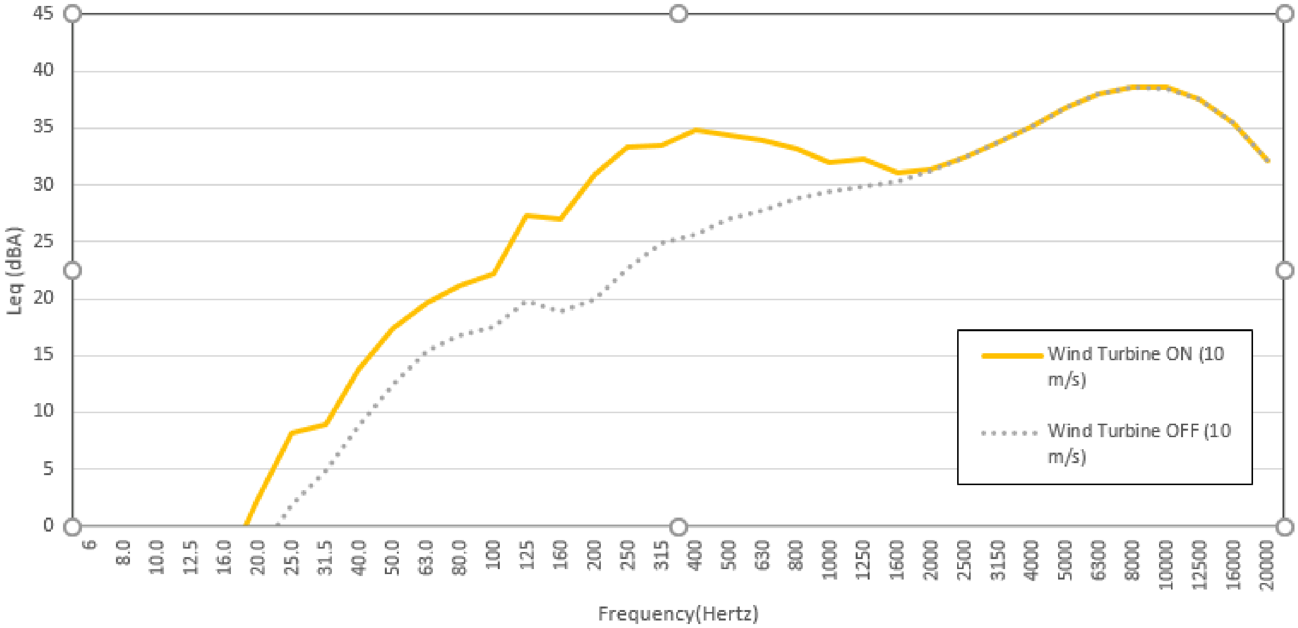

Figure 3-5 BT-M02 Leq Frequency Content per Hub Height Wind Speed (Nighttime 11/24-11/25)

4 DISCUSSION

The Minnesota LWECS guidance are based on total noise levels. When exceedances occur, additional noise assessments are required to determine if nearby wind turbines are significant contributors. In this assessment, the turbine contribution of the sound level was derived by logarithmically subtracting the turbine on from the turbine off measurements. In instances when the turbine Leq contribution is over 50 dBA, it is reasonable to determine that turbines are significant contributors (See Section 2.2).

The sound levels on the two properties were highly variable. As stated in the 2011 Bent Tree acoustic study – "Background levels in rural areas are highly variable and usually highly dependent on the specific wind and atmospheric conditions occurring at a particular moment. "[7]. This was also observed in the June 2017 DNV GL study [1]. However, by analysing the frequency content of the measured signal, filtering by wind direction, sorting by hub height wind speed, and having a good comparison set of on & off data, the assessment shows that turbines are the primary contributor to the acoustic environment under certain atmospheric conditions for Langrud, and potentially Hagens.

Measured turbine contribution in excess of 50 dBA occurred at the Langrud property (BT-M01) at hub height wind speeds of 12 m/s and 13 m/s, while the turbines were operational. When compared to noise levels during turbine off periods, it was also determined that the turbines contribute significantly to total noise exceedances.

