

*Appendix J*  
*Noise Analysis for the Buckeye Wind*  
*Project*





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**ENVIRONMENTAL SOUND SURVEY AND  
NOISE IMPACT ASSESSMENT**

**BUCKEYE WIND PROJECT**

**CHAMPAIGN COUNTY  
OHIO**

PREPARED FOR:

**EverPower Wind Holdings, Inc.**

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## **1.0 INTRODUCTION**

Hessler Associates, Inc. has been retained by EverPower Wind Holdings, Inc. to evaluate potential environmental noise impacts from a proposed wind energy conversion project being developed in Champaign County, Ohio. Plans for the Buckeye Wind Project (The Project) currently call for the installation of approximately 70 wind turbines in the 1.8 to 2.5 MW size range. The specific make and model has not yet been determined. At the present time two candidates are being considered.

The study essentially consists of two phases: (1) a background sound level survey and (2) a computer modeling analysis of future turbine sound levels. The field survey of existing sound levels at the site was carried out to determine how much natural masking noise there might be - as a function of wind speed - at the nearest potentially sensitive receptors 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 tend to reduce the audibility of the wind farm, while low levels of natural noise would permit operational noise from the turbines to be more readily perceptible. The audibility of, and potential impact from, any new noise source is largely a function of how much, if at all, it exceeds the pre-existing background level at a potentially sensitive noise receptor location.

In the second phase of the assessment 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 the potential for perceptibility relative to the background sound level.

## **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 number of statistical sound levels were measured 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 is the “typical” sound level most likely to be observed at any given moment.

The L90 statistical sound level, on the other hand, is commonly used to conservatively quantify background sound levels. The L90 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 “background” level that forms a conservative or “worst-case” basis for evaluating the audibility of a new source.

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. Wind turbines only operate and produce noise when the wind exceeds a certain minimum cut-in speed of roughly 3 or 4 m/s at hub height. Turbine sound levels increase with wind speed up to about 8 to 10 m/s (measured at a standard elevation of 10 m) 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 noise is 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 over the entire sound level survey period at two on-site met towers for later correlation to the sound data.

## 2.2 SITE DESCRIPTION AND MEASUREMENT POSITIONS

The proposed Buckeye Project is generally located a few miles northeast of Urbana, Ohio in a predominantly agricultural area. The site area, which is roughly 9 miles north to south and 7 miles east to west, runs from the vicinity of the town of Mutual up to the environs of Cable in the northern part of Champaign County. The site terrain consists mostly of gently rolling hills with some relatively flat areas. In terms of vegetation, the area is primarily open farm land interrupted by a few scattered wooded areas.

Although the area generally consists of fairly large farms, a number of homes exist on smaller parcels of land between the larger farming properties. Private residences are more or less evenly distributed over the entire site area with intermittent areas of greater density around the small towns and other localities in the area. Turbines are planned throughout the area on fairly large tracts of open land between the residences.

In order to measure existing background sound levels that are representative of those experienced at homes in the vicinity of the turbines, sound level monitors were set up at 9 positions evenly distributed over the proposed project area.

**Graphic A** shows the site area, the proposed turbine locations and the sound level monitoring stations, which are also described below.

### Position 1 – 8077 Stevenson Road

Monitor 1 was situated on a fence post in an open field behind the residence



**Figure 2.2.1** *Monitor 1 – Looking East*



Position 2 – 7498 CR 44

Monitor 2 was located on a post in rear of the residence. The area was surrounded by open farm fields.



**Figure 2.2.2** *Monitor 2 – Looking East*

Position 3 – 2953 Mt. Tabor Road

Monitor 3 was located in an open field on a utility pole along the driveway to the home.



**Figure 2.2.3** *Monitor 3 – Looking North*



Position 4 – 5559 State Road 245E

Monitor 4 was located an open area on a fence post behind the home.



**Figure 2.2.4** *Monitor 4*

Position 5 – 4557 Urbana Woodstock Road

Monitor 5 was positioned on a fence post among a line of trees dividing two fields and adjacent to several homes (across the road).



**Figure 2.2.5** *Monitor 5 – Looking North*





Position 6 – 47 N. Parkview Road

Monitor 6 was located on a tree in the rear yard of the house



**Figure 2.2.6** *Monitor 6 – Looking West*

Position 7 – 345 N. Mutual Union Road

Monitor 7 was attached to a utility pole in the side yard of the house.



**Figure 2.2.7** *Monitor 7 – Looking East*



Position 8 – Opposite 7400 Hwy. 161

Monitor 8 was supported on a young tree behind an unoccupied residence across the road from 7400.



**Figure 2.2.8** *Monitor 8 – Looking North towards Hwy. 161*

Position 9 – 2560 S. Mutual Union Road

Monitor 9 was located on a fencepost at the edge of a large open field behind a church in the village of Mutual.



**Figure 2.2.9** *Monitor 9 – Looking South*

2.3 INSTRUMENTATION AND SURVEY DURATION

Rion Model NL-22 and NL-32, ANSI Type 2, integrating sound level meters were used for the survey. Each instrument was enclosed in a weatherproof case fitted with a 12” microphone boom.



The microphones were protected from wind-induced self-noise by oversized 180 mm (7") diameter foam windscreens (ACO Model WS7-80T). The microphones were also situated at a fairly low elevation of about 1 m above grade so that they were exposed to relatively low wind speeds. As illustrated later in Figure 2.6.1 wind speed normally diminishes rapidly close to the ground, theoretically going to zero at the surface. At a height of 1 m the microphones were nominally exposed to inconsequential wind speeds of about 3 or 4 m/s during the wind conditions of greatest interest (6 to 8 m/s as measured at the IEC standard height of 10 m above grade). Wind tunnel testing [Ref. 8] of microphone self-noise for various windscreens (performed after completion of the Buckeye field survey) confirms that:

- Wind-induced false-signal noise occurs only in the lower frequencies, making the A-weighted sound level relatively insensitive to this effect<sup>1</sup>.
- Significant upward skewing of the A-weighted sound level only begins to occur at wind speeds of around 15 to 20 m/s, which are generally well above the range of interest for wind project background surveys (roughly 3 to 8 m/s at 1 m above grade).
- The ACO WS7-80T windscreen (the type used in the Buckeye survey) was the best performing windscreen out of all tested; i.e. it offered the greatest protection against wind-induced distortion.

Consequently, the as-measured survey levels are considered valid and free of any significant self-generated contamination.

All the instruments were field calibrated with a Brüel and Kjær Type 4230 calibrator at the beginning of the survey and again at the end of the survey. The observed calibration drift was ranged from -0.1 dB to +0.3 dB.

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 14 days beginning at noon on 1/11/08 and ending on 1/25/08.

As can be seen in the photographs in Section 2.2, the trees were bare and the survey was conducted under conservative wintertime conditions. Environmental sound levels are normally lowest at this time of year because wind-induced leaf rustle noise is absent and no insects are present. During the warm weather months significantly higher background sound levels, on the order of 5 to 7 dBA<sup>2</sup>, can be expected due to these two principal causes.

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<sup>1</sup> A-weighting intentionally suppresses the lower frequencies in order to make the overall sound correspond to the way it is subjectively perceived by the human ear. Low frequency sounds are much less perceptible than mid and high frequency sounds. The factors subtracted from the very lowest frequencies in the A-weighting process are large (on the order of 50 dB) and have the effect of canceling the increase caused by wind-induced distortion, which also occurs in the low frequencies. Sound levels without any weighting applied or C-weighted sound levels would, on the other hand, be dramatically affected by wind-induced distortion.

<sup>2</sup> Based on field tests at other wind project sites where identical surveys were completed under both winter and summer conditions. Using the winter sound level to define the year-round background level is highly conservative since much more masking sound generally exists during the warm weather months when people are outside, when windows are open and when the greatest potential for noise impacts exists. This reduction in the potential perceptibility of Project sound during the summer is ignored by using the wintertime background level as a design basis. In the wintertime people are normally inside most of the time with the windows shut and thus significantly more shielded from exterior sounds.

2.4 SURVEY WEATHER CONDITIONS

The weather conditions during the survey were mostly clear and cold with very little precipitation. The only precipitation occurred on January 13 and 17 when each time less than 0.1” of rain/snow fell.

The general weather parameters of temperature, barometric pressure and wind for the survey period, as observed in at a weather station on McAdams Road within the project area near the village of Cable, are illustrated in the graph below.

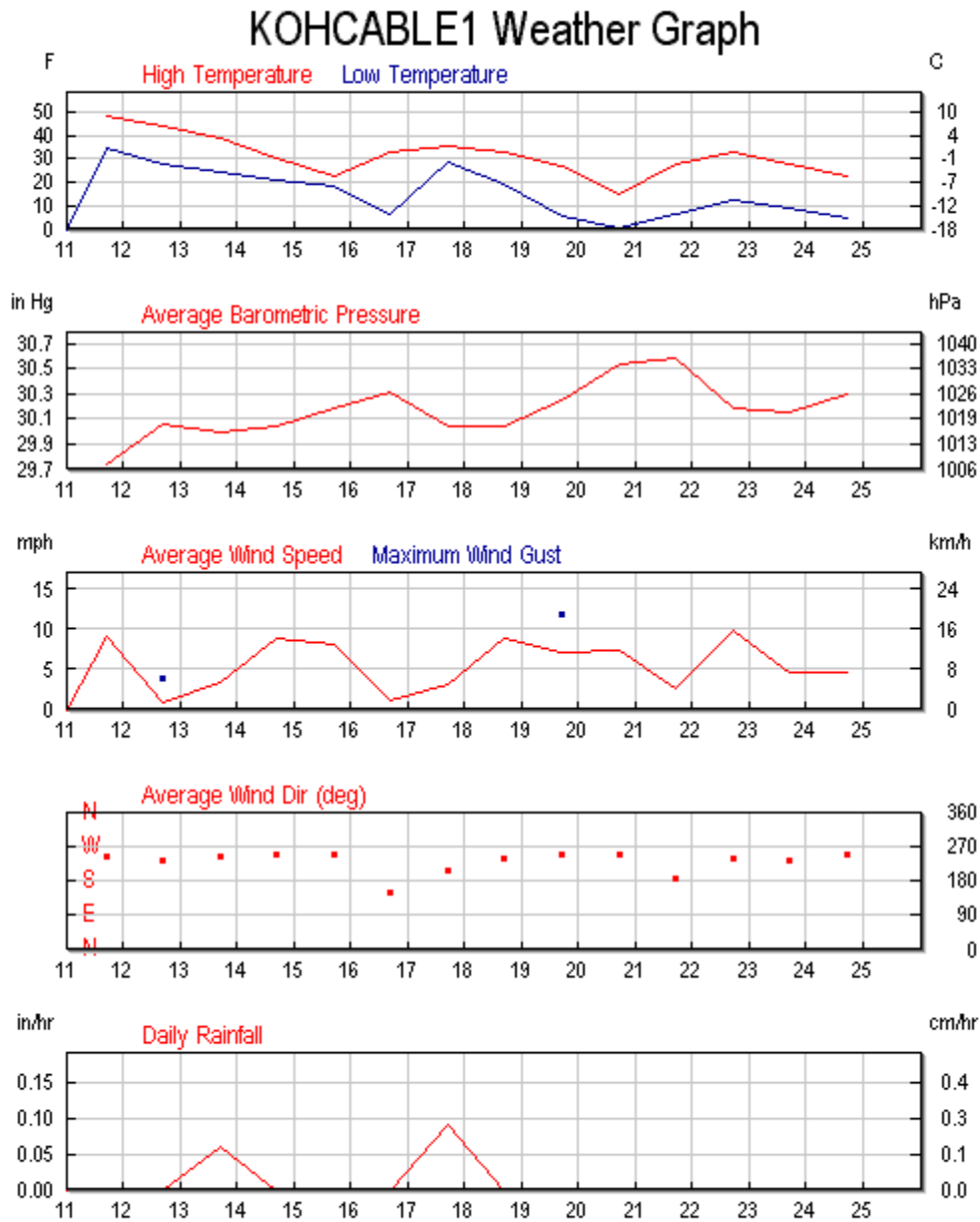


Figure 2.4.1 General Weather Data for the Survey Period as Observed Near Cable, OH

A much more detailed record of the wind speed at the site was measured at a two met towers (Sites 01 and 02) distributed over the project area. Figure 2.4.2 below shows the wind speed measured in 10 minute increments at an anemometer height of 40 m. Since the wind speeds are fairly uniform between the two locations, which are separated by a number of miles, the arithmetic average is considered a reasonably representative record of the typical wind speed over the entire site area.

In Figure 2.4.3 this average is normalized from an elevation of 40 m to a standard elevation of 10 m in accordance with IEC Standard 61400-11 [Ref. 1]. This 10 m height, explained in more detail in Section 2.6 below, is relevant because all wind turbine sound levels are expressed as a function of wind speed at this standard elevation.

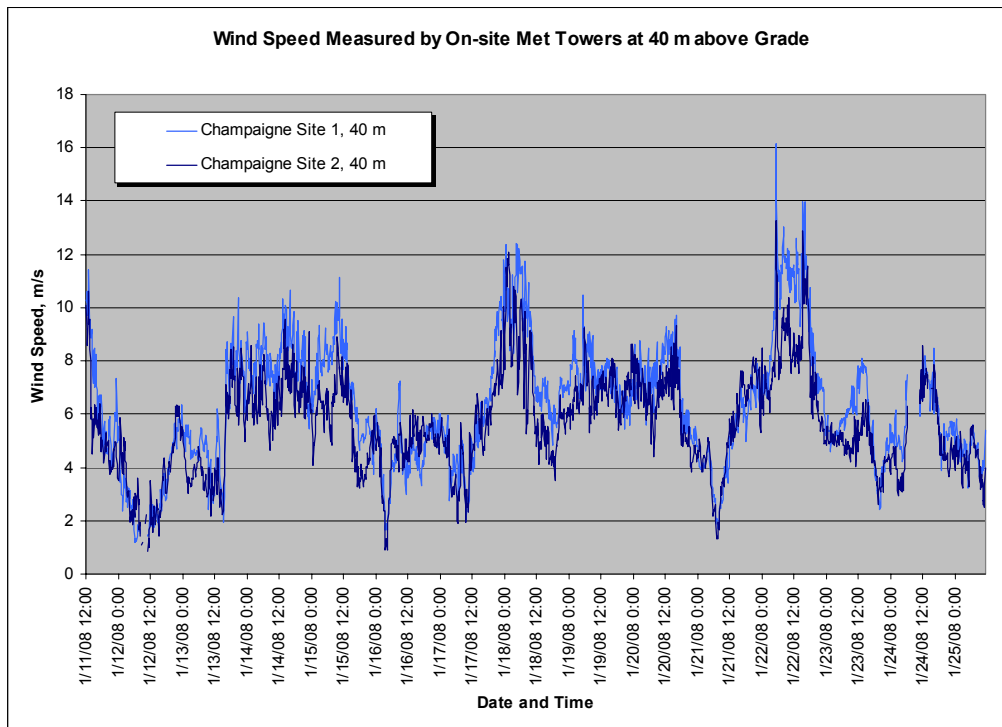
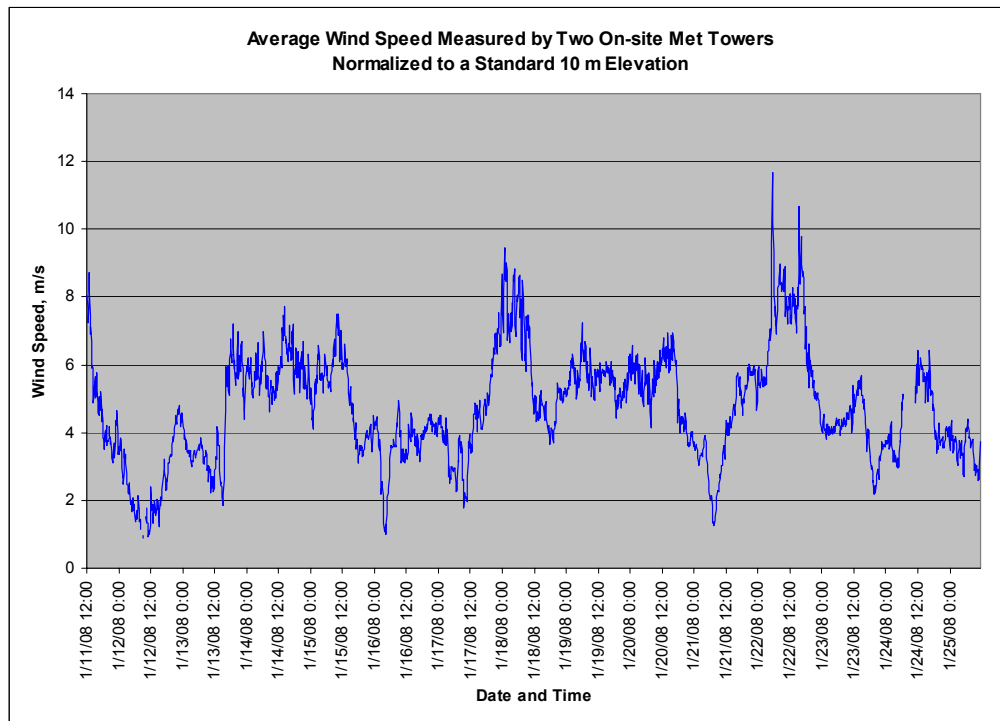


Figure 2.4.2 Wind Speed vs. Time Measured by On-Site Met Towers During the Survey Period



**Figure 2.4.3** Average Site-wide Wind Speed vs. Time Normalized to 10 m

## 2.5 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 noise to obscure potential turbine 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 is the near “worst-case” background level with regard to evaluating potential impacts from a new source since it represents essentially the lowest amount of masking sound.

