Appendix H
Environmental Sound Survey and Noise Impact Assessment

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

ARKWRIGHT SUMMIT WIND FARM

TOWN OF ARKWRIGHT
CHAUTAUQUA COUNTY, NY

PREPARED FOR:

Arkwright Summit Wind Farm, LLC

Prepared by:

COMMONWEALTH OF VIRGINIA
DAVID MARK HESSLER
No. 034628
PROFESSIONAL ENGINEER

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 Arkwright Summit Wind Farm, LLC to evaluate potential noise impacts from the proposed Arkwright Summit Wind Farm (the Project) on residents in the vicinity of the project area, which is located in the Town of Arkwright in Chautauqua County, NY. Current plans call for the installation of approximately 50 wind turbines each with a nominal electrical output somewhere in the 1.5 to 2.1 MW range. The specific turbine type has not yet been selected but it is anticipated that either GE 1.5sle, Vestas V90-1.8MW, or Suzlon S 88 wind turbine generators will be used.

The study essentially consisted of two phases: background sound level surveys under both winter and summer conditions and a computer modeling analysis of future turbine sound levels. The field surveys of existing sound levels at the site were 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 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. Measurements were made during both summer and winter conditions to quantify any possible seasonal differences in environmental sound levels.

In the second phase of the project 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 impact might be.

In addition to local regulatory noise limits, the primary basis for evaluating potential project noise impacts is the Program Policy *Assessing and Mitigating Noise Impacts* issued by the New York State Department of Environmental Conservation (NYSDEC), Feb. 2001. This assessment procedure looks at potential noise impacts in relative rather than absolute terms by comparing expected future sound levels (developed from modeling) to the pre-existing level of background sound (determined from field measurements). The procedure essentially defines a cumulative increase in overall sound level of 6 dBA as the threshold between no significant impact and a potentially adverse impact.

Apart from these state and local metrics a further assessment of the expected impact is also discussed based on the CNR, or Composite Noise Rating, method and field research studies specifically on wind turbine noise that are now available in the professional literature.

2.0 BACKGROUND SOUND LEVEL SURVEYS

2.1 OBJECTIVE AND MEASUREMENT QUANTITIES

The purpose of the surveys 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 under wintertime, leaf-off conditions (when environmental sound levels are typically at a minimum) and during summertime conditions when the trees are fully leafed out. 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, like a car passing by, 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 minimum cut-in speed of roughly 4 m/s (measured at a reference elevation of 10 m). Turbine sound levels increase with wind speed up to about 8 m/s when the sound produced essentially reaches a maximum and no longer increases with wind speed. Consequently, at moderate to high speeds the level of natural masking noise is normally relatively high due to tree or grass rustle while the turbine sound level no longer increases thus reducing the perceptibility of the turbines. In order to quantify the wind-dependency of background sound levels, wind speed was measured over the entire sound level survey period at a met tower near the center of the site for later correlation to the sound data.

2.2 SITE DESCRIPTION AND MEASUREMENT POSITIONS

The proposed turbines in the Arkwright Summit Wind Project are spread out over an area of roughly 20 square miles within the Town of Arkwright, NY. The site area is rural in nature and can be characterized as consisting of numerous scattered residences, mainly along the principal roads, interspersed with several farms of various sizes. Turbines are planned in the largely uninhabited areas between local roads.

The site topography is moderately hilly. In terms of vegetation, the area is a mix of open fields and wooded areas - with wooded areas much more prevalent. Most of the homes are either near wooded areas or have some trees immediately around the house.

Background sound level measurement locations were chosen to evenly cover and represent the entire area as shown in **Graphic A**. Five positions were used for the summertime survey and an additional 3 locations (making 8 altogether) were used for the more critical wintertime survey. The specific positions are listed below along with photographs of some of the locations. As will be noted from the pictures, a variety of settings were deliberately chosen to see if background sound levels were uniform or variable over the site area. For example, some positions are in open fields, some in wooded areas, some near homes, and some in remote areas.

Position 1 – 9351 Center Road
The monitor was attached to a fencepost adjacent to a pasture behind the home and near a barn.

Figure 2.2.1 *Position 1 Looking Northwest*

Position 2 – 9682 Livermore Road
The meter was attached to a post in the rear yard of the house near the barn.

Figure 2.2.2 *Position 2 Looking Northwest*

Position 3 – Meadows Road near Scout Camp
The meter was attached to a tree in a wooded area between a cleared utility right of way and a nearby Boy Scout Camp.

Figure 2.2.3 *Position 3 Looking Northeast toward Scout Camp (clearing barely visible just beyond the woods)*

Position 4 – 8193 Farrington Hollow Road
The monitor was attached to a utility pole in the middle of a large, open alfalfa field.

Figure 2.2.4 *Position 4 Looking Southeast towards House*

Position 5 – 2934 Route 83
The meter was attached to a tree in the front yard of the house. This measurement position was set back from Route 83 by roughly 150 feet.

Figure 2.2.5 *Position 5 Looking North towards House*

Position 6 – 2383 Route 83 (Supplemental wintertime survey location)
The monitor was attached to a tree in the rear yard of the house about 100 feet back from Route 83.

Position 7 – 3053 Straight Road (Supplemental wintertime survey location)
The monitor was attached to a utility in the front yard of the house.

Position 8 – 2910 Straight Road (Supplemental wintertime survey location)
The monitor was attached to a utility pole along Center Road (near its junction with Straight Road) in a large, open pasture.

2.3 INSTRUMENTATION AND DURATION OF SURVEYS

Rion NL Series sound level meters (NL-06, NL-22, and NL-32) ANSI Type 1 and 2 sound level meters were used at locations except Position 1 where a Norsonic 118, ANSI Type 1, 1/3 octave band analyzer was used to record frequency content. Each meter was enclosed in a watertight case. The Rion monitors were fitted with a 12" microphone boom. A Norsonic Model 1212 environmental microphone protection kit was used at Position 1 for the summertime survey only – in the winter survey a boom and large windscreen, as on all other meters, was used.

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 2.7.1 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 typically 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). In any event, self-generated wind noise affects only the extreme lower frequencies and, except in very high wind conditions, has little or no influence on the measured A-weighted level (the quantity sought in the survey) since the lower frequencies are heavily suppressed before the spectrum is summed to give an overall A-weighted level. Consequently, the measured values are considered valid and free of any significant self-generated contamination.

Two surveys were carried out for the project to evaluate possible seasonal differences in background sound levels: one during leaf-on, summertime conditions from September 9 to 25, 2007 and another during wintertime conditions with trees bare from November 29 to December 12, 2007. Altogether on-site measurements were made for a period of approximately one month.

All equipment was field calibrated at the beginning of the survey and again at the end of each survey. The observed calibration drift of all the instruments was less than +/- 0.4 dB in both instances.

2.4 WEATHER CONDITIONS – SUMMER AND WINTER SURVEYS

Weather conditions during the summertime survey in September were characterized by low to moderate wind speeds and little precipitation. The only significant rain (about 0.30 inch each time) fell on September 11 and 14. Wind speeds at the IEC normalization elevation of 10 m above grade were mostly under 8 m/s but two periods of higher winds, up to 10 m/s, were captured during the survey.

The general conditions of temperature, barometric pressure and wind for the summer survey period are shown in the chart below (Figure 2.4.1) as observed at Dunkirk, NY, a few miles northwest of the site area.

The first survey was carried out under warm-weather, leaf-on conditions. Summertime environmental sound levels tend to be somewhat higher than during the winter because leaves rustle in the wind and insects, such as crickets or cicadas, commonly elevate nighttime sound levels.

Weather conditions during the winter survey in late November and early December were characterized by several periods of high wind speeds and several snowfalls. Wind speeds ranging from 0 to 14 m/s (at 10 m) were observed over the survey period.

A partial chart of the general conditions of temperature, barometric pressure and wind for the winter survey period are shown Figure 2.4.2.

The second survey was carried out under cold-weather, leaf-off conditions when the lowest environmental sound levels typically occur because there is less wind-generated sound from trees and vegetation and no insects are active.

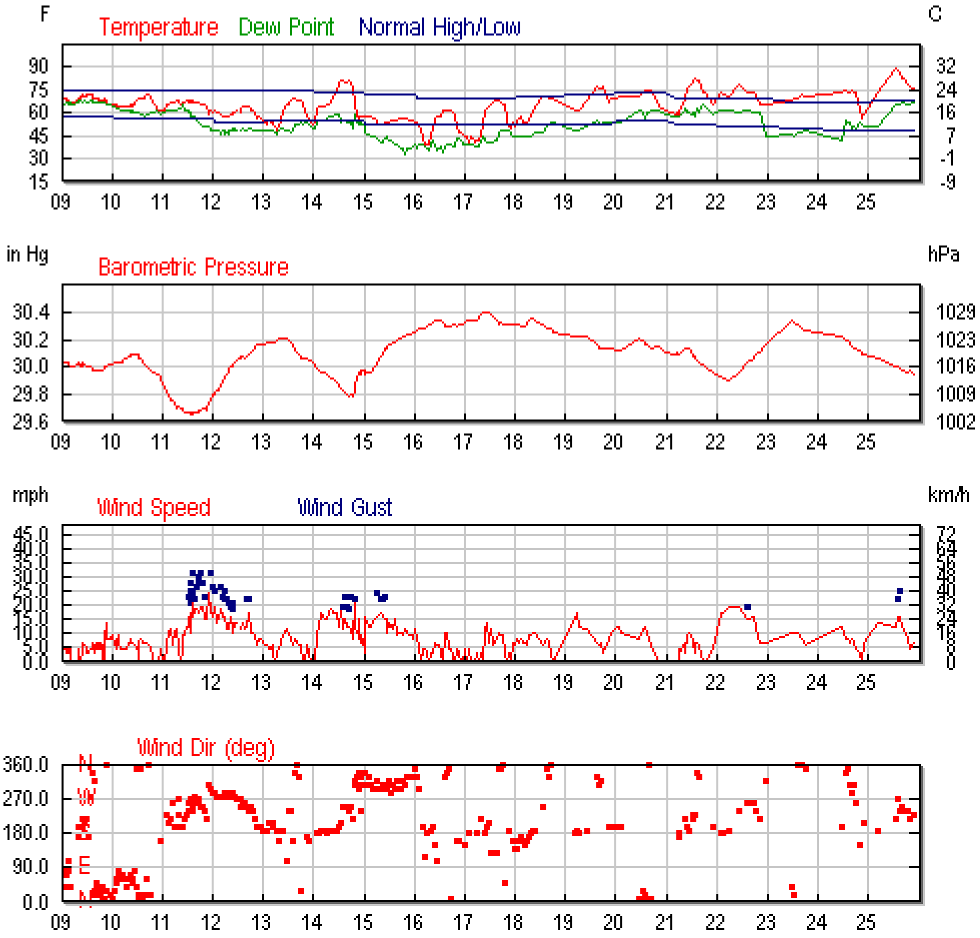
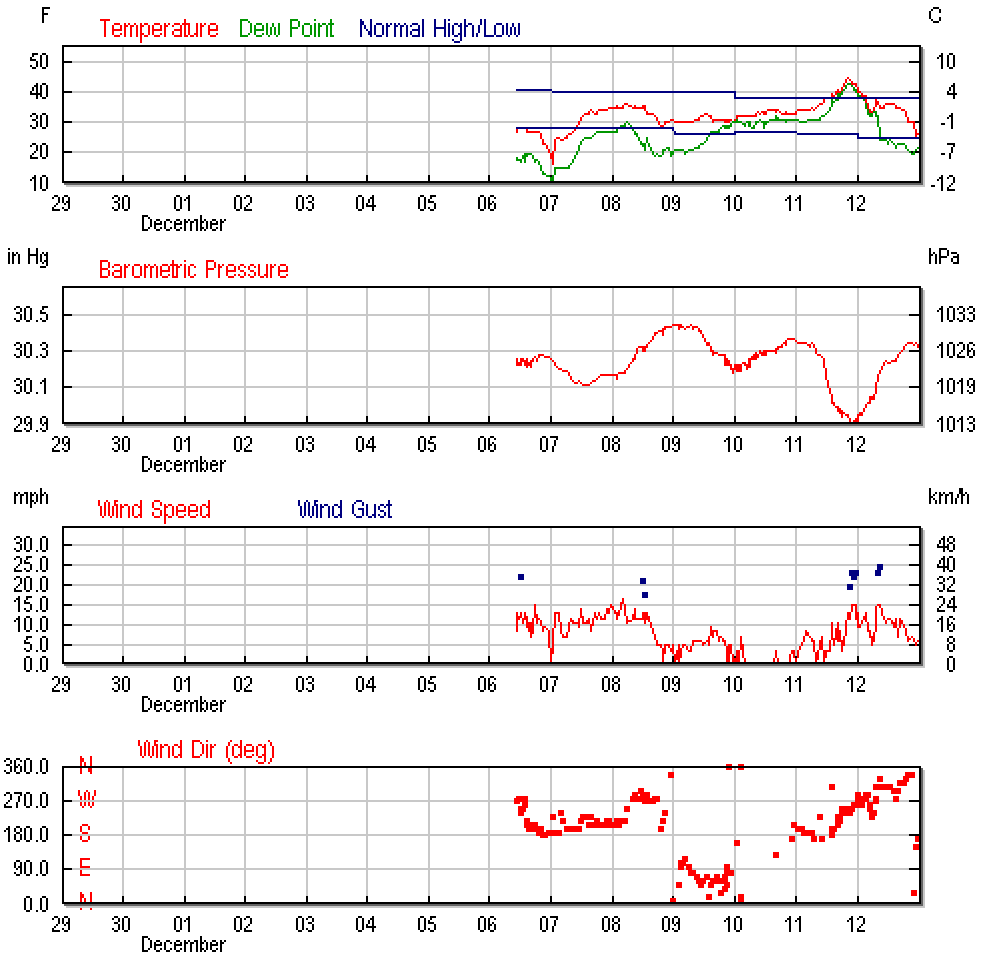


Figure 2.4.1 *General Weather Data for the Summertime Survey Period as Observed in Dunkirk, NY*



2.4.2 *General Weather Data for the Wintertime Survey Period as Observed in Dunkirk, NY (Partial)*

The wind speed at the site itself was measured by a central met tower just off of Center Road. Figure 2.4.3, shows the 10 minute average wind speeds measured by the mast top (49 m) anemometer of Tower 991 during the summer survey. Also shown is the normalized average wind speed per IEC Standard 61400-11 [Ref. 1], Equation 7, at the standard height of 10 m. A roughness length of 0.05 was used, which is associated with “farmland with some vegetation”. The wind speed at this elevation is important because the turbine sound power levels are expressed as a function of wind speed at this standard height.

A similar plot of wind speed vs. time for the winter survey is shown in Figure 2.4.4.