Measured exceedances of total noise at the Hagen property occurred with the turbines off and turbines on. During the first night of the measurements with turbines parked, turbine off levels were louder than turbine on levels. This demonstrates that under some conditions, there is significant noise in the area not caused by turbine operations. On the second night when turbines were off, hub height wind speeds were lower (i.e. not exceeding 10 m/s) and turbine contribution was detectable, however, turbine contribution in excess of 50 dBA was not measured. The resultant data set did not provide turbine off measurements at higher hub height wind speeds. Based on the filtered information from this measurement program, it is difficult to infer the turbine off noise levels at elevated hub height wind speeds with high confidence. The turbine off noise data at lower wind speeds demonstrated a weak relationship when using polynomial and linear regression, yet a linear fit was applied for extrapolating into higher wind speed bins. Although it is likely that the turbine contribution remains significant at the higher wind speeds, it cannot be stated decisively based on the observed data since the turbine off data used in the analysis captures only one night at lower wind speeds. Additional noise measurements, under different wind speeds and directions, would provide for a more robust assessment of wind turbine noise contribution at this property.

A trend was observed at both properties, where the turbine contribution increased beyond 85% rated power. Modern pitched wind turbines typically reach their maximum noise levels at 85%-90% of rated power, after which the noise levels remain fairly constant or occasionally slightly decrease. This is due to the feathering of the blades in higher wind speeds, which limits the rotational speed of the rotor and reduces torque. Therefore, the aerodynamic noise typically does not increase. The Vestas V82 is an active-stall wind turbine. The wind turbine uses a combination of blade pitch control, but also blade stall technology. Stall technology can lead to increased sound level emission at higher wind speeds. Therefore, the observed trend of increased noise beyond 85% of rated power, is likely explained by the wind turbine technology. Based on the information in this report, it is observed that turbine contribution exceedances begin to occur in the 12 m/s hub height wind speed bin, which includes wind speeds from 11.5 m/s and up.

A preliminary acoustic model was developed for the Project in order to determine which turbines would be curtailed [4]. The modeling was done with the CadnaA acoustic propagation software, which uses the ISO 9613-2 model [8]. Model results indicate that the cumulative contribution from all nearby turbines on the Langrud property should be 1-2 dB higher than the Hagen property, for a given hub height wind speed. This preliminary comparative analysis did not consider foliage, property layout or atmospheric conditions. The model did suggest while many turbines have the potential to contribute to the cumulative noise within the acoustic environment, the primary contributor of wind turbine noise at Langrud is the nearest wind turbine (#362) and the primary contributors of wind turbine noise at Hagen are the nearest two turbines (#132) and (#397).

5 CONCLUSION

DNV GL has completed this Phase 2 post-construction noise assessment in accordance with the Phase 2 Post-Construction Noise Measurement Study Protocol (DNV GL Protocol) [3]. Relevant aspects of the IEC 61400-11 Ed 3 standard for wind turbine sound level measurements were also used as reference. More specifically, the assessment was requested by EERA due to an audit conducted in June 2017 [1] which showed total noise exceedances at two complaint receptors within the Project Area; the Hagen and Langrud receptors.

Based on the measured data and analysis, turbine contribution in excess of 50 dBA Leq can occur at the Langrud property when hub height wind speeds reach 11.5 m/s and higher, while extrapolated data shows similar trends for the Hagen property. Sound levels vary greatly depending on hub height wind speed, and wind direction to a lesser degree. Additional data collection would confirm which hub height speeds and direction combination cause exceedances, and would help validate the preliminary findings at the Hagen residence during higher wind speeds.

It is probable that the nearest turbine to the Langrud property is the primary contributor during exceedances. As well, preliminary findings indicate that the two turbines nearest the Hagen property may also contribute to noise exceedances, based on the turbine contribution calculations at lower wind speeds.

6 REFERENCES

[1] DNV GL. Bent Tree Wind Farm: Post-Construction Noise Measurement Assessment. File No 10046144-HOU-R-02-B, 30 August 2017.

[2] Minnesota Department of Commerce, Energy Facilities Permitting. Guidance for Large Wind Energy Conversion System Noise Study Protocol and Report. 8 October 2012.

[3] Minnesota Pollution Control Agency. A Guide to Noise Control in Minnesota – Acoustic Properties, Measurement, Analysis and Regulation. 2008, including Minnesota Administrative Rules 7030.0040 Noise Standards. Posted 12 December 2003; https://www.revisor.leg.state.mn.us/rules/?id=7030.0040.