The L90 sound levels over consecutive 10 minute periods for all 9 positions are plotted below in Figure 2.5.1.

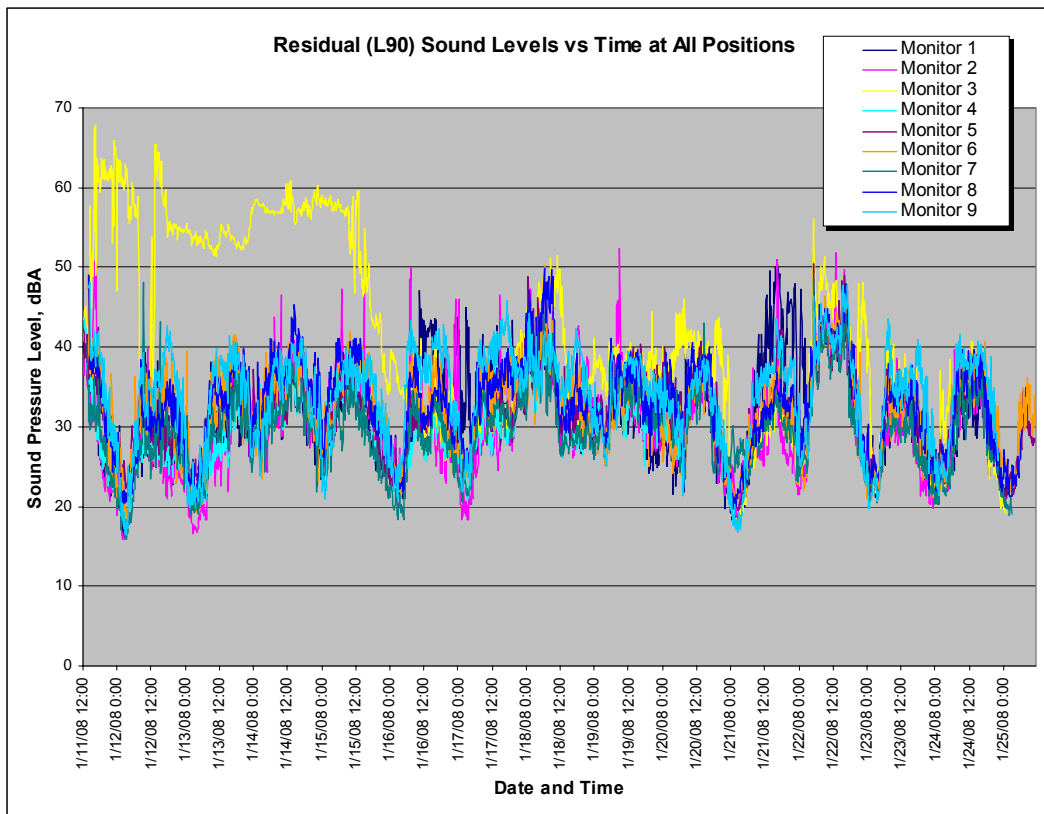
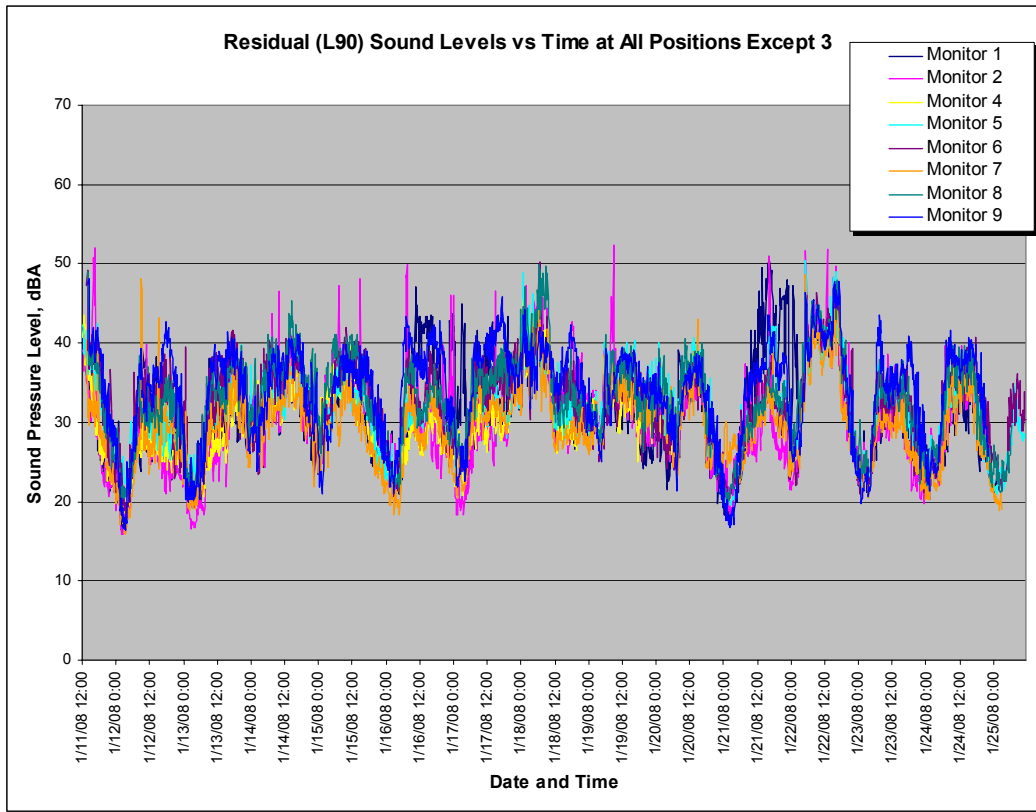


Figure 2.5.1 10 minute L90 Sound Levels at All Monitoring Positions

This plot shows that the L90 sound levels at these very widely distributed locations closely follow the same trends - except at Positions 3 where an apparent instrument malfunction produced spurious data for the first few days (only) of the survey. Omitting this position, the uniformity of sound levels over these many and widely distributed locations is more evident (Figure 2.5.2).



**Figure 2.5.2** 10 minute L90 Sound Levels at All Monitoring Positions Except 3

The consistency in level and behavior as a function of time between these 8 monitoring stations is remarkable given the fact that they were spread out over an area of roughly 77 square miles in a variety of settings. Because of this uniformity it can be concluded that the average sound level of these 8 positions would reasonably represent the sound level anywhere in the vicinity of the site and can be used as a design level. The likelihood of the sound level being substantially and consistently different at a location between the monitoring points is obviously extremely remote. The average, design, L90 sound level is plotted in Figure 2.5.3.

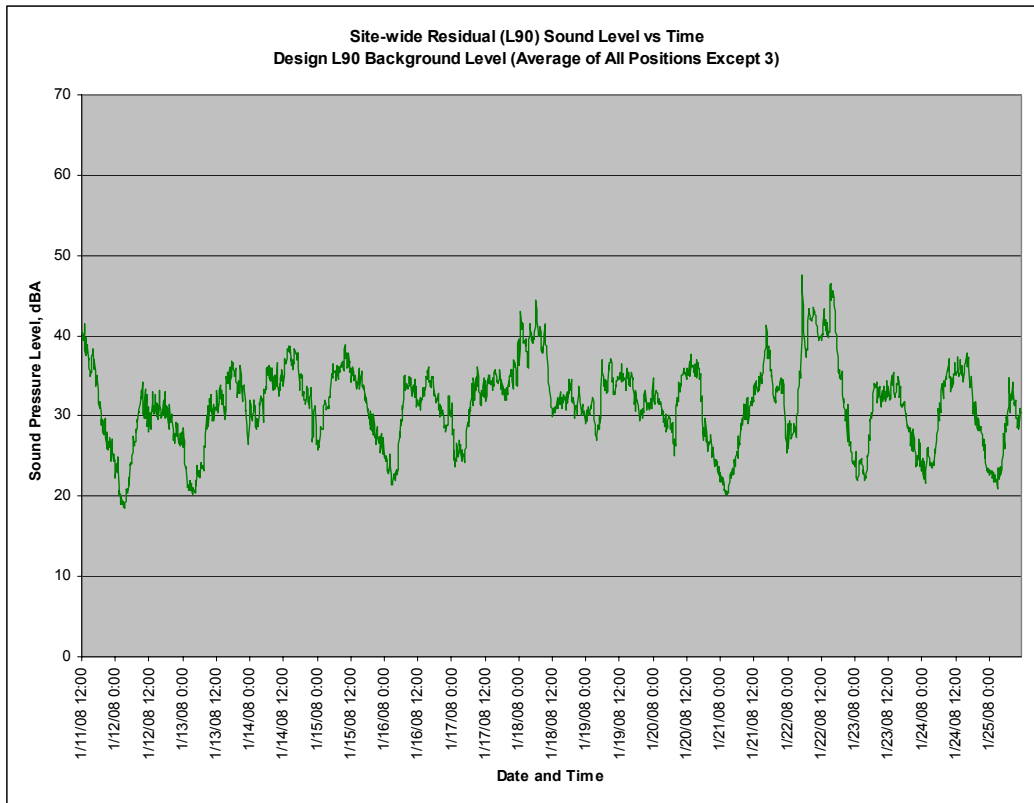


Figure 2.5.3 Average L90 Sound Level – Design Level

Figure 2.5.4 compares the average background L90 sound level to the average wind speed measured by the on-site met towers.

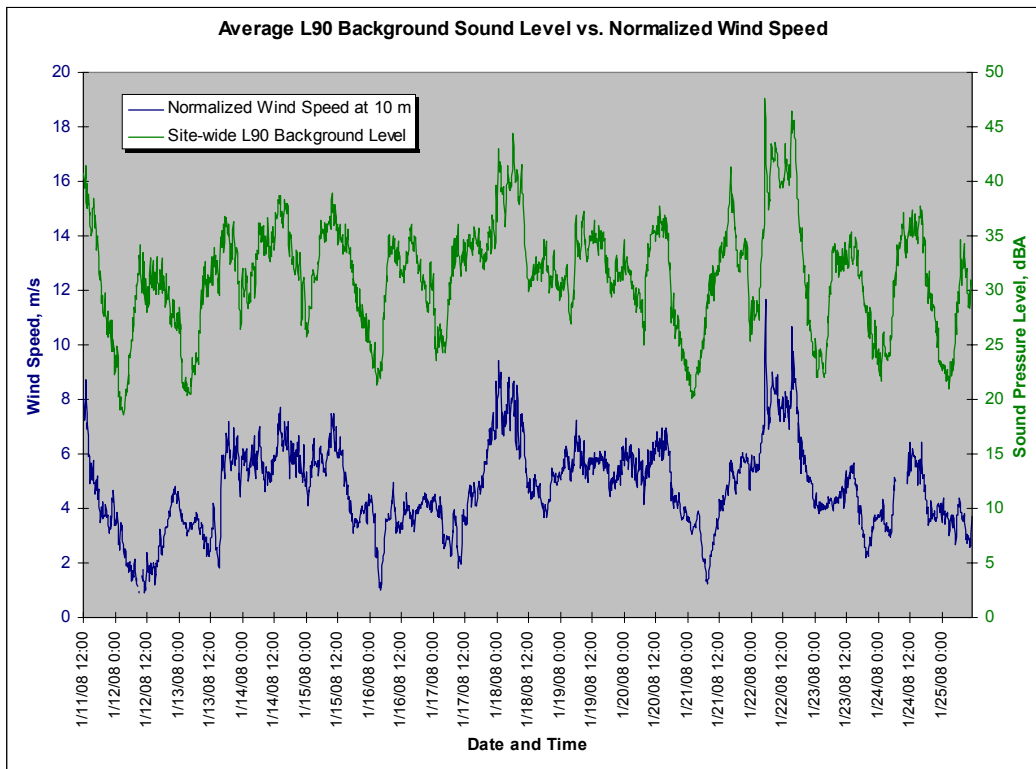


Figure 2.5.4 Design L90 Sound Level Compared to Wind Speed

This plot shows that the near-minimum (L90) background sound levels over the site area are clearly related to wind speed and largely driven by wind-induced natural sounds, although an underlying diurnal, or day-night, variation is also visible where there is brief minimum in the early morning hours on most days.

The dependency of sound levels on both wind speed and time of day can be quantified by replotting the sound data as a function of wind speed for the daytime (7:00 a.m. to 10 p.m.) and nighttime (10 p.m. to 7:00 a.m.) periods. These regression analyses are shown in Figures 2.5.5 and 2.5.6.



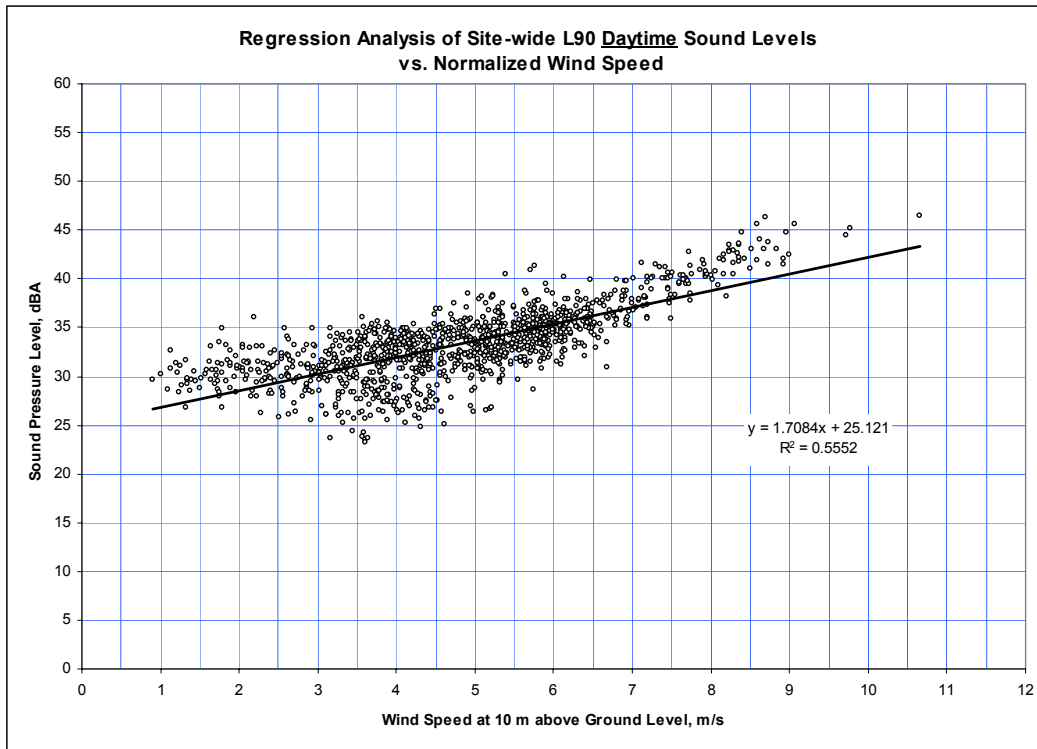


Figure 2.5.5 Correlation Between the L90 Background Level and Wind Speed - *Daytime*