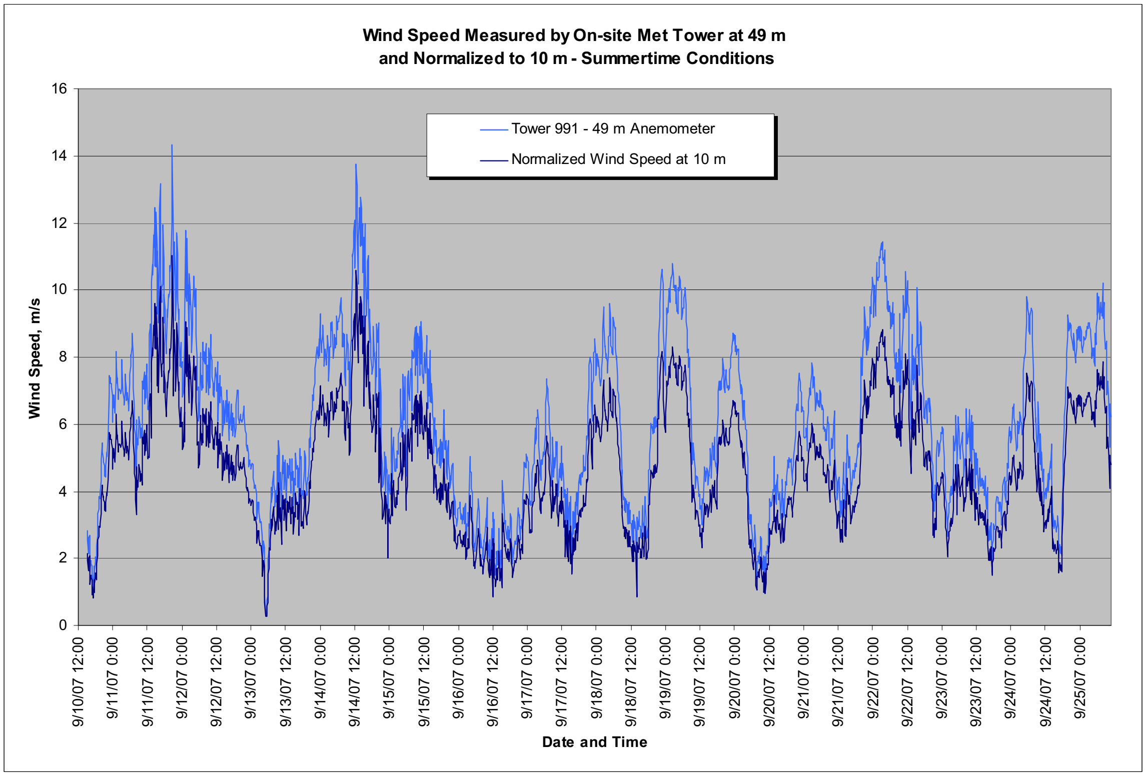


Figure 2.4.3 *Measured Wind Speeds at Site during Summer Sound Survey Period*

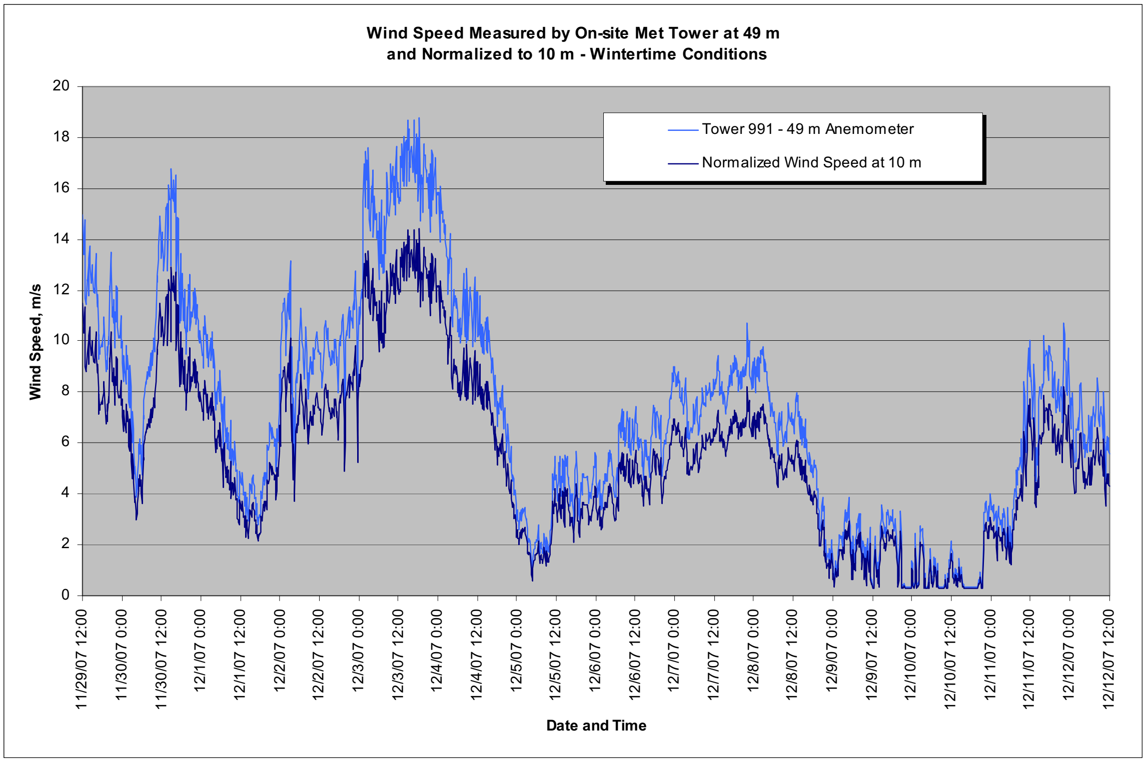


Figure 2.4.4 *Measured Wind Speeds at Site during Winter Sound Survey Period*

2.5 OVERALL RESULTS – SUMMER SURVEY

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 lowest, or near "worst-case", background level with regard to evaluating potential impacts from a new source.

The L90 sound levels over consecutive 10 minute increments for all 5 summertime positions are plotted below for the survey period.

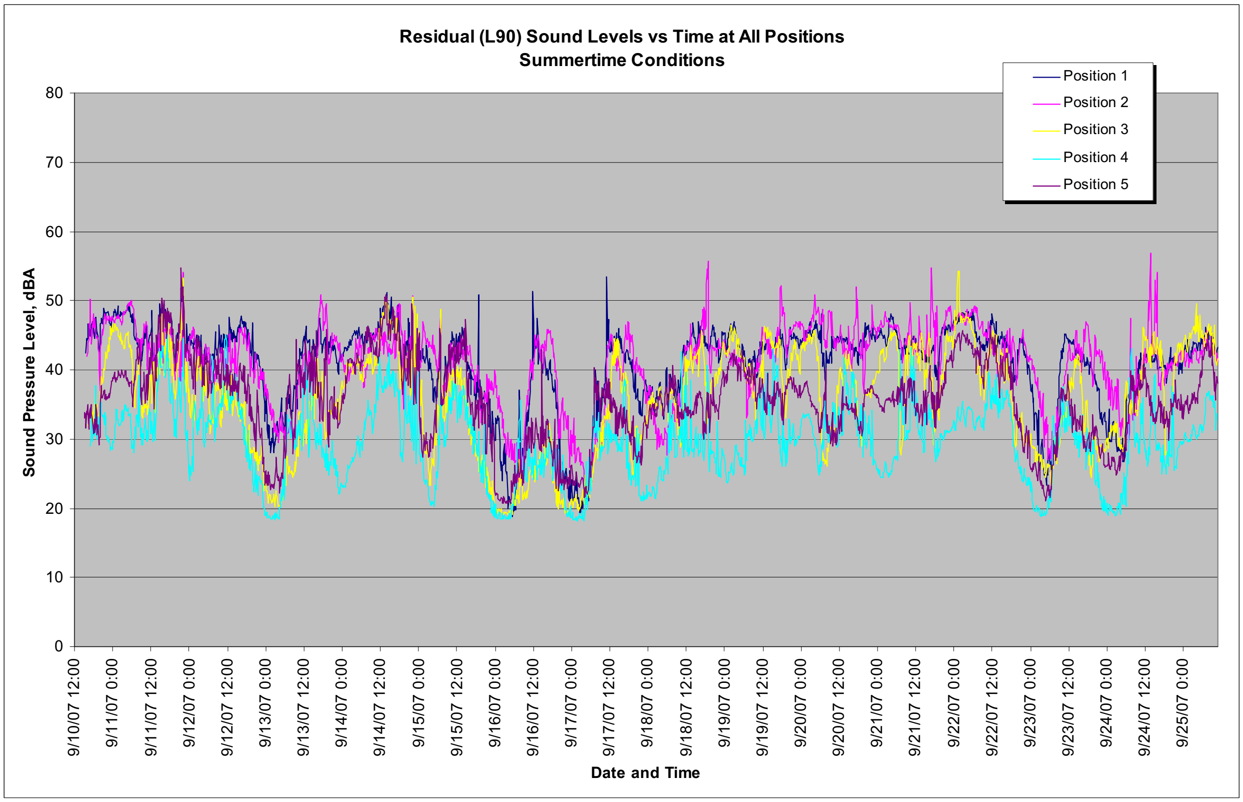


Figure 2.5.1 *10 minute L90 Sound Levels at All Monitoring Positions*

This plot shows that sound levels over the site area are of the same general order of magnitude but that some local variation is present. Experience with many other summertime field surveys indicates that most of the local variation apparent here is a common occurrence likely due to the prevalence and activity level of various insects near each monitoring station. Because insect noise is generally confined to the higher frequencies it plays a fairly minor role in masking mid-frequency wind turbine noise so the scatter in the data is not as substantive or important as it might at first seem. Consequently, the average sound level over all five positions, plotted in Figure 2.5.2 below, is considered a reasonably fair and representative measure of site-wide L90 sound levels and will be taken as the L90 design level.

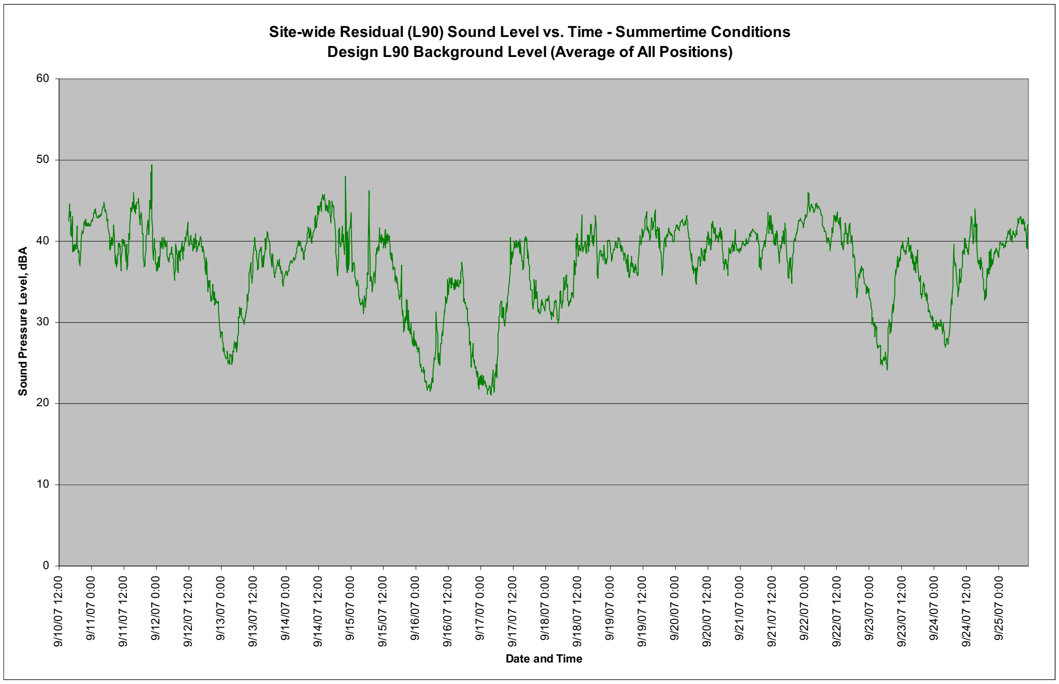


Figure 2.5.2 *Average L90 Sound Level – Design "Worst-case: Background Sound Level*

The average L90 design sound level is plotted against the average wind speed at 10 m in Figure 2.5.3 below.

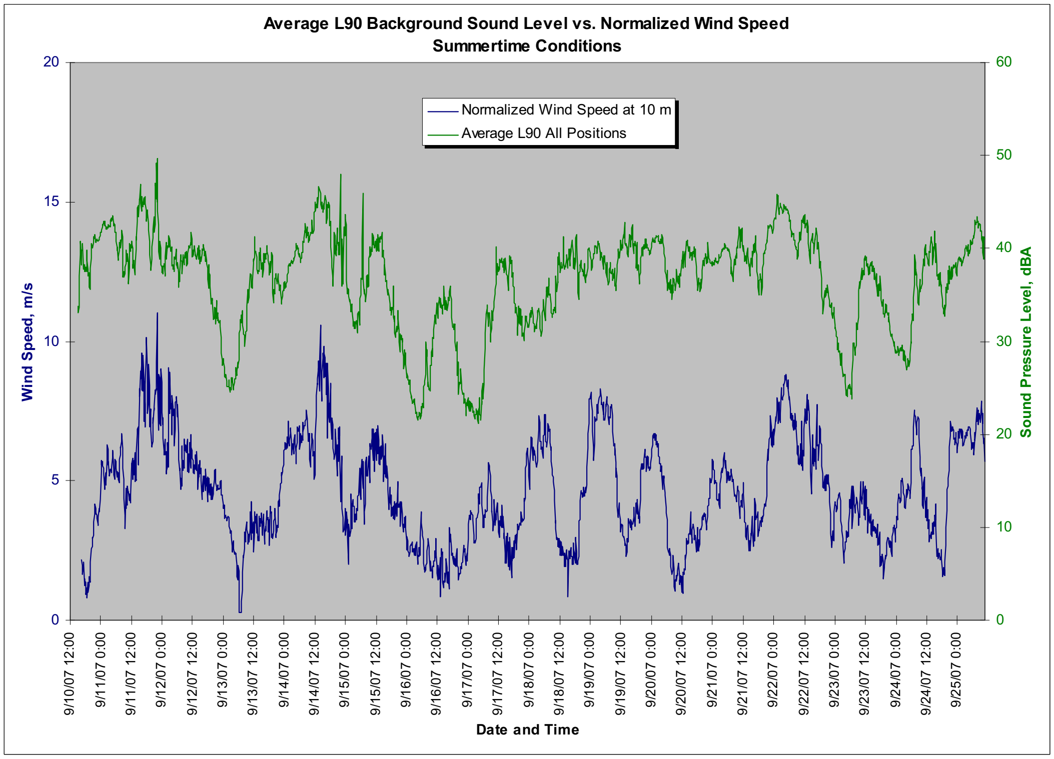


Figure 2.5.3 *Background L90 Sound Levels and Wind Speed*

This plot shows that there is a somewhat vague correlation between sound and wind, which is not surprising because any such correlation is diluted in direct proportion to the prevalence of sounds that are independent of wind speed, such as insects. Nevertheless, the sound peaks do match up well with the periods of maximum wind when tree rustle normally becomes the dominant sound in the environment.

The sound levels discussed so far are all residual, or L90, levels that capture the near minimum sound level that occurred during each 10 minute interval. As such this level is a conservative, “worst-case” design level for evaluating potential impacts since it essentially represents the lowest level of masking sound. By definition, however, the L90 level occurs only a small fraction of the time (10% of the time) and is not a long-term or continuous phenomenon. The average, or Leq, level, on the other hand, is the “typical” sound level that might be heard at any given moment.

Figure 2.5.4 below shows the Leq(10 min) sound levels measured at all five monitoring stations. In this instance, sound levels at each position generally intertwine and the level at any one point is not appreciably or consistently different from that at the others. Consequently, the average of all five levels, plotted in Figure 2.5.5, is considered a valid representation of the site-wide Leq, or “typical” sound level.