[4] DNV GL. Bent Tree Wind Farm: Phase 2 Post-Construction Noise Measurement Study Protocol. 27 September 2017.

[5] Turbine curtailment and wind speed records sent by email from Andrew Hanson, Alliant Power to L. Miltich, Minnesota Department of Commerce, S. Dokouzian, DNV GL, 5 December 2017, "Sound Study Data.xlsx", "Power Curve.xlsx".

[6] International Electrotechnical Commission. IEC 61400-11 Wind Turbine Generator Systems – Part 11: Acoustic Measurement Techniques. 07 November 2012.

[7] Survey of Operational Sound Levels Bent Tree Wind Farm. Hessler Associates, Inc. June 17, 2011.

[8] International Organization for Standardization. ISO 1996-2: Acoustics – Description, measurement, and assessment of environmental noise – Part 2: Determination of environmental noise levels. 2008.

APPENDIX A – NEARBY TURBINES TO MEASUREMENTS POINTS

Turbines within 2.4 km (1.5 miles) of each measurement point are listed in the table below.

Turbine ID	Easting	Northing	Corresponding Measurement Point
T212	463605	4843373	Langrud (M01)
T215	463487	4842910	Langrud (M01)
T220	463543	4842412	Langrud (M01)
T233	462250	4842035	Langrud (M01)
T235	462002	4842033	Langrud (M01)
T236	461353	4841760	Langrud (M01)
T239	462266	4841548	Langrud (M01)
T241	464857	4842126	Langrud (M01)
T242	464133	4841911	Langrud (M01)
T323	461124	4842656	Langrud (M01)
T324	461661	4842451	Langrud (M01)
T325	464357	4842609	Langrud (M01)
T362	462655	4842008	Langrud (M01)
T368	464659	4842396	Langrud (M01)
T369	464424	4842187	Langrud (M01)
T380	462503	4841682	Langrud (M01)
T383	461749	4841732	Langrud (M01)
T385	461300	4842304	Langrud (M01)
T427	464076	4842611	Langrud (M01)
T440	464399	4843200	Langrud (M01)
T122	462032	4848134	Hagen (M02)
T123	461789	4848005	Hagen (M02)

T127	463548	4848137	Hagen (M02)
T131	463816	4847430	Hagen (M02)
T132	463324	4847251	Hagen (M02)
T134	464343	4848417	Hagen (M02)
T135	463846	4848264	Hagen (M02)
T141	464733	4847071	Hagen (M02)
T151	461771	4846535	Hagen (M02)
T152	461356	4846831	Hagen (M02)
T161	463727	4845838	Hagen (M02)
T162	463592	4845462	Hagen (M02)
T163	462497	4845748	Hagen (M02)
T166	461883	4845729	Hagen (M02)
T168	464023	4846121	Hagen (M02)
T169	464341	4845718	Hagen (M02)
T170	464102	4845475	Hagen (M02)
T283	462210	4846230	Hagen (M02)
T284	462537	4846228	Hagen (M02)
T285	464575	4845843	Hagen (M02)
T357	462865	4846369	Hagen (M02)
T358	463725	4846605	Hagen (M02)
T359	464791	4846106	Hagen (M02)
T397	463111	4846525	Hagen (M02)
T420	463205	4847812	Hagen (M02)
T422	461531	4846450	Hagen (M02)
T436	461228	4846459	Hagen (M02)
T437	461406	4846058	Hagen (M02)

T456	462723	4845507	Hagen (M02)

UTM NAD83 Zone 15

APPENDIX B – MEASUREMENT POINT PHOTOS

BT-M01 facing West

BT-M01 facing South

BT-M02 facing Northwest

BT-M02 facing West

APPENDIX C – MICROPHONE WIND SPEED BINS

Appendix C contains measured nighttime sound levels sorted into microphone wind speed bins, by the nearest whole integers. Microphone measurements above 5 m/s were omitted from the noise study. As a result, the 5 m/s bin contains values from 4.5 to 5 m/s only.

The Langrud property was filtered to include wind directions from the west +/- 45 degrees, to concentrate on contributions from the nearest turbines and avoid shielding from the buildings.

The Hagen property was filtered with a directional filter from 250 to 330 degrees. This was done to remove the first night of measurements with the turbines off as further discussed in 3.2, and improve signal-to-noise ratio.

