Hessler Associates, Inc.
Consultants in Engineering Acoustics

3862 Clifton Manor Place
Suite B
Haymarket, Virginia 20169 USA
Phone: 703-753-1602
Fax: 703-753-1522
Website: www.hesslernoise.com

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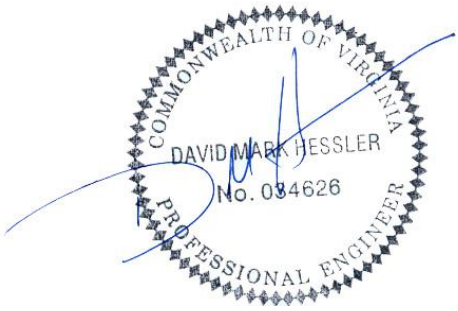
ENVIRONMENTAL SOUND SURVEY AND NOISE IMPACT ASSESSMENT

COPENHAGEN WIND PROJECT

TOWN OF DENMARK
LEWIS COUNTY
NEW YORK

PREPARED FOR:

OwnEnergy, Inc.



Prepared by:

David M. Hessler, P.E., INCE
Principal Consultant
Hessler Associates, Inc.

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1.0 INTRODUCTION

Hessler Associates, Inc. has been retained by OwnEnergy, Inc. to evaluate potential noise impacts from the proposed Copenhagen Wind Project, which is located in the Town of Denmark, Lewis County, New York. The current site plan calls for the installation of 63 General Electric GE 1.6-100 wind turbines, each with a nominal electrical output of 1.6 MW. The proposed turbine locations are mostly on sizeable tracts of rural farm land outside of the villages of Copenhagen and Denmark.

The present study consists of two principal phases: a background sound level survey and a computer modeling analysis of future turbine sound levels. The field survey of existing sound levels at the site was necessary to determine how much natural masking noise there might be - as a function of wind speed - at the nearest residences to the project. The relevance of this is that high levels of background noise due to wind-induced natural sounds, such as tree rustle, would act to reduce or preclude the audibility of the wind farm, while low levels of natural noise would permit operational noise from the turbines to be more readily perceptible. For a broadband noise source the audibility of, and potential impact from, the new noise is a function of how much, if at all, it exceeds the pre-existing background level.

In the second phase of the study an analytical noise model of the project was developed to predict the sound level contours associated with the project over the site area and thereby determine if any nearby residents might be able to discern the turbines above the pre-existing background level and, if so, what the likelihood of an adverse impact might be.

In the absence of any state or local regulatory noise limits, the primary bases for evaluating potential project noise impacts will be the Program Policy *Assessing and Mitigating Noise Impacts* issued by the New York State Department of Environmental Conservation (NYSDEC), Feb. 2001, which uses an ambient-based relative increase approach and certain absolute impact thresholds derived from observations of the actual reaction to comparable wind projects.

1.1 EXECUTIVE SUMMARY

A field survey of existing sound levels throughout the proposed Copenhagen Wind Project site area was carried out to determine how much natural masking sound there might be at residences in the vicinity of the project and how it might affect the perceptibility of sound emissions from the project.

In general, over 2500 measurements were made on a continuous day and night basis over an 18 day period at each of 11 monitoring stations located at typical residences and farms throughout the project area. Environmental sound levels during a wide variety of wind and weather conditions were captured and correlated to the wind speed measured by an on-site 58 m (190 ft.) high anemometer. Thus, the wind conditions that the turbine rotors would see were related to the sound levels occurring simultaneously at ground level at homes in the area. The survey was carried out during late winter conditions when environmental sound levels are generally at an annual minimum.

Although measurements were taken both during the day and at night only the nighttime results, tabulated below as a function of wind speed, were used as a design basis for the assessment.

Table 1.1.1 *Mean Site-wide Nighttime L90 Background Sound Levels as a Function of Wind Speed*

Wind Speed at Standard Elevation of 10 m, m/s	3	4	5	6	7	8	9	10
L90 (Nighttime) Design Sound Level, dBA	**31**	**32**	**32**	**33**	**35**	**37**	**40**	**45**

For design and assessment purposes, a critical wind speed analysis was carried out to determine when the proposed GE 1.6-100 turbines would be most audible relative the background level. Both the background and turbine sound levels vary with wind speed but the greatest disparity between these two levels was found to occur at 7 m/s when the mean L90 background level was measured at 35 dBA and when the turbine sound power level was at its maximum value.

In the absence of any specific regulatory noise limits, two assessment thresholds, both coincidentally occurring at the same value, were established for the modeling analysis.

- A relative increase of 5 dBA above the pre-existing background level per NYSDEC guidelines. In this case 40 dBA based on a background level of 35 dBA measured during critical wind conditions (7 m/s)

- An absolute threshold of 40 dBA – largely defining the point at which complaints are possible but generally rare and unlikely

Using the maximum turbine sound power level of 105 dBA re 1 pW the projected sound emissions from the project were modeled and mapped over the site area in accordance with appropriate standards representing typical or normal atmospheric conditions – with the understanding that project sound levels will vary considerably above and below the mean predicted level with changing atmospheric conditions. Comparisons between modeled sound levels and the levels actually measured at operating wind projects indicate that ISO 9613-2 is quite accurate at predicting the mean project sound level.

Sound levels were plotted out to 40 dBA, which may be taken as the approximate threshold beyond which project sound levels are unlikely to lead to any significant adverse reaction, based on both the relative increase approach of the NYSDEC guidelines and the fact that complaints about wind turbine noise have been found to be rare at or below this sound level. This region – where project sound levels are expected to be higher than 40 dBA - encompasses much of the project area and most of the nearest residences to planned turbine locations. In particular, there are quite a few homes in the region between 40 and 45 dBA, meaning that the average project sound level will be more than 5 dBA above the background and will be clearly perceptible outside of these residences much of the time when the project is operating. Consequently, some potential exists for annoyance and sporadic complaints in this area; although experience with similar projects suggests that if complaints do occur they will be very small in number.

There are a handful of residences just inside the 45 dBA contour in various parts of the site area but they all belong to participating landowners. Issues with noise are much less common with participants than non-participants, as might be expected, but there should be an awareness that a project sound level above 45 dBA in such a rural environment means that the sound emissions from the turbines will be quite prominent and noticeable much of the time as a churning or swishing sound, particularly at night.

It is also important to note that the 40 dBA contour illustrated in the sound contour map is not necessarily the threshold of audibility and the turbines will probably be audible from time to time, depending on wind and weather conditions, for quite some distance beyond this contour line. Because they are entirely dependent on constantly changing wind and atmospheric conditions, wind turbine sound emissions are highly variable with time and will routinely fluctuate above and below the predicted mean level, usually within +/- 5 dBA, but by greater amounts on occasion.

Although concerns are often raised with respect to low frequency or infrasonic noise emissions from wind turbines, no adverse impact of any kind related to low frequency noise is expected from this project. The widespread belief that wind turbines generate excessive or even harmful amounts of low frequency noise is evidently based on misinformation or a confusion of the amplitude modulation typical of wind turbines (i.e. the periodic swishing sound with a frequency of about 1 Hz) with low frequency sound. Numerous studies show that the low frequency content in the sound spectrum of a typical wind turbine is not substantially different than that of the natural background sound level in rural areas. Wind-induced self noise from wind blowing over the microphone, which artificially inflates the low end of the frequency spectrum, is another likely reason that low frequency noise has been incorrectly associated with wind turbines.

Unavoidable but mild noise impacts may occur during the construction phase of the project. Construction noise, sounding similar to that of distant farming equipment is anticipated to be sporadically audible at some homes within the immediate project vicinity on a temporary basis. The maximum magnitude of construction sound levels at the nearest homes to individual turbine locations is not expected to exceed 56 to 63 dBA depending on the particular activity. Higher levels are possible where homes are relatively close to trenching and road building activities.

2.0 BACKGROUND SOUND LEVEL SURVEY

2.1 OBJECTIVE AND MEASUREMENT QUANTITIES

The purpose of the survey was to determine what minimum environmental sound levels are consistently present and available at the nearest potentially sensitive receptors to mask or obscure potential noise from the project. A variety of statistical sound levels were measured at each monitor location in consecutive 10 minute intervals over the entire survey. Of these, the average (Leq) and residual (L90) levels are the most meaningful.

The average, or equivalent energy sound level (Leq), is literally the average sound level over each measurement interval. This measure can be strongly influenced and elevated by sporadic, short-duration noise events, such as cars passing by, and is therefore often unrepresentative of the quiet periods between these events.

The L90 statistical sound level, on the other hand, is commonly used to conservatively quantify background sound levels. The L90, or residual sound level, is the sound level exceeded during 90% of the measurement interval and has the quality of filtering out sporadic, short-duration noise events thereby capturing the quiet lulls between such events. It is this consistently present, near-minimum “background” level that forms a conservative basis for evaluating the audibility of a new source and will be the primary measure relied on in this analysis.

These levels are graphically illustrated in the following generic example.

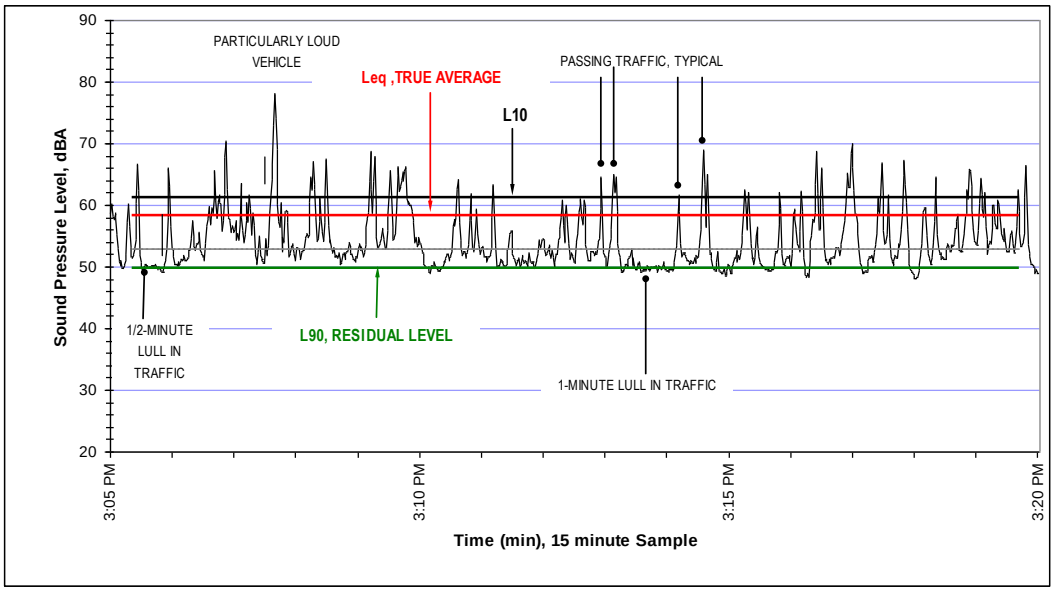

Figure 2.1.1 *Sample 15 minute Measurement Showing L90, Leq and L10 Statistical Sound Levels*

An additional factor that is important in establishing the minimum background sound level available to mask potential wind turbine noise is the natural sound generated by the wind itself. In general, wind turbines only operate and produce noise when the wind exceeds a minimum cut-in speed of roughly 3 or 4 m/s (measured at a reference elevation of 10 m). Turbine sound levels increase with wind speed up to about 7 m/s when the sound produced generally reaches a maximum and no longer increases because the rotor has reached a predetermined maximum rotational speed. Consequently, at moderate to high wind speeds - when turbine sound levels are most significant - the level of natural masking noise is normally also relatively high due to tree or grass rustle thus reducing the perceptibility of the turbines. In order to quantify this effect wind speed was measured, for later correlation to the sound data, by an anemometer at 58 m (190 ft.) above ground level mounted on a met tower in the southeastern part of the site area. Using the wind speed measured high in the air relates the wind conditions associated with turbine operation to the concurrent sound levels experienced at ground level at houses in the project area – locations where the wind speed might very well be negligible even when it is windy at the top of the met mast.