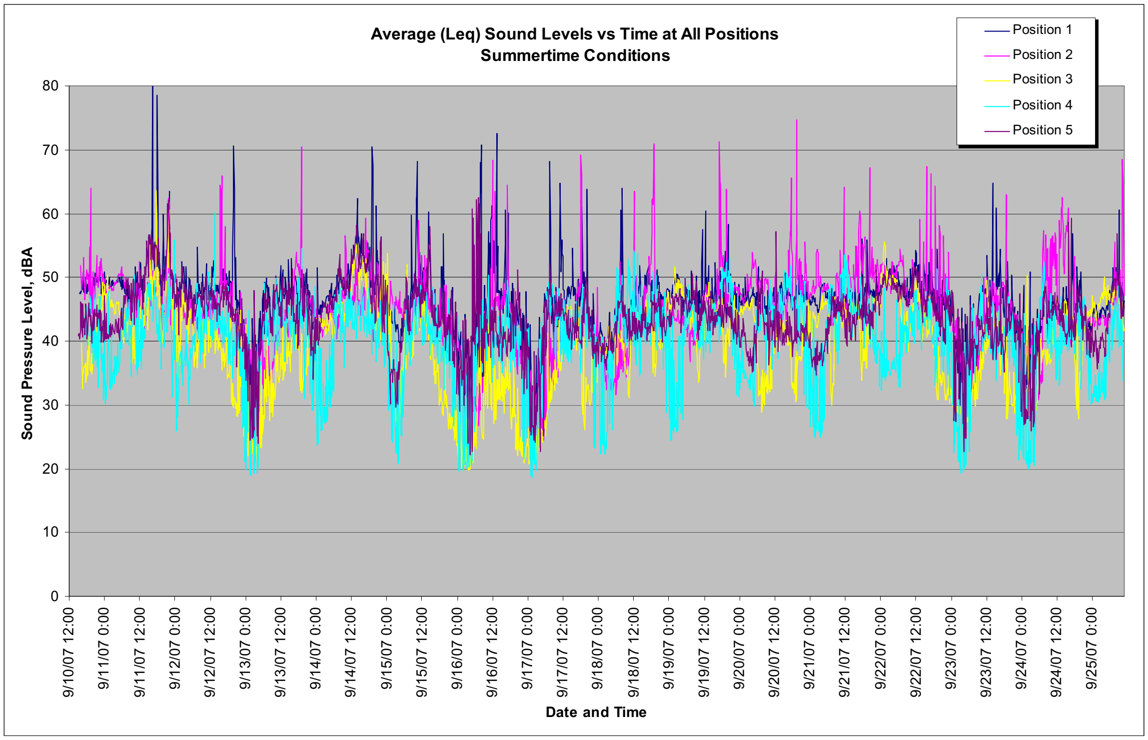


Figure 2.5.4 *10 minute Leq Sound Levels at All Monitoring Positions*

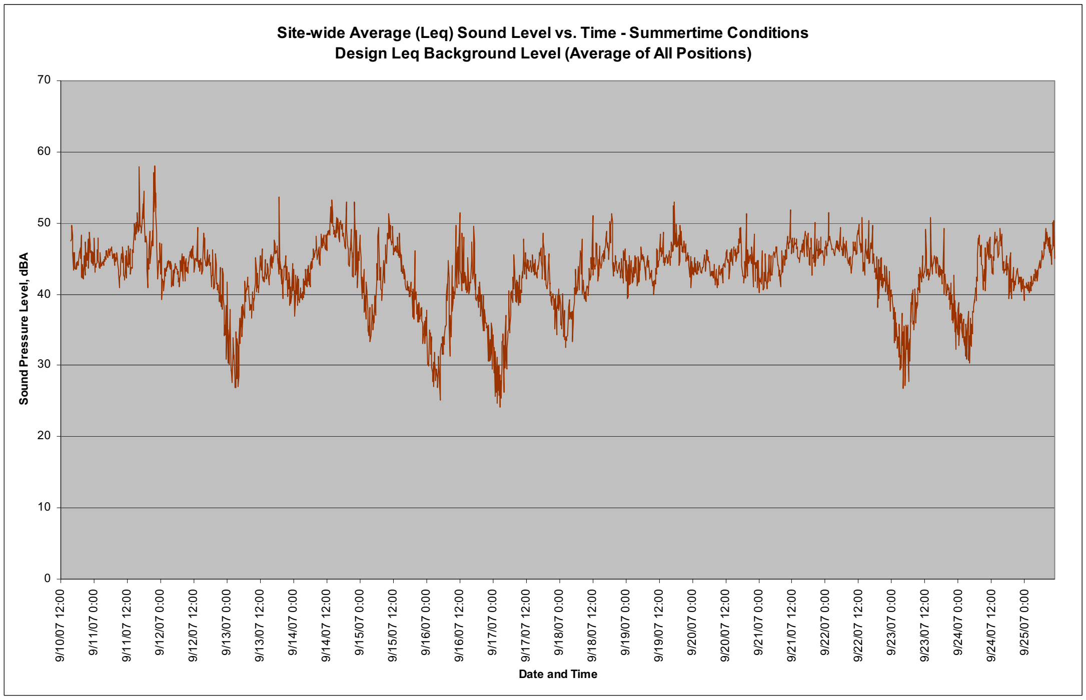


Figure 2.5.5 *Average Leq Sound Level at All Monitoring Positions*

The correlation between the Leq level and wind speed is plotted in Figure 3.5.6.

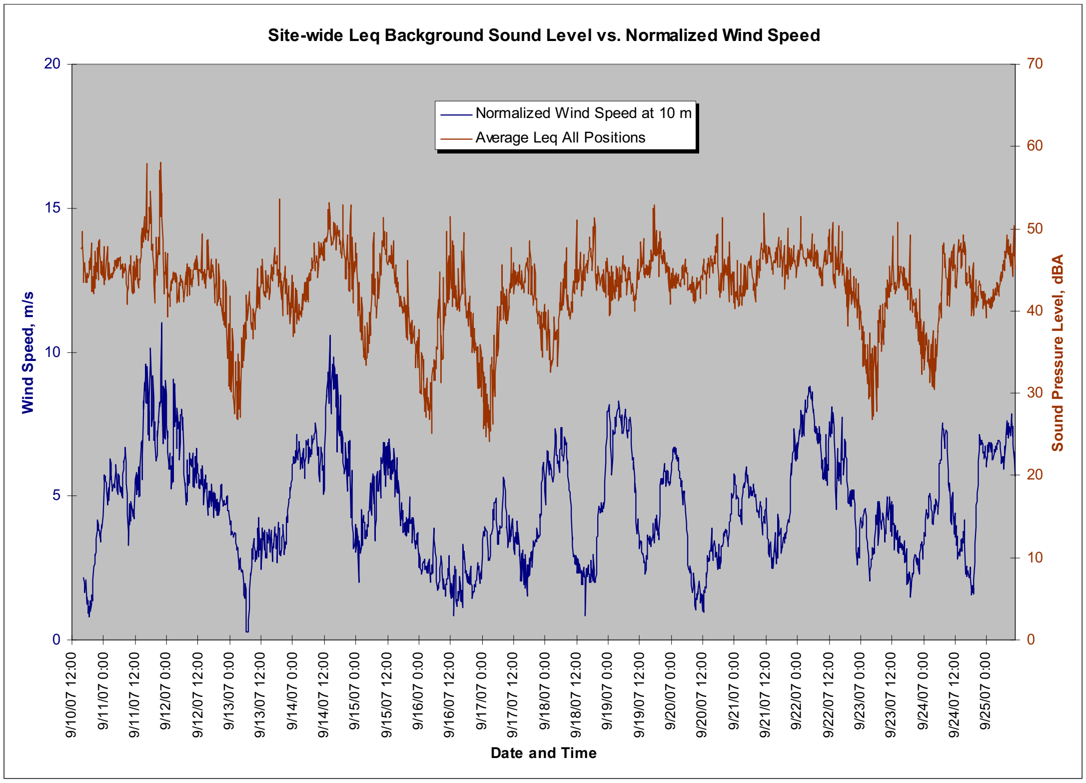


Figure 2.5.6 *Background Leq Sound Levels and Wind Speed*

2.6 OVERALL RESULTS – WINTER SURVEY

The L90 sound levels over consecutive 10 minute increments for all 8 wintertime positions are plotted below in Figure 2.6.1 for the November/December survey period. Three additional measurement positions were added for the winter survey, since measurements taken during leaf-off, cold weather conditions are typically lower than in summer, less prone to contamination and therefore of more importance to the impact assessment.

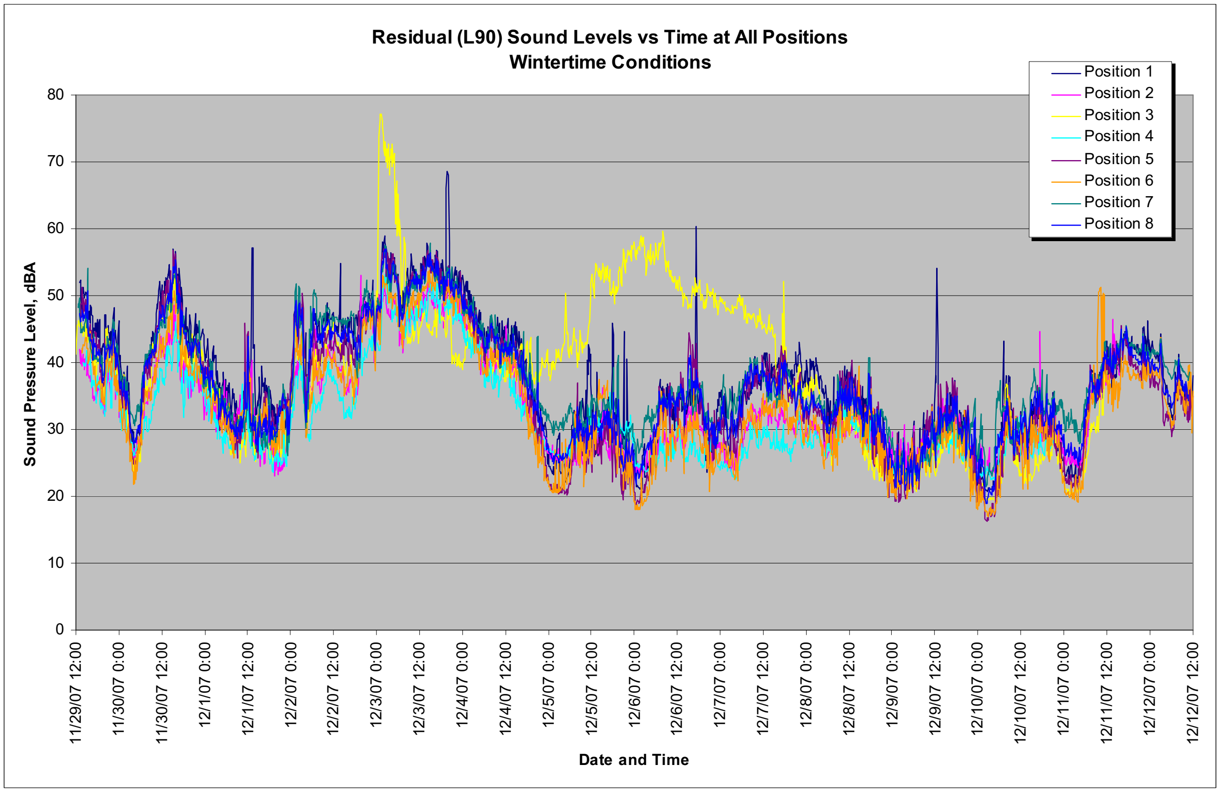


Figure 2.6.1 *10 minute L90 Sound Levels at All Monitoring Positions*

Apart from the anomalously high levels measured part of the time at Position 3, this plot shows that L90 sound levels measured during cold-weather conditions are much more tightly grouped than in the warm weather survey and all closely follow each other even though many of the positions were miles apart. It is not known why unusually high sound levels were observed for a period of several days (only) at Position 3, which is in a remote wooded area. Because of this inexplicable behavior the data measured at this position has been ignored for the entire survey period. The average level excluding Position 3, plotted below, is considered to reasonably represent the site-wide L90 sound level during winter conditions.

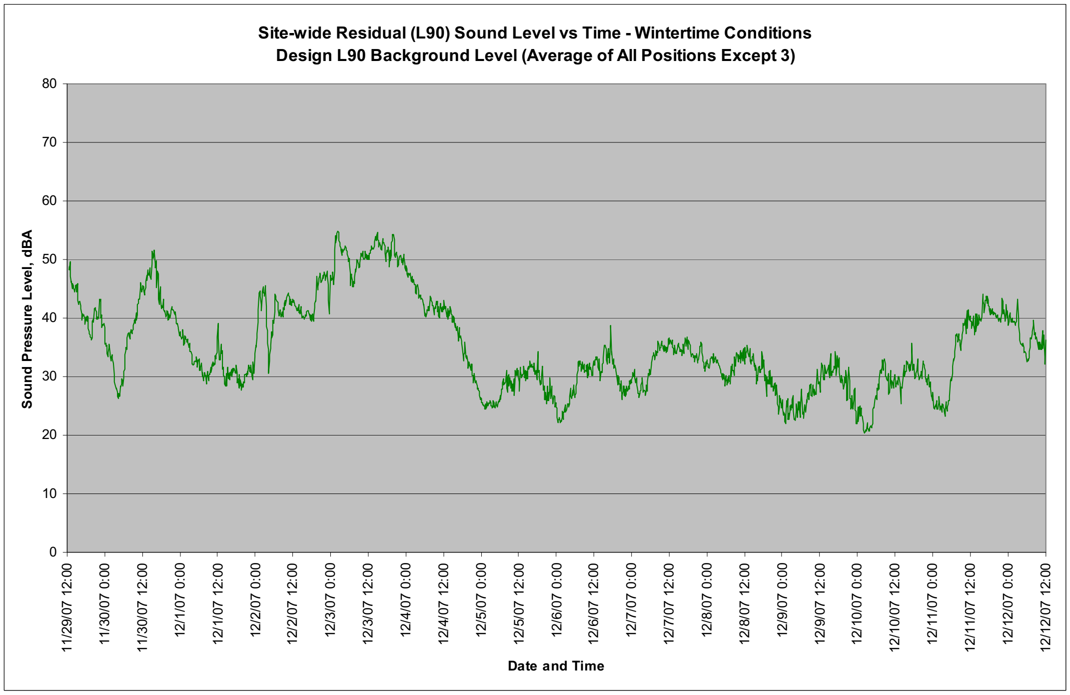


Figure 2.6.2 *Average L90 Sound Level – Design "Worst-case: Background Sound Level*

This average L90 design sound level is plotted against the average wind speed at 10 m in Figure 2.6.3 below.

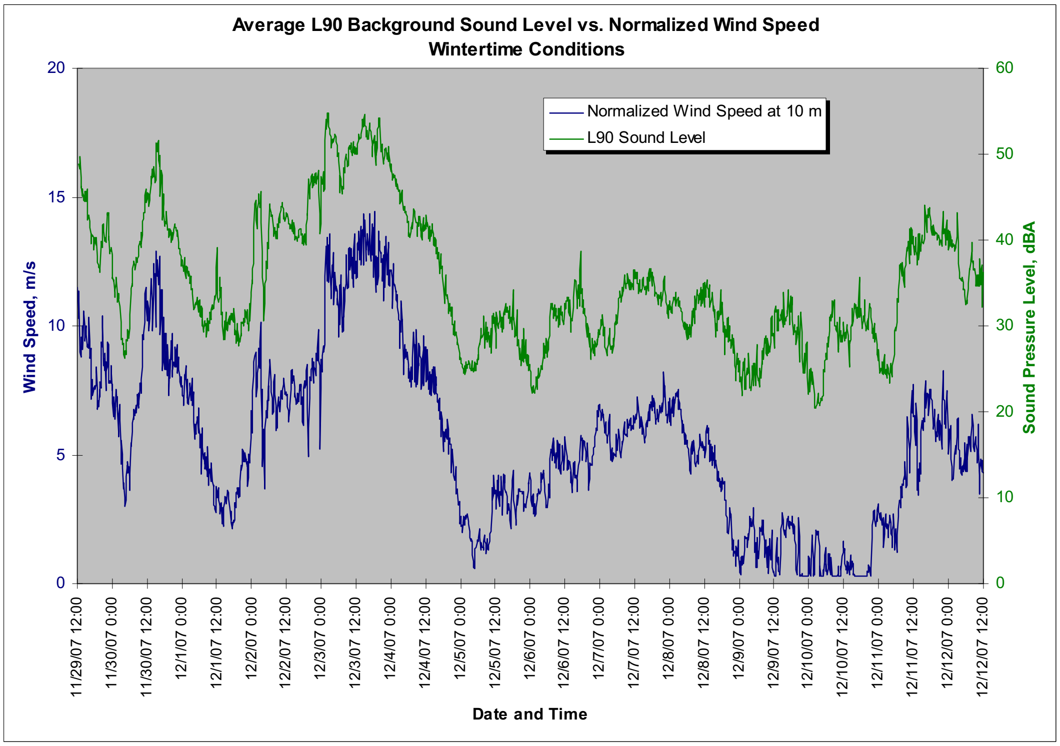


Figure 2.6.3 *Background L90 Sound Levels and Wind Speed*

As opposed to the rather vague correlation between the summer sound levels and wind speed, the winter data show that there is a clear and definite connection between the L90 ambient sound level and wind speed, which is to be expected, since insect activity (a noise source unrelated to wind) is absent.

Figure 2.6.4 below shows the Leq(10 min) sound levels measured at all 8 winter monitoring stations.

