SOUND LEVEL IMPACT ASSESSMENT REPORT

Minuteman Savoy Wind Project
Savoy, MA

Prepared for:

Minuteman Wind, LLC
890 Winter Street, Suite 170
Waltham, MA 02451

Prepared by:

Epsilon Associates, Inc.
3 Clock Tower Place, Suite 250
Maynard, MA 01754

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICIES

1.0 INTRODUCTION AND SUMMARY

This noise analysis for the proposed Minuteman Savoy Wind Project includes a noise-monitoring program to determine existing noise levels, and noise modeling analysis to assess future noise levels when the wind turbines are in operation. The analysis demonstrates that noise from the proposed wind turbines will not cause an impact as it will meet the standards of the Massachusetts Noise Policy, and will be below existing measured baseline noise levels in the area.

2.0 NOISE TERMINOLOGY

There are several ways in which sound (noise) levels are measured and quantified. All of them use the logarithmic decibel (dB) scale. The following information defines the noise measurement terminology used in this analysis.

The decibel scale is logarithmic to accommodate the wide range of sound intensities found in the environment. A property of the decibel scale is that the sound pressure levels of two separate sounds are not directly additive. For example, if a sound of 50 dB is added to another sound of 50 dB, the total is only a three-decibel increase (to 53 dB), not a doubling to 100 dB. Thus, every three dB change in sound levels represents a doubling or halving of sound energy. Related to this is the fact that a change in sound levels of less than three dB is imperceptible to the human ear.

Another property of decibels is that if one source of noise is 10 dB (or more) louder than another source, then the total sound level is simply the sound level of the higher source. For example, a source of sound at 60 dB plus another source of sound at 47 dB is 60 dB.

The sound level meter used to measure noise is a standardized instrument. It contains "weighting networks" to adjust the frequency response of the instrument to approximate that of the human ear under various circumstances. One network is the A-weighting network (there are also B- and C-weighting networks). The A-weighted scale (dBA) most closely approximates how the human ear responds to sound at various frequencies. Sounds are frequently reported as detected with the A-weighting network of the sound level meter. A-weighted sound levels emphasize the middle frequency (*i.e.,* middle pitched – around 1,000 Hertz sounds), and de-emphasize lower and higher frequency sounds. A-weighted sound levels are reported in decibels designated as "dBA."

Because the sounds in our environment vary with time they cannot simply be described with a single number. Two methods are used for describing variable sounds. These are exceedance levels and the equivalent level, both of which are derived from a large number of moment-to-moment A-weighted sound level measurements. Exceedance levels are values from the cumulative amplitude distribution of all of the sound levels observed during a measurement period. Exceedance levels are designated L_n, where n can have a value of 0 to 100 percent. For example:

- L_{90} is the sound level in dBA exceeded 90 percent of the time during the measurement period. The L_{90} is close to the lowest sound level observed. It is essentially the same as the residual sound level, which is the sound level observed when there are no obvious nearby intermittent noise sources.

- L_{50} is the median sound level: the sound level in dBA exceeded 50 percent of the time during the measurement period.

- L_{10} is the sound level in dBA exceeded only 10 percent of the time. It is close to the maximum level observed during the measurement period. The L_{10} is sometimes called the intrusive sound level because it is caused by occasional louder noises like those from passing motor vehicles.

- L_{eq}, the equivalent level, is the level of a hypothetical steady sound that would have the same energy (*i.e.,* the same time-averaged mean square sound pressure) as the actual fluctuating sound observed. The equivalent level is designated L_{eq} and is also A-weighted. The equivalent level represents the time average of the fluctuating sound pressure, but because sound is represented on a logarithmic scale and the averaging is done with linear mean square sound pressure values, the L_{eq} is mostly determined by occasional loud noises.

By using various noise metrics it is possible to separate prevailing, steady sounds (the L_{90}) from occasional, louder sounds (L_{10}) in the noise environment or combined average levels (L_{eq}). This analysis of sounds expected from the Project treats all noises as though they will be steady and continuous and hence the L_{90} exceedance level was used. Baseline noise levels were measured in the vicinity of the proposed wind turbines and were compared to predicted noise levels that were derived based on information provided by the manufacturers of representative wind turbines.