2.2 SITE DESCRIPTION AND MEASUREMENT POSITIONS

The Copenhagen project, as currently planned, consists of 63 wind turbines located on a number of private land parcels, mostly sizeable farms, surrounding, but still some distance from, the villages of Copenhagen and Denmark. The areas where turbines are proposed are generally rural in nature and sparsely populated.

Although there are several ravines, rolling hills and small escarpments within the project area, the topography may more generally be described as flat and none of these terrain features would have any real bearing the on the propagation of sound from the units to residences in area.

Graphic A is a shaded relief map of the site vicinity showing the homes in the area, the turbine locations and the 11 background sound level measurement positions adopted for the survey. These positions were selected to be representative of the acoustic environments experienced at the nearest homes to proposed turbine locations and to generally cover the project area in a fairly uniform manner.

Each location is at or near a typical home or farm in the area. In most cases, the monitor was placed in the rear yard away from exposure to local road traffic and away from any significant source of local contaminating noise that might be generated by human activity or machinery.

Each measurement location is described in further detail below.

Position 1 – 2158 Doran Road

Monitor 1 was situated in an elevated, open field adjacent to a farm house on Doran Road in western part of the project area. An anemometer, measuring the wind speed at microphone height, was also set up at this location.

Figure 2.2.1a *Monitor 1 – Looking NW towards the House*

Figure 2.2.1b *Monitor 1 – Looking SE*

Position 2 – 2213 Rt. 194

Monitor 2 was located in an open field several hundred feet from a farm house on Rt. 194 (in trees).

Figure 2.2.2a *Monitor 2 – Looking NE towards Farm House*

Figure 2.2.2b *Monitor 2 – Looking E*

Position 3 – Deer River Estates, Phalen Drive

Monitor 3 was located in an open field a short distance NW of the Deer River Estates apartment complex on the outskirts of the village of Copenhagen.

Figure 2.2.3a *Monitor 3 - Looking SE towards Apartments (Visible Beyond Trees)*

Figure 2.2.3b *Monitor 3 - Looking N towards Proposed Turbine Locations*

Position 4 – 10423 Stoddard Road

Monitor 4 was located in an open field near a residence on the west side of Stoddard Road. A line of turbines is proposed on a ridge across a shallow ravine approximately 1400 ft. to the west.

Figure 2.2.4a *Monitor 4 – Looking W towards Proposed Turbine Locations on Ridge in the Background*

Figure 2.2.4b *Monitor 4 – Looking SE*

Position 5 – 10533 Stoddard Road

Monitor 5 was located in a field behind a farm house further north on Stoddard Road.

Figure 2.2.5a *Monitor 5 – Looking SE towards Barn, House Beyond but not Visible*

Figure 2.2.5b *Monitor 5 – Looking NW*

Position 6 – Near 3218 Roberts Road

Monitor 6 was located on a utility pole across from several homes near the intersection of Roberts and Vorce Roads.

Figure 2.2.6a *Monitor 6 – Looking S towards Nearest House*

Figure 2.2.6b *Monitor 6 – Looking N*

Position 7 – 3562 Halifax Road

Monitor 7 was located on a pole in the backyard of a residence on Halifax Road.

Figure 2.2.7a *Near Monitor 7 – Looking W towards the House*

Figure 2.2.7b *Monitor 7 – Looking N towards Other Homes in the Area*

Position 8 – Near 3919 Halifax Road

Monitor 8 was located on a utility pole along Halifax Road across the street from several residences.

Figure 2.2.8a *Monitor 8 – Looking N towards Nearest House*

Figure 2.2.8b *Near Monitor 8 – Looking NE*

Position 9 – 9522 Mud Street

Monitor 9 was located in an open area near a farm house on Mud Street in the southeastern part of the project area. A microphone height (1 m) anemometer was also set up at this monitoring station.

Figure 2.2.9a *Monitor 9 – Looking SE towards House*

Figure 2.2.9b *Monitor 9 – Looking NW*

Position 10 – 9929 Rt. 26

Monitor 10 was located in a backyard of a house on the south side of Rt. 26 near the village of Denmark. There are a number of homes along this fairly major and well-travelled road. This particular residence is typical for the locality.

Figure 2.2.10a *Monitor 10 – Looking N towards Other Neighboring Homes*

Figure 2.2.10b *Monitor 10 – Looking SW towards Proposed Turbine Locations on the Distant Ridge*

Position 11 – 9575 Rt. 26

Monitor 11 was located on a fence post in the backyard of a farm house further south from Position 10 on Rt. 26.

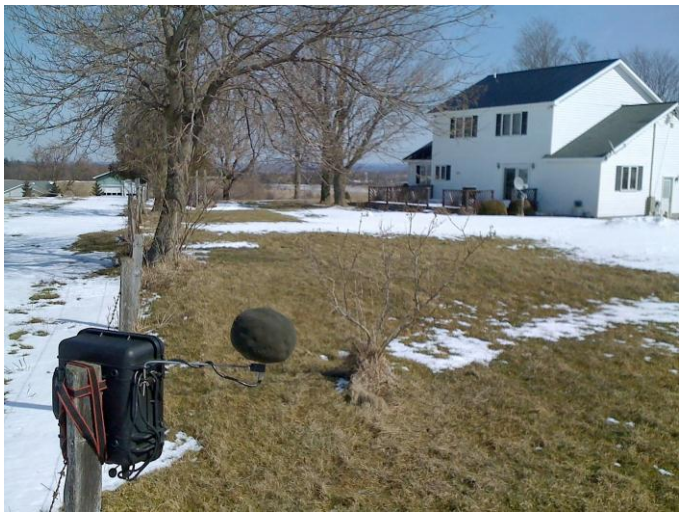

Figure 2.2.11a *Monitor 11 – Looking E towards House*

Figure 2.2.11b *Monitor 11 – Looking N towards a Neighboring Farm*

2.3 INSTRUMENTATION AND SURVEY DURATION

Rion Model NL-31 and NL-21, ANSI Type 1 and 2, respectively, integrating sound level meters were used for the survey. Each instrument was enclosed in a weatherproof case. Some were fitted with a 12" microphone boom that is visible in some of the photos above and some of the microphones were mounted on temporary posts. Oversized, 7 inch diameter windscreens (ACO Type WS7-80T) were used in all cases. All the microphones were located at a height of approximately 1 m above local ground level and positioned away from the instrument box and away from any significant reflective surfaces.

All the instruments were field calibrated with a Brüel and Kjær Type 4230 calibrator at the beginning and end of the survey. The observed calibration drift, or change in the instrument's sensitivity over the survey period, ranged between +0.1 and +0.7 dB at all positions, or +0.4 dB on average.

Each of these instruments is designed for service as a long-term environmental sound level data logger measuring the A-weighted sound level. The meters were all set to continuously record a number of statistical parameters in 10 minute increments, such as the average (Leq), minimum, maximum, and residual (L90) sound levels. The survey period lasted 18 days beginning at noon on March 7 and ending on March 25, 2012.

As is evident from the photographs in Section 2.2, the survey was conducted during late winter conditions when there was snow on the ground and the trees were bare. At this time of year contaminating natural sounds from nocturnal insects, leaf rustle, birds, local human activity, etc. are generally at annual minimum, so the observed sound levels may be considered a conservative measure of the year-round conditions in the area.

2.4 SURVEY WEATHER CONDITIONS

The weather conditions during the survey might be characterized as being generally fair with only a few instances of light snow or very light rain. Temperatures were generally mild and well above the seasonal averages much of the time. Some basic weather parameters over the survey period, as observed at Fort Drum about 8 miles north of the site area, are illustrated below.

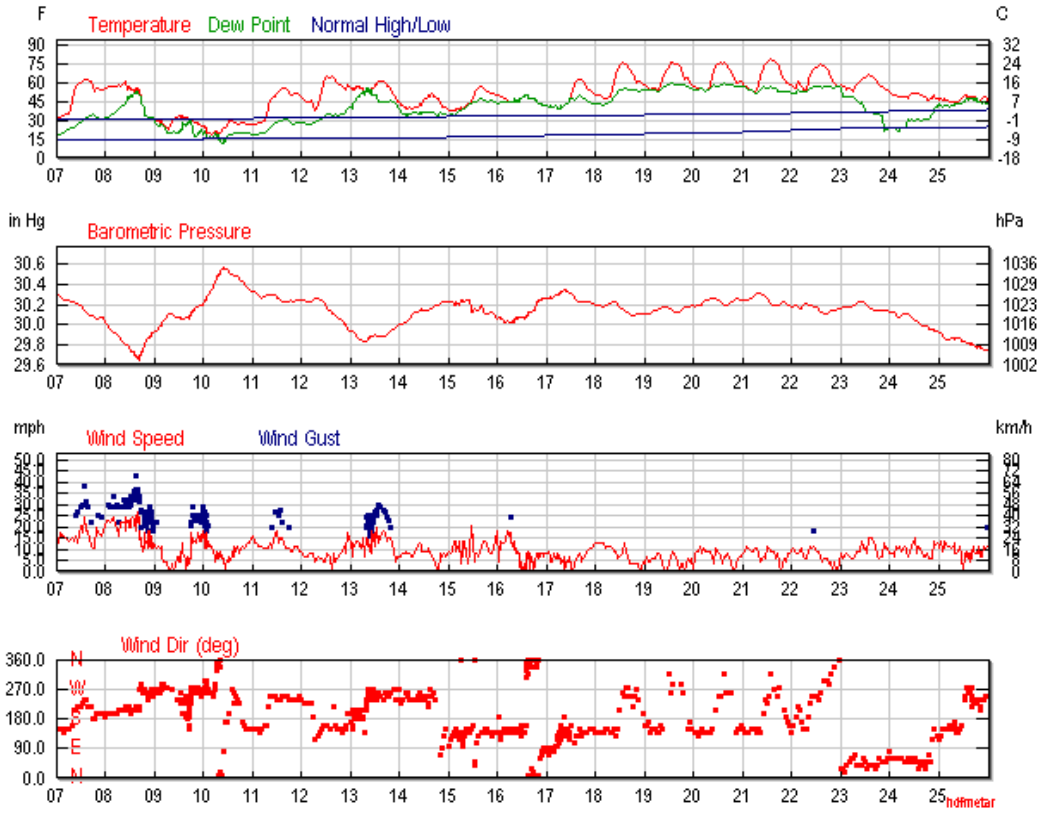

Figure 2.4.1 *General Weather Conditions during the Survey, as Observed at Fort Drum, NY (from www.weatherunderground.com)*

The wind speed at the site itself was measured near ground level (1 m) by temporary weather stations set up at Positions 1 and 9 - and at a high elevation of 58 m (190 ft.) by a met tower located in the southeastern part of the project area. The average wind speed at microphone height recorded by each 1 m anemometer is shown in Figure 2.4.2.

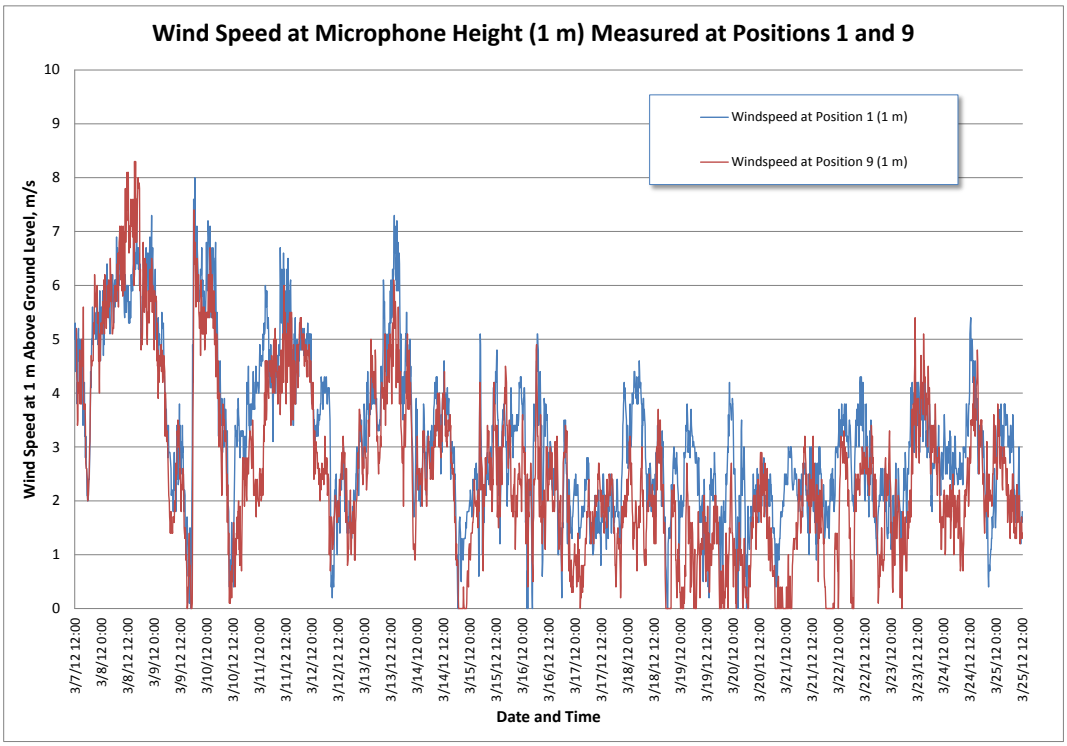

Figure 2.4.2

These two traces are generally coincident suggesting that the near ground wind speed was largely uniform over the site area, at least during windy periods, since the two measurement points were 5.5 miles apart on opposite sides of the project area.