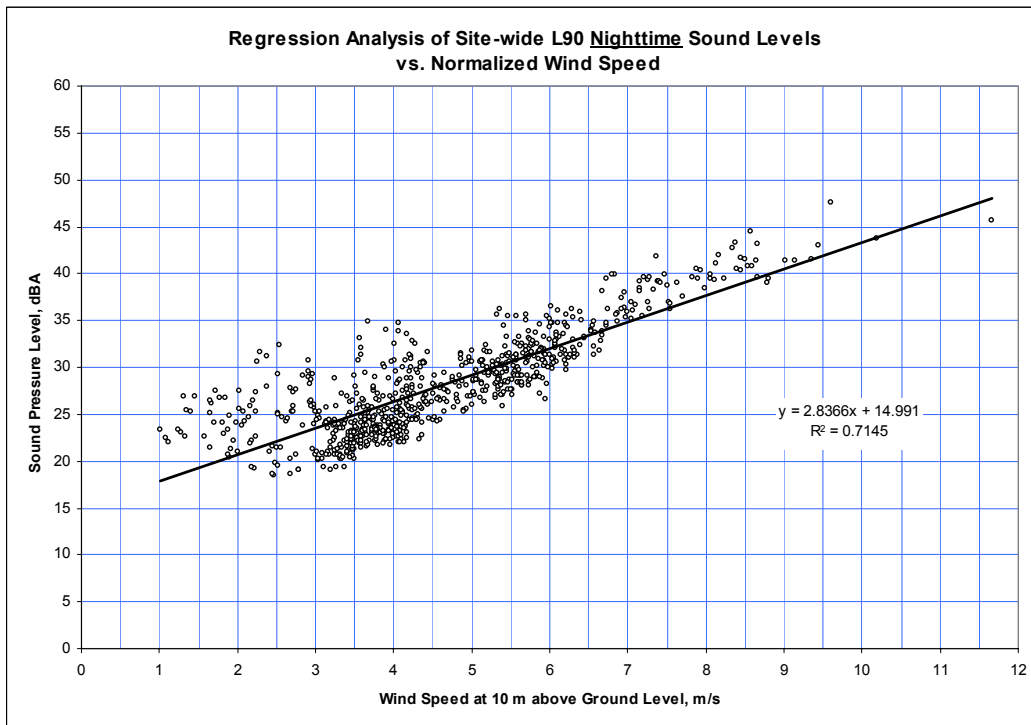


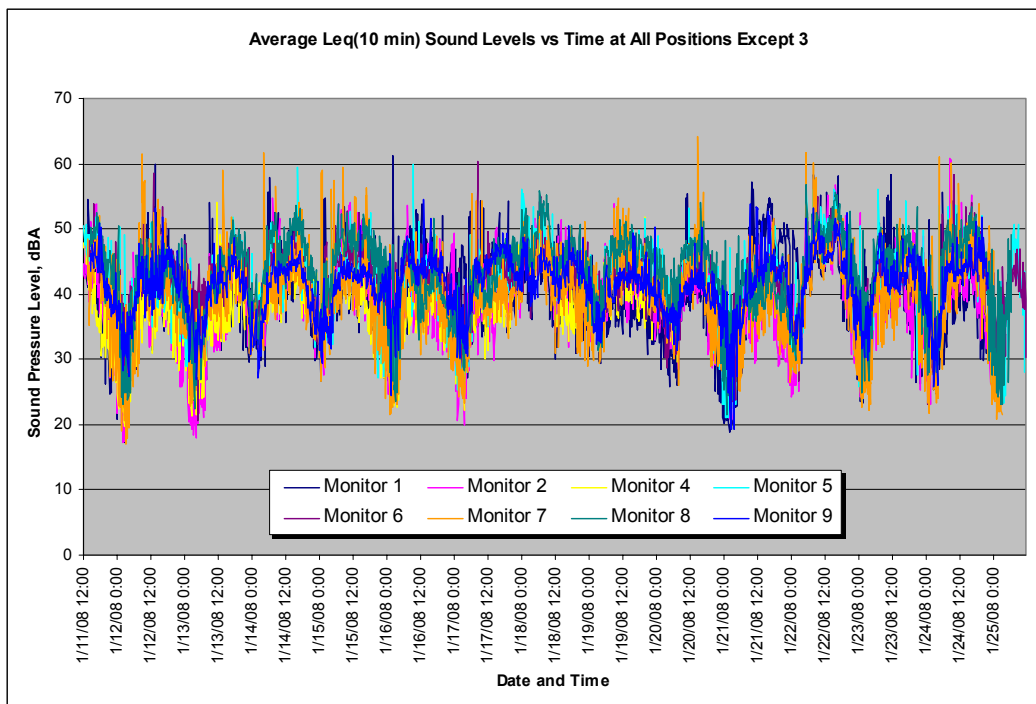
Figure 2.5.6 Correlation Between the L90 Background Level and Wind Speed - *Nighttime*

These plots show that sound levels clearly increase with increasing wind speed regardless of the time day. In general, the nighttime levels have a greater dependency on wind (steeper slope to the trendline) and reach extremely low levels in the 20 to 25 dBA range during calm wind conditions while daytime levels remain relatively elevated during low wind conditions. At higher wind speeds the daytime and nighttime sound levels are nearly the same. The following table summarizes the residual (L90) background levels that characterize the site environment over the range of wind speeds relevant to turbine operation.

**Table 2.5.1** Measured L90 Background Sound Levels as a Function of Wind Speed

Integer Wind Speed at Standardized Elev. of 10 m, m/s	4	5	6	7	8	9	10
<b>Daytime L90 Sound Level, dBA</b>	<b>32</b>	<b>34</b>	<b>35</b>	<b>37</b>	<b>39</b>	<b>40</b>	<b>42</b>
<b>Nighttime L90 Sound Level, dBA</b>	<b>26</b>	<b>29</b>	<b>32</b>	<b>35</b>	<b>38</b>	<b>41</b>	<b>43</b>

The sound levels in Table 2.5.1 can be considered “worst-case” because these background levels represent the lowest levels that are likely to be observed for brief periods during intermittent lulls in all forms of environmental sound (both natural and man-made). By definition, the L90 sound level does not occur over long periods and does not characterize the sound level that is most commonly present. The sound level that is more likely to actually exist most of the time is the average, or Leq, sound level, which may be regarded as the “typical” sound level. The Leq(10 min) sound levels measured over the survey period are plotted below.

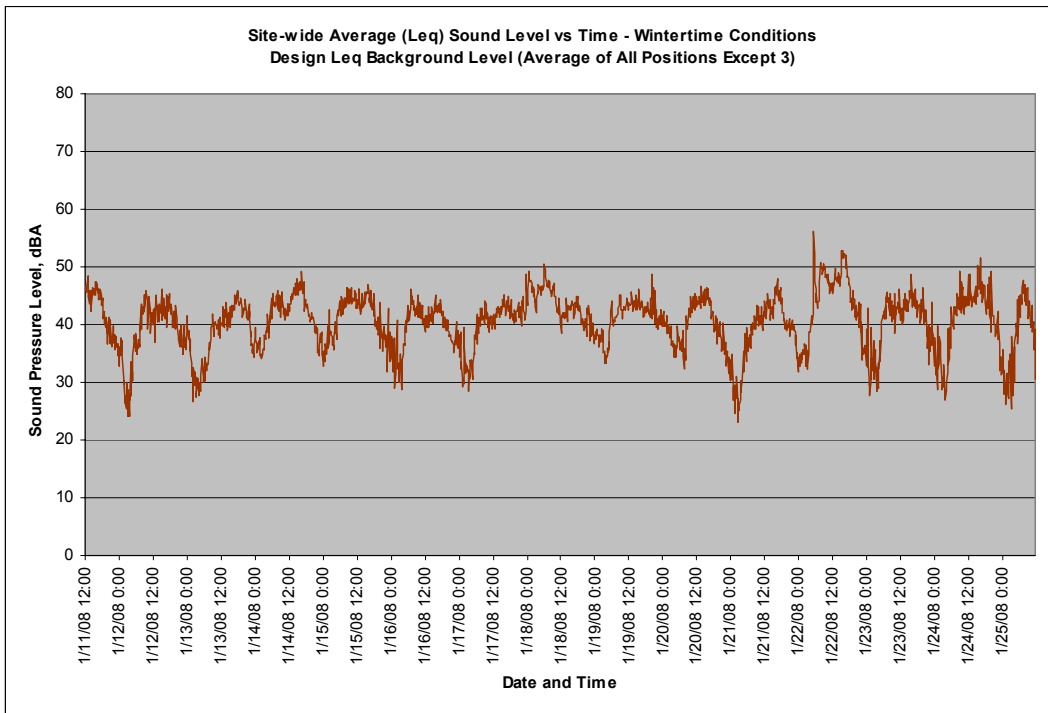


**Figure 2.5.7** Average Sound Levels Measured at All Positions (Except 3)

Although the levels are (naturally) less tightly grouped than in the case of the L90 (Figure 2.5.1), there is still a general uniformity and temporal consistency over all eight widely dispersed positions. Since Leq levels are more easily influenced by sporadic local noise events, such traffic

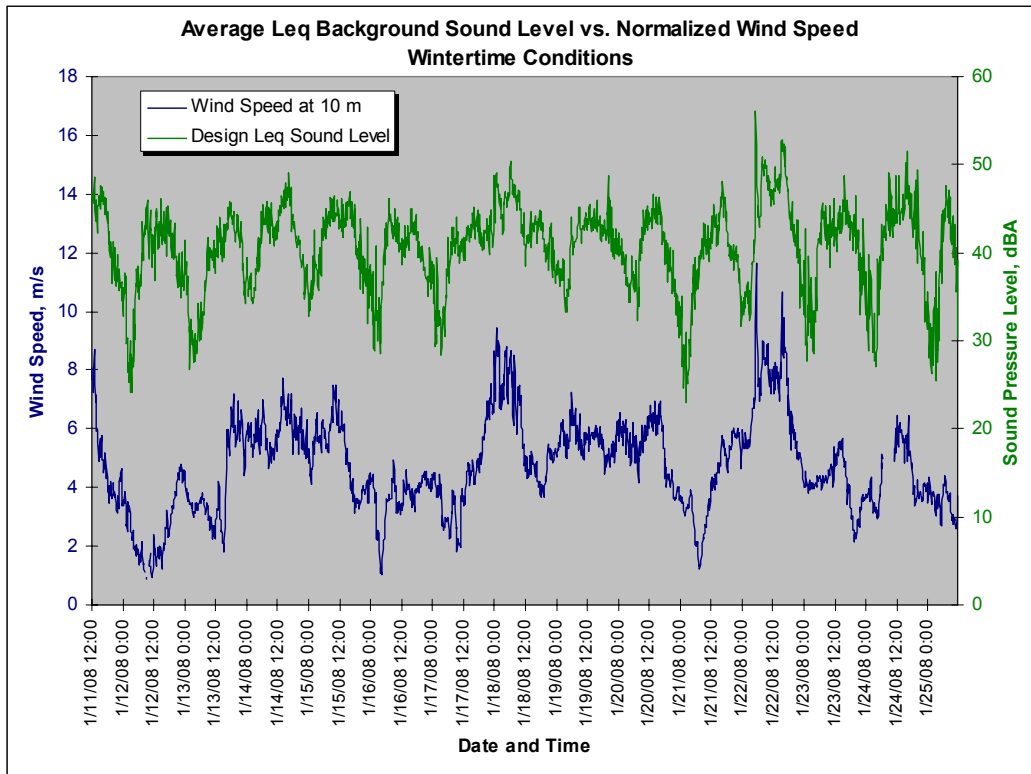


or farm activity, there is a natural tendency for the Leq levels to be less uniform than the L90, which essentially filters out short-duration noise events and defines the underlying minimum level. Nevertheless, it is clear from Figure 2.5.7 that the arithmetic mean of all eight positions would reasonably represent the site-wide average, or “typical” sound level as a function of time. This average design level is plotted in Figure 2.5.8.



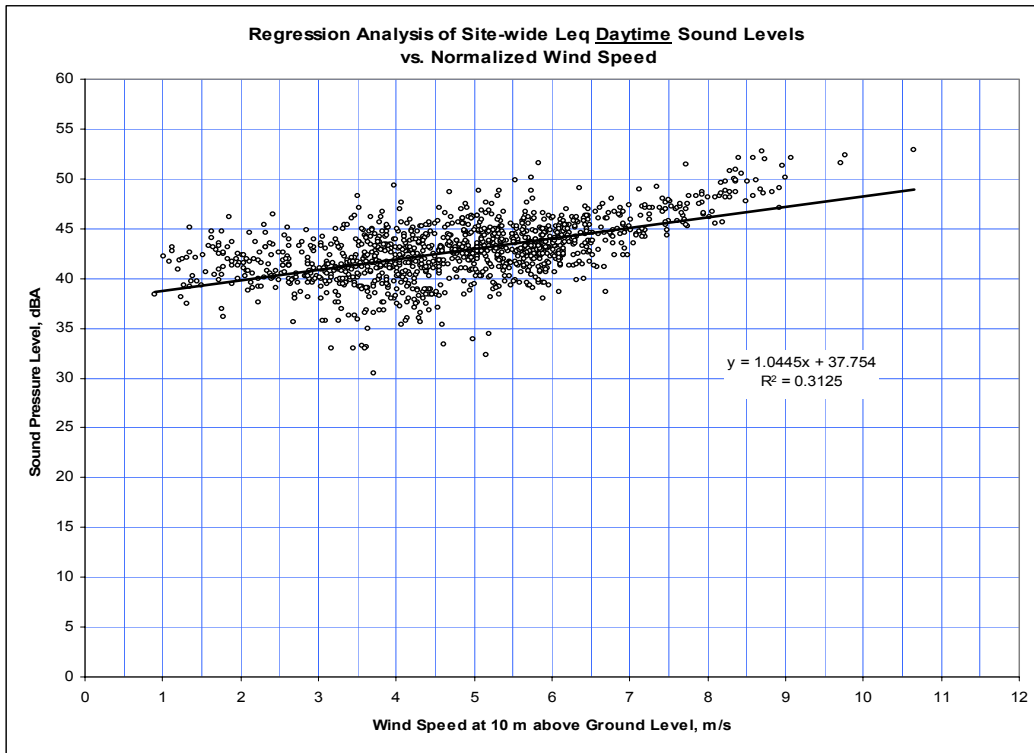
**Figure 2.5.8** Site-wide Average Sound Level

This design level is compared to the concurrent wind speed in Figure 2.5.9.

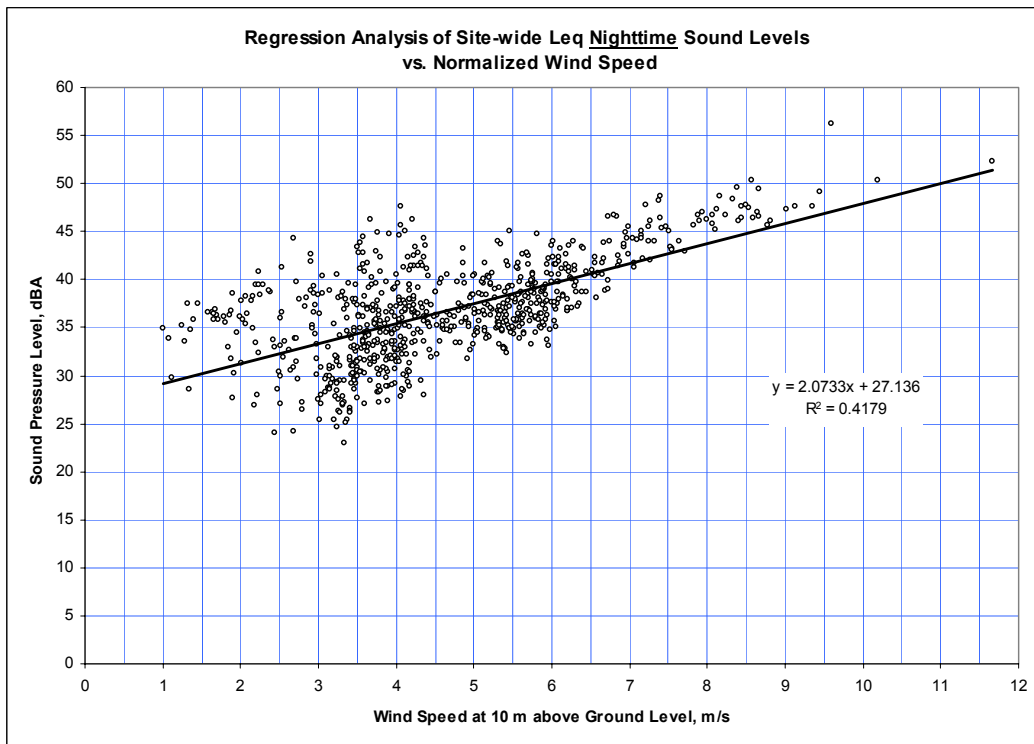


**Figure 2.5.9** Design Leq Sound Level Compared to Wind Speed

While the periods of relatively high winds have corresponding spikes in sound level, indicating a definite correlation, much of the time the relationship between the average sound level and wind speed is obscured by the day-night variation. Nevertheless, the regression analyses below of the daytime and nighttime levels, as a function of wind speed, show that there is still a general dependency on wind speed; i.e. sound levels increase with wind speed.