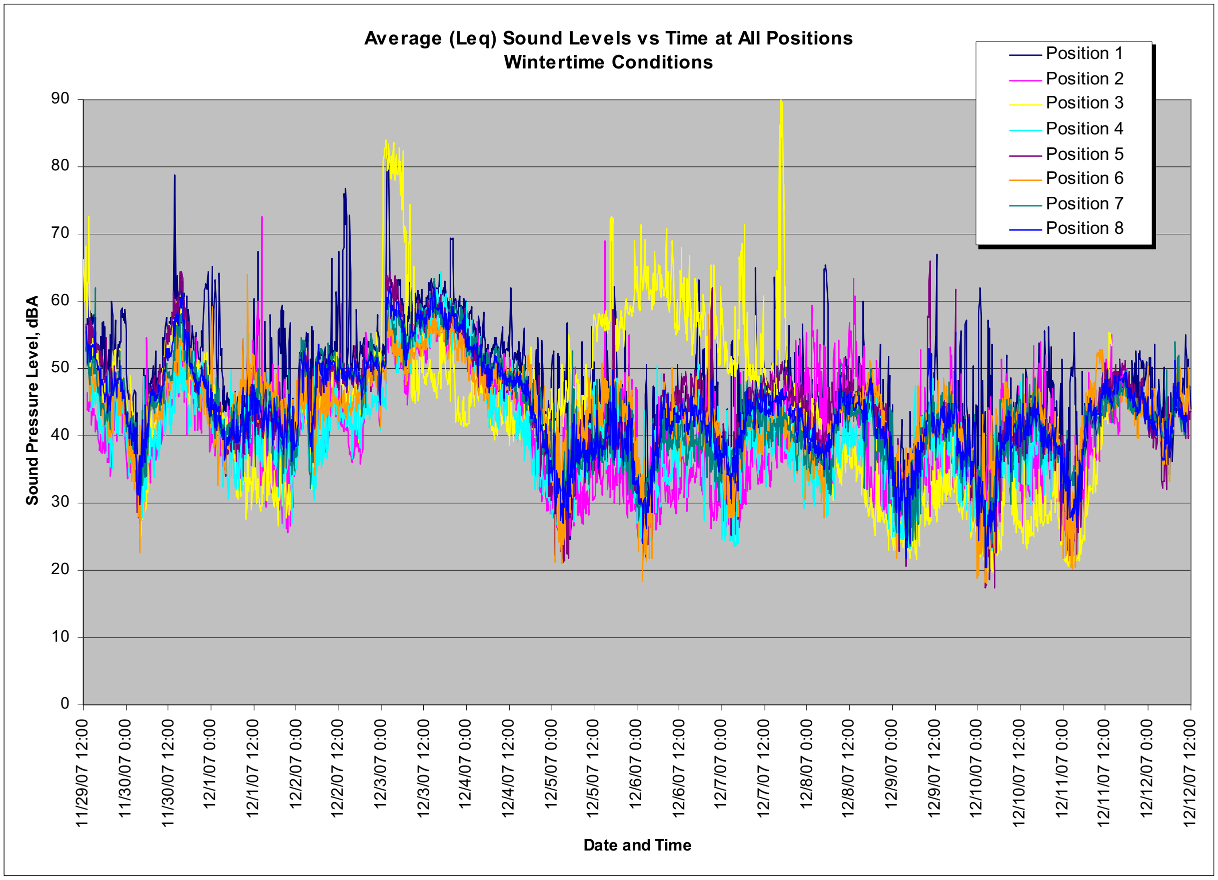


Figure 2.6.4 *10 minute Leq Sound Levels at All Monitoring Positions*

While there is more scatter in the Leq levels, they are still consistent in the sense that no one position - except Position 3 - is substantially different from the rest of the locations. Consequently, the average of the remaining 7 positions, plotted in Figure 2.6.5, is considered a reasonably good representation of the site-wide Leq, or "typical" sound level for wintertime conditions.

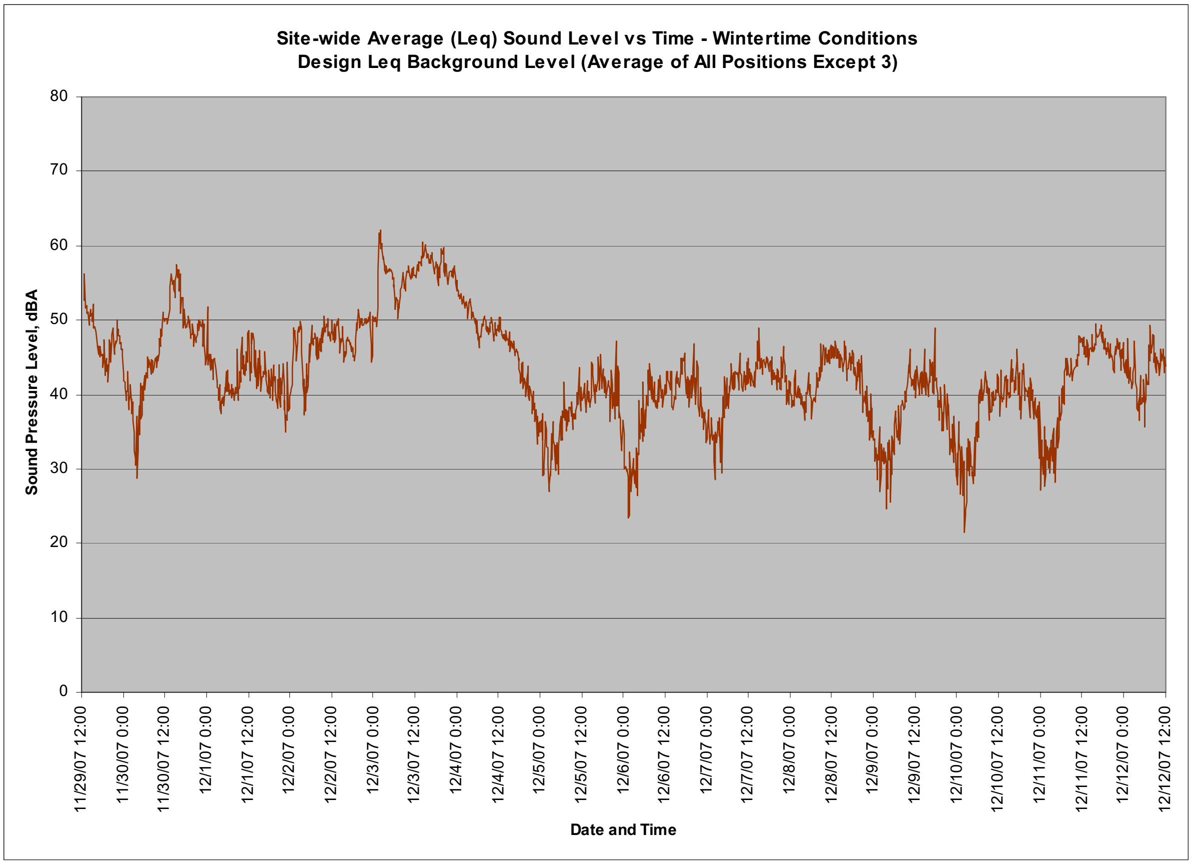


Figure 2.6.5 *Average Leq Sound Level at All Monitoring Positions*

The correlation between the Leq level and wind speed is plotted in Figure 2.6.6. As with the L90 levels, the site-wide, design Leq exhibits a close correlation between sound and wind speed.

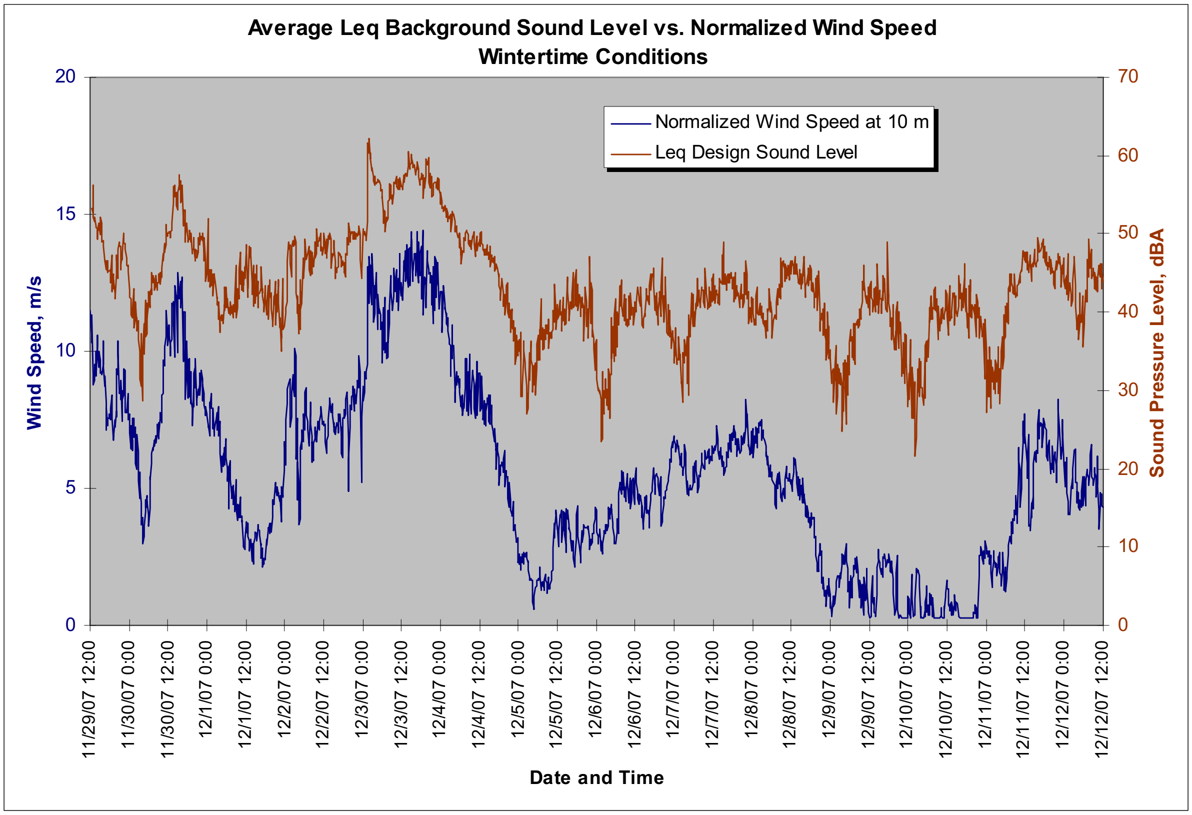


Figure 2.6.6 *Background Leq Sound Levels and Wind Speed*

2.7 WIND SPEED AS A FUNCTION OF ELEVATION

Below about 100 m, wind speed varies with elevation above the ground due to friction with the ground surface and obstacles such as trees. Because this roughness varies from place to place measurements of wind turbine sound power levels and concurrent wind speeds carried out in accordance with IEC Standard 61400-11 [Ref. 1] are normalized to and reported 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 the uniform basis.

The conversion from wind speed at one elevation to the related speed at another elevation is calculated from a formula in the standard (Equation (7), Section 8), which describes a logarithmic profile. For the specific parameters relevant to this project the wind profile resulting from the Eqn.(7) is shown graphically below, in Figure 2.7.1, for an example case where the wind is normalized to a speed of 6 m/s at 10 m.

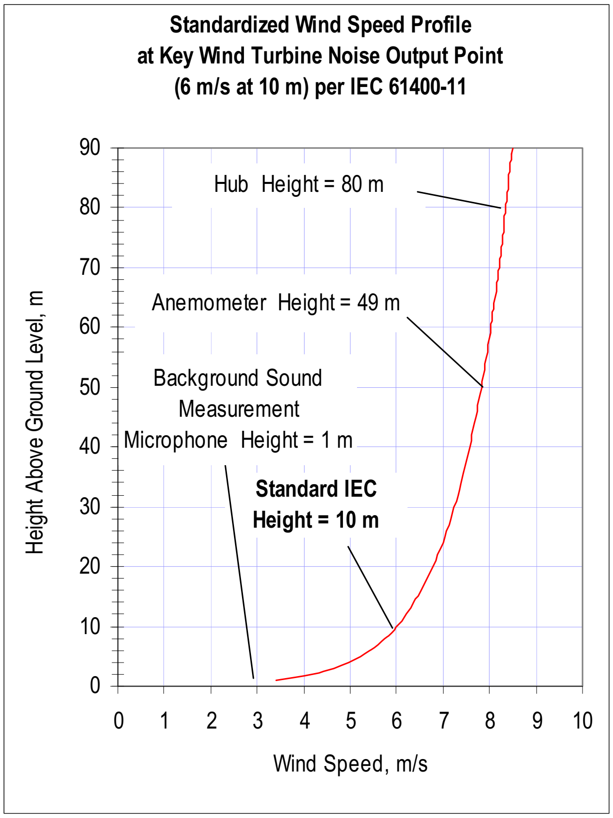


Figure 2.7.1

In this example, a standardized wind speed of 6 m/s at the reference height of 10 m would correspond to wind speed of just under 8 m/s at an anemometer height of 49 m and a speed of about 8.3 m/s at the expected turbine hub height of 80 m.

This plot illustrates that near the surface the wind speed typically drops off rapidly - so measuring background levels with the microphones at a height of about 1 m exposes them to relatively low wind speeds and minimizes the probability of contamination from self-generated noise (wind blowing over the microphone).

2.8 SOUND LEVELS AS A FUNCTION OF WIND SPEED

From the data collected over the two surveys it is possible to determine the A-weighted sound levels that are likely to occur in each season over the wind speed range of interest – generally from 3 to 10 m/s (at 10 m). This range is important with respect to wind turbine sound emissions because turbine sound power levels are variable from cut in around 3 or 4 m/s, where they are minimal, up to about 8 m/s when the rotor first reaches maximum speed and where noise levels are generally maximum. Beyond this point turbine sound level essentially remains constant and no longer increases with wind speed.

The first regression plot below, Figures 2.8.1, quantifies the relationship between wind speed and the L90, or “worst-case” sound level during the leaf-off, cold weather conditions. The second plot, Figure 2.8.2, shows the correlation between the wintertime Leq, or “typical” sound level and wind speed.