Because wind turbine sound power levels (measured in accordance with IEC 61400-11[1]) are expressed in terms of the wind speed at a standard elevation of 10 m above ground level, it is necessary to normalize the high elevation met tower anemometer data to this height. The conversion of wind speed at one elevation to the related speed at another elevation is calculated from an empirically derived formula in Reference 1 (Equation (7), Section 8), which describes an exponential profile.

As a general example, the wind profile resulting from Eqn. (7) is shown graphically below in Figure 2.4.3 for a case where the wind is normalized to a speed of 7 m/s at 10 m. This shows that the simultaneous wind speed at an anemometer height of 60 m would be around 9.3 m/s while at 10 m the wind speed is likely to be substantially lower at 7 m/s. The shape of the profile curve varies with wind speed becoming flatter at low speeds and more curved at higher speeds.

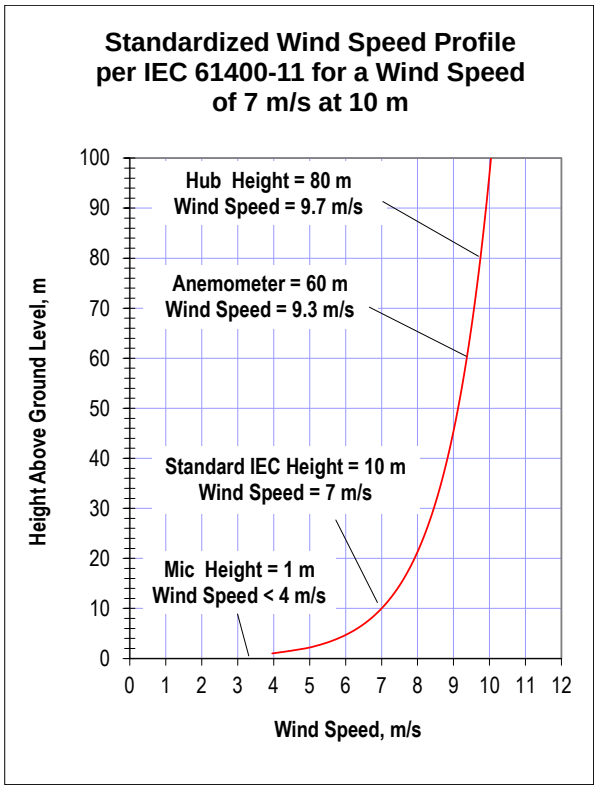

Figure 2.4.3 *Typical Wind Speed Profile above the Surface*

The wind speed measured by the 58 m met tower anemometer - after normalization to 10 m - is shown over the survey period in Figure 2.4.4.

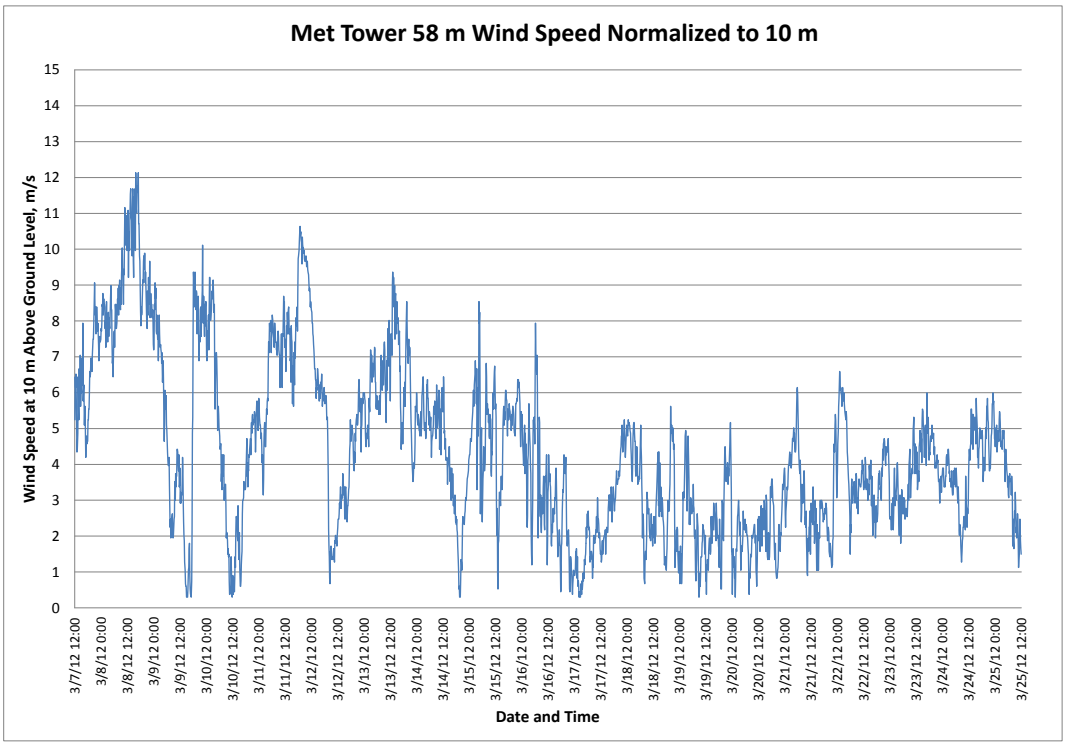

Figure 2.4.4

This plot is similar in appearance to the chart of 1 m wind speeds (Figure 2.4.2) only the magnitudes are generally significantly higher, as would be expected.

2.5 WIND-INDUCED MICROPHONE NOISE

Measurements of environmental sound levels in general and wind turbine sound levels in particular are prone to error caused by wind blowing over the microphone tip – even when an over-sized windscreen is used. In order to quantify this effect and determine how much of what is being measured is distortion and how much is actual sound, a wind tunnel test was carried out in 2008 by Hessler[2] for a variety of common windscreens at the Fraunhofer Institut für Bauphysik in Stuttgart, Germany. In brief, the results of this testing show that artificial, wind-induced self-noise occurs only in the lowest frequencies and, consequently, has very little influence on the measurement of A-weighted sound levels - where the low frequencies are substantially suppressed to make the sound correspond to human ear sensitivity. In general, the study shows that A-weighted sound levels only begin to be significantly affected by self-noise at fairly high wind speeds that are generally above those of interest or relevance to wind turbine projects.

Of the numerous windscreens tested in the study the type used in this survey (the ACO Model WS7-80T) was found to have the least self-noise distortion. From the wind tunnel data it is possible to calculate the A-weighted self-noise level for this windscreen at any wind speed up to about 25 m/s. The mathematical relationship is:

$$Lp(self) = 28.7 \ln (v) - 17.4, \text{ dBA} \quad v > 3 \text{ m/s} \quad (1)$$

Where,

Lp(self) = the A-wtd sound pressure level due solely to self-generated distortion, dBA
v = the wind speed at the microphone, m/s

As can be seen from the equation, the lower the wind velocity the lower the distortion, which is why the survey instruments were located relatively low to the ground at a height of about 1 m where possible. Wind speeds diminish with elevation, theoretically approaching zero at the surface.

As indicated in Figure 2.4.2 above, the wind speed at microphone height (1 m) was measured at Positions 1 and 9, which were generally the most elevated and exposed measurement locations in the survey. The average wind speed (of these two points) will be used to apply a, what turns out to be a very small, correction to the as-measured sound levels in an effort to exclude wind-induced self-noise.

2.6 OVERALL SURVEY RESULTS

As discussed above in Section 2.1, the L90, or residual, sound level is a conservative measure of background sound levels in the sense that it filters out short-duration, sporadic noise events that cannot be relied upon to provide consistent and continual masking sound to obscure potential project noise. This level represents the quiet, momentary lulls between all relatively short duration events, such as cars passing by or tractor activity in a neighboring field. As such, it represents the near-minimum background level.

The L90 sound levels measured over consecutive 10 minute periods for all 11 positions are plotted below in Figure 2.6.1. The results have been edited to discard obviously contaminating noise spikes (i.e. those occurring at only one position).

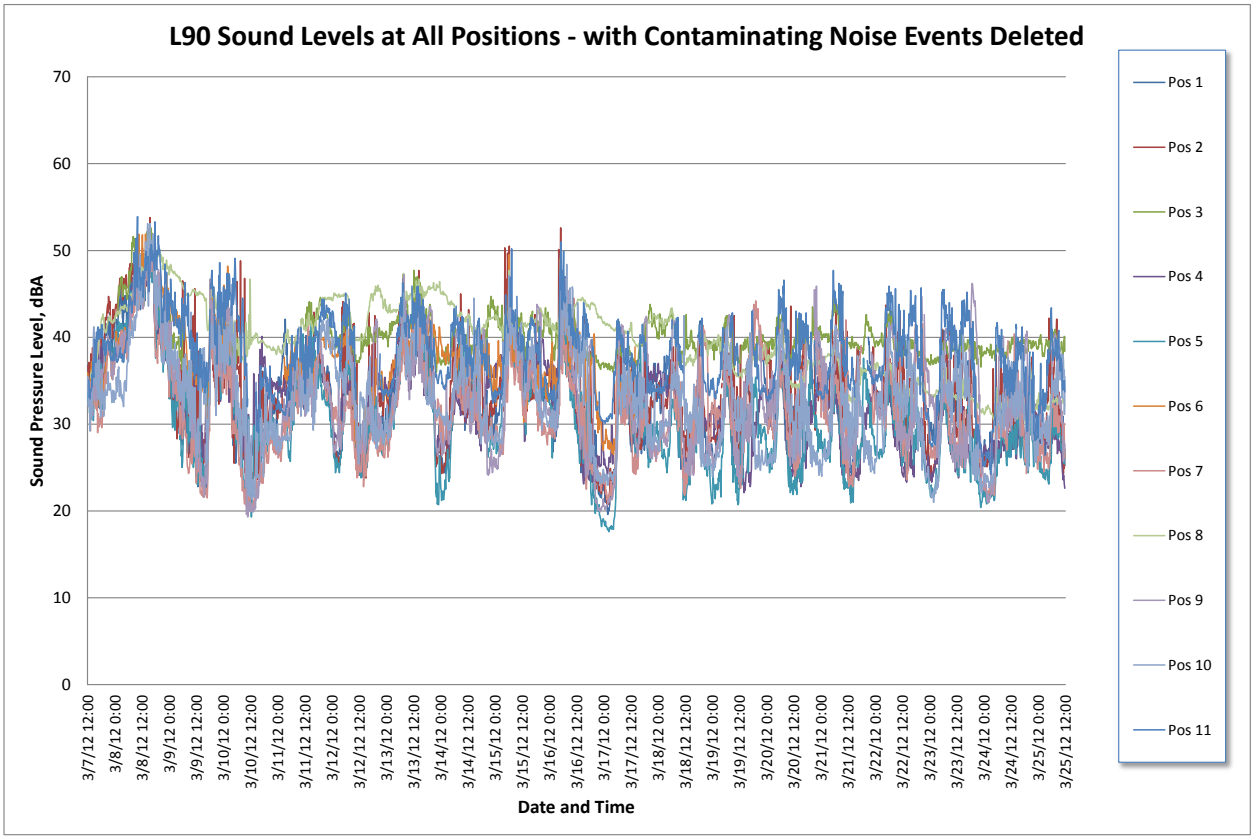

Figure 2.6.1

What stands out in this plot are the levels measured at Positions 3 and 8 (both shaded green), which generally remain elevated when the sound levels at all other locations drop to temporary minima. This behavior indicates that the sound levels at these two locations were subtly affected by the sound of distant water flow. At Position 3 the waterfall in the Deer River gorge is about 1/3 mile away and at Position 8 a small creek was close enough that its sound, as slight as it was, became dominant during otherwise quiet periods. Although these levels reflect the actual natural background level at these particular locations, such sound levels may not be consistent on a year-round basis and, in any event, are not representative of the area as a whole. Consequently, the data from these two positions is best disregarded.