Table C-1 Measured Results Binned per Ground Wind Speed for BT-M01 Langrud

	Turbine OFF			Turbine On			
Microphone Wind Speed (m/s)	**Average Level (dBA)**	**Number of Samples**	**Standard Deviation (dBA)**	**Average Level (dBA)**	**Number of Samples**	**Standard Deviation (dBA)**	**Turbine Contribution (dBA)**
1	41	658	2.8	41	6549	2.9	**34**
2	41	1318	2.2	46	4389	3.5	**44**
3	44	1420	2.0	50	2680	3.2	**49**
4	44	25	2.0	55	693	3.2	**55**
5	41*	1*	-	56	26	2.6	**56***
* – There is higher uncertainty in result since there is only one sample							

Table C-2 Measured Results Binned per Ground Wind Speed for BT-M02 Hagen

	Turbine Off			Turbine On			
Microphone Wind Speed (m/s)	**Average Level (dBA)**	**Number of Samples**	**Standard Deviation (dBA)**	**Average Level (dBA)**	**Number of Samples**	**Standard Deviation (dBA)**	**Turbine Contribution (dBA)**
1	34	1678	2.7	43	7728	2.7	**43**
2	37	676	2.5	46	2096	3.3	**46**
3	40*	1*	-	49	664	2.6	**49***
4	N/A	N/A	N/A	53	282	1.6	**N/A**
5	N/A	N/A	N/A	55	75	1.2	**N/A**
N/A – Not applicable. No measurements were captured in this range. * – There is higher uncertainty in result since there is only one sample							

APPENDIX D – CALIBRATION SHEETS

Certificate of Calibration and Conformance

This document certifies that the instrument referenced below meets published specifications per Procedure PRD-P263; ANSI S1.4-1983 (R 2006) Type 1; S1.4A 1985; S1.43-1997 Type 1; S1.11-2004 Octave Band Class 0; S1.25-1991; IEC 61672-2002 Class 1; 60651-2001 Type 1; 60804-2000 Type 1; 61260-2001 Class 0; 61252-2002.

Manufacturer:	Larson Davis	Temperature:	75.1	°F
Model Number:	831		23.94	°C
Serial Number:	3172	Rel. Humidity:	45.8	%
Customer:	TMS Rental	Pressure:	922.1	mbars
Description:	Sound Level Meter		922.1	hPa

Note: As Found / As Left: In Tolerance

Upon receipt for testing, this instrument was found to be:

Within the stated tolerance of the manufacturer's specification.

Calibration Date: 3/15/2017 Calibration Due:

Calibration Standards Used:

Manufacturer	Model	Serial Number	Cal Due
Stanford Research Systems	DS360	123270	4/19/2017
Larson Davis	2239	109	4/22/2017

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Andy McGuire Signature:

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Certificate of Calibration and Conformance

This document certifies that the instrument referenced below meets published specifications per Procedure PRD-P263; ANSI S1.4-1983 (R 2006) Type 1; S1.4A-1985; S1.43-1997 Type 1; S1.11-2004 Octave Band Class 0; S1.25-1991; IEC 61672-2002 Class 1; 60651-2001 Type 1; 60804-2000 Type 1; 61260-2001 Class 0; 61252-2002.

Manufacturer:	Larson Davis	Temperature:	74.9	°F
Model Number:	831		23.83	°C
Serial Number:	2661	Rel. Humidity:	42.1	%
Customer:	TMS Rental	Pressure:	997.5	mbars
Description:	Sound Level Meter		997.5	hPa

Note: As Found/As Left: In Tolerance

Upon receipt for testing, this Instrument was found to be:

Within the stated tolerance of the manufacturer's specification.

Calibration Date: 9/15/2017 Calibration Due:

Calibration Standards Used:

Manufacturer	Model	Serial Number	Cal Due
Stanford Research Systems	DS360	123270	4/25/2018

This Certificate attests that this Instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Adam Magee Signature: Adam Magee