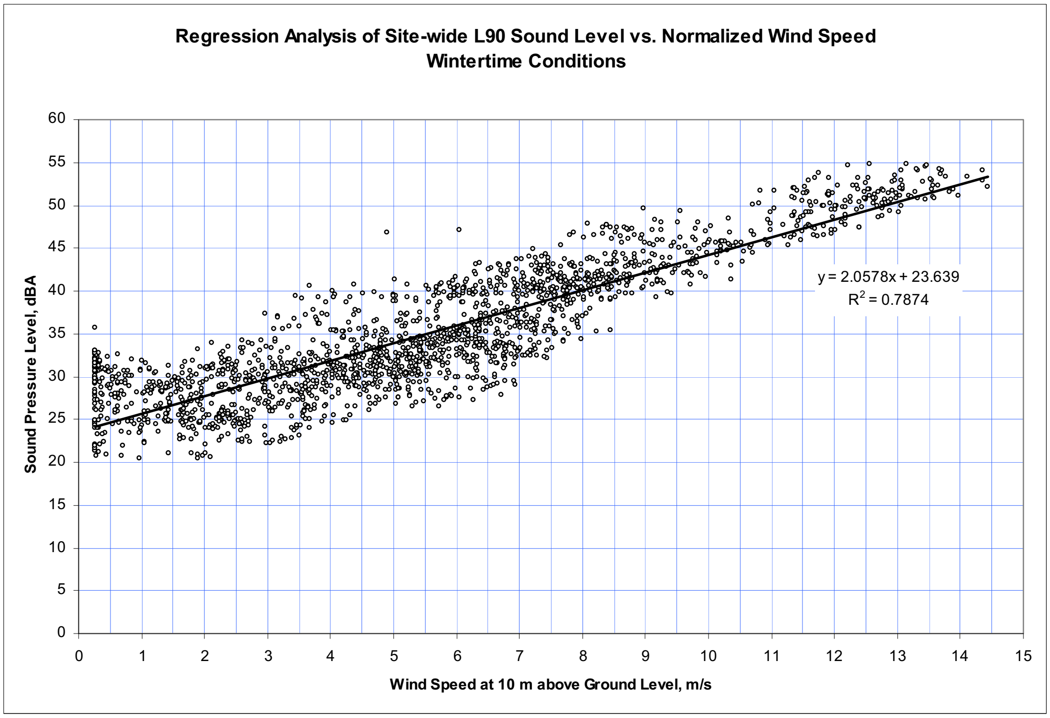


Figure 2.8.1

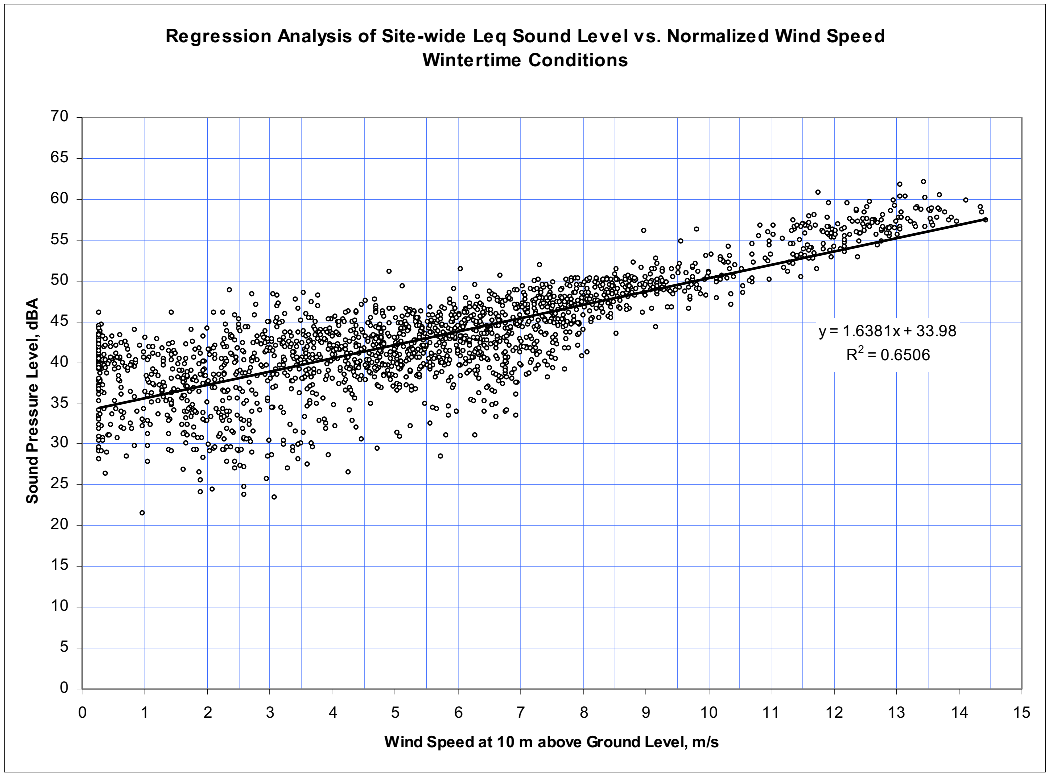


Figure 2.8.2

The regression charts for summertime L90 and Leq sound levels are shown below.

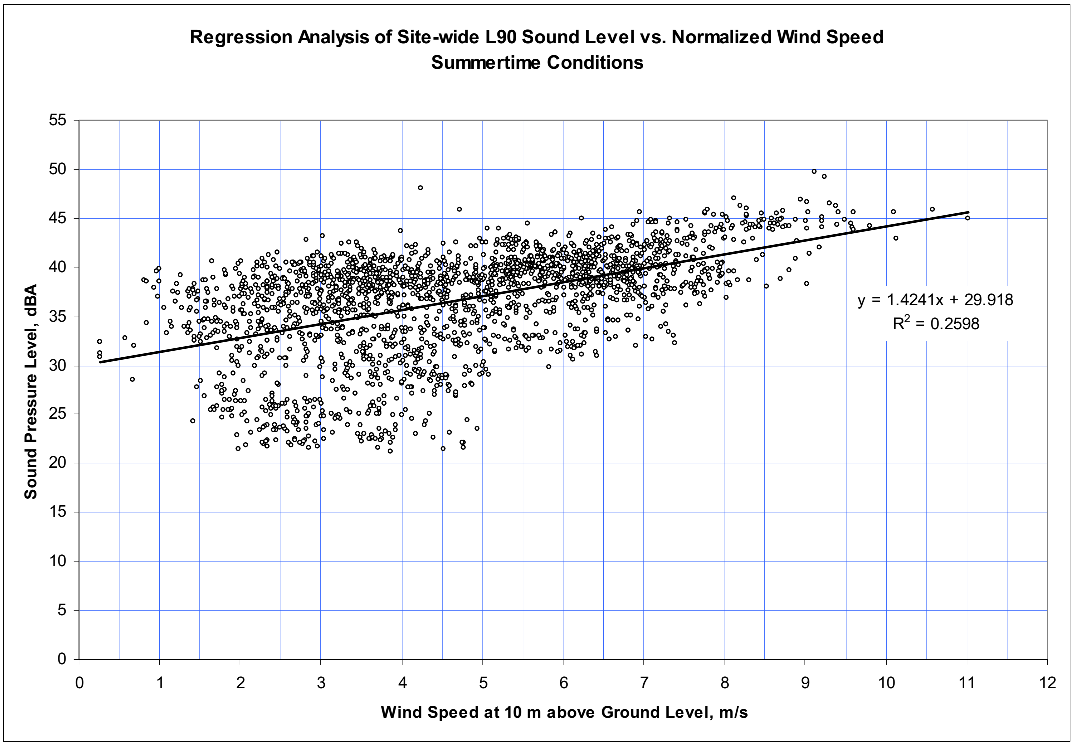


Figure 2.8.3

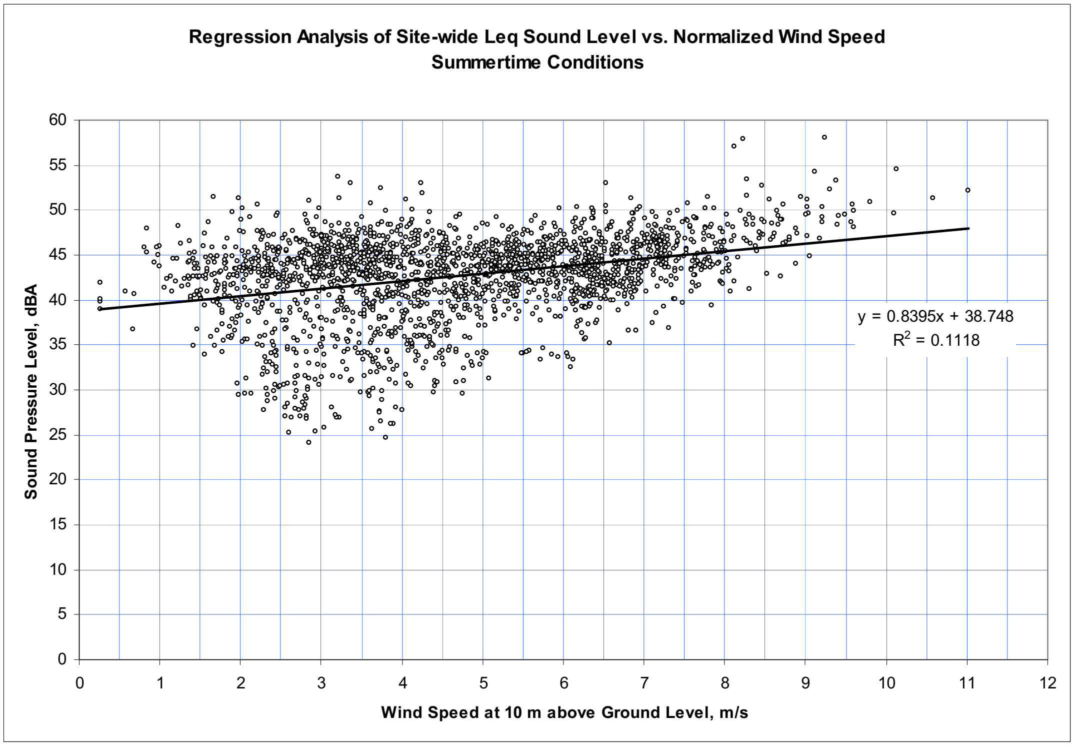


Figure 2.8.4

In general, there is a significantly tighter correlation between the winter sound levels and wind speed as opposed to the summer levels, as evidenced by the R^2 values of the trend lines, but in all cases it can be seen that environmental sound levels increase with wind speed. It would be incorrect to associate a low background level, such as might occur on a calm night, with moderately windy or very windy conditions. The maximum data scatter tends to occur at low wind speeds – below the turbine cut-in speed of about 3.5 m/s – essentially because sound levels are not driven by the wind during calm conditions. Higher correlation, i.e. R^2 values, would certainly occur if only the data above a minimum wind speed of 3.5 m/s were considered.

From the regression charts above the following typical and worst-case background sound levels can be expected at integer wind speeds ranging from 4 to 9 m/s during cold and warm season conditions.

Table 2.8.1 *Measured L90 and Leq Background Sound Levels as a Function of Wind Speed during Winter and Summer Conditions*

Integer Wind Speed at Standardized Hgt. of 10 m, m/s	**4**	**5**	**6**	**7**	**8**	**9**
Worst-Case L90 Sound Level **Cold Weather**, dBA	32	34	36	38	40	42
Typical Leq Sound Level **Cold Weather**, dBA	41	42	44	45	47	49
Worst-Case L90 Sound Level **Warm Weather**, dBA	36	37	39	40	41	43
Typical Leq Sound Level **Warm Weather**, dBA	42	43	44	45	46	46

At higher wind speeds the summer and winter levels aren't all that different with the warm weather levels being just slightly higher. At lower wind speeds there a more pronounced difference in seasonal level but only in terms of "worst-case" L90 levels.

3.0 PROJECT NOISE MODELING AND IMPACT ASSESSMENT

3.1 ASSESSMENT CRITERIA

There are several metrics against which to compare the predicted noise from the project and thereby determine if any adverse environmental impacts might result from it. The first of these measures is a local regulatory noise limit; the second is a set of noise assessment guidelines published by the New York State Department of Environmental Conservation (NYSDEC); and a third approach (modified CNR) looks at the frequency content of both the masking and project sound levels to estimate community reaction.

3.1.1 REGULATORY NOISE LIMITS

The Town of Arkwright has established a local ordinance specifically relating to wind energy facilities (Local Law No. 4 of 2006) that limits noise from any wind energy conversion system (WECS) to **50 dBA** measured in terms of the L10 statistical level at "the nearest residence existing at the time of application". In addition,

> If the ambient sound level exceeds 50 dBA, the standard shall be ambient dBA plus 5 dBA. Independent certification shall be provided before and after construction demonstrating compliance with this requirement.
>
> In the event audible noise due to WECS operation contains a steady pure tone, such as a whine, screech or hum, the standards for audible noise set forth in subparagraph 1) of this subsection shall be reduced by five (5) dBA. A pure tone is defined to exist if the one third (1/3) octave band sound pressure level in the band, including the tone, exceeds the arithmetic average of the sound pressure levels of the two (2) contiguous bands by:
>
> 5 dB for center frequencies of 500 Hz or above
> 8 dB for center frequencies between 160 and 500 Hz
> 15 dB for center frequencies less than or equal to 125 Hz
>
> In the event the ambient noise level (exclusive of the development in question) exceeds the applicable standard given above, the applicable standard shall be adjusted so as to equal the ambient noise level.

It appears that the last paragraph means that if and only if a tone exists then the 5 dBA above ambient allowance for high noise environments does not apply and the criterion would be that Project noise may equal the background level.

It should be noted that the 50 dBA noise limit is expressed as an L10 statistical level. The L10 is the sound level during any given measurement interval that is exceeded only 10% of the time; i.e. 90% of the time the actual sound level is quieter than this value and 10% of the time it is louder. As such, the L10 captures the near-maximum level occurring during the measurement, which, from a practical standpoint, usually consists of contaminating events like cars passing by or dogs barking. In almost all cases an L10 level is, by definition, significantly higher than the average, or Leq, level and much higher than the L90, which captures the near minimum level during the measurement by largely excluding contaminating events. The relevance of this is that any L10 measurements of actual turbine operation taken over any period longer than a few seconds are likely to be biased to the high side by extraneous noise events. Additionally, a fairly sophisticated integrating sound level meter is needed to measure this statistical quantity.

A minimum setback of 1200 ft. from all residences is also required in the law.

There are no other overarching state or federal noise regulations that would apply to the project.

3.1.2 NYSDEC GUIDELINES

In the Program Policy *Assessing and Mitigating Noise Impacts* published by the New York State Department of Environmental Conservation (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 cumulative increases in the total ambient sound level of 6 dBA or less are unlikely to constitute an adverse community impact. From a practical standpoint, because decibels add logarithmically, this threshold means that noise from the project could exceed the existing background level by up to 5 dBA. For example, a background level of 40 dBA plus a project-only sound level of 45 dBA would equal a total cumulative level of 46 dBA – or 6 dBA above the original level.

3.1.3 COMPOSITE NOISE RATING METHOD

An additional approach towards evaluating potential community noise impacts that also considers the frequency content of both the background and the project sound levels is the modified Composite Noise Rating (CNR) method. This method, which is based on case histories of reaction to new noise sources (though not specifically wind turbines), dates back to 1955 [Ref. 2] and with minor modifications has been used by a number of federal agencies including the EPA [Ref. 3].

The procedure involves the following steps:

1. Obtain a baseline rating classification, letter grade, from the predicted sound pressure level spectrum of the new noise source
2. Determine a background (masking noise) correction based on the average measured background sound level spectrum
3. Apply a number of correction factors related to when the source is in operation, the character of the noise and the general attitude of the receiver
4. Determine a final rating classification after application of all corrections and adjustments The final classification defines the expected reaction to the new source

3.2 TURBINE SOUND LEVELS

Several turbine models are currently being considered for this project: the GE 1.5sle, Vestas V90-1.8MW and the Suzlon S 88. All have nearly identical noise emissions.

The noise emissions of each model as a function of wind speed is known from field tests carried out by independent acoustical engineers in accordance with IEC 61400-11 [Ref. 1]. The values for the GE unit are reported in a document entitled *Technical Documentation, Wind Turbine Generator System GE 1.5sl/sle 50 & 60 Hz, Noise Emission Characteristics* [Ref. 7] and in the *General Specification V90-1.8/2.0 MW Optispeed Wind Turbine* [Ref. 14] for the Vestas unit. A Suzlon S 88 unit was tested at the Sankaneri site in Tamil Nadu, India by DEWI [Ref. 17]. For an 80 m hub height, as is planned for this Project, the following overall sound power levels are published for each model as a function of wind speed at the standardized measurement height of 10 m.

Table 3.2.1 *Sound Power Levels vs. Wind Speed for Turbine Models Being Considered for the Project*

Wind Speed at 10 m Height, m/s	**GE 1.5sle Sound Power Level, dBA re 1 pW**	**Vestas V90-1.8MW Mode 0 Sound Power Level, dBA re 1 pW**	**Suzlon S 88 Sound Power Level, dBA re 1 pW**
3	< 96	-	-
4	<96	94.3	-
5	99.1	99.7	-
6	103.0	102.2	103.9
7	104.0	104.0	105.1
8	104.0	103.7	106.2
9	104.0	103.5	106.8
10	104.0	103.5	106.5

The reporting of sound levels below a wind speed of 6 m/s is not required by IEC 61400-11.

At the point of maximum noise generation the following octave band frequency spectra are published for each model.

Table 3.2.2 *Sound Power Level Spectra at Maximum Emissions Point*

Octave Band Center Frequency, Hz	63	125	250	500	1k	2k	4k	8k	dBA
GE 1.5sle Sound Power Level [Ref. 7], dB re 1 pW	**111.3**	**110.1**	**105.8**	**101.8**	**97.9**	**93.3**	**86.3**	**79.2**	**104.0**
V90-1.8MW Sound Power Level [Ref. 15], dB re 1 pW	**111.8**	**107.8**	**103.5**	**100.1**	**97.7**	**94.6**	**91.0**	**78.4**	**104.0**
Suzlon S 88 Sound Power Level [Ref. 17], dB re 1 pW	**113.1**	**113.3**	**110.0**	**104.0**	**97.8**	**94.8**	**90.3**	**81.4**	**106.2**

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, derived value, 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:

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

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 for that distance 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.