A plot of the sound levels at the remaining positions is shown below along with the wind speed at an elevation of 10 m above the surface derived from the mast top met tower anemometer.

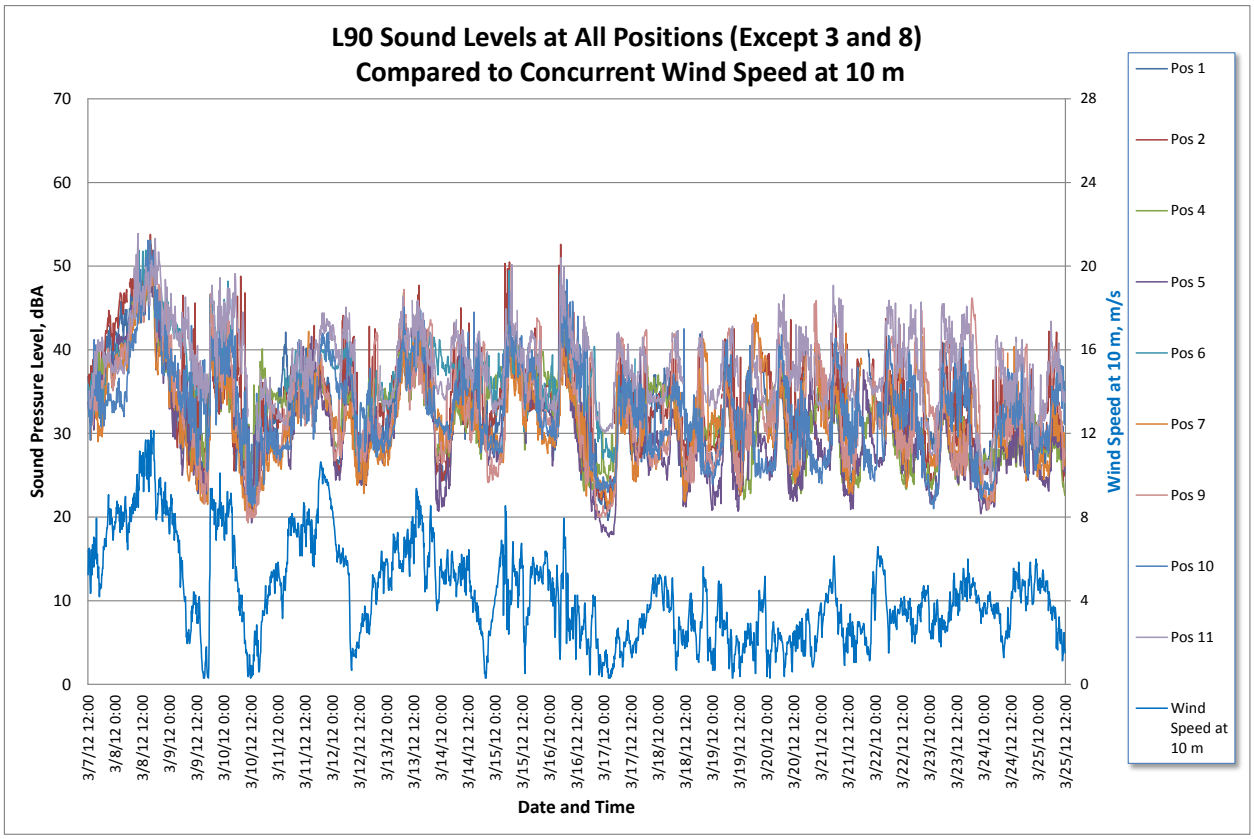

Figure 2.6.2

This plot shows with somewhat greater clarity that the levels at essentially all of these positions follow the same temporal trends, despite their geographical separation, and that they generally intertwine with one another, particularly during the windier periods. Consequently, the arithmetic average of all nine positions can be taken as a reasonable representation of the sound level at any location within the survey area; i.e. as a site-wide design level. In Figure 2.6.3 this design sound level – after an essentially negligible correction for wind-induced self-noise per Section 2.5 - is compared to the wind speed at 10 m as derived above.

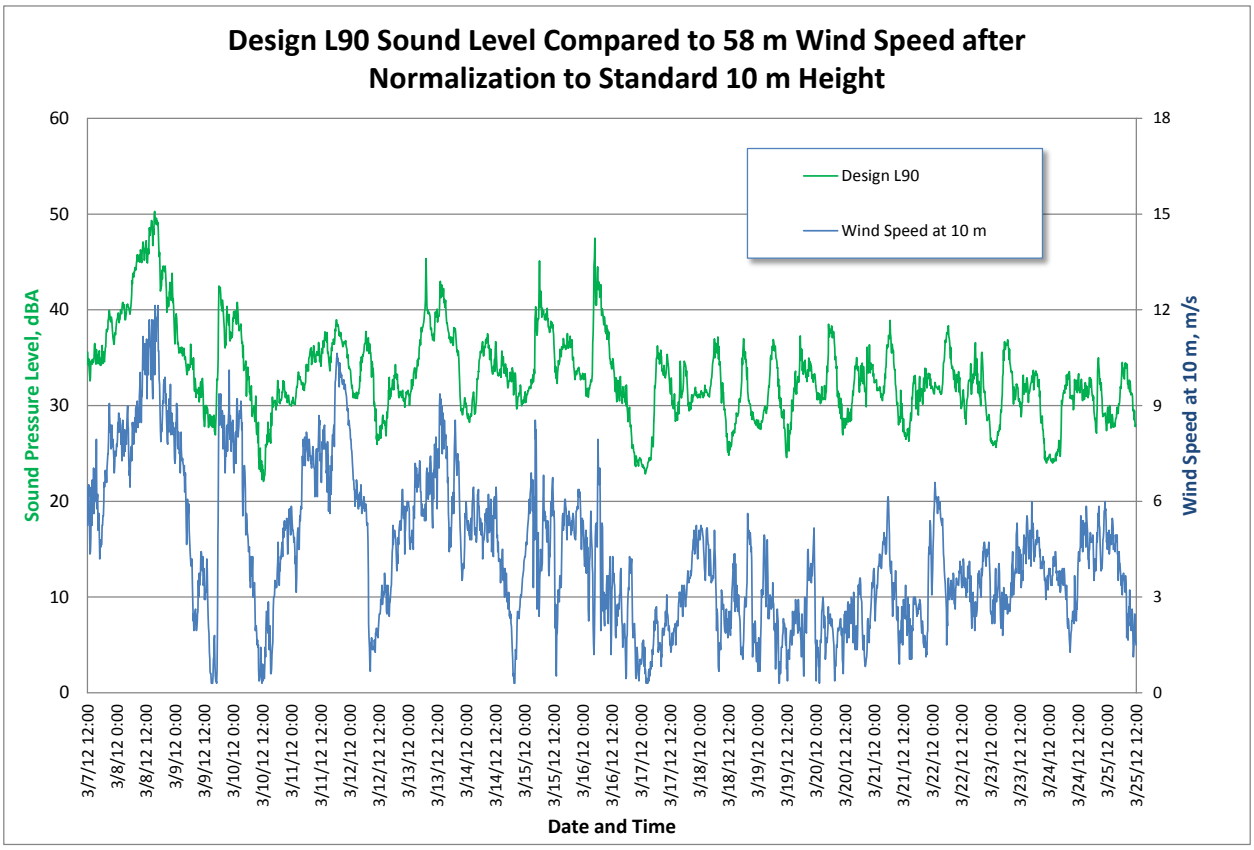

Figure 2.6.3

The generally parallel behavior of the sound level and wind speed traces visible in this graphic makes it clear that natural wind-induced sounds in the environment are the principal reason that the background sound level fluctuates over a very large dynamic range from 25 to 50 dBA. Low levels exist when the wind speed is low but the background level becomes very significant during windy conditions.

It is important to reiterate that the wind speed in Figure 2.6.3 is derived from high elevation measurements – 58 m (190 ft.) above ground level – and represents the wind speed associated with turbine operation. This wind speed, normalized to 10 m, is compared to the near-minimum (L90) sound level measured at 1 m above grade in the yards of residences within the project area.

The correlation between sound and wind can be better seen if the data in Figure 2.6.3 are re-plotted in terms of wind speed rather than time (Figure 2.6.4).

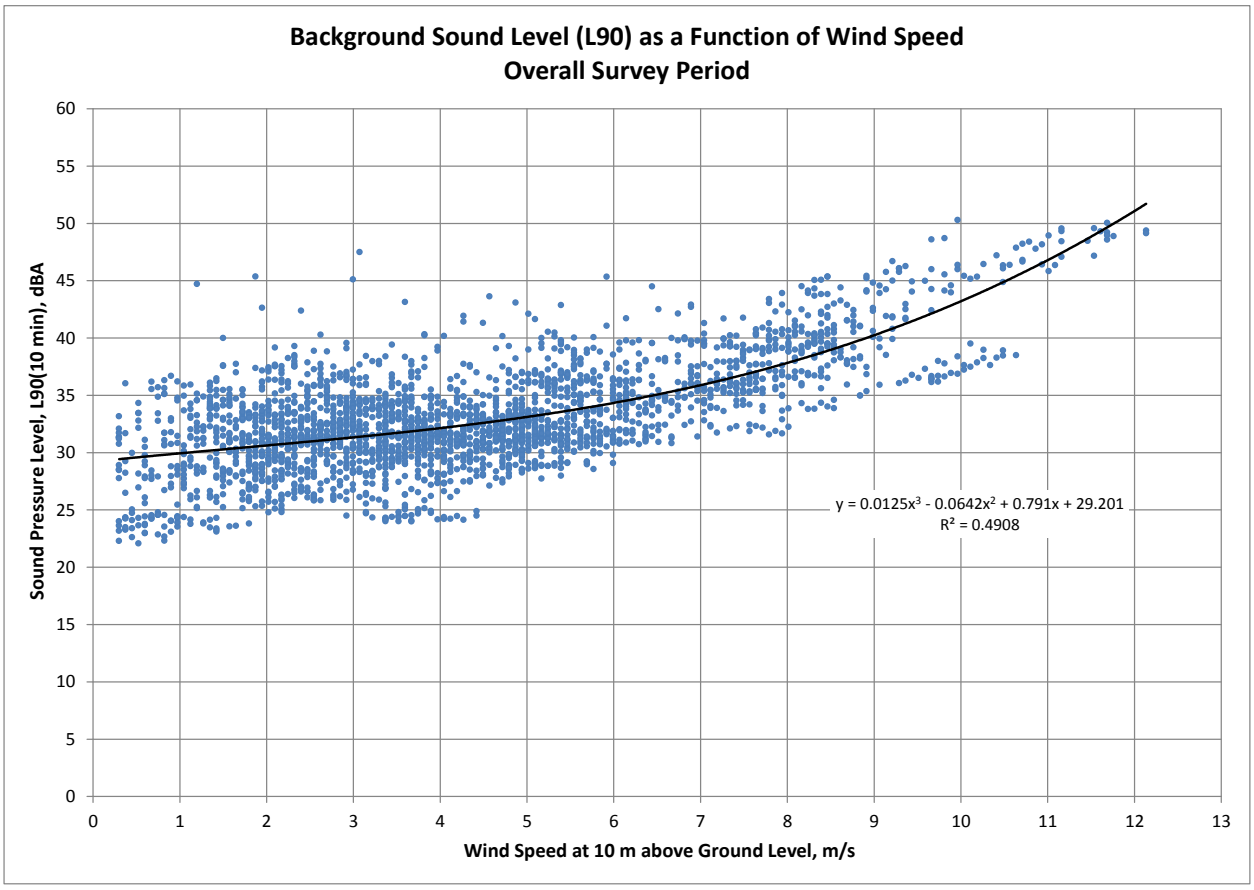

Figure 2.6.4

This plot clearly shows that environmental sound levels are relatively low at low wind speeds (generally in the 25 to 35 dBA range) but increase substantially during windy conditions - to the point where they exceed 40 dBA above a speed of about 9 m/s.