3.0 NOISE REGULATIONS AND CRITERIA

The Massachusetts DEP regulates community noise by its *Noise Policy: DAQC Policy 90-001.* The DEP policy limits source sound levels to a 10-dBA increase above the ambient measured noise level (L_{90}) at the Project property line and at the nearest residences. The policy further prohibits pure tone conditions – when any octave band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by three decibels or more. This Policy is used to determine noise impacts for continuously operating stationary equipment in the state of Massachusetts.

4.0 WIND TURBINE NOISE

Wind turbine noise can originate from two different sources; mechanical generator equipment, and aerodynamic motion of the rotor blades. Prior to the 1990's, both were significant contributors to wind turbine noise. However, recent advances in wind turbine design have greatly reduced the contribution of mechanical noise. A visit to any recently installed windmill, such as the one in Hull, Massachusetts, will show that most of the observed noise comes from the aerodynamic motion of the rotor blades. Aerodynamic noise has also been reduced from modern wind turbines due to slower rotational speeds and changes in materials of construction.

Aerodynamic noise, in general, is broadband (has contributions from a wide range of frequencies) with a slightly higher concentration at lower frequencies. It originates from encounters of the wind turbine blades with localized airflow inhomogeneities and wakes from other turbine blades, and from airflow across the surface of the blades, particularly the front and trailing edges. This noise increases significantly with wind speed; however, because the background noise level also increases significantly with wind speed, wind turbine noise is most noticeable at a wind speed of about 8 meters/second (around 18 mph). Usually, the noise is highest at receptors located directly downwind of the wind turbine site. These conditions will be used to model the expected sound from these wind turbines.

Although wind turbine noise is not separately regulated by Massachusetts DEP, a study of wind turbine noise[1] indicates that, in general, it may be more annoying at a specific noise level than noise from other community noise sources. This is due to the time-varying sound level of the noise as the blades rotate, which makes it more noticeable, and to the nearly continuous (more than several hours at a time) duration of wind turbine noise. This study indicates that some people surveyed found wind turbine noise to be annoying at a level of 35 dBA, and about half of the people surveyed found wind turbine noise to be annoying at a level of about 40 dBA. Therefore, these levels will also be computed and displayed, as guidelines in determining locations where noise annoyance could occur.

5.0 EXISTING CONDITIONS

5.1 Baseline Noise Environment

An ambient noise level survey was conducted to characterize the existing "baseline" acoustical environment in the vicinity of the proposed wind turbine project.

[1] Eja Pederson and Kerstin Persson Waye, "Perception and annoyance due to wind turbine noise—a dose-response relationship", J. Acoustic Soc. Of Am., 116, (6) December, 2004.

Existing noise sources in the vicinity of the proposed turbine locations include: wind noise, and a few birds.

5.2 Noise Measurement Locations

The selection of the sound monitoring receptor locations was based upon a review of the current land use in the area surrounding the proposed wind turbine site. Five noise-monitoring stations were selected in representative locations to obtain a sampling of the ambient baseline noise environment. This area encompasses locations around the proposed wind turbine site. The measurement locations are depicted on Figure 1 and are described below.

- Location 1: at the end of Barnard Road near a residence.
- Location 2: at the southwestern property line.
- Location 3: near residences towards the end of West Hill Road, near the southeast property line corner.
- Location 4: at a wooded location off of Harwood Road at the property line near the northeast corner of the project site.
- Location 5: at a residence along Harwood Road to the north of the site.

5.3 Noise Measurement Methodology

Sound level measurements were made for 20 minutes per location during the daytime (between 12:00 p.m and 3:00 p.m.) on March 15, 2006, and nighttime hours (11:00 p.m. to 3:40 a.m.) on March 14-15, 2006. Since noise impacts are greatest when existing noise levels are lowest, the study was designed to measure noise levels under conditions typical of a "quiet period" for the area. Daytime measurements were scheduled to avoid peak traffic periods.

