Odell Wind Farm

Post-Construction Noise Study Methodology

April 2016

Prepared for:

Odell Wind Farm, LLC
c/o Algonquin Power Co.
354 Davis Road
Oakville, Ontario L6J 2X1

Prepared by:

160 Federal Street
Boston, Massachusetts 02110

TABLE OF CONTENTS

1.0 INTRODUCTION 1
2.0 NOISE CRITERIA 1
3.0 MEASUREMENT METHODS 3
3.1 Instrumentation 3
3.2 Field Measurement Procedure 4
4.0 MEASUREMENT LOCATIONS 5
5.0 DATA PROCESSING AND REPORTING 8
6.0 CONCLUSION 10

LIST OF TABLES

Table 2-1. Minnesota Noise Standards 2
Table 3-1. Measurement Equipment Used 3
Table 4-1. Post-Construction Sound Monitoring Locations 6

LIST OF FIGURES

Figure 3-1. Sound Monitoring Station 4
Figure 4-1. Project Area and Post-Construction Sound Monitoring Locations 7
Figure 5-1. Example - Time History Series Plot 9
Figure 5-2. Example – Spectral Sound Pressure Level Plot 9

ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
Commission	Minnesota Public Utilities Commission
dB	decibel
dBA	A-weighted decibel
dBC	C-weighted decibel
Hz	Hertz
kHz	kiloHertz
L_{eq}	equivalent sound level
L_n	statistical sound level
L_{50}	median sound level; noise level exceeded 50 percent of the time period
L_{90}	residual sound level; noise level exceeded 90 percent of the time period
L_{10}	intrusive sound level; noise level exceeded 10 percent of the time period
LWECS	Large Wind Energy Conversion System
ML	monitoring location
MPCA	Minnesota Pollution Control Agency
mph	miles per hour
MW	megawatt
NAC	Noise Area Classification
NIST	National Institute of Standards and Technology
Project	Odell Wind Farm

1.0 INTRODUCTION

Odell Wind Farm, LLC plans to construct and operate the Odell Wind Farm (Project), which is considered a Large Wind Energy Conversion System (LWECS) as defined in the Wind Siting Act, Minnesota Statutes, Chapter 216F. The Project will be located within Cottonwood, Jackson, Martin, and Watonwan counties near Mountain Lake, Minnesota. The planned output for the Project is up to 200 megawatt (MW) of wind energy capacity using 100 turbines.

This post-construction noise study methodology was prepared to satisfy the requirements of Section 6.6 of Odell Wind Farm, LLC's Site Permit issued by the Minnesota Public Utilities Commission (Commission) and the Minnesota Department of Commerce, *Energy Facility Permitting Guidance for Large Wind Energy Conversion System Noise Study Protocol and Report*. Specifically, Section 6.6 of the Site Permit states:

> *The Permittee shall file a proposal with the Commission at least fourteen (14) days prior to the pre-operation compliance meeting for the conduct of a post-construction noise study. Upon the approval of the Commission, the Permittee shall carryout the study. The study shall be designed to determine the operating LWECS noise levels at different frequencies and at various distances from the turbines at various wind directions and speeds. The Permittee shall file the study within eighteen (18) months after commercial operation.*

In addition, the Minnesota Department of Commerce, prescribes that the monitoring will provide information to:

1. confirm the validity of the noise modeling conducted prior to permit issuance or prior to construction;
2. assess the modeling as a predictor of probable compliance with Minnesota noise standards; and
3. determine the noise levels at different frequencies and at multiple distances from the turbines at various wind directions and speeds.

Therefore, the post-construction noise study methodology will document Project sound levels at various frequencies and distances from the turbines under a range of operational conditions through the collection of operational sound level measurements and a comparative analysis with pre-construction and background sound level measurements.

This protocol, prepared by Tetra Tech, Inc., describes the proposed measurement methodology, equipment, monitoring locations, and information related to data processing and reporting.