**Figure 2.5.10** Correlation Between the Leq Background Level and Wind Speed – Daytime



**Figure 2.5.10** Correlation Between the Leq Background Level and Wind Speed - Nighttime

As with the L90 levels, the nighttime levels have a somewhat stronger dependency on wind speed.

The following table summarizes the “typical”, Leq background levels that characterize the site environment over the range of wind speeds relevant to turbine operation.

**Table 2.5.2** *Measured Leq Background Sound Levels as a Function of Wind Speed*

Integer Wind Speed at Standardized Elev. of 10 m, m/s	4	5	6	7	8	9	10
<b>Daytime Leq</b> Sound Level, dBA	<b>42</b>	<b>43</b>	<b>44</b>	<b>45</b>	<b>46</b>	<b>47</b>	<b>48</b>
<b>Nighttime Leq</b> Sound Level, dBA	<b>35</b>	<b>38</b>	<b>40</b>	<b>42</b>	<b>44</b>	<b>46</b>	<b>48</b>

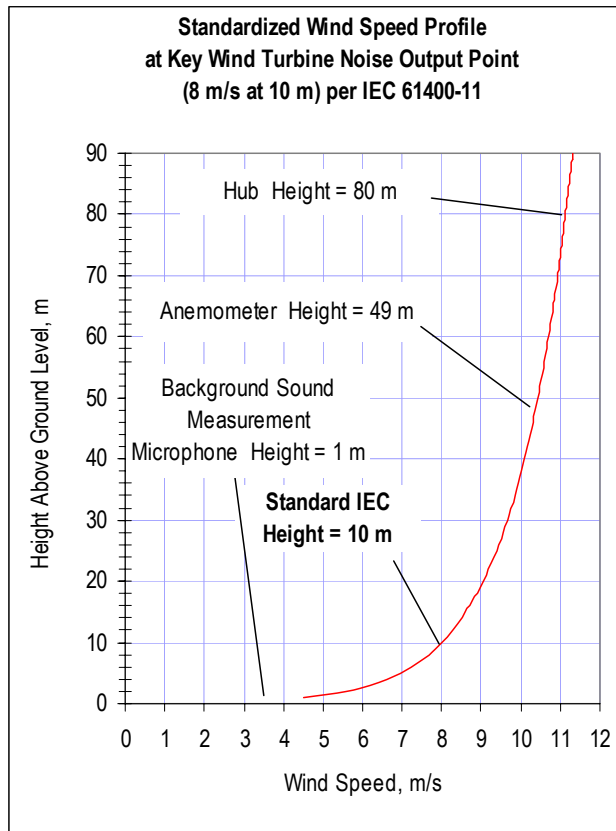
These average levels range from about 6 to 10 dBA higher than the residual, L90 levels (Table 2.5.1).

## 2.6 WIND SPEED AS A FUNCTION OF ELEVATION ABOVE GROUND LEVEL

Below about 100 m, wind speed varies with elevation above the ground due to friction with the surface and obstacles, such as trees. Because this roughness varies from place to place measurements of wind turbine sound power levels carried out in accordance with IEC Standard 61400-11 [Ref. 1] are normalized to, and reported in terms of, the wind speed at a reference height of 10 m. This enables the nominal sound level of different makes and models of wind turbines to be compared on a uniform basis.

The conversion of wind speed at one elevation to the related speed at another elevation is calculated from a formula in the IEC standard (Equation (7), Section 8), which describes a logarithmic profile. This profile was determined empirically from wind speed measurements at various heights over a long period of time and is intended to represent average or normal conditions. It should be understood that the shape of this curve can certainly vary from this norm during temperature inversions and other atmospheric conditions that occur a small percentage of the time but as a design condition this curve reasonably captures the wind speed profile during most normal conditions.

As an example, the wind profile resulting from Eqn.(7) is shown graphically below in Figure 2.6.1 for the case where the wind is normalized to a speed of 8 m/s at 10 m. The shape of the profile curve varies with wind speed becoming flatter at low speeds and more curved at higher speeds.



**Figure 2.6.1** Typical Wind Speed Profile above the Surface

### 3.0 PROJECT NOISE MODELING AND IMPACT ASSESSMENT

#### 3.1 ASSESSMENT CRITERIA

##### 3.1.1 General Sound Impacts at Residences

There are no national or state laws that would specifically limit Project noise. In the absence of any specific or absolute noise level limits, potential noise from the Project will be evaluated in terms of its likely audibility or perceptibility relative to the background sound level at residences – where people are most likely to be most of the time.

In general, a new broadband noise source without any distinctive character to it, such as tonality or impulsiveness, must have a sound level that is about 5 dBA higher than the background before it begins to be perceptible to most people. For wind turbines, however, the threshold of perception is somewhat lower because the sound sometimes has a mildly periodic quality associated with blade “swish” that makes it more readily perceptible than a steady, bland sound of the same magnitude. The sound level rises and falls slightly at about 1 second intervals, since only the down-coming blade briefly generates aerodynamic noise followed by a very short pause until the next blade comes around. This phenomenon, referred to as amplitude modulation, makes wind turbines more readily perceptible than other sounds of comparable magnitude. Although this modulation in the sound has a “frequency” of about 1 Hz it is *not* low frequency or infrasonic noise, as is often mistakenly believed. Because of this characteristic wind turbine noise is

normally perceptible when its overall A-weighted sound level is less than 5 dBA above the background level.

Having said that, however, setting the nominal impact threshold at a point 5 dBA above the prevailing background level represents a reasonable design target in the sense that it balances the interests of all parties. On the one hand, the allowable sound level must not be so low and restrictive that, for all practical purposes, nothing can be built while, on the other hand, the project sound level must not be so loud that it leads to legitimate disturbance at a large number of homes. A design goal of limiting the project sound level to 5 dBA over the background strikes a reasonable balance between these extremes. This approach is commonly used in siting analyses for all types of new infrastructure projects and is currently being used for numerous wind energy projects in New York State, for example, per a set of guideline recommendations [Ref. 10] promulgated by that State's Department of Environmental Conservation (NYSDEC).

It is important to note, though, that this threshold point does *not* define the limit of audibility. Beyond it project sound levels will be relatively low during most normal conditions and the likelihood of widespread adverse reaction to project noise is considered small. In order to make the project completely inaudible or preclude the possibility of *any* adverse reaction to noise at all under all atmospheric conditions, vast setback distances would be required – distances that would probably be impossible to realize at most potential wind project sites east of the Mississippi River.

One additional point on this design approach is that for wind turbine projects in particular the threshold of potential disturbance can not and should not be *rigidly* defined as a specific absolute or relative decibel level because reaction to wind turbine noise is highly subjective and individual. For example, experience on other projects indicates that many people have no adverse reaction to levels that are much more than 5 dB over the ambient while complaints have been received from locations where the sound level from the project is equivalent to or even below the background level. Consequently, a 5 dBA increase should be viewed as the center point of a fairly wide gray area of potential reaction and is intended to strike a reasonable balance between the interests of the project developer and non-participating neighbors rather than define a hard and fast boundary between acceptable and unacceptable sound levels.

### 3.1.2 *Sound Impacts at Project Boundaries*

The relative design criterion described above is considered appropriate for application at existing permanent residences where people actually are most of the time. At the boundaries of the Project, or, more specifically, at the property lines of adjoining non-participating land parcels it is not practical to use an ambient-based, incremental increase design criterion since that would effectively limit any development to a few turbines on vast tracts of land. A relatively low Project sound level at property lines is also unnecessary in just about every case because no one is usually permanently present at the fringe of a land parcel to be potentially affected by noise.

In the rare instances where property line noise limits have been imposed on wind turbine developments (in our experience with dozens of projects), an absolute noise limit of 50 dBA is typically used. This limit reasonably caps Project sound levels at property lines and will be adopted as a design goal here.

## 3.2 TURBINE SOUND LEVELS

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. At the present time two different makes and models of turbine are being considered:



- Nordex N90/2500 LS – 90 m rotor, 2.5 MW power output
- REpower MM92 – 92 m rotor, 2.0 MW power output

The sound emissions from both turbines are similar, as might be expected since both have nearly identical rotors. The overall sound power levels of each unit as a function of wind speed is tabulated below. These levels come from field tests of operating units carried out by independent acoustical engineers [Refs. 7 and 9] in accordance with IEC 61400-11 [Ref. 1]. A uniform 80 m hub height is assumed.

**Table 3.2.1** Sound Power Levels vs. Wind Speed of Candidate Turbine Models

Wind Speed at 10 m Height, m/s	Nordex N90/2500 LS Sound Power Level, dBA re 1 pW	REpower MM92 Sound Power Level, dBA re 1 pW
4	98	-
5	101	101.6
6	103	103.6
7	104	104.4
8	104.5	105
9	104.8	105
10	105	105

Because the REpower values are slightly higher, the modeling studies will rely exclusively on these sound levels as inputs.

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 specialized, calculated measure, expressed in terms of Watts, that is primarily used for acoustical modeling and in 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:

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

Where,

$L_w$  = Sound Power Level

$L_p$  = 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 ( $4\pi 100^2$ ) 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 advantage of a power level is that the sound pressure level of the source can be calculated at any distance; hence its importance to noise modeling.

3.3 CRITICAL DESIGN LEVELS

From the field survey it was determined that the background sound level varies with wind speed and time of day. From Table 3.2.1 in the preceding section it can be seen that the turbine sound levels also vary with wind speed. The two values must be compared under the same wind conditions for the comparison to be meaningful. For example, it would be incorrect to compare the maximum turbine sound level, which requires high winds for it to occur, to the background sound level on a calm night.

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 compares the sound power levels of the design turbine (the REpower MM92) to the daytime L90 and Leq background levels measured during the survey. In both cases, the maximum differential occurs during 6 m/s wind conditions. At lower and higher wind speeds the differentials are lower indicating that turbine noise is less perceptible relative to the background level.

**Table 3.3.1** Comparison of *Daytime* Background and REpower MM92 Turbine Sound Levels to Determine Critical Design Level (at Maximum Differential)

Wind Speed at 10 m, m/s	4	5	6	7	8	9	10
Turbine Sound Power Level, dBA re 1 pW	-	101.6	<b>103.6</b>	104.4	105	105	105
<b>Typical</b> Background Sound Level, <b>Leq</b> , dBA	42	43	<b>44</b>	45	46	47	48
Differential, dB <b>Maximum in Bold</b>	-	58.6	<b>59.6</b>	59.3	58.9	57.8	56.8
<b>Worst-Case</b> Background Sound Level, <b>L90</b> , dBA	32	34	<b>35</b>	37	39	40	42
Differential, dB <b>Maximum in Bold</b>	-	67.9	<b>68.2</b>	67.3	66.2	64.5	62.8

At night the critical wind speed shifts down to 5 m/s as illustrated in Table 3.3.2. Even though the turbine sound level is slightly lower at 5 m/s the potential for impact is slightly greater than it would be at 6 m/s.

**Table 3.3.2** Comparison of **Nighttime** Background and REpower MM92 Turbine Sound Levels to Determine Critical Design Level (at Maximum Differential)

Wind Speed at 10 m, m/s	4	<b>5</b>	6	7	8	9	10
Turbine Sound Power Level, dBA re 1 pW	-	<b>101.6</b>	103.6	104.4	105	105	105
<b>Typical</b> Background Sound Level, <b>Leq</b> , dBA	35	<b>38</b>	40	42	44	46	48
Differential, dB <b>Maximum in Bold</b>	-	<b>64.1</b>	64.0	62.8	61.3	59.2	57.1
<b>Worst-Case</b> Background Sound Level, <b>L90</b> , dBA	26	<b>29</b>	32	35	38	41	43
Differential, dB <b>Maximum in Bold</b>	-	<b>72.4</b>	71.6	69.6	67.3	64.5	61.6

The following table summarizes the design parameters, representing critical conditions, to be used in the modeling assessment.

**Table 3.3.3** Summary of Critical Design Parameters

Conditions	Critical Wind Speed at 10 m, m/s	Design Turbine Sound Power Level, dBA re 1 pW	Measured Background Sound Level, dBA	Nominal Impact Threshold (Background + 5 dBA), dBA
Typical Daytime	6	103.6	44	49
Worst-Case Daytime	6	103.6	35	40
Typical Nighttime	5	101.6	38	43
Worst-Case Nighttime	5	101.6	29	34

The frequency content of the REpower MM92 turbine sound power level that goes along with the A-weighted values of 103.6 and 101.6 dBA is not given in the manufacturer’s sound emissions information [Ref. 9]; consequently, octave band spectra values have been estimated based on the 8 m/s spectrum of the Nordex turbine. Each band has been adjusted by a uniform constant to make the spectrum add up to the known A-weighted overall value.

**Table 3.3.4** Design Sound Power Level Frequency Spectra

Octave Band Center Frequency, Hz	31.5	63	125	250	500	1k	2k	4k	8k	dBA
Est. REpower MM92 Sound Power at <b>6 m/s</b> , dB re 1 pW	<b>118</b>	<b>114</b>	<b>110</b>	<b>107</b>	<b>100</b>	<b>95</b>	<b>95</b>	<b>90</b>	<b>79</b>	<b>103.6</b>
Est. REpower MM92 Sound Power at <b>5 m/s</b> , dB re 1 pW	<b>116</b>	<b>112</b>	<b>108</b>	<b>105</b>	<b>98</b>	<b>93</b>	<b>93</b>	<b>88</b>	<b>77</b>	<b>101.6</b>

As mentioned above, the frequency spectrum of the MM92 turbine is not given in the manufacturer's sound information, so it is not known whether sound emissions of this model are tonal or not. What can be said is that it would be highly unusual for the sound to have any tones since just about all turbines of this general size class have a smooth, broadband frequency spectrum.

### 3.4 NOISE MODELING METHODOLOGY

Using the design sound power level spectra in Table 3.3.4 above, Project sound levels were calculated using the Cadna/A<sup>®</sup>, ver. 3.7 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. The modeling software is essentially an automated version of ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors* [Ref. 3], which is the primary worldwide standard for such calculations.

The rolling topography of this site has been incorporated into the model using topographical maps of the area.

Each turbine is represented as a point noise source at a height of 80 m above the local ground surface (typical design hub height).

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 essentially open farmland, which is acoustically soft. The ground absorption coefficient (from ISO 9613) 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, to be conservative a value of 0.5 has been used.

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 a theoretical worst-case condition at any given receptor point based on the following assumptions:

- **Critical Wind Speeds** – 6 and 5 m/s wind conditions are modeled representing the points where the least amount of masking noise is likely to be present relative to the turbine sound level
- **Wintertime Background Levels** – the background survey was conducted under wintertime conditions when ambient levels are normally at an annual minimum (without leaves rustling or summer insects). Summertime levels are normally found to be 5 to 7 dBA, which is substantial.
- **Conservative L90 Background Level** – assessments based on the L90 background represent the potential impact only during momentarily lulls in environmental background. Most of the time (90% of the time) a higher background sound level will actually exist.
- **Low Ground Porosity** – normally open fields are considered more acoustically absorptive than assumed in the model
- **Observer Outside** – the plotted sound levels occur outside; sound levels inside of any dwelling will be 10 to 20 dBA lower
- **Downwind Sound Level** – the downwind sound level is assumed to exist in all directions from every unit



### 3.5 PRELIMINARY NOISE MITIGATION STUDIES

The turbine locations and general site plan for this Project have been in development for quite some time and the current layout has been shaped to a very large degree by concerns about potential noise impacts. At least 7 or 8 previous site plans have been modeled over the last year with a view towards proactively identifying and alleviating any significant noise impacts. Applying the general criteria outlined in Section 3.1, many turbines have been moved further from residences or to entirely different properties and an even larger number have been completely removed from the Project to reduce the potential for adverse noise impacts. The current site plan is the result of this extensive noise mitigation effort.