The sound levels were measured at locations near adjacent residences at a height of five feet above the ground and at locations where there were no large reflective surfaces to affect the measured levels. There was snow cover on the ground, which tends to absorb sound, reducing background noise levels. The measurements were made under typical wind turbine operational conditions (6-12 mph from the northwest during the day, and 5-15 mph from the northwest during the night). Wind speed measurements were made with a Davis Instruments TurboMeter electronic wind speed indicator, and temperature and humidity measurements were made using a Weksler Instruments model 317 glass sling psychrometer. Unofficial observations about meteorology or land use in the community were made to characterize the existing sound levels in the area and to estimate the noise sensitivity at properties near the proposed wind turbine project.

Figure 1 Sound Level Measurement Locations

5.4 Measurement Equipment

A CEL Instruments Model 593.C1 Precision Sound Level Analyzer equipped with a CEL-257 Type 1 Preamplifier, a CEL-250 half-inch microphone and a four-inch foam windscreen were used to collect broadband and octave band ambient sound pressure level data. The instrumentation meets the "Type 1 - Precision" requirements set forth in American National Standards Institute (ANSI) S1.4 for acoustical measuring devices. The meter was tripod-mounted at a height of five feet above ground. The meter was equipped with an internal octave band filter set along with data logging capabilities. The meter processed one sample per second using the "slow" response of the instrumentation.

Statistical levels were calculated from the 1200 sound levels collected during each 20-minute sampling period. Octave band levels for this study correspond to the same data set processed for the broadband levels. The measurement equipment was calibrated in the field before and after the surveys with a CEL-284/2 acoustical calibrator which meets the standards of IEC 942 Class 1L and ANSI S1.40-1984.

5.5 Baseline Ambient Noise Levels

The existing ambient noise environment is impacted by wind rustling in the trees, a few birds, and an occasional airplane. Baseline noise monitoring results are presented in Table 1, and summarized below. There were no "pure tones" measured during the measurement program. Nighttime levels were higher than daytime levels due to stronger winds at night.

- The daytime residual background (L_{90} dBA) measurements ranged from 44 to 48 dBA;
- The nighttime residual background (L_{90} dBA) measurements ranged from 43 to 50 dBA;
- The daytime equivalent level (L_{eq} dBA) measurements ranged from 49 to 61 dBA;
- The nighttime equivalent level (L_{eq} dBA) measurements ranged from 52 to 67 dBA.

Table 1 Baseline Ambient Noise Measurements – Near Proposed Wind Turbine Facility, Savoy, MA

							Octave Bands (Hz)								
Receptor I.D	Start	L_{10}	L_{50}	L_{90}	L_{eq}	L_{max}	31.5	63	125	250	500	1000	2000	4000	8000
	Time	(dBA)	(dBA)	(dBA)	(dBA)	(dBA)	L_{90}	L_{90}	L_{90}	L_{90}	L_{90}	L_{90}	L_{90}	L_{90}	L_{90}
Loc 1 Day	14:10	58	49	45	58	75	52	50	46	47	45	40	34	23	15
Loc 1 Night	01:22	62	49	47	61	77	53	52	49	48	46	41	35	25	19
Loc 2 Day	13:34	60	52	48	56	71	53	51	48	48	46	43	40	32	24
Loc 2 Night	00:41	62	56	49	59	70	55	52	48	49	47	44	41	35	29
Loc 3 Day	15:22	57	50	47	53	67	53	51	48	48	46	41	36	26	19
Loc 3 Night	23:13	53	46	43	52	72	51	50	47	43	41	38	33	23	16
Loc 4 Day	12:04	52	47	44	49	60	49	47	45	45	43	39	34	25	17
Loc 4 Night	02:19	55	48	43	52	65	50	48	47	45	42	38	34	26	18
Loc 5 Day	12:42	66	49	44	61	75	54	50	46	44	43	39	34	27	21
Loc 5 Night	02:54	73	60	50	67	78	58	57	53	51	49	46	41	34	27

Notes:

1. Daytime weather: Temperature = 31^{0}F, RH = 80%, skies cloudy, winds were from the northwest at 3-6 mph with gusts up to 13 mph.
   Nighttime weather – Temperature = 31^{0}F, RH = 80%, skies cloudy, winds were from the northwest at 6-10 mph with gusts up to 19 mph.