The limited frequency resolution of the octave band power level spectra shown in Table 3.2.2 does not provide any significant information as to whether the noise is tonal or not. A finer 1/3 octave band spectrum, or better, is needed to see if any prominent discrete tones exist. Figure 3.2.1 below is a plot of the 1/3 octave spectra published for both turbine models during a 7 m/s wind (the maximum noise point). This chart shows that, apart from a small blip at 160 Hz in the GE spectrum, the sound is distinctly broadband in nature; i.e. evenly distributed over the audible frequency spectrum. The spectra for the Vestas and Suzlon units are completely smooth throughout.

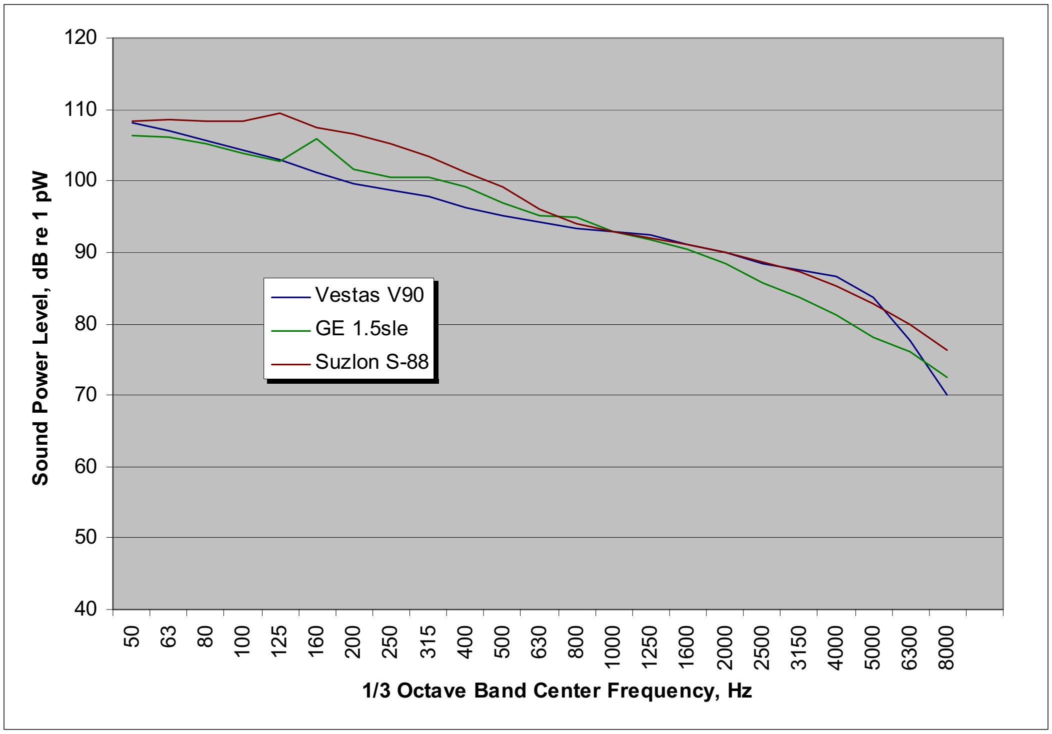


Figure 3.2.1 *Maximum 1/3 Octave Band Sound Power Level Frequency Spectra of Turbines being Considered for the Project*

A commonly used numerical definition for a discrete tone originally published by the U.S. Environmental Protection Agency as a part of a "Model Community Noise Control Ordinance" [Ref. 3]) and used in the town law is frequency dependent and defines a tone as existing when a single 1/3 octave band exceeds the average of the two adjacent bands by more than the following amounts:

Frequency Band Range	Exceedance
31.5 – 125 Hz	15 dB
160 – 400 Hz	8 dB
500 – 8000 Hz	5 dB

The exceedance amounts are frequency dependent because lower frequency tones are much harder to subjectively perceive than high frequency tones; i.e. the ear is much less sensitive to lower frequency sound in general.

Evaluated against this standard in the following table the small prominence at 160 Hz in the GE turbine power level spectrum falls well short of being a "tone".

Table 3.2.2 *Slightly Prominent Frequency Band in GE 1.5sle Sound Power Level Spectrum Compared to EPA and Town Prominent Discrete Tone Definition*

Nominal Frequency, Hz	1/3 Octave Band Sound Power Level of Prominence and Two Adjacent Bands, dB re 1 pW	Exceedance above Average of Adjacent Bands, dB	Threshold for Tones Between 160 and 400 Hz, dB
160	102.8 **105.8** 101.6	3.6	8

It should also be noted that the sound power level spectra in general represent the frequency spectrum measured fairly close to the turbine (at roughly 120 m). Recall that a power level is developed by adding a frequency-independent area term to a sound pressure level measurement. At the minimum setback distance of 1200 feet (365 m) or more the minor spike in GE spectrum is likely to substantially flatten out and become even more inconsequential. Consequently, all of the possible turbine models envisioned for the project are expected to be non-tonal sources.

3.3 CRITICAL DESIGN LEVELS

From the field survey it was determined that the background sound level varies with wind speed. From Table 3.2.1 above it can be seen that the turbine sound levels also vary with wind speed. In order to carry out the ambient-based NYSDEC assessment procedure some specific background level must be established against which to compare Project noise and calculate cumulative increases.

As shown in Table 3.2.1 above, the Suzlon turbine produces a somewhat higher sound levels at all wind speeds – so, for clarity and simplicity, the S 88 turbine will be taken as the worst-case design model for the remainder of the assessment.

In addition, it is important to note that since the S 88 has a higher electrical output than the other models, 6 fewer units will be needed to realize the overall production goal for the project. The modeling does not eliminate these 6 units and includes the full original number

of turbines. If the S 88 is selected, 6 turbines will be eliminated from the site plan and noise impact will be one of the primary bases for determining which units to remove.

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, Table 3.3.1, shows that this worst-case situation does not necessarily occur at the highest wind speeds when the turbines produce the most noise, as might be intuitively expected, but rather at an intermediate wind speed of 6 m/s, in most cases, where the differential between the background levels and the turbine sound power level is greatest.

Table 3.3.1 *Comparison of Background and Suzlon S 88 Turbine Sound Levels to Determine Critical Design Level (at Maximum Differential)*

Integer Wind Speed at Standardized Hgt. of 10 m, m/s	**6** Critical Wind Speed	**7**	**8**	**9**	**10**
Suzlon S 88 Sound Power Level, dBA re 1 pW	**104**	**105**	**106**	**107**	**107**
Typical Leq Sound Level **Cold Weather**, dBA	**44**	45	47	49	50
Turbine Power Level – Background Sound Level Differential	**60** Max	60	59	58	56
Worst-Case L90 Sound Level **Cold Weather**, dBA	**36**	38	40	42	44
Turbine Power Level – Background Sound Level Differential	**68** Max	67	66	65	62
Typical Leq Sound Level **Warm Weather**, dBA	44	45	**46**	46	47
Turbine Power Level – Background Sound Level Differential	60	60	**61 Max**	60	59
Worst-Case L90 Sound Level **Warm Weather**, dBA	**39**	40	41	43	44
Turbine Power Level – Background Sound Level Differential	**65** Max	65	65	64	62

Although the ostensible design point under warm weather typical conditions is a wind speed of 8 m/s, the use of the lower 6 m/s wind conditions has been adopted for all cases for the following reasons:

1. To change the design conditions only for the warm typical case to 8 m/s would add unnecessary complexity to the plots and prevent them from being compared on a level basis.

2. The "warm typical" case, based on the measured summertime Leq background level,

is the least critical of any case and is largely there to provide a context for the more important L90 results.

3. The physical location of the nominal impact threshold would be the in same place if the design wind speed were based on an 8 m/s wind because its value would increase by 2 dBA to 51 dBA (5 dBA over the higher background sound level 46 dBA at that wind speed) and the turbine sound power level would also increase by 2 dBA (from 104 to 106 dBA re 1 pW) - the net result; however, would be a wash since the two changes would essentially cancel each other in the sense that the threshold value moves inward while the turbine sound level moves outwards (both by the same amount).

4. Experience with many other similar surveys and analyses indicates that a 6 m/s wind speed is almost always the critical wind speed - and it would be here for all cases except for a very slight and negligible change of 1 dB in the differential calculation for the warm typical case (61 versus 60 dB in Table 3.3.1).

Consequently, for design purposes, the background levels measured during a **6 m/s** wind will be used as a basis to calculate the NYSDEC cumulative increase thresholds for modeling and impact assessment purposes and the associated turbine sound power level of **104 dBA re 1 pW** at that wind speed will be used. This approach is conservative in the sense that turbine noise will be somewhat or significantly less prominent at all other wind speeds relative to the background level.

The following table summarizes the NYSDEC impact thresholds based on a 6 dBA cumulative increase in the overall sound level.

Table 3.3.2 *Critical Design Levels and NYSDEC Impact Thresholds*

Season and Type of Impact	Measured Critical Background Level at 6 m/s, dBA	Impact Threshold - Project-only Sound Level, dBA	Cumulative Sound Level with Project Operating, dBA (6 dBA above Background Level)
Typical Impact Based on Leq Cold Weather, dBA	44	**49**	50
Worst-Case Impact Based on L90 Cold Weather, dBA	36	**41**	42
Typical Impact Based on Leq Warm Weather, dBA	44	**49**	50
Worst-Case Impact Based on L90 Warm Weather, dBA	39	**44**	45

Because the frequency content of the turbine sound power level at 6 m/s is not given in the Suzlon report, the octave bands have been estimated by subtracting 2.3 dB from the 8 m/s data so that the spectrum adds up to the known overall sound power level of 103.9 dBA during 6 m/s wind conditions. The resulting spectrum below will be used in the modeling study.

Table 3.3.3 *Suzlon S 88 Sound Power Level Spectrum during a 8 m/s Wind and Estimated* ***Design Level*** *Spectrum at 6 m/s*

Octave Band Center Frequency, Hz	63	125	250	500	1k	2k	4k	8k	dBA
Sound Power Level at 8 m/s, dB re 1 pW	113.1	113.3	110.0	104.0	97.8	94.8	90.3	81.4	**106.2**
Adjustment Factor, dB	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	
Estimated Lw at 6 m/s, dB re 1 pW – **Design Level**	**110.8**	**111.0**	**107.7**	**101.7**	**95.5**	**92.5**	**88.0**	**79.1**	**103.9**

3.4 NOISE MODELING METHODOLOGY

Using the design sound power level spectrum in Table 3.3.3 above, sound level contour plots for the site were calculated using the Cadna/A®, 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. In this case, the topography has been incorporated into the model because it is fairly significant. Each turbine is represented as a point noise source at a height of 80 m above the local ground surface (design hub height). The receptor height is set at a standard elevation of 1.5 m above grade; this keeps the predicted levels on an equal footing with the background measurements, which were measured at a similar elevation.

The site plan used in the analysis is the latest known layout as of January 2009 and includes the full complement of 44 turbines despite the fact that only 38 turbines will actually be installed if the higher power, S-88 turbine is used.

Apart from the turbines, the only other potential source of noise associated with the project is the step up transformer in the electrical substation where output from the project is connected to an existing transmission line. This substation is located outside of the project area some distance to the west in an area that is fairly remote from any homes. The nearest residence is about 540 ft. away from the transformer. The substation has not been included in the model partly because it is remote from the principal project area but, more importantly, because its A-weighted sound level, the quantity calculated by the program and depicted in the plots, does not characterize its potential noise impact in any meaningful way. Transformer noise is essentially tonal in character, a buzzing sound at 60 and 120 Hz, and the octave band sound spectrum that might be used as a model input is too broad to convey any tonal content. In any event, any tones from the relatively small transformer associated with the project are not expected to be significant at the nearest houses, although it may be faintly audible during calm and quiet periods.

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 essentially consists of acoustically absorptive wooded areas or open farm fields. The ISO ground absorption coefficient ranges from 0 for water or hard concrete surfaces to 1 for absorptive surfaces, such as farm fields, wooded areas or sand. Consequently, a higher coefficient on the order of 0.8 or 0.9 could be justified here; however, for conservatism a value of 0.5 has been used.

Foliage in thickly wooded areas normally provides some additional sound attenuation (a separate phenomenon from ground absorption). Even though this site is mostly wooded this potentially significant loss has been neglected in all calculations since this attenuation would not be present in the wintertime.

Although wind direction effects can be modeled with this software, to be conservative the noise level from each turbine is assumed to be the downwind sound level in *all directions simultaneously*. In other words, although physically impossible, an omni-directional 6 m/s wind is assumed. This approach yields a contour plot that essentially shows the maximum possible sound level at any given point and sometimes also shows levels that cannot possibly occur – such as between two or more adjacent turbines, since the wind would have to be blowing in two opposing directions at the same time. In a more realistic scenario with, for example, a wind out of the west the contour lines would occur closer to the turbines on the west side and would remain largely as shown on the east.

At the risk of overestimating potential Project sound levels, the various conservative assumptions in the modeling analysis have been applied to ensure that Project noise does not exceed predicted levels under most normal conditions and also to allow some design margin for times when atmospheric conditions may occasionally favor noise propagation relative to average conditions, such as during temperature inversions. Sound levels that are lower than those predicted in the modeling plots are expected to occur almost all of the time. The model represents a theoretical worst-case condition at any given receptor point that would require a convergence of the following conditions:

- **Wind Direction** – from *all* the turbines towards any given receptor point
- **Wind Speed** - only a 6 m/s wind nominally produces the plotted contours; under all other wind conditions the impact threshold contour lines would contract closer to the turbines by several decibels, or more
- **Low Ground Porosity** – normally woods and farm fields are more 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

3.5 MODEL RESULTS AND IMPACT ASSESSMENT – NYSDEC CRITERION

Preliminary noise modeling indicated that the potential for community noise impacts exists with this Project. This early modeling work essentially performed the function of the First Level Noise Impact Assessment in the NYSDEC assessment procedure and indicated that a Second Level assessment was necessary. A Second Level noise model considers the actual circumstances of the site including any attenuation that might be afforded by such factors as terrain, vegetation or man-made barriers.

The overall results of the Second Level model are shown in Plots 1 through 4, summarized below, where the outermost sound level contour is associated with a specific limit or threshold based on the assumed background level and season.

Plot 1 – Typical Impact – Cold Weather Conditions
Plot 2 – Worst-case Impact – Cold Weather Conditions
Plot 3 – Typical Impact – Warm Weather Conditions
Plot 4 – Worst-case Impact – Warm Weather Conditions

These plots illustrate the Project-only sound levels that might occur under the conservative assumptions described above in Section 3.4.

Plot 1 shows the Project sound levels out to a level of 49 dBA, which represents the 6 dBA cumulative increase threshold recommended by the NYSDEC based on the measured average, or Leq, sound level (44 dBA) during a 6 m/s wind in the wintertime. The region inside the threshold line represents the area where turbine noise might result in an adverse impact relative to the "typical" background level. In this instance, all homes are clearly well outside the 49 dBA threshold line, which occurs quite close to each turbine and well short of the minimum 1200 ft. (365 m) setback. This plot indicates that no significant adverse impact might be expected under typical wintertime conditions.

In **Plot 2** the sound emissions of the Project are shown out to 41 dBA, which is the NYSDEC 6 dBA increase threshold if the background sound level during cold weather conditions is taken to be the residual, or L90. This is the background sound level that occurs for only a small percentage of the time during lulls in the wind and when all sources of man-made noise are at a temporary minimum. This plot is significantly different from Plot 1 in that a number of homes are inside of the nominal impact threshold line. Under these specific circumstances – wintertime, 6 m/s wind, background level at a minimum – Project noise may be clearly perceived by some of the nearest residents and some degree of adverse reaction is possible. The areas most likely experience these relatively elevated sound levels would be along Center Road between Straight and Ball Roads. Project noise might also be more perceptible at some homes along a section of Rt. 83 east and west of its intersection with Center Road, although traffic noise may provide some additional masking part of the time.

In **Plot 3** the "typical" impact threshold of 49 dBA for warm weather conditions is illustrated. Since the average (Leq) background sound level was found to be the same in the summer as it is in the winter, the small regions of potential impact immediately around each turbine are the same as in Plot 1.