### 3.6 MODEL RESULTS – CURRENT SITE PLAN

#### 3.6.1 *Daytime Conditions*

Sound contour plots for “typical” and “worst-case” daytime conditions are shown in Plots 1A – 1D.

**Plots 1A and 1B**, showing the northern and southern halves of the project, respectively, illustrate the sound emissions of the Project during a critical 6 m/s wind (when the Project is nominally most likely to be audible above the background level) with the impact threshold of 49 dBA based on the measured Leq background level of 44 dBA. These plots show that a sound level of 49 dBA occurs fairly close to each turbine and well short of any homes. Consequently, there is a very low probability of an adverse impact during these conditions; i.e. turbine sound levels will not be 5 dBA or more above the background and may, in fact, be comparable to or below the typical (Leq) environmental sound level of 44 dBA.

If the background level is based on the L90, on the other hand, the potential impact threshold moves considerably outward, as shown in **Plots 1C and 1D**. In this instance, a few residences, most of which are project participants, fall inside the nominal 40 dBA – but the vast majority of residences in the area are outside of this zone.

#### 3.6.2 *Nighttime Conditions*

During the night, when somewhat lower background sound levels evidently exist, there is a greater potential that the turbines will be clearly audible at some residences, but only during lulls in the background level.

**Plots 2A and 2B** show the Project sound emissions during a critical 5 m/s wind plotted out to the nominal (background plus 5 dBA) design threshold of 43 dBA based on the typical measured Leq background level. As with the daytime “typical” case, all homes in the Project area lie outside of the threshold.

When the background level momentarily decreases, however, it appears likely that the Project will become distinctly audible, at least intermittently, over a fairly wide area (**Plots 2C and 2D**). Because a nighttime L90 of only 29 dBA was measured during critical 5 m/s wind conditions the nominal impact threshold is about 34 dBA. Because there are a number of homes with predicted sound level of more than 34 dBA some adverse reaction to Project noise appears to be possible during these particular conditions.

Although this model indicates that there is a potential for a moderate noise impact, it is important to realize that this particular case combines a number of assumptions that taken together intentionally represent the worst possible impact during normal atmospheric conditions, such as:

- A 5 m/s wind speed is represented. Turbine audibility would be lower at all other wind speeds higher and lower.
- The background masking sound is based on the L90 level, which captures momentary lulls in the background level
- The background level was measured during wintertime conditions, when environmental sound levels are normally the lowest
- Few people are actually outside in the winter or engaging in activities where environmental quiet is important
- The wind would need to be blowing from all the nearest turbines directly towards the point of observation
- Observer outside (inside levels should be 10 to 20 dBA lower)
- Maximum critical turbine sound level

These conservative assumptions and worst-case conditions have been consciously adopted for the analysis because the perceptibility of turbine noise varies with atmospheric conditions, such as during temperature inversions and periods of unusual wind stratification. Consequently, there are likely to be times, when these conditions exist, when the actual sound will exceed the conservatively predicted levels in the plots. Of course, there will also be times, probably the majority of the time, when the perceptibility of Project noise will be less than indicated in the graphics.

As a general additional comment, it is important to note that in the particular case of wind turbine noise a 5 dBA increase does not represent the point of inaudibility. Operational sound emissions from wind turbines are often unsteady and variable with time largely because the wind does not always blow in a completely smooth and ideal manner. When unsettled air or gusty winds interact with the rotor, or the airflow is not perfectly perpendicular to the rotor plane, an increase in turbulence and noise results. On top of this, turbines often (although not always) produce a periodic swishing sound. These characteristics make operational noise more perceptible than it would be if it were bland and continuous in nature. Consequently, wind turbines can commonly be discerned at fairly large distances even though the actual sound level may be relatively low and/or comparable to the magnitude of the background level; therefore the possibility of impacts at residences beyond the impact thresholds shown in the plots certainly cannot be ruled out. There may also be times, due to wind and atmospheric conditions, when project sound levels temporarily increase to levels that are significantly higher than the predicted mean levels. During these - usually brief - periods of elevated noise complaints also may occur.

### 3.6.3 *Property Line Sound Levels*

**Plots 3A and 3B** were prepared specifically to show the relationship between the 50 dBA sound contour and the boundaries of participating land parcels. A 50 dBA design target is assumed, since it represents a reasonable and common limit for property line sound levels associated with wind projects. As these plots show, sound levels of 50 dBA or more are almost entirely confined to participating properties. There are only a few places where units are sited close to boundaries where sound levels may exceed 50 dBA (by no more than a few decibels) for a short distance into a neighboring property. In a few places turbines are shown on ostensibly non-participating land parcels but our understanding is that final leasing arrangements are imminent/likely but have not yet been concluded.

### 3.7 LOW FREQUENCY NOISE

Modern 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 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 this effect no longer exists with the upwind blade arrangement used today.

Concerns about excessive low frequency noise from proposed wind farms are commonly voiced but they have apparently grown out of misinformation or anecdote (probably stemming from early downwind turbine designs) without any basis in current fact. The widespread belief that wind turbines generate excessive or even harmful amounts of low frequency or infrasonic noise is evidently based on 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. Another, and probably more likely, explanation is that any measurement taken during windy conditions will erroneously exhibit elevated levels of low frequency noise caused by wind flowing over the microphone tip - whether a wind turbine is present or not. This self-induced, false-signal distortion is commonly mistaken for actual noise from wind turbines (see Ref. 8 for more information on self-induced wind noise).

A study by Sondergaard [Ref. 4] was carried out with the specific objective of determining whether large wind turbines produce significant low frequency noise. Extremely careful measurements were made based on the IEC 61400-11 measurement procedure using multiple elaborate microphone windscreens to preclude low frequency self-noise contamination. The results of this testing show that for a typical turbine its sound levels taper down steadily in magnitude towards the low end of the frequency spectrum and that the sound energy below about 40 Hz is actually comparable to the sound energy in the natural rural environment where the measurements were made (as shown in Figure 3.7.1).

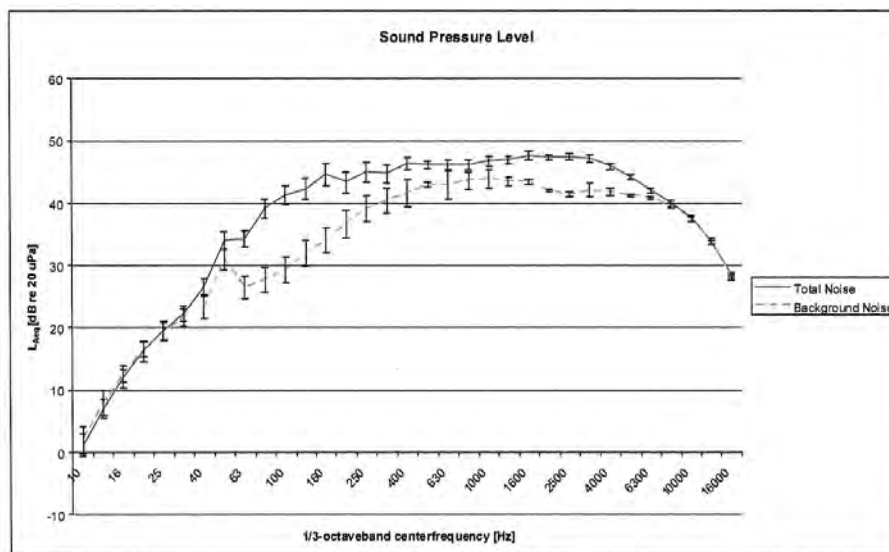
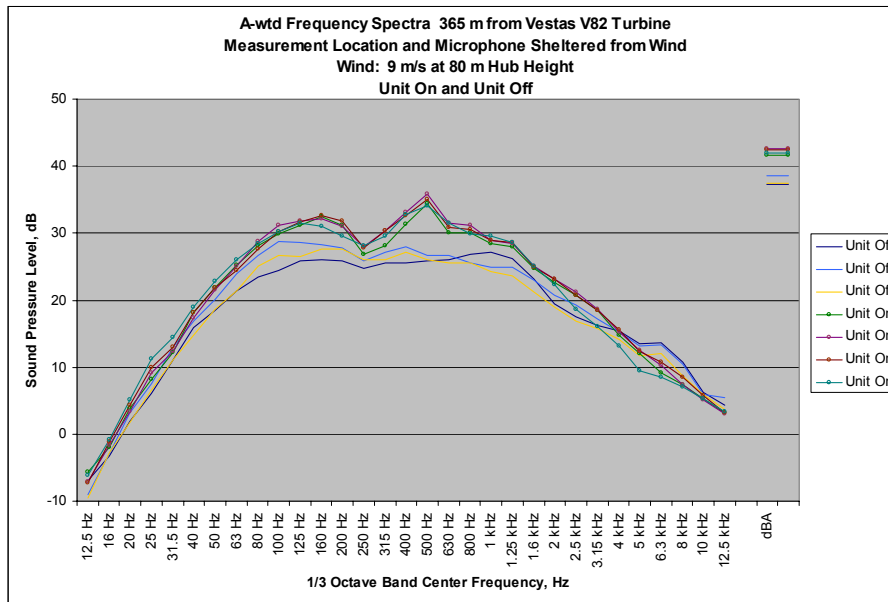


Figure 21 Spectra of total noise and background noise for a 1.5 MW wind turbine. A 50 Hz frequency from a nearby power line influences the measurements.

Figure 3.7.1 Measured Turbine Sound Level down to 10 Hz Relative to Background Sound Level (Sondergaard)

The plot below of on-off measurements made by Hessler Associates at an operating project similar to Buckeye shows an almost identical result.



**Figure 3.7.2** Measured Turbine Sound Level Spectrum down to 12.5 Hz Relative to Background Sound Level (Hessler)

### 3.8 CONSTRUCTION NOISE

Noise from construction activities associated with the Project is likely to temporarily constitute a moderate, unavoidable impact at some of the homes in the Project area. 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 sound 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. [Ref. 6]), are shown below in Table 3.8.1. 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 [Ref. 11] 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 typical minimum setback distance of 1000 ft. and the distance at which construction sound levels are likely to become inconsequential (at a level of about 35 dBA). A value of 35 dBA is used here because construction noise, unlike operational noise from the project, has no dependency on wind speed and is likely to occur during times of calm when background sound levels are minimal. A sound level of 35 dBA during the day – when construction occurs – can generally be considered a negligible sound level even in the almost total absence of any natural environmental background sound.

**Table 3.8.1 Construction Equipment Sound Levels by Phase**

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

There may be some cases where road construction or trenching operations occur closer to homes. Higher sound levels are certainly possible if this work occurs very close to any homes. For example, a short-term sound level of about 80 dBA is theoretically possible where the distance to nearby work is about 200 feet. Every effort should be made in these cases to inform any affected

residents in advance that this kind of work will be occurring, when it is anticipated and how long it is expected to last.

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 two-week field survey of existing background sound levels at nine positions distributed throughout the proposed Buckeye Wind Project was carried out to determine how much natural masking sound there might be in the area and how it might affect the perceptibility of noise from the Project.

In general, sound levels throughout the site area show a definite dependency on wind speed underlying a daily pattern of quiet sound levels at night and higher sound levels during the day. Typical sound levels, quantified by the average, or Leq, level, ranged from 43 to 44 dBA during the day at key wind speeds of 5 to 6 m/s and from 38 to 40 dBA at night under the same wind conditions. The Leq sound level is the level most likely, statistically, to be observed at any given moment. The residual, or L90, sound levels were found to range from 34 to 35 dBA during the day and from 29 to 32 dBA at night during 5 to 6 m/s wind conditions. The L90 statistical sound level captures the momentary, quiet lulls between sporadic noise events. A higher sound level exists 90% of the time.

At higher wind speeds, beyond 6 m/s, the background level continues to rise while the turbine sound level essentially tops out and levels off making Project noise progressively less audible under high wind conditions. At lower wind speeds turbine noise diminishes rapidly going to zero below the cut-in wind speed of around 3 m/s at the hub height.

The projected noise emissions from the Project were conservatively modeled and mapped over the site area in accordance with appropriate ISO standards. The site topography was accurately recreated in three-dimensions in the model. An analysis of the wind-dependent sound power levels associated with the two turbine models currently being considered for the Project was carried out to identify the critical wind speed conditions, both during the day and at night, when turbine noise is potentially loudest relative to the amount of background masking sound. From this analysis it was determined that wind speeds of 6 m/s and 5 m/s during the day and night, respectively, were the critical conditions.

The turbine locations and general site plan for this Project have been in development for quite some time and the current layout has been shaped to a very large degree by concerns about potential noise impacts. At least 7 or 8 previous site plans have been modeled over the last year with a view towards proactively identifying and alleviating any significant noise impacts. Many turbines have been moved further from residences or to entirely different properties and an even larger number have been completely removed from the Project to reduce the potential for adverse noise impacts. The current site plan is the result of this extensive noise mitigation effort.

In the absence of any regulatory noise limits for the Project, a design goal threshold of 5 dBA above the background level was used to represent the potential impact threshold. Noise models of Project sound levels were developed for daytime and nighttime conditions based on both the “typical” (Leq) and “worst-case” (L90) background levels. These analyses indicate all residences within the Project area lie outside of the nominal impact threshold, regardless of time of day, based on the average measured background level at critical wind speeds. It is only during “worst-

case” nighttime conditions when the background sound level momentarily reaches a minimum that Project noise is likely to be distinctly audible at a significant number of residences.

It is important to note that the modeling has been carried out in a consciously conservative manner and lower sound levels than shown in the plots and discussed above may actually occur much of the time. This approach was taken in recognition of two facts uniquely relevant to wind turbine noise:

- 1) Predictions made using ISO 9613, the worldwide standard for noise propagation calculations, characterize sound levels under average or normal conditions. There will be times when atmospheric conditions, temperature gradients and wind shear gradients cause sound levels at any given location to vary above and below the nominal prediction value largely because wind turbine sound originates at a high elevation above the ground making it more susceptible to atmospheric influences. This means that somewhat higher sound levels from the Project may well occur from time to time.
- 2) The audibility of wind turbine noise relative to normal wind-driven environmental sound is enhanced by the fact that the sound may not be steady but rather might have a periodic quality to it, often described as a swishing sound. This amplitude modulation, or repeated raising and lowering of the sound level makes turbine noise perceptible at significantly lower levels than an invariant sound of the same magnitude. In addition, the general sound (whether a swish is present or not) is likely to vary with time making it more noticeable than it might otherwise be.

Consequently, every possible conservative assumption has been employed in the assessment to allow some design margin for these circumstances and avoid underestimating the potential impact of the Project.

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, measurement error (wind-induced low frequency self-noise) 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 no higher than that of many other common sounds.