2. Road surfaces were mainly dry during the nighttime measurements and snow covered during the daytime measurements.

3. All sampling periods were approximately 20 minutes duration.

4. Daytime measurements were collected on March 15, 2006
   Nighttime measurements were collected on March 14-15, 2006

6.0 FUTURE CONDITIONS

6.1 Equipment and Operating Conditions

The wind turbines modeled for this project are Liberty 2500 kW wind generators made by the Clipper Wind Corporation. The wind turbines will have three blades and be placed on 80 meter high towers. Under operational conditions, they will rotate at a speed of 18 R.P.M., which means a windmill blade will pass by about every second. In general, the turbines will be operational when the wind is blowing at speeds between 12 and 40 mph. Each of these turbines has an A-weighted sound power level of 106 dBA (based on power pressure emitted from the turbine in the nacelle) under peak relative noise producing operating conditions (wind speed of 18 mph), measured according to international standard IEC 61400-11, Wind Turbine Generator Systems-Part 11; Acoustic Noise Measurement Techniques.

6.2 Modeled Sound Level Results

Sound levels were modeled using the Wind Pro wind turbine modeling software. This software is designed to model power production and environmental aspects of wind turbine installations, including wind turbine noise emissions. It calculates wind turbine noise according to standard ISO 9613-2. It incorporates octave and A-weighted sound power levels measured for a variety of wind turbines under typical and peak noise operating conditions, including the ones modeled in this study.

Sound levels from the proposed wind turbines were modeled at nearby receptors using gridded receptors at a spacing of 25 meters. These sound levels were computed assuming that the receptors are located directly downwind, and the wind conditions are 18 mph (8 m/s), the worst case assumption. Under typical operating conditions, (winds variable from 0 to 30 mph, with direction ranging from southwest to northwest), noise levels will be slightly (about 1-3 dBA) lower. Sound levels were predicted assuming that vegetation provided some damping of wind turbine sound.

The results are shown as color contour plots in Figure 2 showing expected sound levels from 35 to 55 dBA. They are also displayed at the measurement locations in Table 2. In general, the noise results indicate that expected sound levels from the proposed wind turbines will be lower than existing background levels at all residential locations. These noise levels will be below existing day and nighttime background levels; however, due to the time-modulated nature of the windmill noise, turbine noise may be slightly audible to the nearest residents.

Figure 2 Sound Level Modeling Results

The noise levels expected from the wind turbines will cause a slight increase in overall noise levels at the nearest residential receptors, of between 0 and 1 dBA (see Figure 3). In the cross country ski area to the east, peak noise levels should be less than 1 dBA higher at the property line. These changes are negligible. A change in sound levels of 3 dBA or less is generally considered imperceptible.[2] These increases will be well below the Massachusetts Noise Policy criteria of 10 dBA over existing L_{90} levels. There will also be no pure tone noise from the generators.

Table 2 Comparison of Future Predicted Nighttime Sound Levels with Existing Background – MA Noise Policy Criteria

Location	Lowest Existing L_{90} - Nighttime (dBA)	Future L_{90} - Project (dBA)	Future L_{90} – Nighttime Total (dBA)	Increase (dBA)
Loc. 1 - Barnard Road Residence	47	34	47	<1
Loc. 2 - Southwestern PL	49	41	50	1
Loc. 3 – West Hill Road – SE PL	43	31	43	<1
Loc. 4 - Harwood Road – NE PL	43	35	44	1
Loc. 5 – Harwood Road Residence	50	33	50	<1

2 Noise Control for Buildings, Manufacturing Plants, Equipment and Products, Hoover & Keith, Inc., 1981, Houston, TX, page 1-8.

Figure 3

Sound Level Increase