Finally, the "worst-case" impact during the warm weather months is illustrated in **Plot 4**, based on the L90 level of 39 dBA measured during the leaf-on, summertime survey. In this case, essentially all the residences in the project area are beyond the associated 44 dBA impact threshold. Consequently, an adverse impact appears unlikely under all normal conditions in the summer, which is good because people are normally outside and windows are open making the community generally more sensitive to noise impacts than during the cold weather months.

This series of plots essentially demonstrates that the Project is not expected to generate sound levels above the NYSDEC 6 dBA cumulative impact threshold at any residences in the Project area except from time to time in the winter - theoretically 10% of the time during worst-case wind conditions. During the winter Project noise is less likely to be noticeable in any event since people are inside most of the time.

As a general additional comment, it is important to note that in the particular case of wind turbine noise a cumulative 6 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, a temporary 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. These possible impacts would be associated with cumulative increases of less than 6 dBA – principally in the 3 to 6 dBA range. A 3 dBA *cumulative* increase would mean that the project-only sound level was equivalent to the background.

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 MODEL RESULTS AND IMPACT ASSESSMENT – CNR METHOD

As discussed in Section 3.1.3 above, the Composite Noise Rating (CNR) method for evaluating potential noise impacts compares the background level to the predicted level of intrusive noise in terms of frequency content (as opposed to the A-weighted sound level alone) and other factors in order to predict community reaction. The derivation of these ratings is outlined below.

The first step in the evaluation process is to plot the octave band frequency spectrum of the predicted Project-only sound level at a point of interest against a set of curves that generally map the perceptibility of the noise as a function of frequency. In Figure 3.6.1 below predicted Project sound level spectra ranging from 35 to 50 dBA in 5 dB increments are shown against the baseline CNR rating curves. This range covers all potential Project sound levels over the site area. A classification letter, applicable to the regions between each curve, is assigned according to the highest region that the spectrum touches.

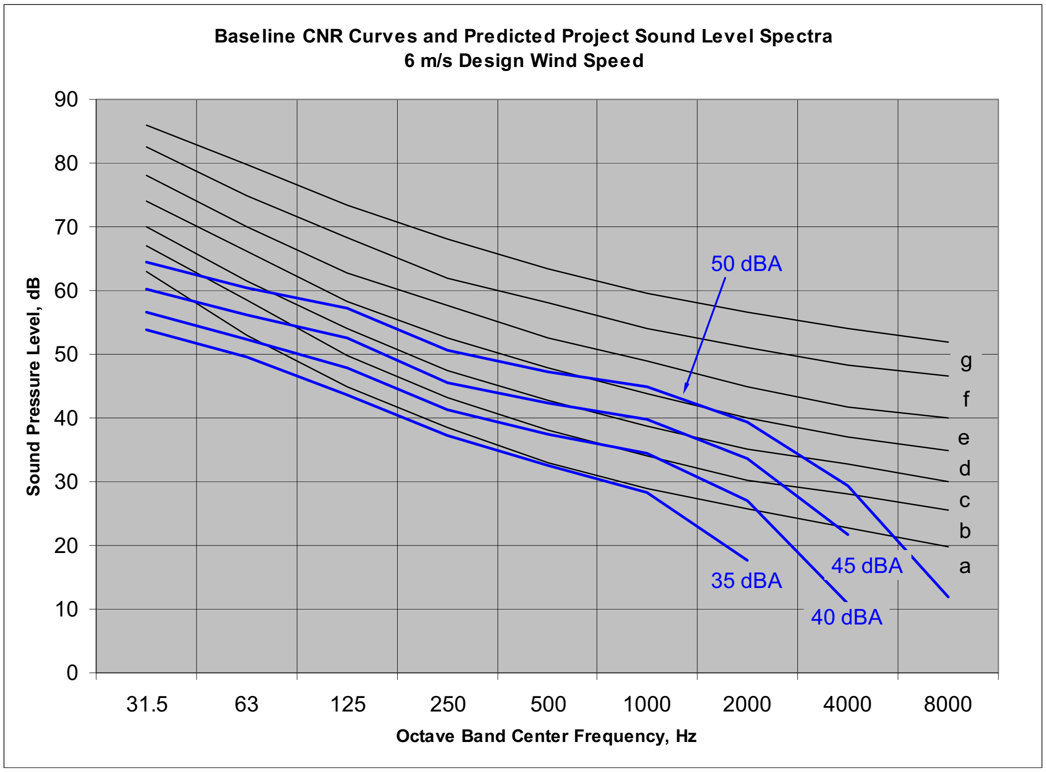


Figure 3.6.1

The baseline CNR classifications are listed in Table 3.6.1.

Table 3.6.1 *Baseline CNR Classifications*

Project-only Sound Level, dBA	Baseline CNR Classification
50	e
49	d
48	d
47	d
46	d
45	d
44	c
43	c
42	c
41	c
40	b
39	b
38	b
37	b
36	b
35	a

Starting from this baseline rating classification a series of corrections or adjustments are made to estimate the final classification, which, in turn, gives an indication of the potential community reaction.

The first principal correction is for background masking noise. A second chart of curves is used to determine how well or poorly the background sound level frequency spectrum would act to mask the project sound level. The highest region intercepted determines the correction factor. Figure 3.6.2 shows the background correction for “typical” warm and cold season conditions based on the measured average, or Leq, level at the critical wind speed of 6 m/s.

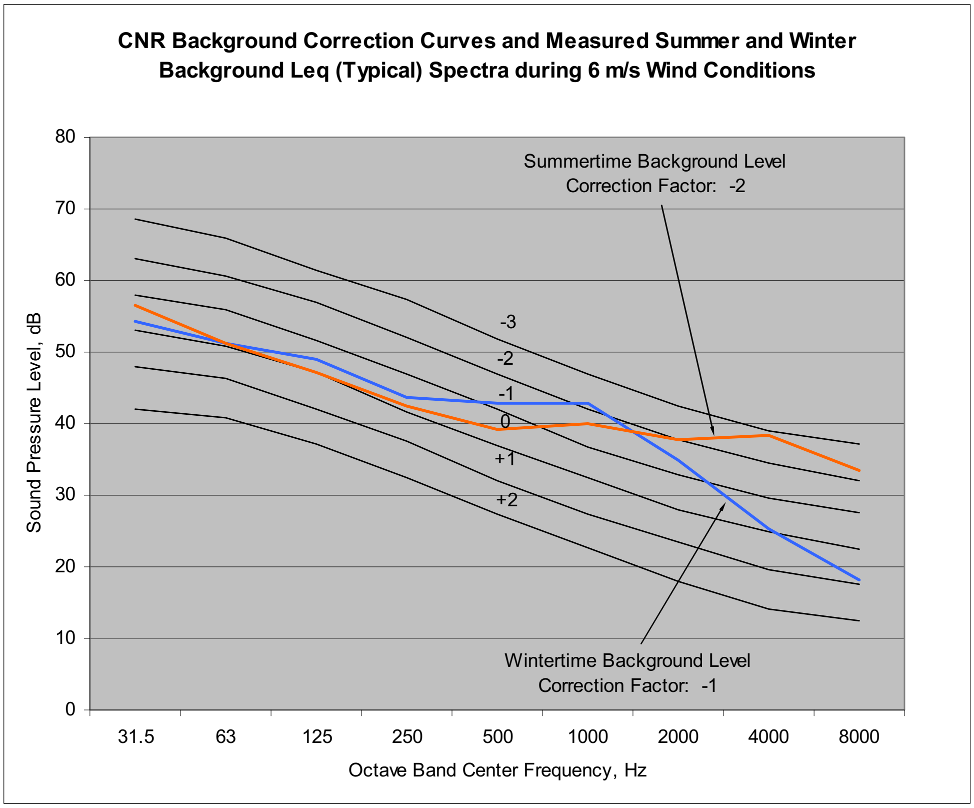


Figure 3.6.2

Figure 3.6.3 shows the background corrections during "worst-case" conditions based on the L90 sound level.

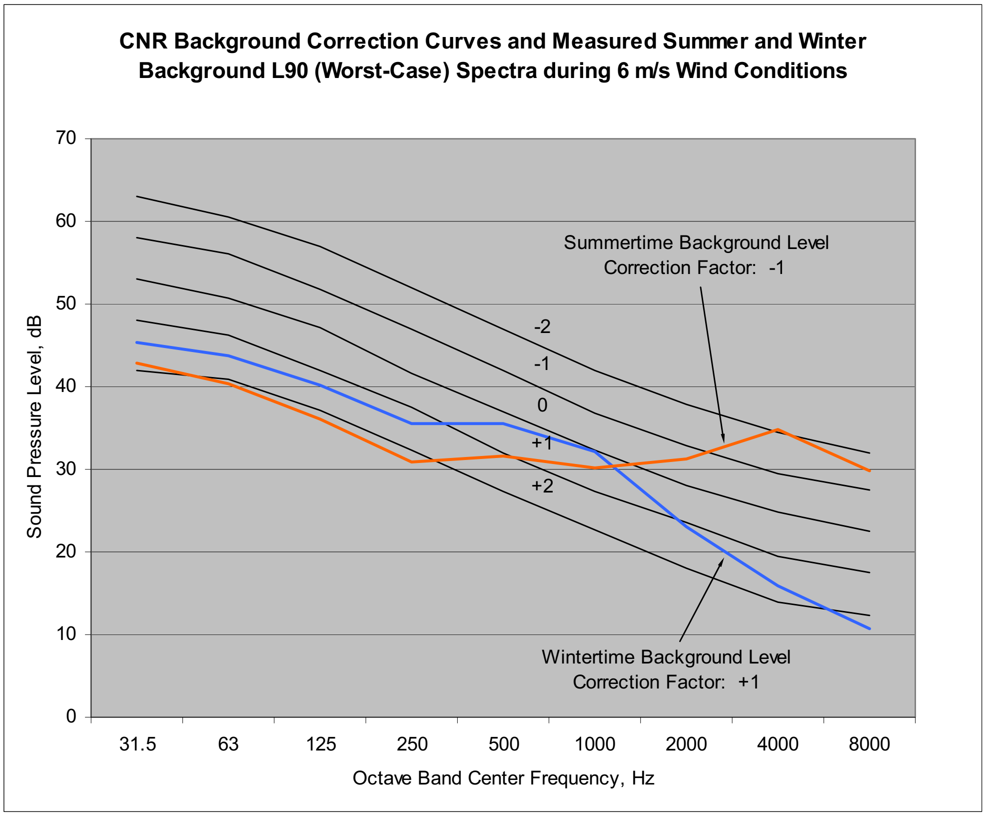


Figure 3.6.3

Not surprisingly the summertime background levels are significantly higher in the high frequencies where leaf rustle and insect noise occurs, resulting in larger negative correction factors. In essence, these charts show that there will be more environmental sound present during the warmer months of the year when the trees have leaves to obscure operational noise from the project.

The remaining corrections to the baseline CNR rating relate to the temporal nature of the new noise source, its character and the general attitude of the observer.

The temporal correction accounts for the duration of the ostensibly intruding noise and when it occurs during the day or night and whether it changes with the seasons. Wind turbines do not operate on a continuous basis and much of the time when they are running winds are light and no significant noise is generated; consequently, a correction factor of **-1** for partial operation has been assumed.

The character correction takes into consideration the fact that noises that contain any kind of tone, impulse or excessive low frequency content are more apt to be considered objectionable than a broadband noise of the same magnitude. In the case of wind turbines, observed from a distance of at least 1200 feet, none of these particular character features will actually be present in the sound; however, wind turbines of this type do produce a certain amplitude modulation, or intermittent whooshing sound associated with the rotor that increases the perceptibility of the sound. Consequently, a character adjustment factor of **+1** has been used in the CNR assessment.

The final correction factor, ranging from -1 to +1, is associated with previous exposure and attitude. As it relates to the specific situation of a new wind energy project, the best interpretation of this correction is thought to be as follows:

Table 3.6.2 *CNR Correction Factors Related to Receptor Attitude*

CNR Correction Factor	Interpreted Significance
-1	Known to be favorable towards the project or project participant
0	Neutral or attitude unknown
+1	Known to be opposed to the project

While the specific attitudes towards the project are not known on a house by house basis, a local poll conducted by Siena College indicates that 79.2% of residents in the area are supportive of the project. Consequently, a correction factor of -1 applies to most of the community. However, to be conservative, correction factor of **0**, or neutral, has been assumed for all receptors.

The final CNR classification for a specific receptor location is determined by applying the correction factors to the baseline letter grade. For example, a baseline rating of “c” with a net correction of -1 would result in a final rating of “B”, or one letter below the starting value. The nominal meaning of this final rating is given in the chart below.

Table 3.6.3 *Final CNR Ratings and Predicted Reactions*

CNR Rating	Significance
A	No Reaction
B	
C	Sporadic Complaints
D	
E	Widespread Complaints or Single Threat of Legal Action
F	
G	Several Threats of Legal Action or Strong Appeals to Local Officials to Stop the Noise
H	
I	Vigorous Action

The following table relates predicted Project-only sound levels, illustrated graphically in the sound contour plots, with CNR ratings for the both warm and cold weather conditions.

Table 3.6.4 *CNR Ratings Associated with Predicted Project Sound Levels*

Predicted Project-only Sound Level, dBA	CNR Rating – Typical Wintertime Conditions	CNR Rating – Worst-Case Wintertime Conditions	CNR Rating – Typical Summertime Conditions	CNR Rating – Worst-case Summertime Conditions
44	B	D	A	B
43	B	D	A	B
42	B	D	A	B
41	B	D	A	B
40	A	C	<A	A
39	A	C	<A	A
38	A	C	<A	A
37	A	C	<A	A
36	A	C	<A	A
35	<A	B	<A	<A

The chart begins with 44 dBA because that is the maximum Project sound level predicted at any residence within the site area.

What these listings both show is that little or no reaction is expected under most conditions, since the CNR rating is “B” or lower in most instances. As shown in Table 3.6.3, the expected impact associated with a “B” rating is between “no reaction” and “sporadic complaints”.

It is only during worst-case, wintertime conditions (6 m/s wind, bare trees and the background level at a momentary lull) that a rating of “D” - between “sporadic” and “widespread complaints” - is predicted for receptors with predicted Project sound levels in the 41 to 44 dBA range.

This conclusion essentially agrees with the implications of Plots 1 through 4 where all homes are outside of the threshold where a potentially adverse impact might occur except during worst-case winter conditions when a relatively low level of background masking sound exists. Under these specific circumstances people standing outside a number of homes may hear Project sound levels that are more than 5 dBA above the background level.

While these two independent assessment methodologies point to a likelihood of some complaints in the wintertime, it should be noted once again that the modeling is conservative in the following ways:

- Minimal background masking noise, which occurs infrequently, is assumed
- All of the turbines are assumed to be operating at a near maximum sound power level of 104 dBA re 1 pW despite the fact momentarily calm conditions are implicit in the L90 background sound level
- A critical wind speed of 6 m/s is assumed to be blowing – at all other wind speeds the potential intrusiveness of project noise would be less – based on the met tower data a wind speed in the 5.5 to 6.5 m/s range occurs only about 13% of the time
- Any given point is assumed to be simultaneously downwind of every turbine in the project and therefore experiencing a *theoretical* maximum project noise level
- The predicted sound levels occur outside; *interior* sound levels would be substantially lower
- Despite the fact that nearly 80% of the people apparently have a favorable attitude towards the project - making them much less likely to take issue with the audibility of the Project - a neutral attitude is assumed in the CNR calculation.

Additionally, this potential impact occurs only during windy conditions in the winter when people are unlikely to be outside for any extended period of time, or to be engaged in any outdoor activity, such as snowmobiling or plowing, where environmental quiet is of prime importance. No serious adverse reaction is predicted by either methodology during summertime conditions when people are active outside and/or house windows might be open.

3.7 COMPLIANCE WITH THE LOCAL WIND ENERGY FACILITY LAW

It is evident from the plots that, at least under the normal weather and wind conditions depicted, a Project-only sound level of 50 dBA or more will not occur at any homes or other sensitive receptors within the Project Area as required by the Town of Arkwright. Certain unusual and unsettled wind conditions, such as might be associated with the arrival a thunderstorm or frontal system, may cause project noise to briefly increase to or above 50 dBA but, based on field surveys of completed projects, these occurrences are expected to be fairly rare and very short-lived.