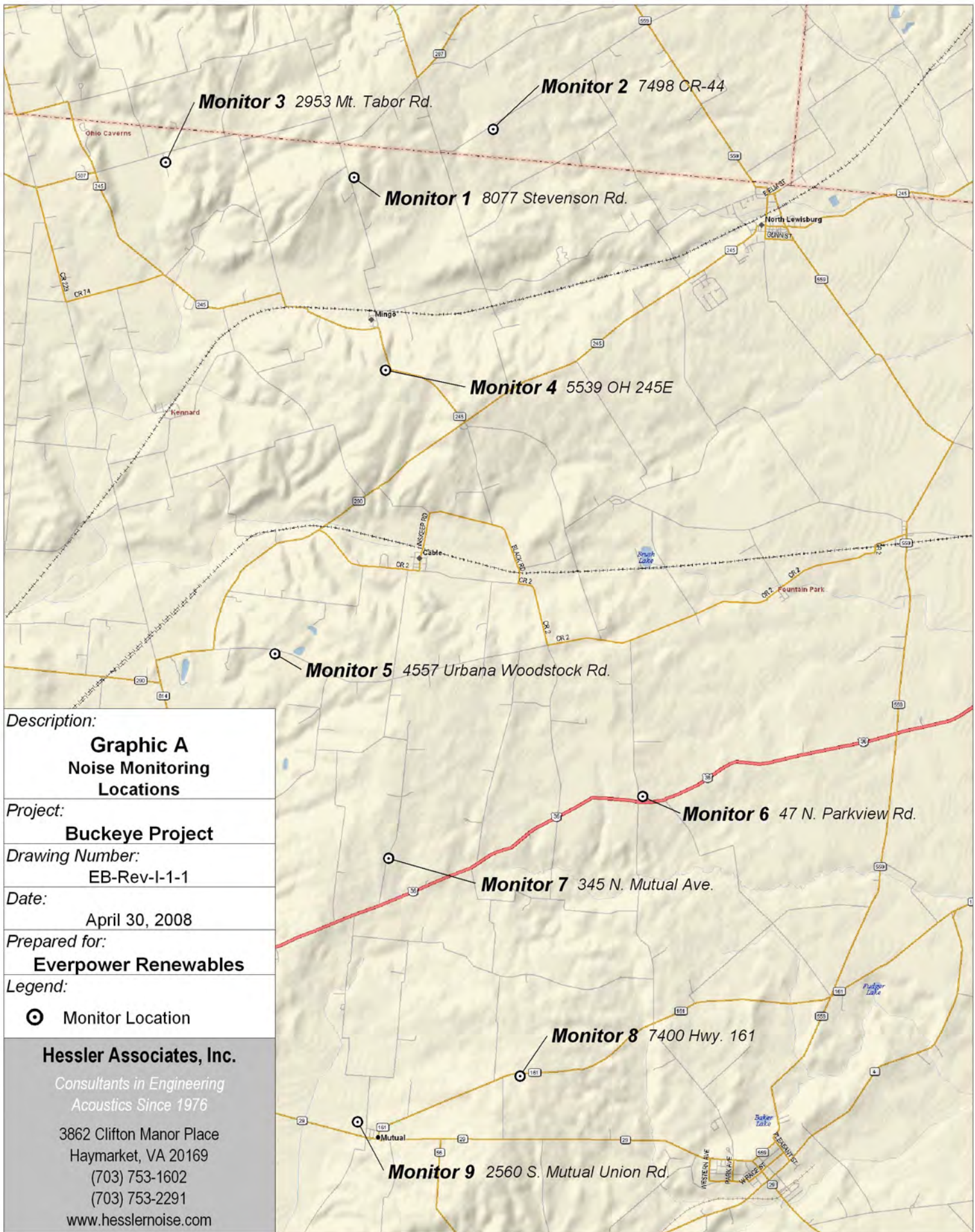
Unavoidable but mild noise impacts may occur during the construction phase of the project. Construction noise, sounding similar to that of distant farming equipment is anticipated to be sporadically audible at many homes within the immediate project vicinity on a temporary basis. The maximum magnitude 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/or road building activities.

END OF REPORT TEXT

**REFERENCES**

1. International Electromechanical Commission (IEC) 61400-11:2002(E) *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques*, Second Edition 2002-12.
2. Nordex Energy GmbH, *Noise Emission Nordex N90/2500 LS*, 80 m Hub Height, Warranty Levels, Nov. 28, 2005.
3. International Organization for Standardization, ISO 9613-2 *Acoustics – Attenuation of Sound during Propagation Outdoors*, Part 2, “A General Method of Calculation”, Geneva, 1989.
4. Sondergaard, B., Hoffmeyer, D, *Low Frequency Noise from Wind Turbines*, Proceedings from Wind Turbine Noise 2007, Lyon, France, Sept. 21, 2007.
5. U. S. Environmental Protection Agency, Report NTID300.3 *Community Noise*, Washington, DC, 1971.
6. Empire State Electric Energy Research Corporation, *Power Plant Construction Noise Guide*, Bolt Beranek and Newman Report 3321, May 1977.
7. WINDTEST Kaiser-Wilhelm-Koog GmbH, *Auszug WT 4226/05 aus dem Pruefbericht WT 4212/05 zur Schallemission der Windenergieanlage vom Typ Nordex N90/2500 LS*, April 18, 2005.
8. Hessler, G. F., Hessler, D.M., Brandstaett, P., Bay, K, “Experimental study to determine wind-induced noise and windscreen attenuation effects on microphone response for environmental wind turbine and other applications”, *Noise Control Engineering Journal*, J.56, July-August 2008.
9. REpower Systems, *Sound Power Level MM92 Evolution*, 80 m Hub Height, Feb. 19, 2007.
10. New York State Department of Environmental Conservation, *Program Policy Assessing and Mitigating Noise Impacts*, 2002.
11. U. S. Dept. of Transportation, Federal Highway Administration, *Roadway Construction Noise Model User’s Guide*, Table 1, Jan. 2006.





<b>Description:</b>	<b>Graphic A Noise Monitoring Locations</b>
<b>Project:</b>	<b>Buckeye Project</b>
<b>Drawing Number:</b>	<b>EB-Rev-I-1-1</b>
<b>Date:</b>	<b>April 30, 2008</b>
<b>Prepared for:</b>	<b>Everpower Renewables</b>
<b>Legend:</b>	<b>○ Monitor Location</b>
<b>Hessler Associates, Inc.</b>	
<i>Consultants in Engineering Acoustics Since 1976</i>	
3862 Clifton Manor Place Haymarket, VA 20169 (703) 753-1602 (703) 753-2291 www.hesslernoise.com	



Description:  
**Plot 1A**  
 Predicted Sound Contours (dBA) Plotted to  
 Nominal Impact Threshold of 49 dBA for  
 Typical Daytime Conditions (6 m/s Wind)  
 Northern Project Area

Project:  
**Buckeye**

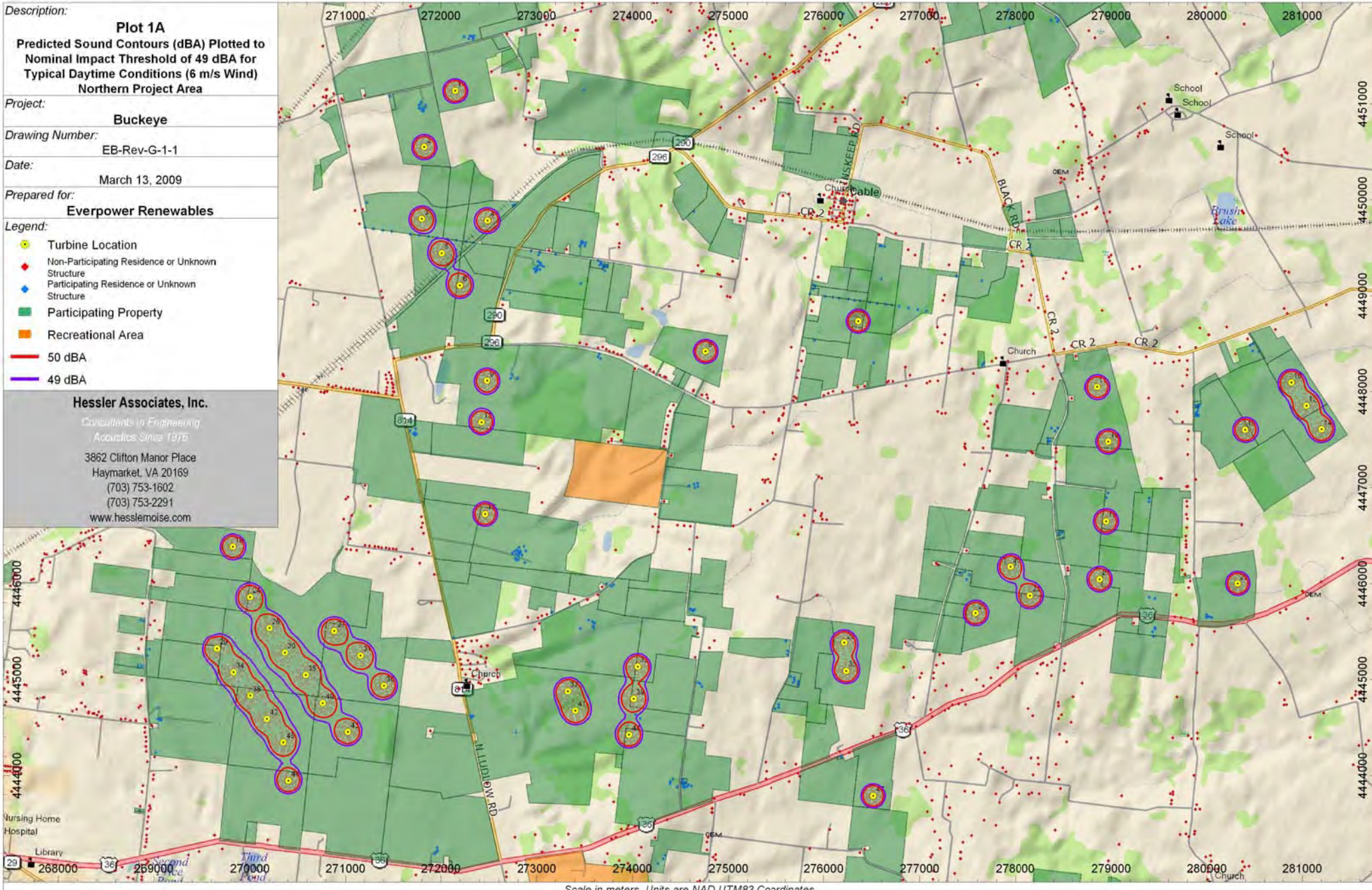
Drawing Number:  
 EB-Rev-G-1-1

Date:  
 March 13, 2009

Prepared for:  
**Everpower Renewables**

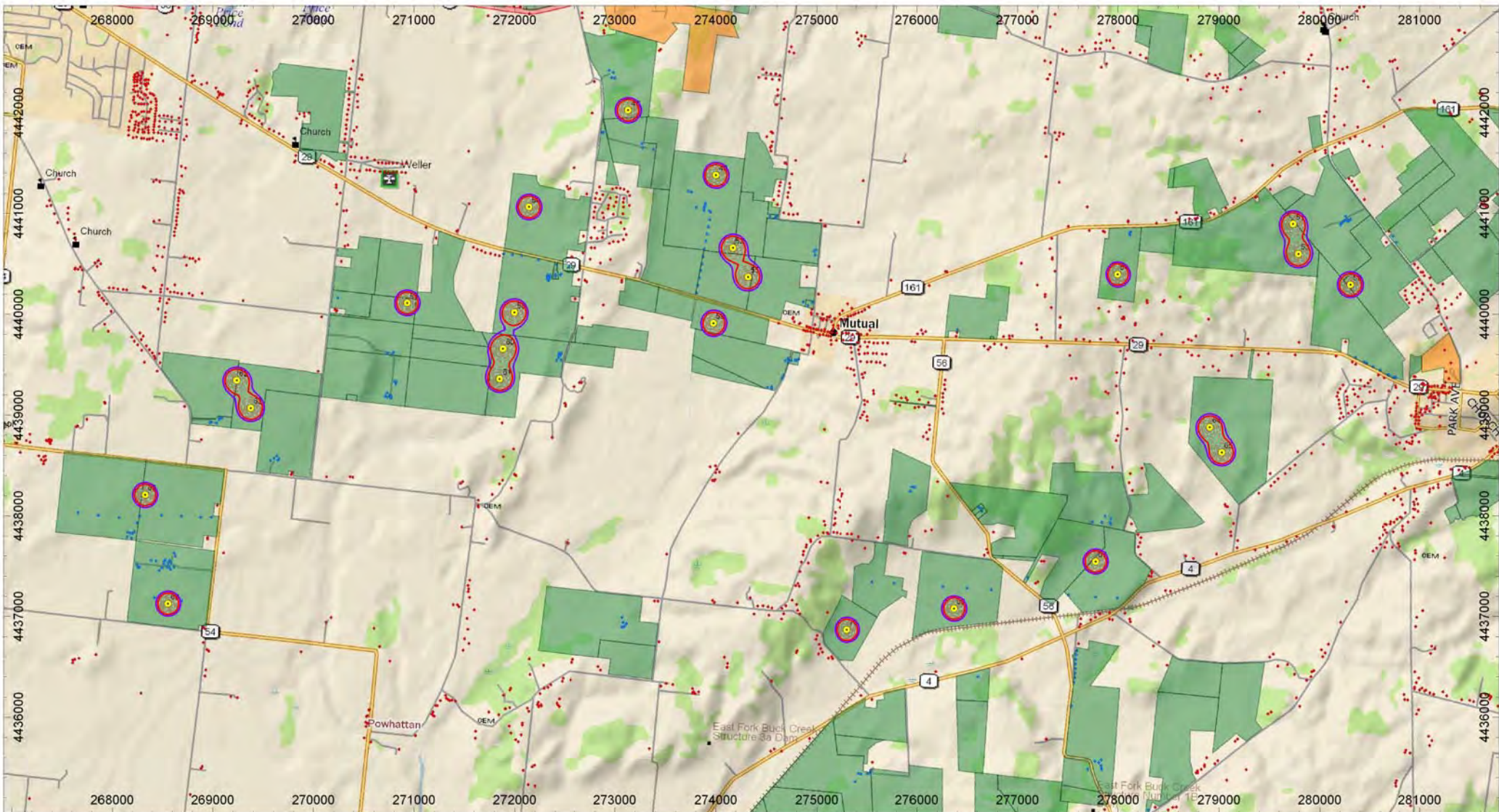
- Legend:
- Turbine Location
  - Non-Participating Residence or Unknown Structure
  - Participating Residence or Unknown Structure
  - Participating Property
  - Recreational Area
  - 50 dBA
  - 49 dBA

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Scale in meters. Units are NAD UTM83 Coordinates





Project: **Buckeye**

Prepared for: **Everpower Renewables**

Date: **March 13, 2009**

Drawing #: **EBII-Rev-G-1-2**

Description: **Plot 1B**

**Predicted Sound Contours (dBA) Plotted to Nominal Impact Threshold of 49 dBA for Typical Daytime Conditions (6 m/s Wind) - Southern Project Area**

- Legend:
- ◆ Non-Participating Residence or Unknown Structure
  - ◆ Participating Residence or Unknown Structure
  - 50 dBA
  - Participating Property
  - Recreational Area
  - 49 dBA
  - Turbine Location

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Description:  
**Plot 1C**  
 Predicted Sound Contours (dBA) Plotted to  
 Nominal Impact Threshold of 40 dBA for  
 Worst Case Daytime Conditions (6 m/s Wind)  
 Northern Project Area