Figure 2.6.4 plots the results from the overall survey period, including both daytime and nighttime measurements. Because the potential for disturbance is normally greater at night, the nighttime (only) sound levels will be used as a design basis for the assessment of possible impacts. Figure 2.6.5 is a regression analysis of only the L90 sound levels measured at night – 10 p.m. to 7 a.m.

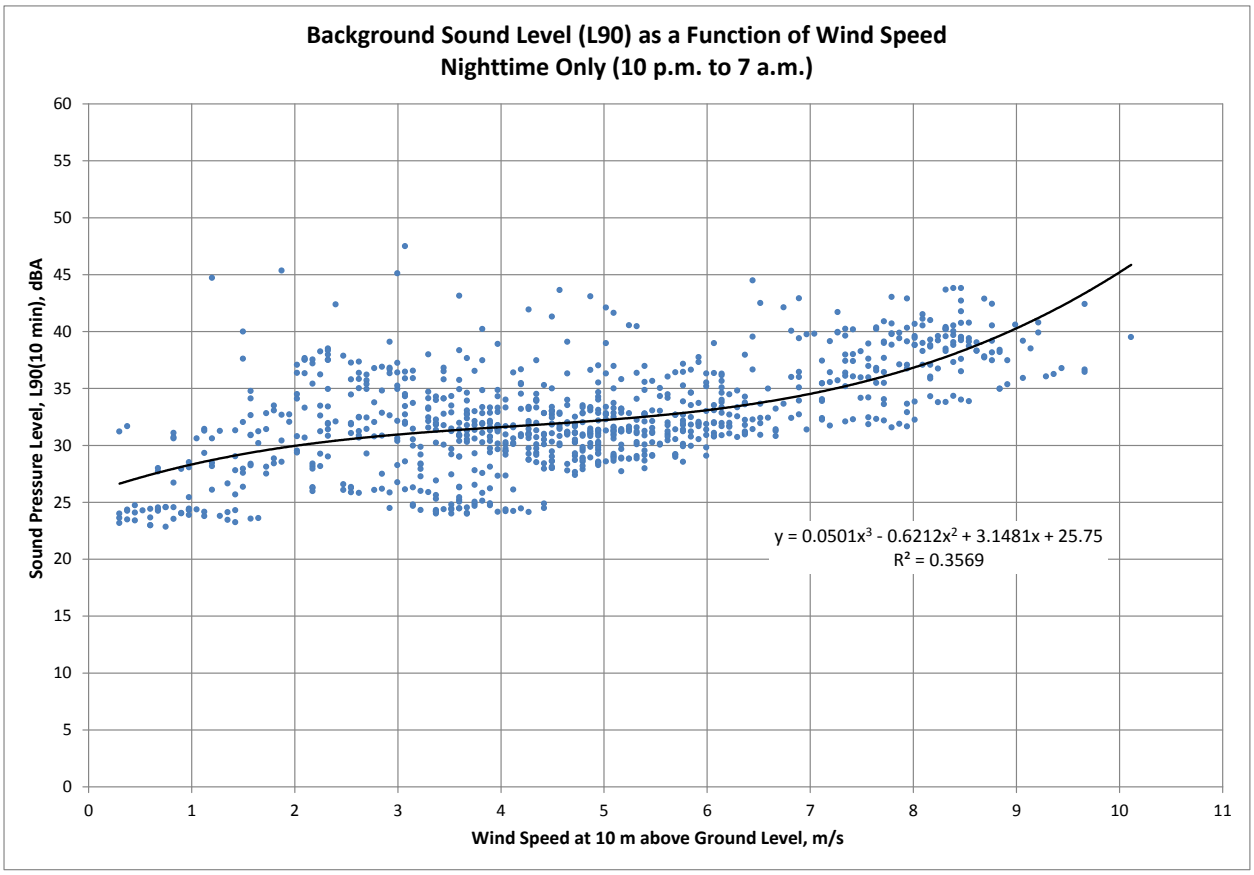

Figure 2.6.5

The central tendency towards higher sound levels with increasing wind speed is less clear at night but still present.

The following table summarizes the mean L90 background levels that are likely to be observed at any point within the project area at night over the range of wind speeds relevant to turbine operation.

Table 2.6.1 *Mean Site-wide Nighttime L90 Background Sound Levels as a Function of Wind Speed*

Wind Speed at Standard Elevation of 10 m, m/s	3	4	5	6	7	8	9	10
L90 (Nighttime) Design Sound Level, dBA	**31**	**32**	**32**	**33**	**35**	**37**	**40**	**45**

3.0 PROJECT NOISE MODELING AND IMPACT ASSESSMENT

3.1 ASSESSMENT CRITERIA

In the absence of any local, state or federal noise regulations, the project's potential noise impact can be evaluated in terms of the noise guidelines published by the New York State Department of Environmental Conservation (NYSDEC) and the observed reaction to other comparable wind projects in New York and elsewhere.

In the Program Policy *Assessing and Mitigating Noise Impacts* published by the NYSDEC (2001) a methodology is described for evaluating potential community impacts from any new noise source. The method is fundamentally based on the perceptibility of the new source above the existing background sound level.

It is a well-established fact - for a new broadband, atonal noise source with a frequency spectrum similar to that of the background - that a cumulative increase in the total sound level of about 5 or 6 dBA at a given point of interest is required before the new sound begins to be clearly perceptible or noticeable to most people. Cumulative increases of between 3 and 5 dBA for a source of this kind are generally regarded as negligible or hardly audible. Lower sound levels from the new source are "buried" in the existing background sound level and become progressively less perceptible. The specific language relating to these perceptibility thresholds in the NYSDEC program policy (Section V B(7)c) is a follows:

> Increases ranging from 0-3 dB should have no appreciable effect on receptors. Increases from 3-6 dB may have potential for adverse noise impact only in cases where the most sensitive receptors are present. Sound pressure increases of more than 6 dB may require closer analysis of impact potential depending on existing SPL's [sound pressure levels] and the character of surrounding land use and receptors.

What this essentially says is that increases in the total ambient sound level of 6 dBA or less are unlikely to constitute an adverse community impact. If this is interpreted conservatively as a *cumulative* increase of 6 dBA, this threshold means that sound levels from the project could exceed the existing background level by up to 5 dBA. For example, a project-only sound level of 40 dBA logarithmically added to a background level of 35 dBA would equal a total cumulative level of 41 dBA – or 6 dBA above the original level.

In addition to this relative increase approach, the potential impact from the project may also be evaluated in terms of its absolute level at potentially sensitive receptors. Peer-reviewed research[3] published in the *Noise Control Engineering Journal* suggests, based on sound testing at a number of newly completed wind projects very comparable to this one, that complaints about noise become very rare when the mean project sound level is below about 40 dBA – essentially irrespective of the prevailing background sound level. It is only project sound levels significantly in excess of 40 dBA (usually in the 45 to 50 dBA range) that typically lead to serious annoyance or complaints, and even then at fairly low levels of about 4 to 6% of the total exposed population within about 2000 ft. of a turbine[(ibid)]. Complaints in the 40 to 45 dBA range were generally observed at a rate of about 2% of the total population in close proximity to turbine locations. Consequently, it is preferable to limit wind project sound levels to 40 dBA at residences, if possible, and such a target is recommended as an *ideal* design target for new projects[(ibid)].

In summary, then, the metrics or thresholds for evaluating potential noise impacts from this project would consist of:

- A relative increase of 5 dBA above the pre-existing background level per NYSDEC guidelines.
- An absolute level of 40 dBA – largely defining the point at which complaints are possible but generally rare and unlikely

3.2 TURBINE SOUND LEVEL

The starting point for any wind turbine noise modeling study is the sound level, or more specifically, the sound power level of the turbine model that will be used in the project.

In this instance, the overall, A-weighted sound power level for the GE 1.6-100 turbine, tested in accordance with IEC 61400-11, has been obtained from General Electric in the form of an up-to-date (2012) general specification[4]. The overall A-weighted sound power levels as a function of wind speed are tabulated below.

Table 3.2.1 *GE 1.6-100 Sound Power Level Data, 80 m Hub Height*

Wind Speed at 10 m, m/s	5	6	7	8	9	10	11
Sound Power Level from GE Product Specification, dBA re 1 pW	97.8	102.4	105.0	105.0	105.0	105.0	105.0

It should be noted that an uncertainty of +/- 2 dBA with respect to the values above is given in the technical specification.

The specification also states that this model does not produce any significant audible tones at the standard (IEC) test distance for this model of 130 m (426 ft.). The prominence and audibility of tones decreases with distance so if no tones were detected at this relatively short distance then it is all the more likely that no tones will be perceptible at much greater receptor distances.

3.3 CRITICAL DESIGN LEVELS

From the field survey it was determined that the nighttime background sound level varies with wind speed; essentially increasing indefinitely. From Table 3.2.1 above it can be seen that the turbine sound level also varies with wind speed just after cut-in and then plateaus fairly quickly at a fixed maximum value irrespective of wind speed. The two quantities must be compared under the same wind conditions to be meaningful. For example, it would be incorrect to compare the maximum turbine sound level, which occurs only during relatively high winds, to a very low background sound level that might occur on a calm night when the project is idle.

In terms of potential noise impacts the worst-case combination of background and turbine sound levels would occur at the wind speed where the background level is lowest relative to the turbine sound level – or, in other words, where the differential between the background level and turbine sound power level is greatest.

The following chart shows that this worst-case situation occurs at a wind speed of 7 m/s. During this particular wind condition project noise would theoretically be most prominent and audible relative to the background masking noise. At higher wind speeds the background level continues to rise while the turbine sound level remains the same making the project progressively less audible under high wind conditions. At lower wind speeds the turbine sound level falls off more steeply than the background level also making the turbines progressively less perceptible.

Table 3.3.1 *GE 1.6-100 Sound Power Levels and Background Levels vs. Wind Speed*

Ref. Wind Speed Measured at 10 m, m/s	5	6	**7**	8	9	10	11
Turbine Sound Power Level, dB re 1 pW	98	102	**105**	105	105	105	105
Mean Nighttime L90 Background Sound Level, L90, dBA	32	33	**35**	37	40	45	52
Differential	66	69	**70**	68	65	60	53

Consequently, the critical design wind speed for this project would be 7 m/s when the turbines would be generating a sound power level of 105 dBA re 1 pW and when the mean nighttime background sound level is 35 dBA. This would put the nominal design goal for the project, per NYSDEC guidelines (a 5 dBA increase), at 40 dBA at potentially sensitive receptors. This relative threshold is also happens to be coincident with the absolute ideal design goal of 40 dBA.

The frequency spectrum associated with this overall sound power level of 105 dBA re 1 pW is given below (per the manufacturer's specification[4]).