2.0 NOISE CRITERIA

At the state level, the Minnesota Pollution Control Agency (MPCA) regulations (Chapter 7030, Noise Pollution Control) provide numerical decibel limits applicable during operation of wind energy projects. The noise standards are absolute and independent of the existing acoustic environment and are defined according to Noise Area Classification (NAC), which is based on the land use activity at the receiver. NAC 1 represents the most sensitive land uses, such as medical and other health services, educational services, religious activities, transient lodging, residential hotels, and household units, which are assessed in this preliminary screening level acoustic modeling analysis. The MPCA noise standards, which are applicable to all sources, identify statistical limits that are also based on time of day (Table 2-1).

Table 2-1. Minnesota Noise Standards

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

3.0 MEASUREMENT METHODS

Equipment, measurement settings, and data collected for the post-construction measurements will be consistent with MPCA requirements outlined in the *Measurement Procedure for Non-Impulsive Noise*, designated by MPCA as method NTP-1, and the Minnesota Department of Commerce, *Energy Facility Permitting Guidance for Large Wind Energy Conversion System Noise Study Protocol and Report*.

3.1 Instrumentation

All measurements will be taken with a Larson Davis 831 real-time sound level analyzer equipped with a PCB model 377B02 ½-inch precision condenser microphone. This instrument has an operating range of 5 decibels (dB) to 140 dB and an overall frequency range of 8 to 20,000 hertz (Hz) and meets or exceeds all requirements set forth in the American National Standards Institute (ANSI) standards for Type 1 sound level meters for quality and accuracy (precision). All instrumentation components, including microphones, preamplifiers and field calibrators, will have current laboratory certified calibrations traceable to the National Institute of Standards and Technology (NIST). Meters are always in-situ field calibrated prior to each measurement period. Table 3-1 provides a summary of the measurement equipment.

Table 3-1. Measurement Equipment Used

Description	Manufacturer	Type
Signal Analyzer	Larson Davis	831H
Weather Transmitter	Vaisala	WXT520
Microphone	PCB	377B02
Windscreen	ACO Pacific	7-inch
Calibrator	Larson Davis	CAL200

The monitoring stations are designed for service as a long-term environmental sound level data-logger measuring devices. Each sound level analyzer will be enclosed in a weatherproof case and equipped with a self-contained microphone tripod. The microphone and windscreen were tripod-mounted at an approximate height of 1.5 to 1.7 meters (4.9 to 5.6 feet) above grade. When sound measurements are attempted in the presence of elevated wind speeds, extraneous noise can be self-generated across the microphone and is often referred to as pseudonoise. Air blowing over a microphone diaphragm creates a pressure differential and turbulence. All sound level analyzer microphones are protected from wind-induced pseudonoise by a 180-millimeter (7-inch) diameter foam windscreen made of specially prepared open-pored polyurethane. By using this microphone protection, the pressure gradient and turbulence are effectively moved farther away from the microphone, minimizing self-generated wind-induced noise. Figure 3-1 shows a photograph of a sound monitoring station.

Select monitoring locations will also be equipped with a Vaisala portable weather transmitter. The Vaisala unit monitors wind speed and direction via an ultrasonic anemometer, and also measures barometric pressure, temperature and humidity, total rainfall, and duration of rainfall. The Vaisala unit is also able to distinguish between precipitation types such as rain, hail, and snow. Weather data collected by the Vaisala unit will be supplemented by data obtained from on-site meteorological stations operated by Odell Wind Farm, LLC, shown on Figure 4-1.

Figure 3-1. Sound Monitoring Station

3.2 Field Measurement Procedure

A fixed outdoor monitoring location (ML) will be chosen at each receptor to be representative of areas of frequent outdoor use. At each ML, the sound level analyzer is set up, field-calibrated, and programmed to data log continuously during daytime (7:00 a.m. to 10:00 p.m.) and nighttime (10:00 p.m. to 7:00 a.m.) periods.