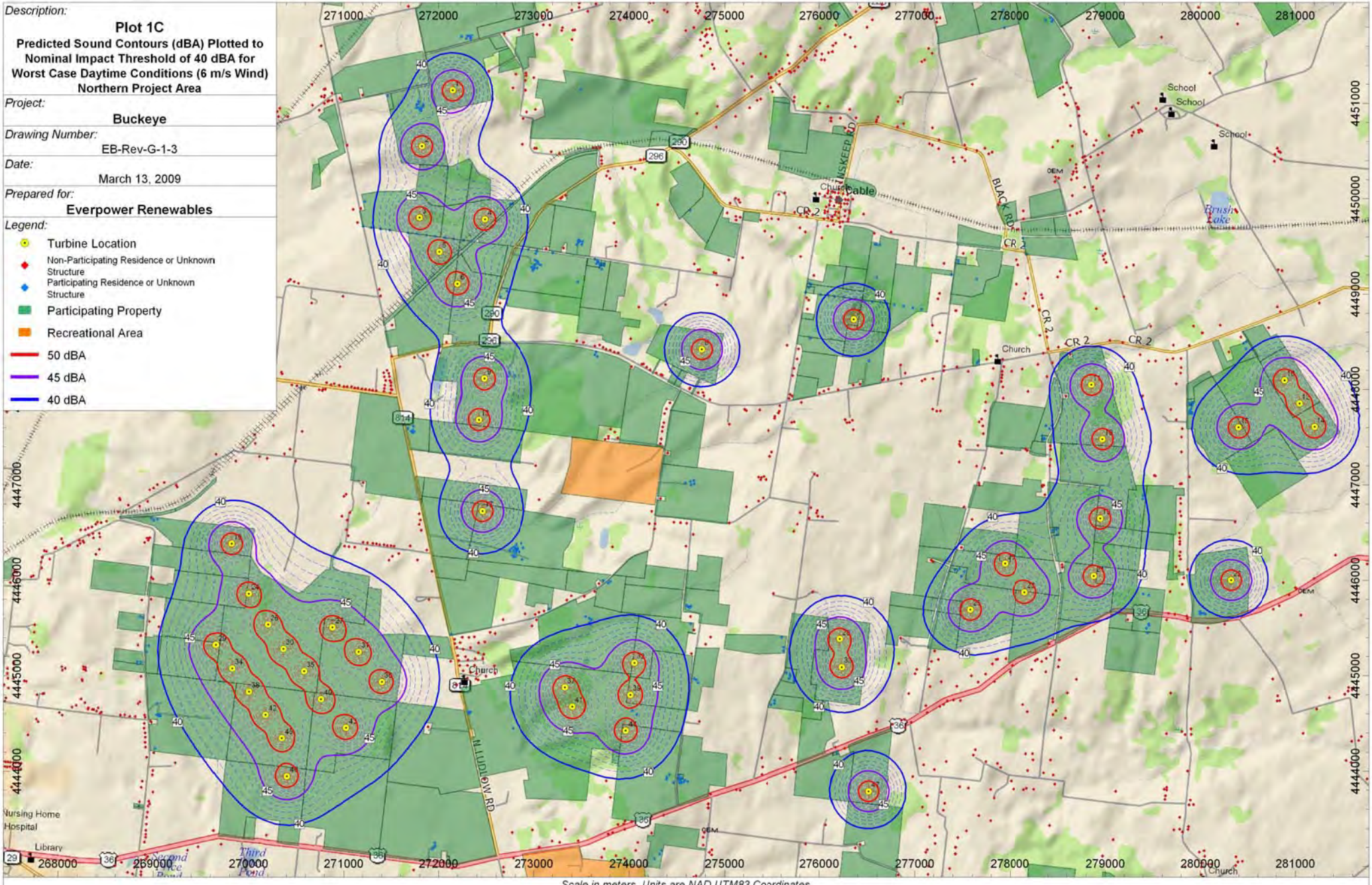
Project:  
**Buckeye**

Drawing Number:  
 EB-Rev-G-1-3

Date:  
 March 13, 2009

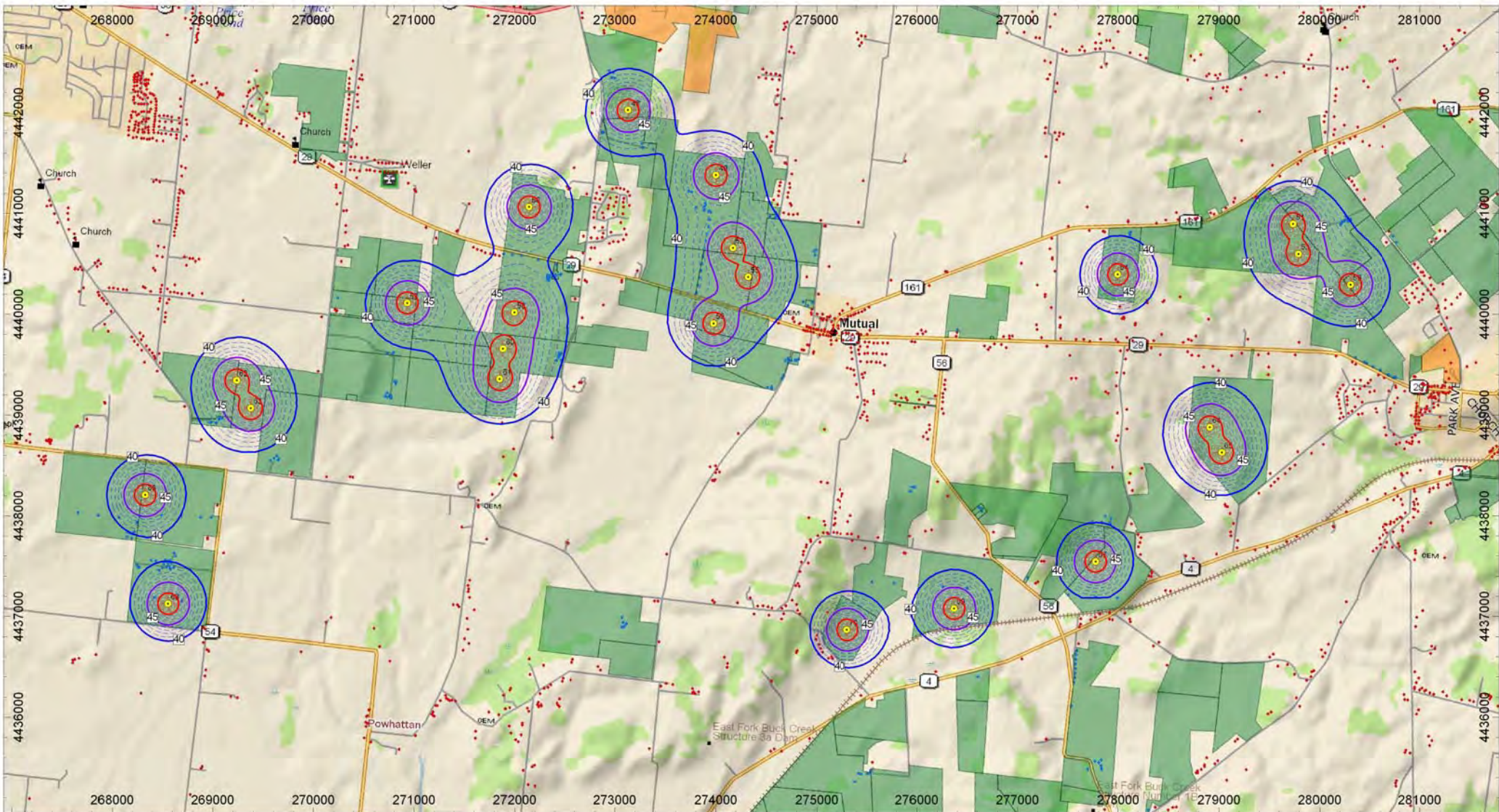
Prepared for:  
**Everpower Renewables**

- Legend:
- Turbine Location
  - Non-Participating Residence or Unknown Structure
  - Participating Residence or Unknown Structure
  - Participating Property
  - Recreational Area
  - 50 dBA
  - 45 dBA
  - 40 dBA



Scale in meters. Units are NAD UTM83 Coordinates





Project: **Buckeye**

Prepared for: **Everpower Renewables**

Date: **March 13, 2009**

Drawing #: **EBII-Rev-G-1-2**

Description: **Plot 1D**  
**Predicted Sound Contours (dBA) Plotted to**  
**Nominal Impact Threshold of 40 dBA for**  
**Worst Case Daytime Conditions (6 m/s Wind)**  
**Southern Project Area**

Legend:

- ◆ Non-Participating Residence or Unkown Structure
- ◆ Participating Residence or Unkown Structure
- 50 dBA
- Participating Property
- Recreational Area
- 45 dBA
- Turbine Location
- 40 dBA

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Description:  
**Plot 2A**  
 Predicted Sound Contours (dBA) Plotted to  
 Nominal Impact Threshold of 43 dBA for  
 Typical Nighttime Conditions (5 m/s Wind)  
 Northern Project Area

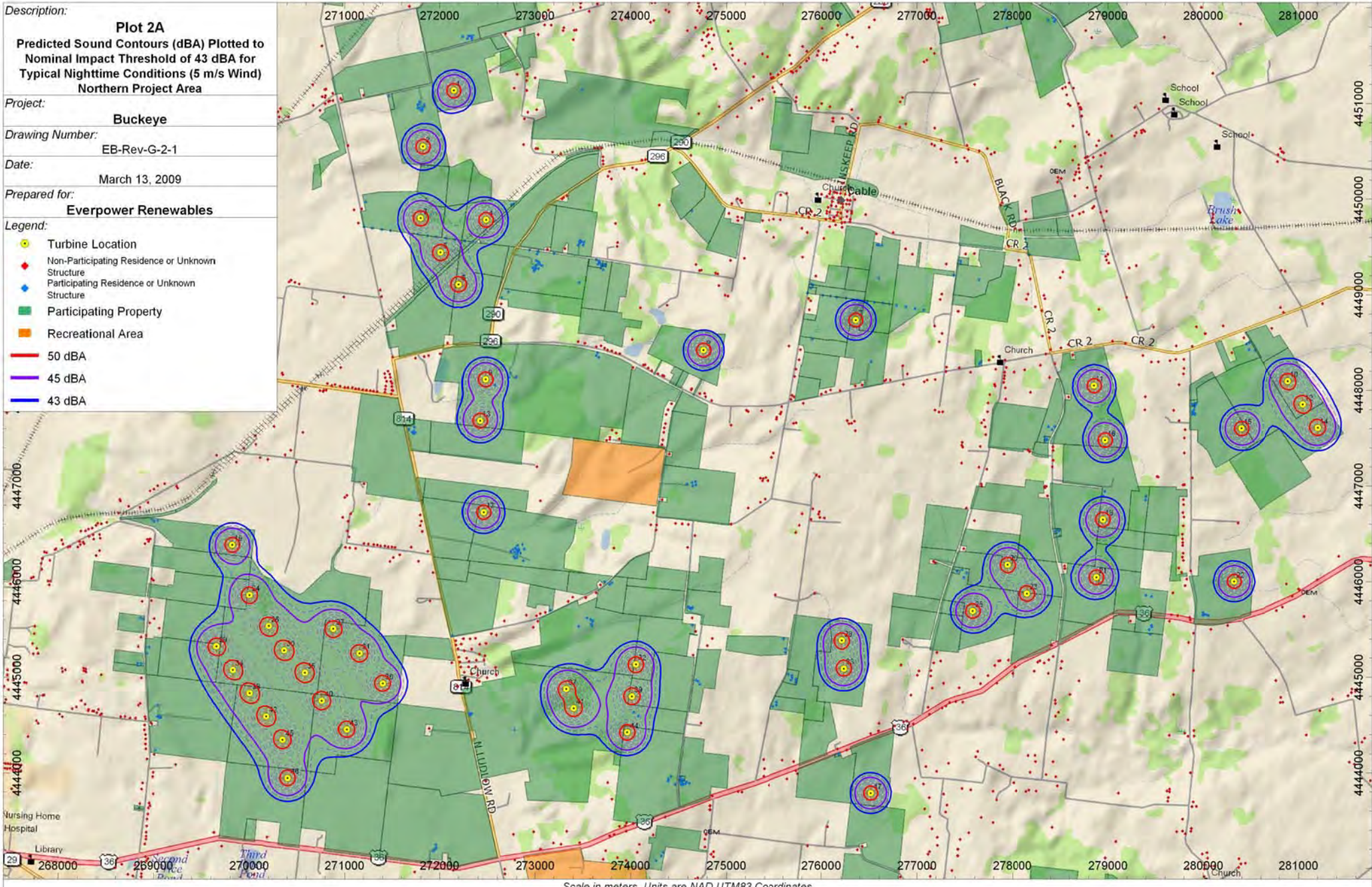
Project:  
**Buckeye**

Drawing Number:  
 EB-Rev-G-2-1

Date:  
 March 13, 2009

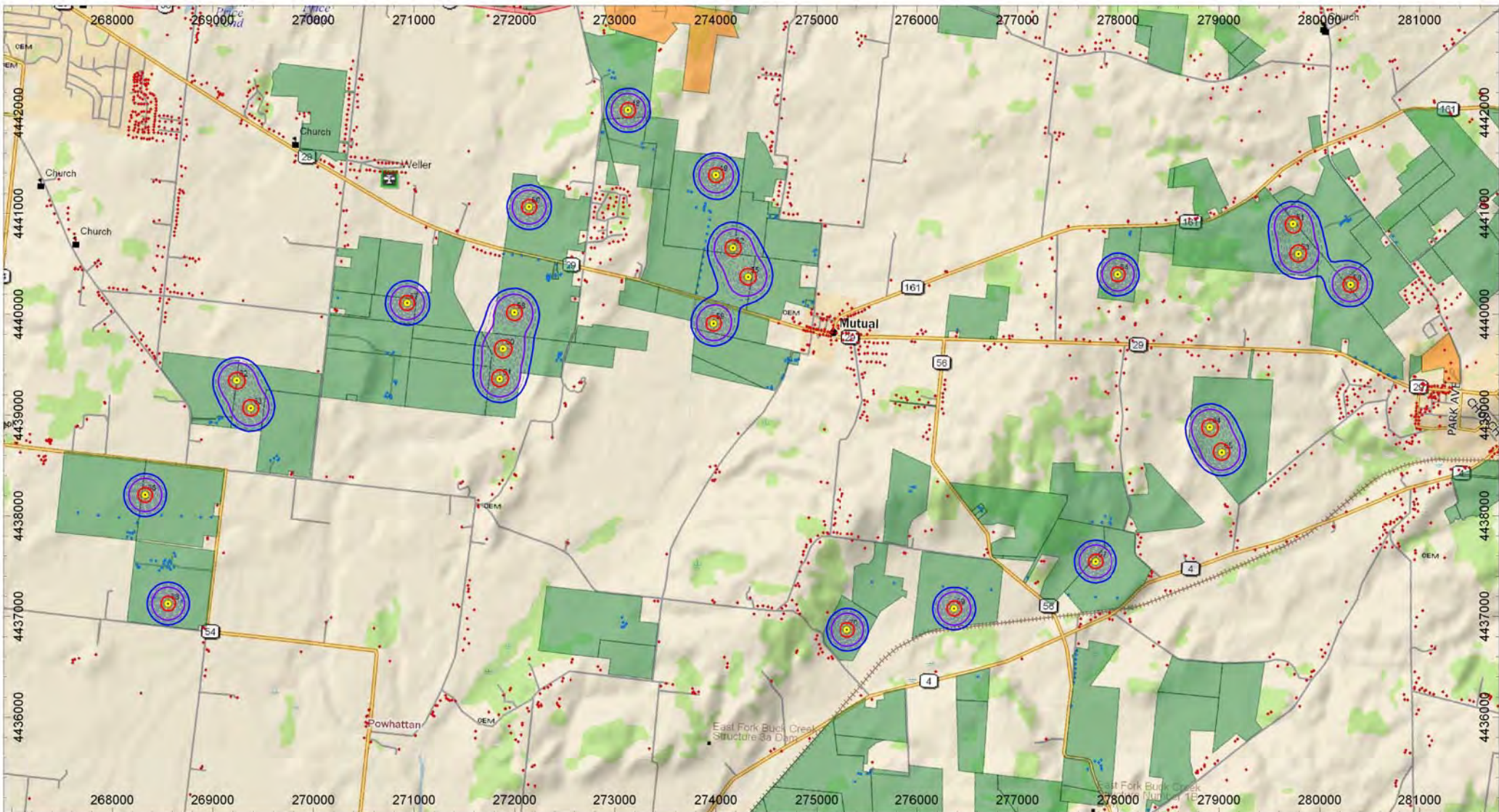
Prepared for:  
**Everpower Renewables**

- Legend:
- Turbine Location
  - Non-Participating Residence or Unknown Structure
  - Participating Residence or Unknown Structure
  - Participating Property
  - Recreational Area
  - 50 dBA
  - 45 dBA
  - 43 dBA



Scale in meters. Units are NAD UTM83 Coordinates





Project: **Buckeye**

Prepared for: **Everpower Renewables**

Date: **March 13, 2009**

Drawing #: **EBII-Rev-G-2-1**

Description: **Plot 2B  
Predicted Sound Contours (dBA) Plotted to  
Nominal Impact Threshold of 43 dBA for  
Typical Nighttime Conditions (5 m/s Wind)  
Southern Project Area**

Legend:

- ◆ Non-Participating Residence or Unkown Structure
- ◆ Participating Residence or Unkown Structure
- 50 dBA
- Participating Property
- Recreational Area
- 45 dBA
- Turbine Location
- 43 dBA

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Description:  
**Plot 2C**  
 Predicted Sound Contours (dBA) Plotted to  
 Nominal Impact Threshold of 34 dBA for  
 Worst Case Nighttime Conditions (5 m/s Wind)  
 Northern Project Area