Table 3.3.2 *GE 1.6-100 (Max.) Design Sound Power Level Spectrum*

Octave Band Center Frequency, Hz	31.5	63	125	250	500	1k	2k	4k	8k	dBA
Sound Power Level, dB re 1 pW	*122**	115	110	105	102	101	96	87	70	**105**

** Not reported by GE. Estimated value.*

It is important to note in this context that a sound *power* level is not the same thing as a sound *pressure* level, which is the familiar quantity measured by instruments and perceived by the ear. A power level is a largely intangible, calculated measure, expressed in terms of Watts, that is primarily used for acoustical modeling and design analyses. It is a function of both the sound pressure level produced by a source at a particular distance and the effective radiating area or physical size of the source. The basic mathematical relationship between power and pressure is as follows:

$$Lw = Lp + 10 \log (A), \text{ dB re 1 pW}$$

Where,

Lw = Sound Power Level
Lp = Sound Pressure Level
A = The effective radiating surface area at the point of the pressure level measurement, m^2

In general, the ostensible magnitude of a sound power level is always considerably higher than the sound pressure level near a source because of the area term. For example, the sound *pressure* level at 100 m from a wind turbine might be about 53 dBA and the area term at this distance (10 log ($4\pi 100^2$)) would be 51 dBA with a resulting total *power* level of 104 dBA re 1 pW (the units of power levels are always denoted as decibels with reference to 1 picoWatt, or 10^{-12} W).

The fundamental purpose of a power level is to provide a means of calculating the sound pressure level of a source at any distance; hence its importance to noise modeling. It is *not* the sound pressure level at the hub or near the unit, as is sometimes believed.

3.4 NOISE MODELING METHODOLOGY

Using the design sound power level spectrum in Table 3.3.2 above, project sound levels were calculated using the Cadna/A®, ver. 4.2 noise modeling program developed by DataKustik, GmbH (Munich). This software enables the project and its surroundings, including terrain features, to be realistically modeled in three-dimensions.

3.4.1 *Modeling Standards and Uncertainty*

Cadna/A® modeling software is essentially an automated version of ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors*[5], which is the primary worldwide standard for sound predictions and modeling. Having said that, it should be noted that ISO 9613-2 was not written with wind turbines in mind and its applicability to elevated sources (in this case 80 m) and long propagation distances is occasionally questioned. Table 5 in the standard gives an estimated uncertainty of +/- 3 dBA for noise sources up to 30 m high and for propagation distances up to 1000 m. This 30 m height figure is sometimes interpreted to mean that the standard cannot be used for 80 or 100 m high sources, but it is just that no specific uncertainty range is given for such cases, not that the standard is inappropriate. The principal sound propagation loss in wind turbine modeling is simple geometric spreading of the sound wave, which is an axiomatic law of physics that has no dependence on the specific point of origin or its height above ground level. In fact, comparisons, such as in Figure 3.4.1.1 below, between predictions and measurements of wind turbine noise at many positions at many sites indicate that ISO 9613-2 is a perfectly valid methodology for the prediction of wind turbine sound levels; i.e. the model predictions agree quite well with the mean measured sound level.

This is true despite the fact ISO 9613-2 was never designed to consider the short-term atmospheric conditions to which wind turbines are subject - such as wind and temperature gradients, stability, turbulence, etc. - and was always intended to portray very long-term or average propagation conditions under slightly conservative downwind conditions. Consequently, the model results using this standard need to be interpreted as the expected sound level under “average” conditions, meaning that the actual sound level will be close to the prediction much of the time but higher *and* lower levels will occur with equal regularity due to fluctuating atmospheric conditions, which affect both the generation and propagation of wind turbine noise. The plot below shows a typical comparison between the measured project-only sound levels as a function of wind speed over a two week period compared to predictions at various integer wind speeds. The model predictions tend to agree with the central trend line. The scatter evident in this chart is normal and inevitable and reflects the natural variability of wind turbine sound levels as observed at a distant point.

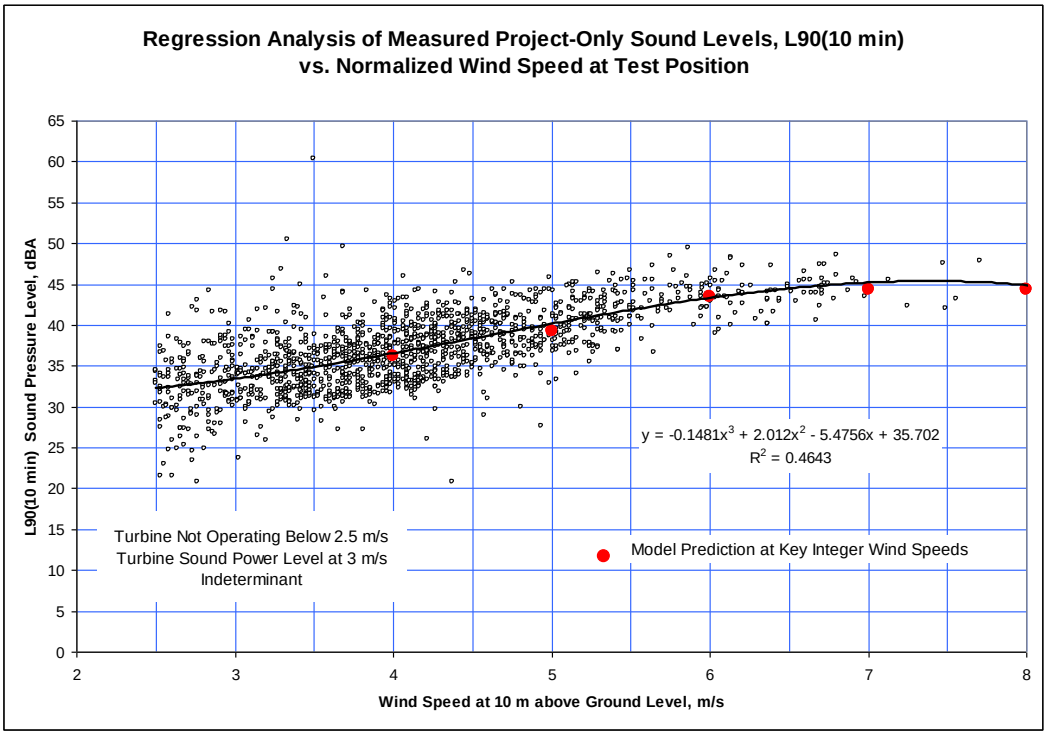

Figure 3.4.1.1 *Comparison Between Measured and Predicted Sound Levels at a Typical Wind Farm as a Function of Wind Speed – Ag=0.5 and No Uncertainty Added to Turbine Power Level*

Because the results exemplified by Figure 3.4.1.1 are typical irrespective of turbine model, number of nearby turbines, hub height, test position, geographic location, time of year or any other factor, the addition of positive uncertainty factors to the input sound power level to account for possible error in the modeling methodology and/or for the measurement uncertainty nominally associated with the IEC 61400-11 test standard would result in an over-prediction relative to the actual average sound level. Similarly, the use of a 0 ground absorption coefficient (Ag in ISO 9613-2) indicating a perfectly reflective ground surface (instead of a mid-range 0.5 coefficient) would have a similar effect.

Figure 3.4.1.2 below also illustrates the typical correlation between measured and modeled levels, this time as a function of time rather than wind speed. Differences occur because the modeled performance (orange trace) is dependent purely on wind speed while the actual sound level (green trace) varies due to both wind speed and all other atmospheric phenomena, such as wind and thermal gradients, cloud cover, stability, etc. – effects that don't lend themselves in any kind of practical way to calculation. Nevertheless, the graphic shows that the direct application of ISO 9613-2 yields a very reasonable result corresponding to the mean sound level of the project over time. If a positive uncertainty factor of, say, 3 or 4 dBA were added to the prediction to cover possible error in the turbine source level or modeling methodology the model results would consistently overestimate the sound emissions from the project and suggest a substantially higher noise impact than is, in fact, the case.

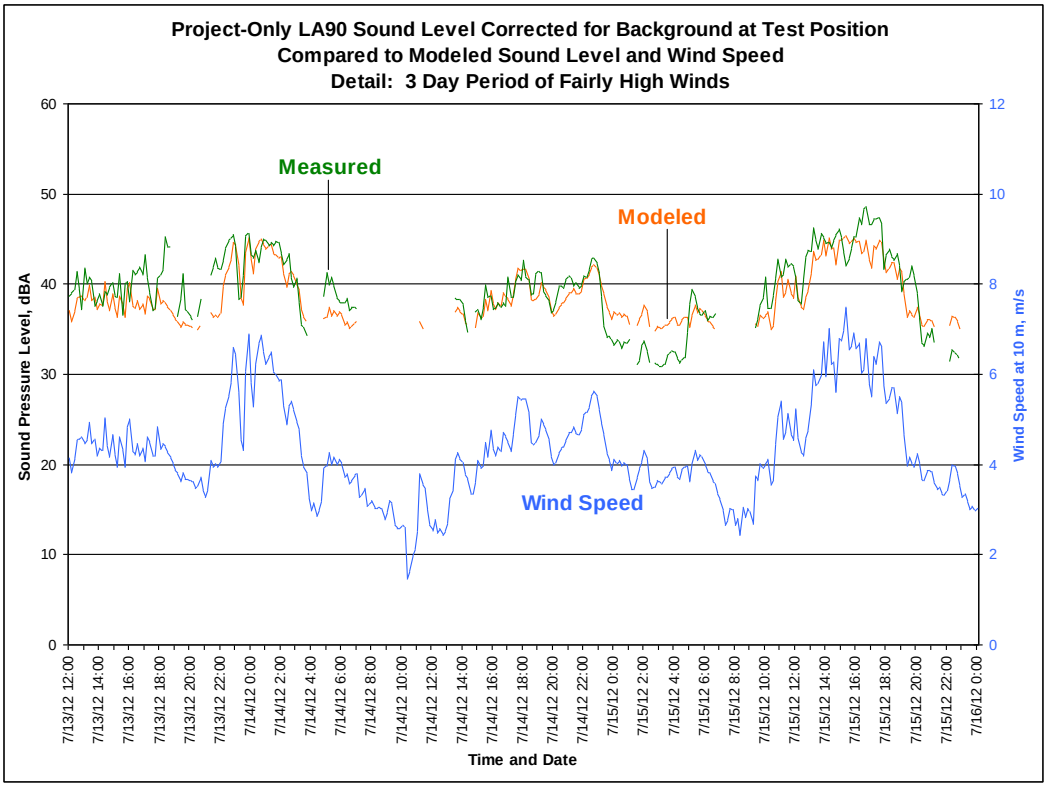

Figure 3.4.1.2 *Comparison Between Measured and Predicted Sound Levels at a Typical Wind Farm as a Function of Time*

3.4.2 *Modeling Assumptions*

Each turbine is represented as a point noise source at a height of 80 m above the local ground surface. Although there are some ravines and small hills within the project area, none of these features are large enough to have any significant bearing on the sound propagation calculations, so flat ground has been assumed.

A somewhat conservative ground absorption coefficient of 0.5 has been assumed in the model since all of the intervening ground between the turbines and potentially sensitive receptors is either open fields or woods, both of which are acoustically soft. The ground absorption coefficient (from ISO 9613-2) ranges from 0 for water or hard concrete surfaces to 1 for absorptive surfaces such as farm fields, woods or sand. Consequently, a ground absorption coefficient on the order of 0.8 or 0.9 could be justified here; however, a value of 0.5 has been used largely because such a value has been found to lead to agreement between predicted and measured level in rural farm country (as in the figures in Section 3.4.1 above, for instance).

The downwind sound level – the value measured in the IEC sound power level test - is assumed to exist in all directions simultaneously. This approach essentially represents a hypothetical situation where the wind is blowing from all directions at the same time making the predictions valid for any given wind direction.

In general, then, the model represents the following conditions at any given receptor point:

- **Observer Outside** – the plotted sound levels occur outside; sound levels inside of any dwelling will be 15 to 20 dBA, or more, lower.
- **Maximum Turbine Sound Level** - the maximum turbine sound level is used.
- **Cool Season, Nighttime L90 Background Levels** – the background survey was carried out during late winter conditions when environmental sound levels are generally at annual minimum. Based on other surveys of seasonal variation it is quite possible that the background level during the warmer months would be significantly higher.
- **Low Ground Porosity** – Open fields would normally be considered somewhat more acoustically absorptive than is assumed in the model.
- **Downwind Sound Level** – the downwind sound level measured per IEC 61400-11 is assumed to exist in all directions from every unit.

3.5 MODEL RESULTS

The overall results from the model are shown in **Plot 1**, which illustrates the mean sound levels exclusively from the project that are expected to occur under the conditions described above.