Each sound analyzer will be programmed to measure and log broadband A-weighted, C-weighted, and unweighted sound pressure levels in 10- and 1-minute time intervals, as well as a number of statistical sound levels (L_n). The L_n provide the sound level exceeded for that percentage of time over the given measurement period. For example, the L_{10} level is often referred to as the intrusive noise level and is the sound level that is exceeded for 10% of the measurement period. The equivalent sound level (L_{eq}), L_{10}, L_{50} (median), and L_{90} (residual sound level) sound metrics will be data-logged. Data will be collected in 1/1 and 1/3 octave bands spanning the frequency range of 8 Hz to 20 kilohertz (kHz). To summarize, to fully characterize the ambient acoustic environment of the Project area the following information will be collected:

- A-weighted (dBA) L_{10}, L_{50}, L_{90} and L_{eq} values on an hourly basis;
- C-weighted (dBC) L_{10}, L_{50}, L_{90} and L_{eq} values on an hourly basis;
- Unweighted (dB) L_{10}, L_{50}, L_{90} and L_{eq} values on an hourly basis;
- A-weighted (dBA) one-third octave-band sound levels ranging from 6.3 Hz to 20 kHz;
- C-weighted (dBC) one-third octave-band sound levels ranging from 6.3 Hz to 20 kHz; and
- Unweighted (dB) one-third octave-band sound levels ranging from 6.3 Hz to 20 kHz.

At least three measurement locations will include continuous or triggered audio recording. This audio file will allow the review of actual noise events that influenced noise-monitoring results. Through this review, extraneous noise events may be identified and excluded from the data set. Temporary weather stations at the most open and exposed measurement locations will be used to record wind speed at microphone height and other parameters, such as precipitation and humidity.

A post-construction sound survey of 7 to 14 days be conducted within 18 months of the commercial operation date. However, survey could be extended in the event that the data collected may not be considered representative of normal Project operation due to reasons such as meteorological conditions, equipment malfunction, etc.

For any purpose relating to the Minnesota noise standard, the MPCA recommends the removal of noise data where wind speeds at microphone height (at least 3 feet above the surface) are greater than 11 miles per hour (mph). In addition, the MPCA requests the removal of noise data during periods of precipitation. Accordingly, Tetra Tech will remove these data and this subset will be used for further data processing.

4.0 MEASUREMENT LOCATIONS

In July 2013, a pre-construction baseline sound survey was conducted by WSB & Associates, Inc., which included three MLs within the Project area as well as one off-site ML that were determined to be representative of the existing ambient acoustic environment within the Project area. For the post-construction sound survey, Tetra Tech plans to use four MLs within the Project area and two MLs outside of the Project area. Two MLs will be new, three MLs will be the same as those used during the pre-construction baseline sound survey, and one ML outside of the Project area will be located near where the pre-construction survey occurred but not at the exact location due to limitations on property access. Prior to the sound monitoring program, Odell Wind Farm, LLC will arrange for any necessary landowner permissions needed so that Tetra Tech may access property and deploy equipment. Monitoring locations within the Project area were selected with some of the following considerations:

1. MLs were selected based on their geographical location within the Project area and with respect to the proposed wind turbine locations;
2. Incorporating all three MLs included within the Project area during the pre-construction sound survey would allow for a direct comparison of sound levels before and after Project operation; and
3. One ML (ML-2) will be in proximity to the receptor with the highest predicted received sound levels as established via Project acoustic modeling analysis.

Per the Minnesota Department of Commerce guidance, monitoring will not be conducted in areas that are expected to reflect or absorb sound or where there are obstructions to sound. In terms of scheduling, monitoring is planned to occur within approximately two weeks of the anniversary starting date of the pre-construction baseline sound survey so that the same seasonal time period is captured.

Table 4-1 summarizes the selected MLs including their UTM coordinates, nearest turbine relative to each ML, and distance from each ML to the nearest turbine. Figure 4-1 also presents the location of the proposed MLs relative to the Project; ML-1 and ML-2 are representative of participating and non-participating receptors and ML-1 is where pre-construction monitoring occurred. ML-1 and ML-2 are predicted to experience the highest levels of Project-related noise based on the pre-construction noise modeling results. Monitoring will occur at these locations or other locations expected to experience Project noise impacts based on previous modeling. ML-3 and ML-4 are consistent with pre-construction monitoring locations in the northern and eastern portions of the Project area, respectively. All four MLs are located in different sectors of the Project area, thereby capturing Project sound levels from various distances and directions.