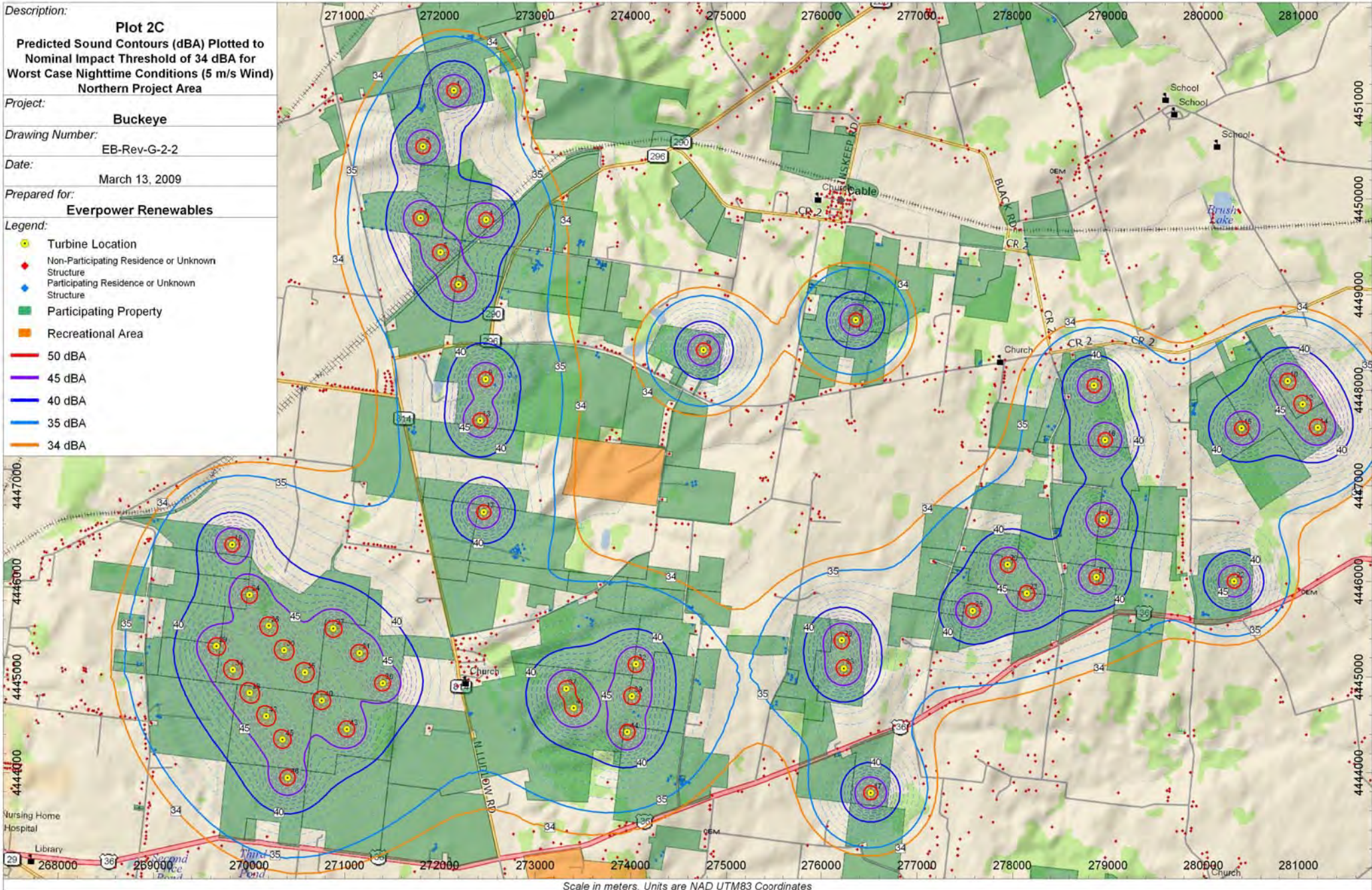
Project:  
**Buckeye**

Drawing Number:  
 EB-Rev-G-2-2

Date:  
 March 13, 2009

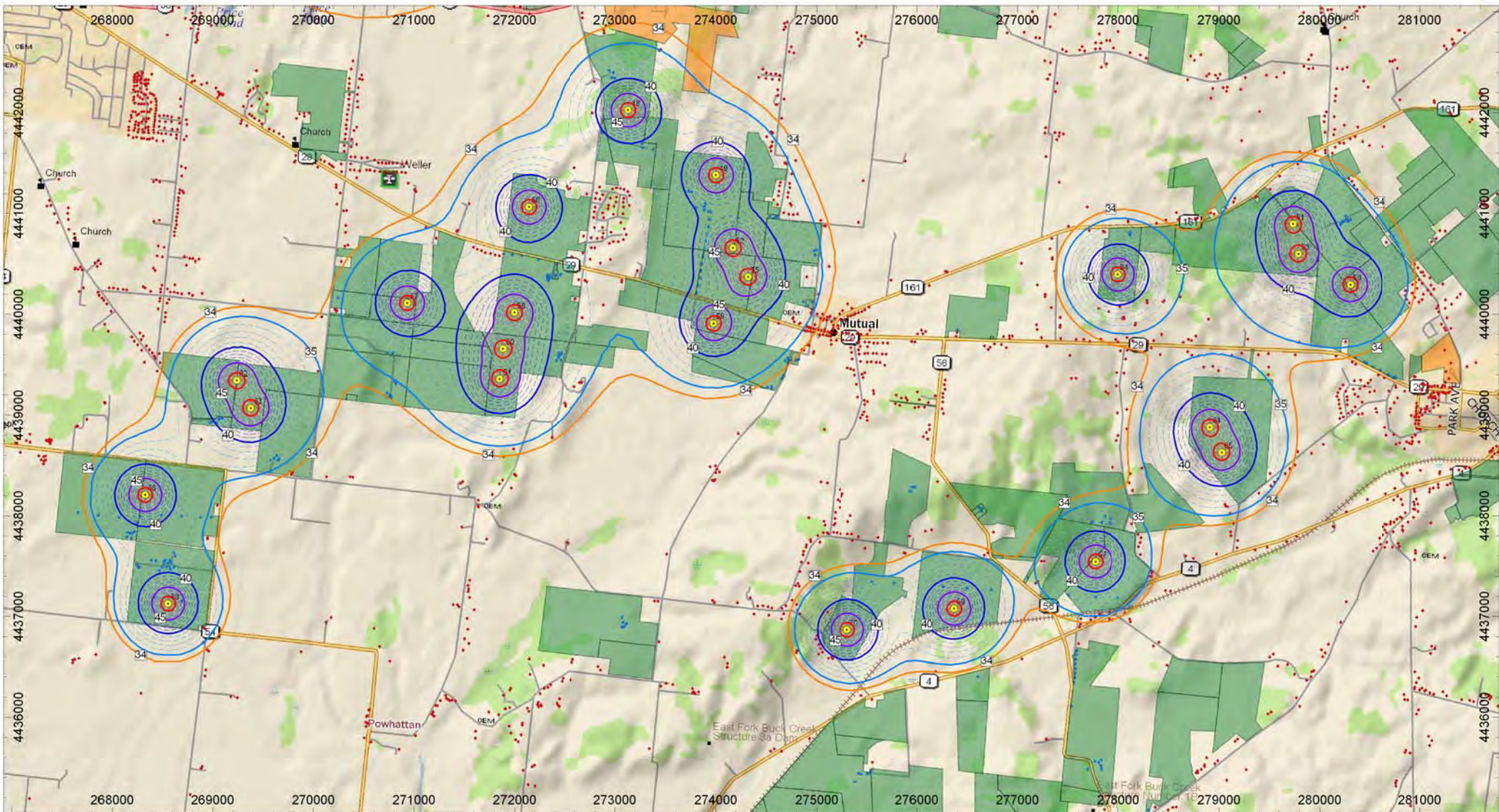
Prepared for:  
**Everpower Renewables**

- Legend:
- Turbine Location
  - Non-Participating Residence or Unknown Structure
  - Participating Residence or Unknown Structure
  - Participating Property
  - Recreational Area
  - 50 dBA
  - 45 dBA
  - 40 dBA
  - 35 dBA
  - 34 dBA



Scale in meters. Units are NAD UTM83 Coordinates





Project: **Buckeye**

Prepared for: **Everpower Renewables**

Date: **March 13, 2009**

Drawing #: **EBII-Rev-G-2-2**

Description: **Plot 2D**  
**Predicted Sound Contours (dBA) Plotted to**  
**Nominal Impact Threshold of 34 dBA for**  
**Worst Case Nighttime Conditions (5 m/s Wind)**  
**Southern Project Area**

- Legend:
- ◆ Non-Participating Residence or Unkown Structure
  - Participating Property
  - Turbine Location
  - ◆ Participating Residence or Unkown Structure
  - Recreational Area
  - 45 dBA
  - 40 dBA
  - 35 dBA
  - 34 dBA

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Description:  
**Plot 3A**  
 Predicted Sound Contours (dBA) Plotted to  
 Typical Property Line Design Goal of 50 dBA  
 (6 m/s Wind Conditions)  
 Northern Project Area

Project:  
**Buckeye**

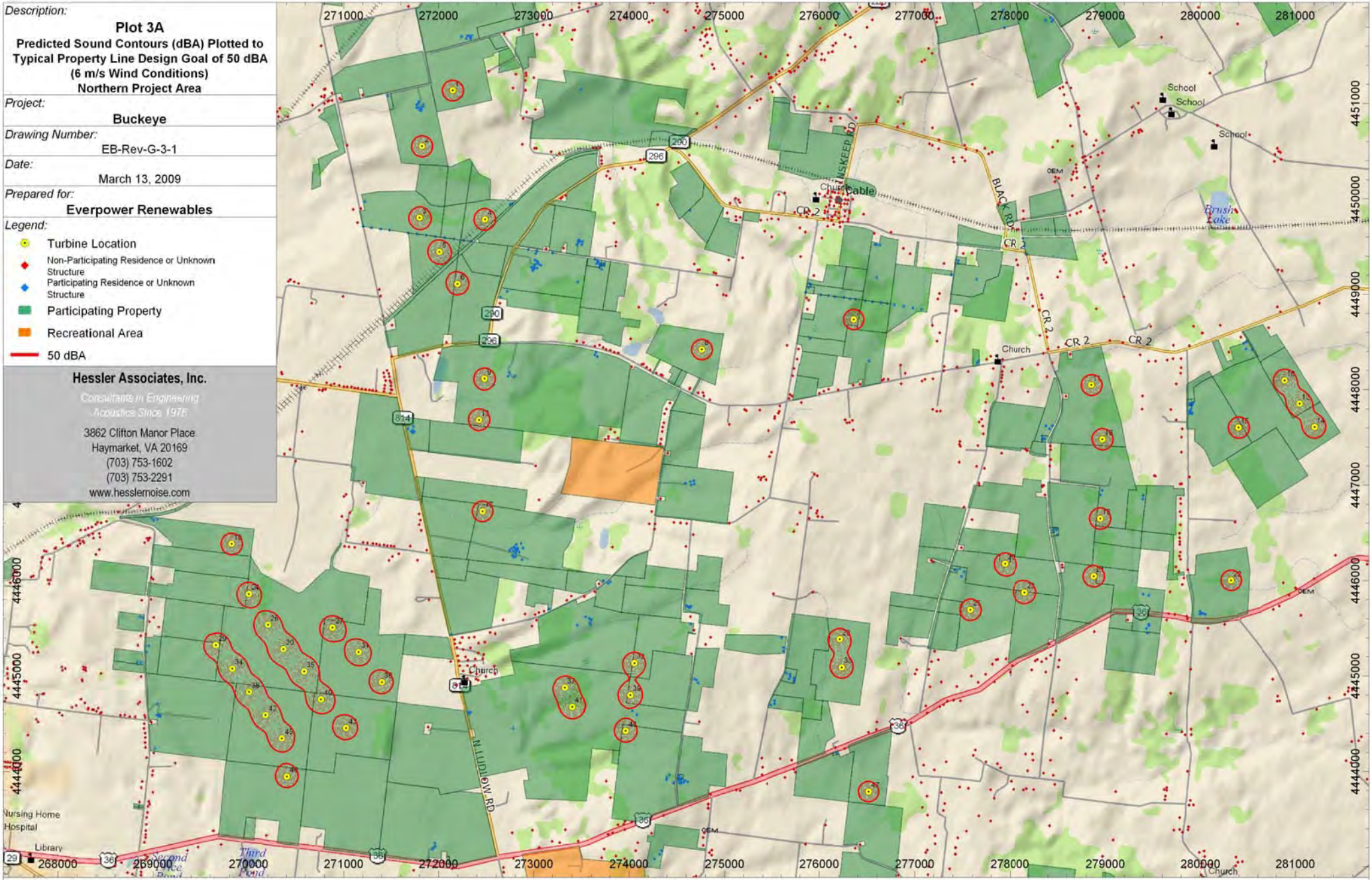
Drawing Number:  
 EB-Rev-G-3-1

Date:  
 March 13, 2009

Prepared for:  
**Everpower Renewables**

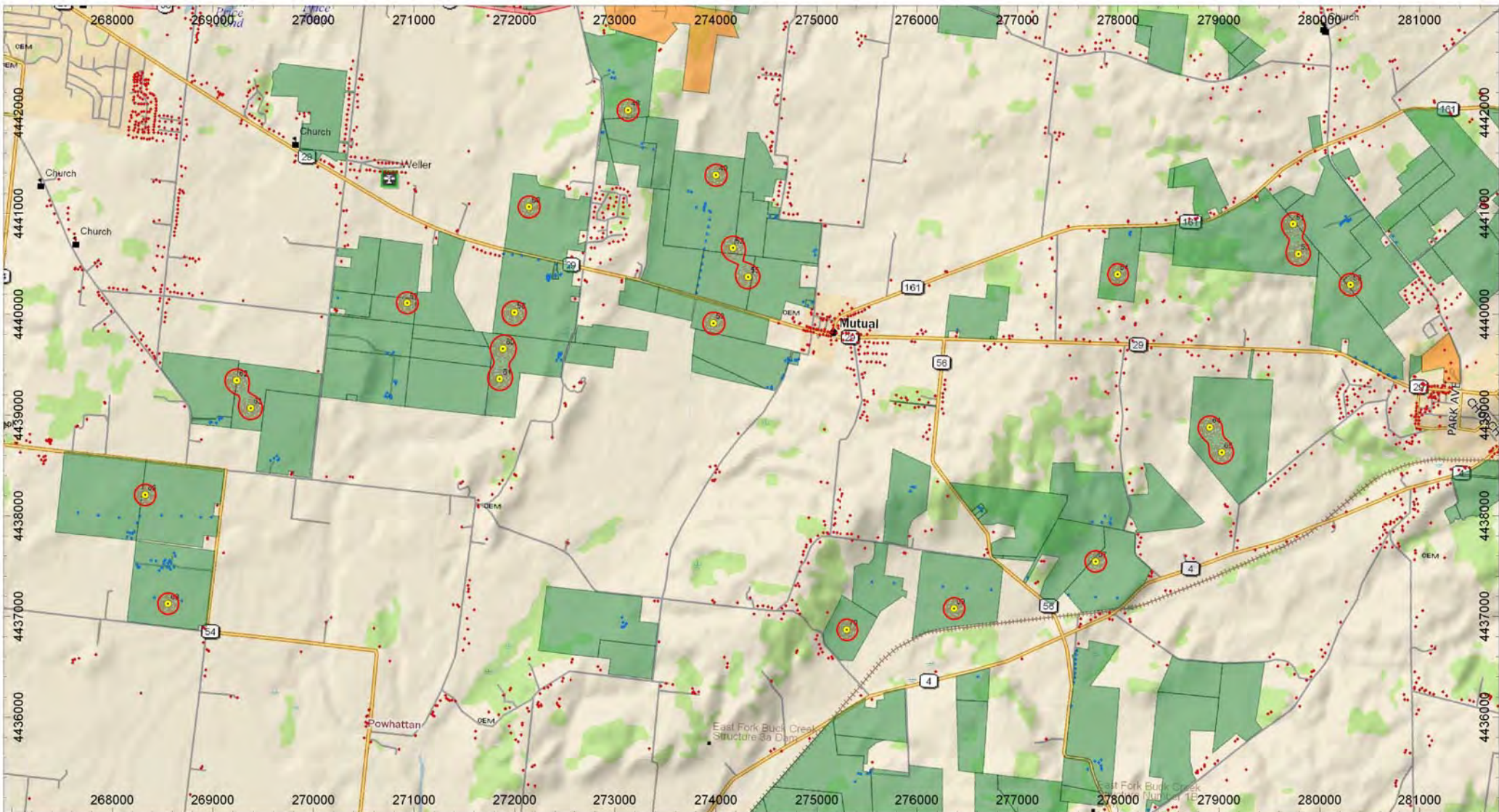
- Legend:
- Turbine Location
  - Non-Participating Residence or Unknown Structure
  - Participating Residence or Unknown Structure
  - Participating Property
  - Recreational Area
  - 50 dBA

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Project: **Buckeye**

Prepared for: **Everpower Renewables**

Date: **March 13, 2009**

Drawing #: **EBII-Rev-G-3-1**

Description: **Plot 3B  
Predicted Sound Contours (dBA) Plotted to  
Typical Property Line Design Goal of 50 dBA  
(6 m/s Wind Conditions)  
Southern Project Area**

Legend:

- ◆ Non-Participating Residence or Unknown Structure
- ◆ Participating Residence or Unknown Structure
- 50 dBA
- Participating Property
- Recreational Area
- T Turbine Location

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