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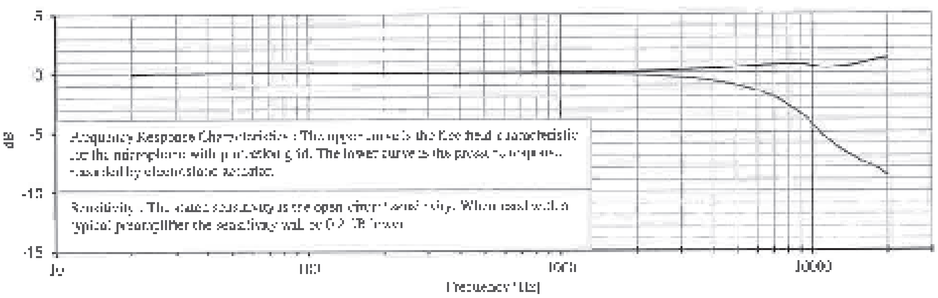
Manufacturer:	PCB	**Customer:**	TMS Rental
Model Number:	377B02	**Address:**	
Serial Number:	158135		
Asset ID:		**Calibration Date:**	Jul 27, 2017 12:22:03
Description:	Free Field Microphone	**Due Date:**	

Sensitivity:	**250 Hz**	**1 kHz**		**Temperature:**	75 (24)	°F (°C)
	-26.72	-26.79	dB re. 1V/Pa	**Humidity:**	46	%
	46.15	45.76	mV/Pa	**Ambient Pressure:**	992.1	mbar
Cal. Results:	In Tolerance			**Polarization Voltage:**	0	VDC



Traceability: The calibration is traceable through 683/284413-14

Notes: Calibration results relate only to the items calibrated.
This certificate may not be reproduced, except in full, without written permission.
This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
Measurement uncertainty (250 Hz sensitivity calibration) at 95% confidence level 0.40 dB.
Calibrated per procedure PRD-P204

User Note: As Found / As Left: In Tolerance.

Frequency Response with reference to level at 250 Hz

Frequency (Hz)	Upper (dB)	Frequency (Hz)	Upper (dB)	Frequency (Hz)	Upper (dB)	Frequency (Hz)	Upper (dB)
20	-0.11	630	0.03	4500	0.38		
25	-0.01	800	0.04	5000	0.46		
31.5	-0.04	1000	0.05	5600	0.54		
40	0.01	1120	0.06	6300	0.62		
50	0.01	1250	0.06	7100	0.68		
63	0.02	1400	0.08	8000	0.69		
80	0.01	1600	0.07	9000	0.72		
100	0.02	1800	0.09	10000	0.77		
125	0.02	2000	0.11	11200	0.78		
160	0.01	2240	0.13	12500	0.46		
200	0.00	2500	0.17	14000	0.60		
250	0.00	2800	0.20	16000	0.59		
315	0.00	3150	0.24	18000	1.08		
400	-0.01	3550	0.24	20000	1.26		
500	0.02	4000	0.22				

Technician: Ed Devlin

Approval:

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
GRAS	40AG	9542	9/20/2016	9/20/2017

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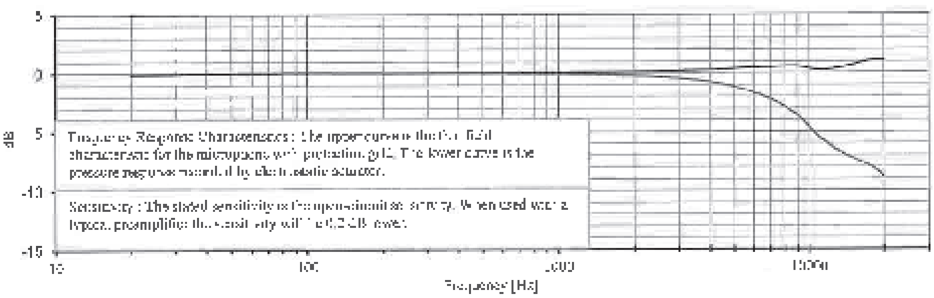
Manufacturer:	PCB			**Customer:**	TMS Rental	
Model Number:	377B02			**Address:**		
Serial Number:	155539					
Asset ID:				**Calibration Date:**	Jul 27, 2017 11:00:00	
Description:	Free-Field Microphone			**Due Date:**		
Sensitivity:	250 Hz	1 kHz		**Temperature:**	76 (24)	°F (°C)
	-26.47	-26.55	dB re. 1 V/Pa	**Humidity:**	44	%
	47.47	47.04	mV/Pa	**Ambient Pressure:**	992.7	mbar
Cal. Results:	In Tolerance			**Polarization Voltage:**	0	VDC