Table 4-1. Post-Construction Sound Monitoring Locations

Monitoring Location ID	UTM Coordinates		Nearest Wind Turbine	Distance to Nearest Wind Turbine (feet/meters)	Description
	Easting (meters)	Northing (meters)			
ML-1	340,698	4,858,461	T-82	2,103/641	Pre-construction monitoring location and participant expected to experience the highest Project noise impacts based on previous modeling analysis.
ML-2	341,857	4,855,594	T-29	1,824/556	Non-participant expected to experience the highest Project noise impacts based on previous modeling analysis.
ML-3	347,457	4,861,873	T-104	1,932/589	Pre-construction monitoring location in the northern portion of the Project area.
ML-4	344,729	4,853,570	T-11	617/188	Pre-construction monitoring location in the eastern portion of the Project area.
ML-5	352,814	4,863,281	T-111	14,190/4,325	Background monitoring located to the northeast of the Project area near where pre-construction monitoring occurred.
ML-6	334,812	4,855,238	T-55	16,660/5,078	Background monitoring location located to the southwest of the Project area.

Primary Turbine Location

Alternate Turbine Location

Monitoring Location

Noise Sensitive Receptor

0 0.5 1

Miles

N

Figure 4-1
Project Area and Post-Construction
Sound Monitoring Locations
Cottonwood & Jackson County, Minnesota

Algonquin TETRA TECH

Source: Map adapted from Microsoft Bing Aerial Map Server, Algonquin Energy (Turbine Locations), Tetra Tech (Noise Sensitive Receptors & Monitoring Locations)

#1972015 S:\Projects\Algonquin Power\Cad\ltGIS\4-1.mxd dustin.mencel

While pre-construction measurements were performed, collection of additional background sound level measurements concurrent with operational sound level measurements is recommended. The purpose of these MLs is to establish the background noise levels outside of the Project area in locations and settings that are similar in nature to the on-site positions but remote from all turbine noise. Background measurement locations will be sited at least 1.5 miles from the nearest turbine to ensure that noise from operating wind turbines will not affect measurement data. On-site and background measurements off-site will be recorded concurrently.

Two MLs, ML-5 and ML-6, are located at least 2 miles outside the Project area. Information from ML-5 and ML-6 will be employed to provide further insight into background sound levels expected within the Project area. ML-5 will be located to the northeast of the Project area. It is expected that ML-5 will be sited near the off-site ML employed in the 2013 pre-construction baseline sound survey, which was located between 395th St and 400th St (CR 10) west of 630th Ave (CR 2). ML-6 will be located southwest of the Project area. This site is expected to have a similar ambient acoustic environment to that of ML-5 based on land use and proximity to major roadways.

5.0 DATA PROCESSING AND REPORTING

After the conclusion of the post-construction sound survey, a final report will be produced, which will provide a description of the measurement equipment, methodology, and sound survey results. The results of the post-construction sound survey will be presented in several different ways as prescribed in the Minnesota Department of Commerce, *Energy Facility Permitting Guidance for Large Wind Energy Conversion System Noise Study Protocol and Report*.

For data analysis, two data sets will be reviewed. One data set (data set 1) will include the entire measurement duration, and a second data set (data set 2) will exclude data collected during periods of high winds (greater than 11 mph at microphone height) and sporadic noise events. Data set 1 will present measurement data as the raw, unprocessed monitoring data, collected both inside and outside of the Project area, with minimal data processing. The data set will include all measurement data, regardless of wind speed at microphone height. The measurement data will be post-processed to exclude sporadic noise events. Data set 2 will be presented for comparison with MPCA noise standards. Data set 2 will be post-processed to exclude anomalous and spurious noises, such as planes flying over, passing cars, etc. Data set 2 will also exclude periods of precipitation and high winds at microphone height, per MPCA procedures. The resulting data set will be compared with Minnesota Pollution Control Noise Standards for residential land uses (MN Rules 7030.0040).