Sound levels have been mapped out to 40 dBA, which, as discussed in Section 3.1, may be taken as the approximate threshold beyond which project sound levels are unlikely to lead to any significant adverse reaction based on both the relative increase approach of the NYSDEC guidelines and the fact that complaints about wind turbine noise have been found to be rare at or below this sound level. This region – where project sound levels are expected to be higher than 40 dBA - encompasses much of the project area and most of the nearest residences to planned turbine locations. In particular, there are quite a few homes in the region between 40 and 45 dBA, meaning that the average project sound level will be more than 5 dBA above the background and will be clearly perceptible outside of these residences much of the time when the project is operating. Consequently, some potential exists for annoyance and sporadic complaints in this area; although experience with similar projects suggests that if complaints do occur they will be very small in number (on the order of 2%).

There are a handful of residences just inside the 45 dBA contour in various parts of the site area but they all belong to participating landowners. Issues with noise are much less common with participants than non-participants, as might be expected, but there should be an awareness that a project sound level above 45 dBA in such a rural environment means that the sound emissions from the turbines will be quite prominent and noticeable much of the time as a churning or swishing sound, particularly at night.

It is also important to note that the 40 dBA contour illustrated in the sound contour map is not necessarily the threshold of audibility and the turbines will probably be audible from time to time, depending on wind and weather conditions, for quite some distance beyond this contour line. Because they are entirely dependent on constantly changing wind and atmospheric conditions, wind turbine sound emissions are highly variable with time and will routinely fluctuate above and below the predicted mean level, usually within +/- 5 dBA, but by greater amounts on occasion.

3.6 LOW FREQUENCY NOISE

Modern pitch-regulated wind turbines of the type proposed for this project do not generate low frequency or infrasonic noise to any significant extent and no impact of any kind, whether related to annoyance or health, is expected from this. Early wind turbines with the blades downwind of the support tower were prone to producing a periodic thumping noise each time a blade passed the

tower wake – but, apart from one or two stall-regulated models, this particular effect no longer exists with the upwind blade arrangement used today. Stall-regulation is one approach for controlling the blades in order to maintain a steady power output in variable wind conditions. This mechanism, which is now a rarity, may be able to generate inaudible infrasonic pulses, along with considerable audible noise, during very high wind conditions (exceeding to 10 to 13 m/s). A recent field study by Rand and Ambrose[6] at a site with several stall-regulated turbines reports complaints and adverse health effects from these inaudible sounds; however, based on our own field experience with this particular turbine model, the pulses appear to be associated with this specific turbine and appear to primarily affect persons with a pre-disposition to motion or sea-sickness. Such effects are not anticipated from the pitch-regulated GE turbines planned for the Copenhagen Project.

Concerns about excessive low frequency noise from proposed wind farms are commonly voiced but they have apparently grown out of internet misinformation or anecdote without any basis in fact. The widespread belief that wind turbines produce elevated or even harmful levels of low frequency and infrasonic sound is unfounded, as proven repeatedly and independently by numerous investigators[7,8,9,10,11], and may have arisen from a confusion between periodic amplitude modulation noise and actual low frequency noise. Problematic levels of low frequency noise (i.e. those resulting in perceptible vibrations and complaints) are most commonly associated with simple cycle gas turbines, which without doubt produce tremendous energy in the low end of the spectrum – vastly more than could ever be produced by a wind turbine. In over 30 years of investigating complaints about obvious low frequency noise from gas turbines, concerns about adverse health impacts have never arisen.

When amplitude modulation does occurs it is usually at a rate of about once per second, or 1 Hz, which is the blade passing frequency of a typical three-bladed rotor turning at 20 rpm. Although the "frequency" of its occurrence at 1 Hz obviously falls at the extreme low end of the frequency spectrum, this noise is not "low frequency" or infrasonic noise, per se. It is simply a periodic sound where the actual frequency spectrum may contain some slightly elevated levels in the lower frequencies but where the most prominent noise is roughly centered around 500 Hz near the middle of the audible frequency spectrum.

The mistaken belief that wind turbines produce high levels of low frequency noise can also be attributed, perhaps even more definitively, to wind-induced microphone error where wind blowing through virtually any windscreen will cause the low end, and only the low end, of the frequency spectrum to substantially increase due to self-generated distortion. The magnitude and frequency response of this error has been theoretically/mathematically quantified by van den Berg[10] and empirically by Hessler[12] by subjecting a variety of commonly used windscreens to known air speeds in a massively silenced wind tunnel – thereby directly measuring the frequency response to air flow alone. The results of this wind tunnel experiment were used to evaluate measurements of actual wind turbine noise at a site in Southern Minnesota by Hessler in 2008[13].

Figure 3.6.1 below shows, as another example, the frequency spectra measured at a wind site in Wisconsin all the way down to 0.4 Hz (in the extreme infrasound region of the spectrum) at a location surrounded by 12 Vestas V90 turbines (some as close as 1250 ft.) with the project operating and then a few minutes later with all the turbines shut down. The wind speed at the microphone was approximately 5 to 6 m/s during both measurements.

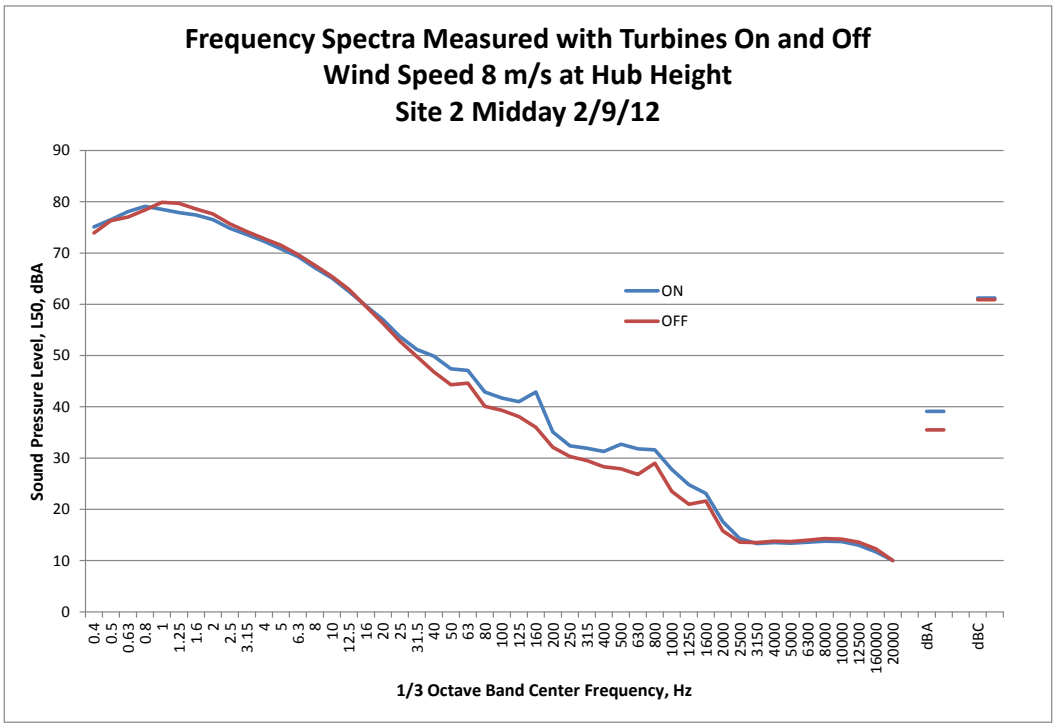

Figure 3.6.1

The salient point is that the two measurements show essentially the same values in the low frequencies (below about 20 Hz). Since there was clearly no source of low frequency noise present in the background measurement (taken in a remote farm field with all the surrounding turbines deliberately idled), the low frequency levels - in both measurements – simply represent self-generated distortion and are not the actual sound emissions of anything.

What this shows is that virtually any measurement taken under moderately windy conditions will be severely affected by false-signal noise in the lower frequencies, even when a large windscreen is used, as in the example above. The measurement will appear to show high levels of low frequency noise whether a wind turbine is present - or not.

A final example of this is Figure 3.6.2, which shows the C-weighted sound levels measured over a two week period at a residence surrounded by several wind turbines and simultaneously by a monitor located miles away from the project area in a similar setting (rural Midwestern farm country). In simple terms, C-weighted sound levels are driven by the low end of the frequency spectrum and are a measure of the low frequency content of the spectrum – whether real or artificial.

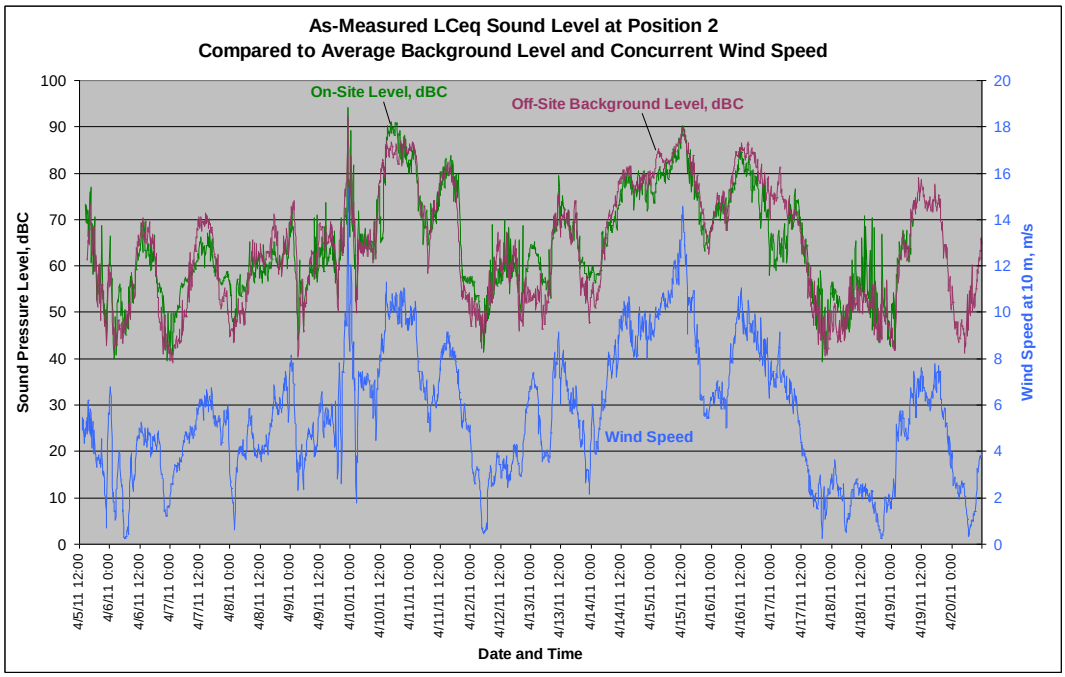

Figure 3.6.2

In essence, the levels are largely the same at both places and are more a measurement of the prevailing local wind speed and its effect on the microphone than any real source of low frequency noise. This same behavior is also evident in the previous example (Figure 3.6.1) where the C-weighted sound level is the same (61 dBC) whether the turbines were operating or shutdown.

3.7 CONSTRUCTION NOISE

Noise from construction activities associated with the project may temporarily constitute a moderate, unavoidable impact at some homes in the project area fairly close to turbine sites or adjacent to trenching operations. Assessing and quantifying these impacts is somewhat difficult because construction activities will constantly be moving from place to place around the site leading to highly variable impacts with time at any given point.

In general, the maximum potential noise impact at any single residence might be analogous to a few days to a few weeks of repair or repaving work occurring on a nearby road or to the sound of machinery operating on a nearby farm. More commonly (at houses that are some distance away), the sounds from project construction are likely to be faintly perceived as the far off noise of diesel-powered earthmoving equipment characterized by such things as irregular engine revs, back up alarms, gravel dumping and the clanking of metal tracks.

Construction of the project is anticipated to consist of several principal activities:

- Access road construction and electrical tie-in line trenching
- Site preparation and foundation installation at each turbine site
- Material and subassembly delivery
- Erection

The individual pieces of equipment likely to be used for each of these phases and their typical sound levels as reported in the *Power Plant Construction Noise Guide* (Empire State Electric Energy Research Corp.[14]) are shown below in Table 3.7.1. It should be noted that the reference

used for equipment sound levels is quite old, dating back to 1977, and that the levels in it are roughly 5 dBA higher than the values that can be found in more recent references, such as from the FHWA[15] for modern construction equipment. These older, higher values have been deliberately used purely to be conservative. Also shown are the maximum total sound levels that might temporarily occur at a distance of 1000 ft. and the distance at which construction sound levels are likely to become inconsequential (at a level of about 35 dBA).