Traceability:	The calibration is traceable through 683/284413-14.
Notes:	Calibration results relate only to the items calibrated.
	This certificate may not be reproduced, except in full, without written permission.
	This calibration is performed in compliance with ISO 9001, ISO 17025 and ANSI Z540.
	Measurement uncertainty (250 Hz sensitivity calibration) at 95% confidence level: 0.20 dB.
	Calibrated per procedure PRD-P204
User Note:	As Found / As Left, In Tolerance

Frequency Response with reference to level at 250 Hz

Frequency (Hz)	Upper (dB)	Frequency (Hz)	Upper (dB)	Frequency (Hz)	Upper (dB)	Frequency (Hz)	Upper (dB)
20	0.10	630	-0.01	4500	0.20		
25	-0.10	800	0.03	5000	0.35		
31.5	-0.06	1000	0.01	5600	0.45		
40	0.03	1120	0.05	6300	0.47		
50	0.02	1250	0.05	7100	0.51		
63	0.02	1400	0.05	8000	0.56		
80	0.05	1600	0.05	9000	0.57		
100	0.03	1800	0.07	10000	0.56		
125	0.03	2000	0.09	11200	0.23		
160	0.01	2240	0.11	12500	0.31		
200	0.01	2500	0.14	14000	0.54		
250	0.00	2800	0.16	16000	0.87		
315	0.00	3150	0.20	18000	1.12		
400	-0.0?	3550	0.22	20000	1.12		
500	0.01	4000	0.24				

Technician: Bradly Haarmeyer

Approval: [signature]

Reference Equipment Used:

Manuf	*Model*	*Serial*	*Cal. Date*	*Due Date*
GRAS	40AG	58934	9/20/2016	9/20/2017

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Manufacturer:	Larson Davis	Asset ID:	
Model:	CAL200	Calibration Date:	Jul 11, 2017 12:52:07
Serial Number:	13271	Due Date:	
Description:	Acoustic Calibrator	Technician:	Ed Devlin
Customer:	TMS Rental	Approval:	

Calibration Results:	Temperature:	24 °C (75 °F)
Measured SPL : 94.01 dB re. 20µPa	Humidity:	46.00%
Measured Frequency : 1,000.00 Hz	Pressure:	993.3 mbar

Upon receipt for calibration, the instrument was found to be:
WITHIN the stated tolerance of the manufacturer's specification.

Note: **As Found / As Left: In Tolerance.**

Measurement uncertainty at 95% confidence level: 0.25 dB

The subject instrument was calibrated to the indicated specification using standards stated below or to accepted values of natural physical constants. This document certifies that the instrument met the following specification

This calibration is traceable through : 683/284413-14

Notes:
The calibration was performed under operating procedures intended to implement the requirements of ISO 9001, ISO 17025 and ANSI Z540. Unless otherwise noted, the reported value is both "as found" and "as left" data. Calibration results relate only to the items calibrated. This certificate may not be reproduced, except in full, without written permission.

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
GRAS	40AG	9542	9/20/2016	9/20/2017

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Manufacturer:	Larson Davis	Asset ID:	
Model:	CAL200	Calibration Date:	Jul 11, 2017 12:56:30
Serial Number:	13271	Due Date:	
Description:	Acoustic Calibrator	Technician:	Ed Devlin
Customer:	TMS Rental	Approval:	

Calibration Results:

Measured SPL : 114.05 dB re. 20µPa		Temperature:	24 °C (75 °F)
Measured Frequency : 1,000.00 Hz		Humidity:	46.00%
		Pressure:	993.3 mbar

Upon receipt for calibration, the instrument was found to be:
WITHIN the stated tolerance of the manufacturer's specification.

Note: **As Found / As Left: In Tolerance.**

Measurement uncertainty at 95% confidence level: 0.25 dB

The subject instrument was calibrated to the indicated specification using standards traceable to or to accepted values of natural physical constants. This document certifies that the instrument met the following specification

This calibration is traceable through : 683/284413-14

Notes:
The calibration was performed under operating procedures intended to implement the requirements of ISO 9001, ISO 17025 and ANSI Z540. Unless otherwise noted, the reported value is both "as found" and "as left" data. Calibration results relate only to the items calibrated. This certificate may not be reproduced, except in full, without written permission.

Reference Equipment Used:

Manuf.	*Model*	*Serial*	*Cal. Date*	*Due Date*
GRAS	40AG	9542	9/20/2016	9/20/2017

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