Time series charts will be created for each monitoring location showing A-weighted and C-weighted L_{eq}, L_{90}, L_{50}, and L_{10} sound metrics. These data will be normalized by the wind speed measured by the highest anemometers on all on-site met towers to a standard height of 10 m per Equation (7) of IEC 61400-11. On the same chart, a time series for precipitation and wind speed at both hub height and microphone height will also be presented. For the charts presenting sound levels for wind speeds less than 11 mph, only the L_{10} and L_{50} sound metrics will be described for comparison with the Minnesota noise standards. All data points that appear to be associated with local contaminating noises (i.e., "spikes" of sporadic noise such as a dog barking, or other observed change in sound level not accompanied by a simultaneous spike in wind speed) will be excluded. Any hourly L_{10} and L_{50} determinations that are above the daytime or nighttime Minnesota noise standards will be highlighted. Figure 5-1 shows an example of a time history graph depicting the L_{eq} sound level versus wind speed. Figures in the final report will also present results of other sound metrics and precipitation, as applicable, as mentioned above.

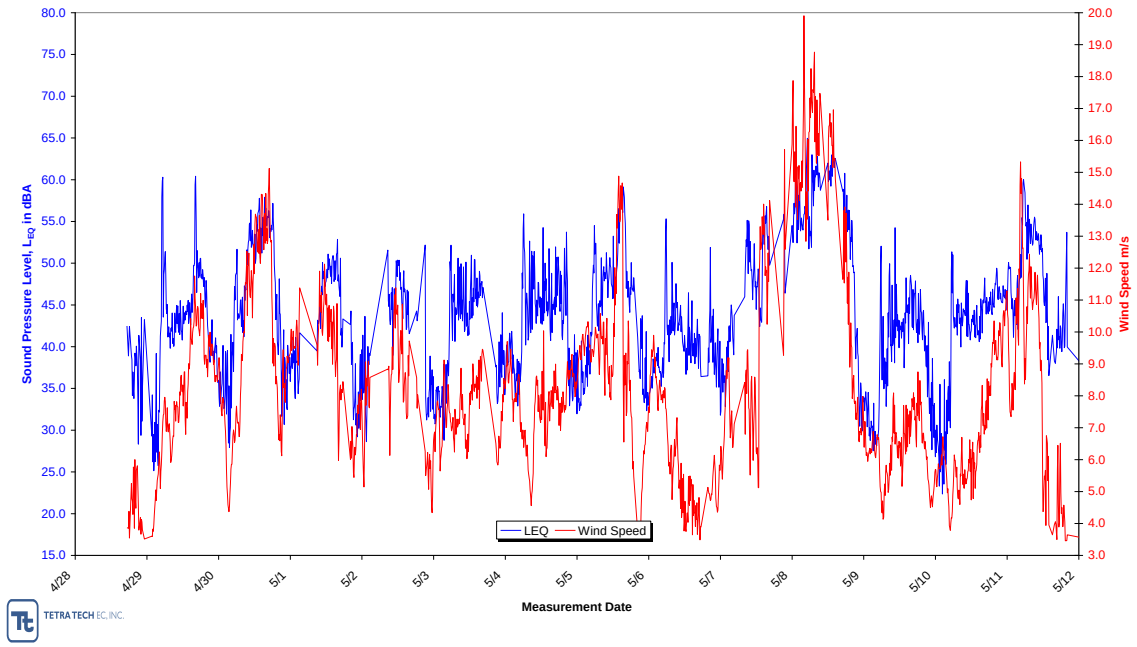

Figure 5-1. Example - Time History Series Plot

Results will also be reported in terms of 1/3 octave band levels for the worst-case receptors predicted by the model and for the off-site monitoring location collecting background sound level data. The 1/3 octave band analysis will be conducted using A-weighted and C-weighted frequencies spanning 12.5 Hz to 20 kHz. Figure 5-2 shows an example of how unweighted spectral data will be presented on a 1/3 octave band basis.