Table 3.7.1 *Construction Equipment Sound Levels by Phase*

Equipment Description	Typ. Sound Level at 50 ft., dBA [Ref. 6]	Est. Maximum Total Level at 50 ft. per Phase, dBA*	Max. Sound Level at 1000 ft., dBA	Distance at which Construction Noise is likely to fall to 35 dBA, ft.
Road Construction and Electrical Line Trenching				
Dozer, 250-700 hp	88	92	63	7600
Front End Loader, 300-750 hp	88			
Grader, 13-16 ft. blade	85			
Excavator	86			
Foundation Work, Concrete Pouring				
Piling Auger	88	88	59	5900
Concrete Pump, 150 cu yd/hr	84			
Material and Subassembly Delivery				
Off Hwy Hauler, 115 ton	90	90	61	6700
Flatbed Truck	87			
Erection				
Mobile Crane, 75 ton	85	85	56	4800

* Not all vehicles are likely to be in simultaneous operation. Maximum level represents the highest level realistically likely at any given time.

What the values in this table generally indicate is that, depending on the particular activity, sounds from construction equipment are likely to be at least intermittently audible at distances of up to about 1.5 miles. At the very worst, however, sound levels ranging from 56 to 63 dBA might temporarily occur over several weeks at the nearest homes to turbine construction sites. Such levels would not generally be considered acceptable on a permanent basis or outside of normal daytime working hours (when all project construction is planned), but as a temporary, daytime occurrence construction noise of this magnitude may go unnoticed by many in the area. For others, project construction noise may be an unavoidable but temporary impact.

The estimated sound levels at 50 ft. in Table 3.7.1 also demonstrate that a maximum allowable sound level of 80 dBA recommended in the NYSDOT construction noise guidelines is only likely to occur at, or within 200 ft. of any specific construction site (a 12 dB reduction from the maximum level of 92 dBA at 50 ft. down to 80 dBA would occur at a distance of about 200 feet). Consequently, construction activities at the site of each turbine will result in sound levels that are substantially below 80 dBA at any homes due to the setback distances of more than 1000 feet. There may be some cases; however, where road construction or trenching operations occur closer

to homes. A short-term sound level of 80 dBA or more is theoretically possible where this distance is less than about 200 feet.

Noise from the very small amount of daily vehicular traffic to and from the current site of construction should be negligible in magnitude relative to normal traffic levels and temporary in duration at any given location.

4.0 CONCLUSIONS

A field survey of existing sound levels throughout the proposed Copenhagen Wind Project site area was carried out to determine how much natural masking sound there might be at residences in the vicinity of the project and how it might affect the perceptibility of sound emissions from it.

In general, over 2500 measurements were made on a continuous day and night basis over an 18 day period at each of 11 monitoring stations located at typical residences and farms throughout the project area. Environmental sound levels during a wide variety of wind and weather conditions were captured and correlated to the wind speed measured by an on-site 58 m (190 ft.) high anemometer. Thus, the wind conditions that the turbine rotors would see were related to the sound levels occurring simultaneously at ground level at homes in the area. The survey was carried out during late winter conditions when environmental sound levels are generally at an annual minimum.

Although measurements were taken both during the day and at night only the nighttime results, tabulated below as a function of wind speed, were used as a design basis for the assessment.

Table 4.0.1 *Mean Site-wide Nighttime L90 Background Sound Levels as a Function of Wind Speed*

Wind Speed at Standard Elevation of 10 m, m/s	3	4	5	6	7	8	9	10
L90 (Nighttime) Design Sound Level, dBA	**31**	**32**	**32**	**33**	**35**	**37**	**40**	**45**

For design and assessment purposes, a critical wind speed analysis was carried out to determine when the proposed GE 1.6-100 turbines would be most audible relative the background level. Both the background and turbine sound levels vary with wind speed but the greatest disparity between these two levels was found to occur at 7 m/s when the mean L90 background level was measured at 35 dBA and when the turbine sound power level was at its maximum value.

In the absence of any specific regulatory noise limits, two assessment thresholds, both coincidentally occurring at the same value, were established for the modeling analysis.

- A relative increase of 5 dBA above the pre-existing background level per NYSDEC guidelines. In this case 40 dBA based on a background level of 35 dBA measured during critical wind conditions (7 m/s)

- An absolute threshold of 40 dBA – largely defining the point at which complaints are possible but generally rare and unlikely

Using the maximum turbine sound power level of 105 dBA re 1 pW the projected sound emissions from the project were modeled and mapped over the site area in accordance with appropriate standards representing typical or normal atmospheric conditions – with the understanding that

project sound levels will vary considerably above and below the mean predicted level with changing atmospheric conditions. Comparisons between modeled sound levels and the levels actually measured at operating wind projects indicate that ISO 9613-2 is quite accurate at predicting the mean project sound level.

Sound levels were plotted out to 40 dBA, which may be taken as the approximate threshold beyond which project sound levels are unlikely to lead to any significant adverse reaction, based on both the relative increase approach of the NYSDEC guidelines and the fact that complaints about wind turbine noise have been found to be rare at or below this sound level. This region – where project sound levels are expected to be higher than 40 dBA - encompasses much of the project area and most of the nearest residences to planned turbine locations. In particular, there are quite a few homes in the region between 40 and 45 dBA, meaning that the average project sound level will be more than 5 dBA above the background and will be clearly perceptible outside of these residences much of the time when the project is operating. Consequently, some potential exists for annoyance and sporadic complaints in this area; although experience with similar projects suggests that if complaints do occur they will be very small in number.

There are a handful of residences just inside the 45 dBA contour in various parts of the site area but they all belong to participating landowners. Issues with noise are much less common with participants than non-participants, as might be expected, but there should be an awareness that a project sound level above 45 dBA in such a rural environment means that the sound emissions from the turbines will be quite prominent and noticeable much of the time as a churning or swishing sound, particularly at night.

It is also important to note that the 40 dBA contour illustrated in the sound contour map is not necessarily the threshold of audibility and the turbines will probably be audible from time to time, depending on wind and weather conditions, for quite some distance beyond this contour line. Because they are entirely dependent on constantly changing wind and atmospheric conditions, wind turbine sound emissions are highly variable with time and will routinely fluctuate above and below the predicted mean level, usually within +/- 5 dBA, but by greater amounts on occasion.

Although concerns are often raised with respect to low frequency or infrasonic noise emissions from wind turbines, no adverse impact of any kind related to low frequency noise is expected from this project. The widespread belief that wind turbines generate excessive or even harmful amounts of low frequency noise is evidently based on misinformation or a confusion of the amplitude modulation typical of wind turbines (i.e. the periodic swishing sound with a frequency of about 1 Hz) with low frequency sound. Numerous studies show that the low frequency content in the sound spectrum of a typical wind turbine is not substantially different than that of the natural background sound level in rural areas. Wind-induced self noise from wind blowing over the microphone, which artificially inflates the low end of the frequency spectrum, is another likely reason that low frequency noise has been incorrectly associated with wind turbines.

Unavoidable but mild noise impacts may occur during the construction phase of the project. Construction noise, sounding similar to that of distant farming equipment is anticipated to be sporadically audible at some homes within the immediate project vicinity on a temporary basis. The maximum magnitude of construction sound levels at the nearest homes to individual turbine locations is not expected to exceed 56 to 63 dBA depending on the particular activity. Higher levels are possible where homes are relatively close to trenching and road building activities.

END OF REPORT TEXT

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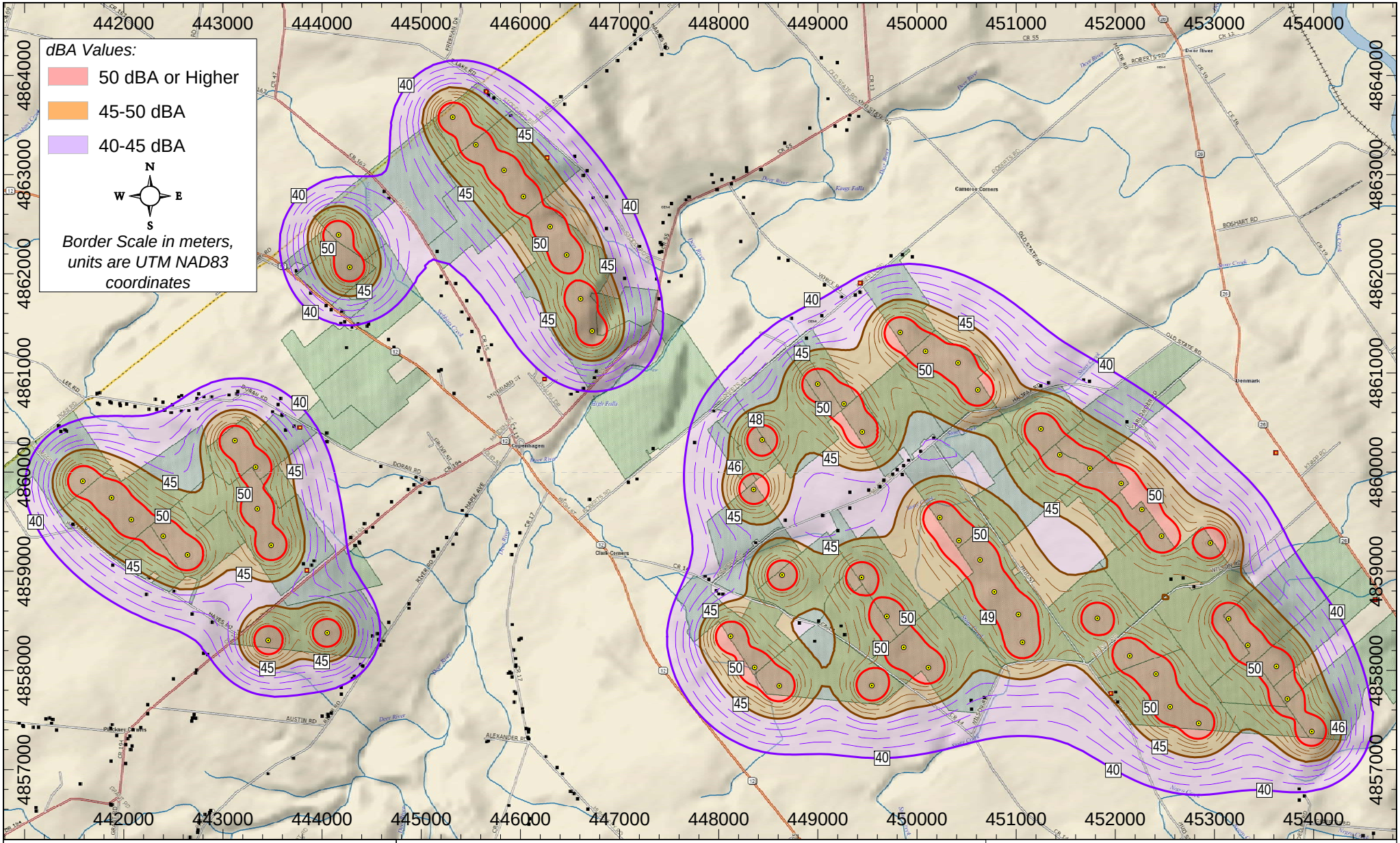

Project: **Copenhagen Wind Farm**	*Description:* **Plot 1**	*Legend:*
Prepared for: **OwnEnergy**	**Predicted Sound Contours (dBA) of GE 1.6-100 Turbines with an Omnidirectional 7 m/s Wind or greater**	Turbine Location
Date: January 24, 2013 / *Drawing #:* OC-Rev-D-1-1		Nearby Residence
		Participating Property

Hessler Associates, Inc.
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Since 1976

3862 Clifton Manor Place, Suite B
Haymarket VA, 20169
www.hesslernoise.com
(703) 753-2291 (703) 753-1602