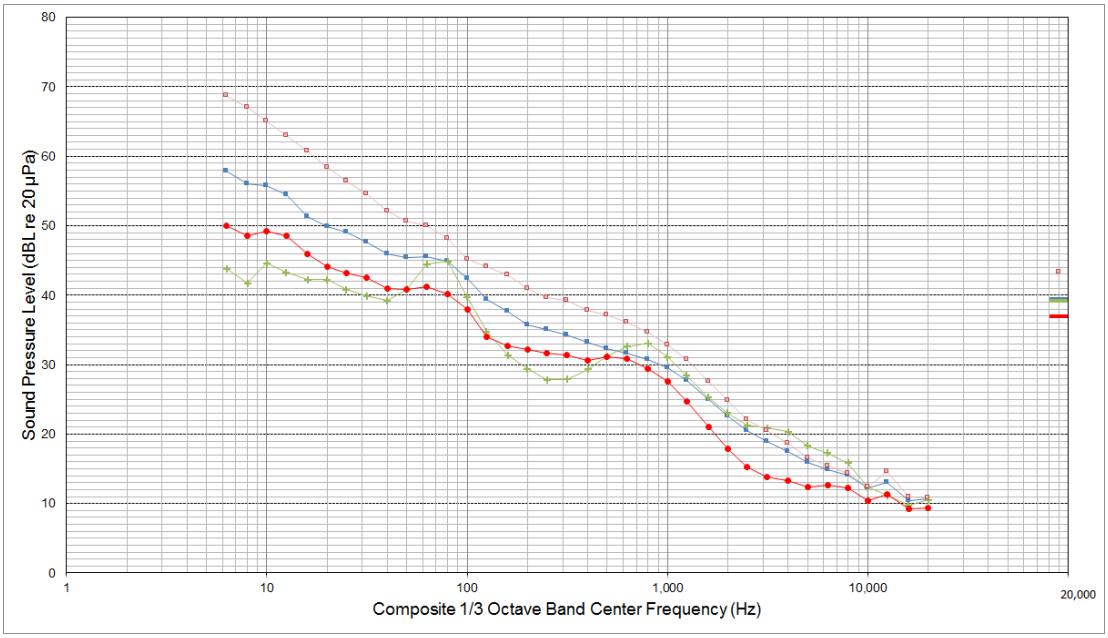

Figure 5-2. Example – Spectral Sound Pressure Level Plot

A map will also be presented showing the modeling that was completed previously in support of Project permitting. The sound contours will be presented as line, or transparent shading, in 5 dB increments overlaid on aerial imagery and the final Project wind turbine layout. Since modeling was completed prior to

construction, an explanation of the methodology, assumptions and applicable noise criteria will be provided.

The noise study report will also include a comparative analysis of measurement results to the preconstruction predicted sound levels for the Project. In addition, a summary of the L_{10} and L_{50} hourly determinations that are above the Minnesota noise standards for each monitoring location and a narrative conclusion regarding how well the results provide information regarding the modeling as a predictor of probable compliance with the Minnesota noise standards will be provided. An overall evaluation of how the results validate or do not validate the pre-construction sound modeling will be given.

The final noise study report will be e-filed and will include a cover letter summarizing the results and conclusions. Any changes from the approved protocol will be documented with an explanation as to the necessity of the changes and any impact the changes may have on interpretation of results. The previously e-filed protocol will also be included as an attachment, and information will be given regarding approvals of the protocol by the Commission and how and when the approvals were obtained.

6.0 CONCLUSION

Tetra Tech has designed this post-construction noise study plan in coordination with Odell Wind Farm, LLC to comply with the Project site permit reporting requirements. The final results will be compared to the pre-construction modeling results and will be evaluated with respect to the applicable design goal or ordinance limit. This proposed study plan establishes the procedures that will be used in the demonstration of compliance with the requirements of Section 6.6 of Odell Wind Farm, LLC's Site Permit issued by the Commission and the Minnesota Department of Commerce, *Energy Facility Permitting Guidance for Large Wind Energy Conversion System Noise Study Protocol and Report*.