3.8 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 technology 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. A paper on this particular subject - "How the 'mythology' of infrasound and low frequency noise related to wind turbines might have developed" - by Dr. Geoff Leventhall, a highly respected acoustician in the field of low frequency noise, is attached as **Annex A**.

In addition a new study has been recently completed by Sondergaard [Ref. 12] 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 measurement procedure using multiple elaborate wind screens over a microphone placed on a reflective ground plate (where the wind velocity is theoretically zero) to preclude self-noise contamination. The results of this testing show that for a typical 1.5 MW 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 or less than the sound energy in the natural rural environment where the measurements were made (as shown in Figure 3.8.1).

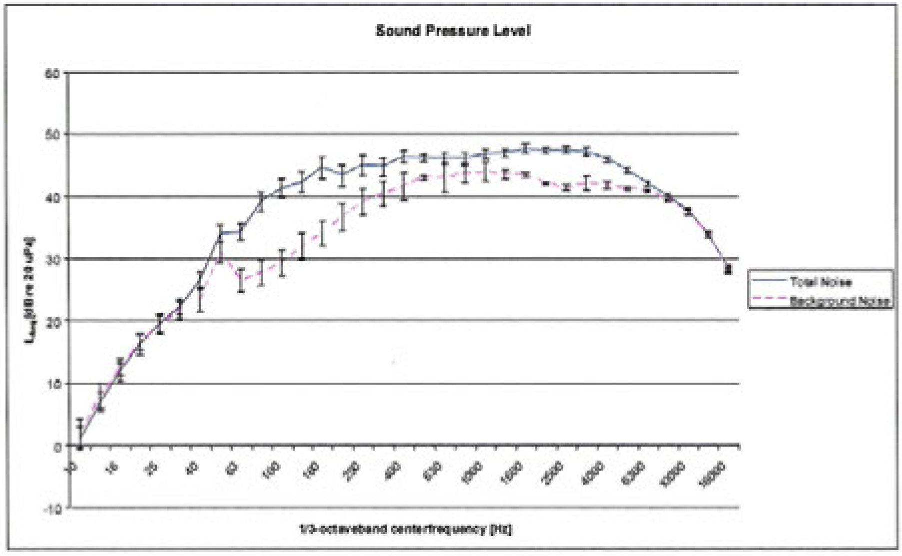


Figure 21 Spectra of total noise and background noise for a 1.5 MW wind turbine. A 50 Hz frequency from a nearby power line influences the measurements.

Figure 3.8.1 *Measured Turbine Sound Level down to 10 Hz Relative to Background Sound Level (Sondergaard)*

It is generally thought by acousticians specializing in wind turbine noise that amplitude modulation, or the swishing sound, with a “frequency” of about 1 Hz is, in fact, what many people are actually are mean by the term “low frequency noise”.

Another measure of low frequency noise is the “C-weighted sound level”, which does not substantially suppress the lower frequencies to the extent A-weighting does. Because of this characteristic, C-weighted sound levels are most commonly used to measure and evaluate noise sources that produce significant amounts of low frequency noise - like combustion turbines. In ANSI Standard B133.8 *Gas Turbine Installation Sound Emissions* [Ref. 5] a threshold level of 75 to 80 dBC is given as the approximate on-set point for complaints and the perception of vibrations due to airborne sound.

The maximum predicted C-weighted sound level for any residence within the site area is 60 dBC. This level is well below the threshold of perception therefore no adverse impact is expected at any receptors from low frequency noise.

3.9 CONSTRUCTION NOISE

Noise from construction activities associated with the Project may temporarily constitute a moderate, unavoidable impact at some homes in the Project Area. Assessing and quantifying these impacts is 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 noise levels as reported in the *Power Plant Construction Noise Guide* (Empire State Electric Energy Research Corp., [Ref. 6]) are tabulated below in Table 3.12.1. It should be noted that this reference is quite old, dating back to 1977, and the equipment sound levels in it are somewhat higher than the values that can be found in more recent references, such as from the FHWA [Ref. 16] for modern construction equipment. These older, higher values have been deliberately used just to be conservative.

Table 3.9.1 shows the maximum total sound levels due to construction at each turbine site that might temporarily occur at the closest non-participating residences at least 1200 ft. away. The distance from a specific construction site to the point where construction noise would drop to 40 dBA is also shown in the table. A bland, steady sound of level of 40 dBA is generally considered so quiet (about the sound level in a library) that it is not usually viewed as objectionable even when the background, or masking, sound level is negligible. Unlike for the operational Project, wind speed is irrelevant to the background level during the construction phase and there will be times when construction is occurring during calm and quiet periods.

Table 3.9.1 *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 a Setback Distance of 1200 ft., dBA	Distance Until Sound Level Decreases to 40 dBA, ft.
Road Construction and Electrical Line Trenching				
Dozer, 250-700 hp	88	92	61	5500
Front End Loader, 300-750 hp	88			
Grader, 13-16 ft. blade	85			
Excavator	86			
Foundation Work, Concrete Pouring				
Piling Auger	88	88	57	4200
Concrete Pump, 150 cu yd/hr	84			
Material and Subassembly Delivery				
Off Hwy Hauler, 115 ton	90	90	59	4800
Flatbed Truck	87			
Erection				
Mobile Crane, 75 ton	85	85	54	3400

* 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 significant at distances of up to 5500 feet – which means that construction will occur close enough to many homes within the Project area that its noise will be clearly audible.

Sound levels ranging from 54 to 61 dBA might temporarily occur at the closest homes over several weeks due to construction activities at each turbine location and somewhat higher levels might be temporarily experienced at homes that are very close to road construction or trenching operations. 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 Project Area. For others, Project construction noise may be an unavoidable temporary impact.

The estimated sound levels at 50 ft. in Table 3.9.1 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 distance of at least 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, but such instances are considered unlikely because there aren't many instances where construction activities are required fairly close to homes and also because conservative values from a somewhat antiquated 1977 reference [Ref. 6] have been deliberately used for the equipment.

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 (even given the rural nature of the roads in the Project area) and temporary in duration at any given location.

4.0 CONCLUSIONS

A field survey of existing sound levels under both wintertime and summertime conditions within the Arkwright Summit Wind Farm Project Area indicates that background sound levels are variable and dependent on wind speed, particularly during the winter. Noises from roadways and other man-made sources are relatively insignificant over most of the site and existing sound levels are dominated by natural sources.

A regression analysis of sound levels vs. wind speed shows that the average, or “typical” background sound level increases with wind speed and ranges from about 41 to 45 dBA, irrespective of season, over the range of wind speeds where turbine noise is variable; i.e. from about 4 m/s (measured at a standard elevation of 10 m) to 7 m/s when the turbine rotor reaches maximum rotational speed and sound output becomes constant. The residual (L90) sound level increases from 32 to 38 dBA over the same wind speed range during winter conditions and from 36 to 40 in the summer. A fairly uniform sound level was found to exist at all 5 monitoring stations used for the warm weather survey and at 7 of the 8 positions used for the winter survey. Consequently, the average sound levels from all positions, except for the one anomalous winter position, accurately characterize the site-wide sound level.

A comparison, as a function of wind speed, between the background sound levels and the variable sound power level of Suzlon S 88 turbine (the design case turbine) indicates that the maximum potential for an adverse impact from noise occurs at a wind speed of 6 m/s. At this wind speed the greatest differential generally exists between the turbine sound level and the amount of masking background noise available to obscure Project noise. This analysis showed that the "typical" (Leq) background sound level likely to exist under these conditions was **44 dBA** and the "worst-case", near minimum (L90) sound level, was **36 dBA** in winter and **39 dBA** in summer. By definition L90 sound levels only occur 10% of the time, so these lower "worst-case" levels do not represent the permanent background sound level, but rather momentarily low levels.

In the New York State Department of Environmental Conservation's Program Policy *Assessing and Mitigating Noise Impacts* a cumulative increase in total sound level up to 6 dBA is characterized as having "potential for adverse noise impact only in cases where the most sensitive of receptors are present" and is suggested as a threshold for determining what areas might be adversely impacted by a new noise source and what areas should see "no appreciable effect". For this site a 6 dBA cumulative increase is associated with a Project-only sound level of **49 dBA** (44 + 49 = 50 dBA, or 6 dBA above the background level) for "typical" conditions and **41 to 44 dBA**, depending on season, when the background sound level is at a momentary minimum ("worst-case" conditions.

A "Second Level" modeling study carried out per the NYSDEC guidelines showed that the region where noise impacts might occur (i.e. where an increase of 6 dBA or more is predicted) does not encompass any homes based on summertime conditions but does potentially affect some homes during worst-case, winter conditions when the wind is blowing at 6 m/s and the background sound level is at a temporary minimum. However, during this period residents are likely to be less sensitive to these temporary impacts because they generally spend more time indoors during windy wintertime conditions.

An analysis of potential Project noise impact based on the modified CNR method was also carried out, which evaluates the frequency content of the background and Project sound levels and considers other factors such as the temporal characteristics of the noise source and any character content. This analysis independently confirmed the findings of the modeling analysis using the NYSDEC guidance.

In theory, these analyses indicate that a mild, seasonally dependent adverse impact may occur but it should be noted that the modeling is conservative in a number important respects:

- The L90 background level that is assumed in the "worst-case" analyses represents the quietest lulls between wind gusts, cars passing by, dogs barking, etc. As such, this level quantifies a very low value for masking environmental noise. Most of the time a substantially higher background sound level will exist.

- If the Suzlon S 88 turbine is selected for Project, 6 turbines will be removed from the plan because of this model's greater power output relative to the other turbines being considered. Noise impact will be one of the principal criteria for determining which units to eliminate.

- The noise model assumes that a 6 m/s wind is blowing simultaneously from all directions and that the turbine sound level experienced at any given point is the sound level that would occur downwind from all turbines in the Project. Such a sound level is a physical impossibility in many situations. For example, a receptor between two turbines cannot possibly be downwind from both units at the same time.

- The ground surface is assumed to have a fairly low absorptivity – normally wooded areas (which cover most of the site) and farm fields are highly absorptive.

- An impact is predicted for a community with a "neutral" attitude towards the Project whereas it appears from a Siena College survey that nearly 80% of residents in the area favor the Project. Complaints or issues with fairly low levels wind project noise are highly unlikely from project proponents.

- The predicted sound levels occur *outside*. Sound levels inside of any dwelling will be 10 to 20 dBA lower. This reduction generally puts the Project sound level inside any home below the sleep disturbance threshold of 30 dBA published by the World Health Organization [Ref. 10]

These conservative assumptions are intended to over-estimate Project sound levels under most normal conditions so that some allowance or safety factor exists to cover the intermittent occurrence of certain atmospheric conditions that allow turbine noise to be more readily perceived, such as during stable atmospheric conditions that sometime develop in the evening or at night.

Given the fact that actual levels lower than those predicted levels are expected to occur most of the time, a mildly adverse reaction may be possible from some residents in the Project area while the possibility of stronger reactions cannot be ruled out. The density of turbines, their proximity to residences and the relatively low background sound levels found during the field surveys mean that some level of dissatisfaction may occur but only during certain circumstances.

In any event, the modeling analysis shows that full compliance with the local law relating to wind energy facilities is expected. The maximum allowable sound level of 50 dBA is predicted to occur well short of any residence or potentially sensitive receptor.

Although concerns are often raised with respect to low frequency noise emissions from wind turbines, no adverse impact of any kind related to low frequency noise is expected from this Project. The results of a carefully controlled field study are given demonstrating that a typical 1.5 MW wind turbine produces no significant noise below about 40 Hz. In addition, the maximum (conservatively) predicted C-weighted sound level at any receptor is at least 15 dBC below the minimum threshold of perception.

Unavoidable 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 most homes within the immediate Project vicinity on a temporary basis. The maximum magnitude of construction noise at the nearest homes to individual turbine locations is not expected to exceed 54 to 61 dBA depending on the particular activity. Somewhat higher levels are possible where road building or trenching activities occur fairly close to homes.

END OF REPORT TEXT

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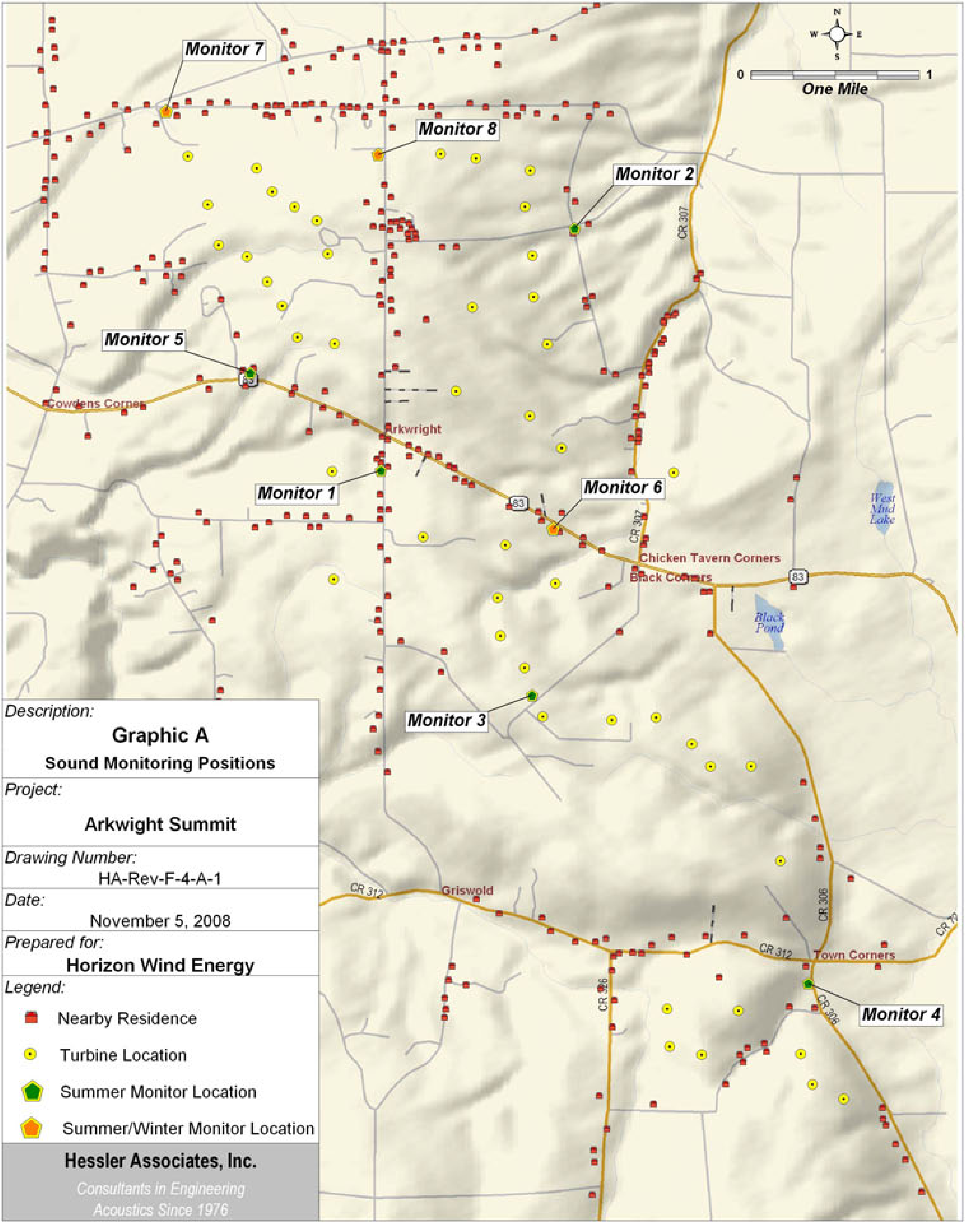

Description:

Graphic A

Sound Monitoring Positions

Project:

Arkwight Summit

Drawing Number:

HA-Rev-F-4-A-1

Date:

November 5, 2008

Prepared for:

Horizon Wind Energy

Legend:

- 🟥 Nearby Residence
- ⊙ Turbine Location
- ⬟ Summer Monitor Location
- ⬟ Summer/Winter Monitor Location

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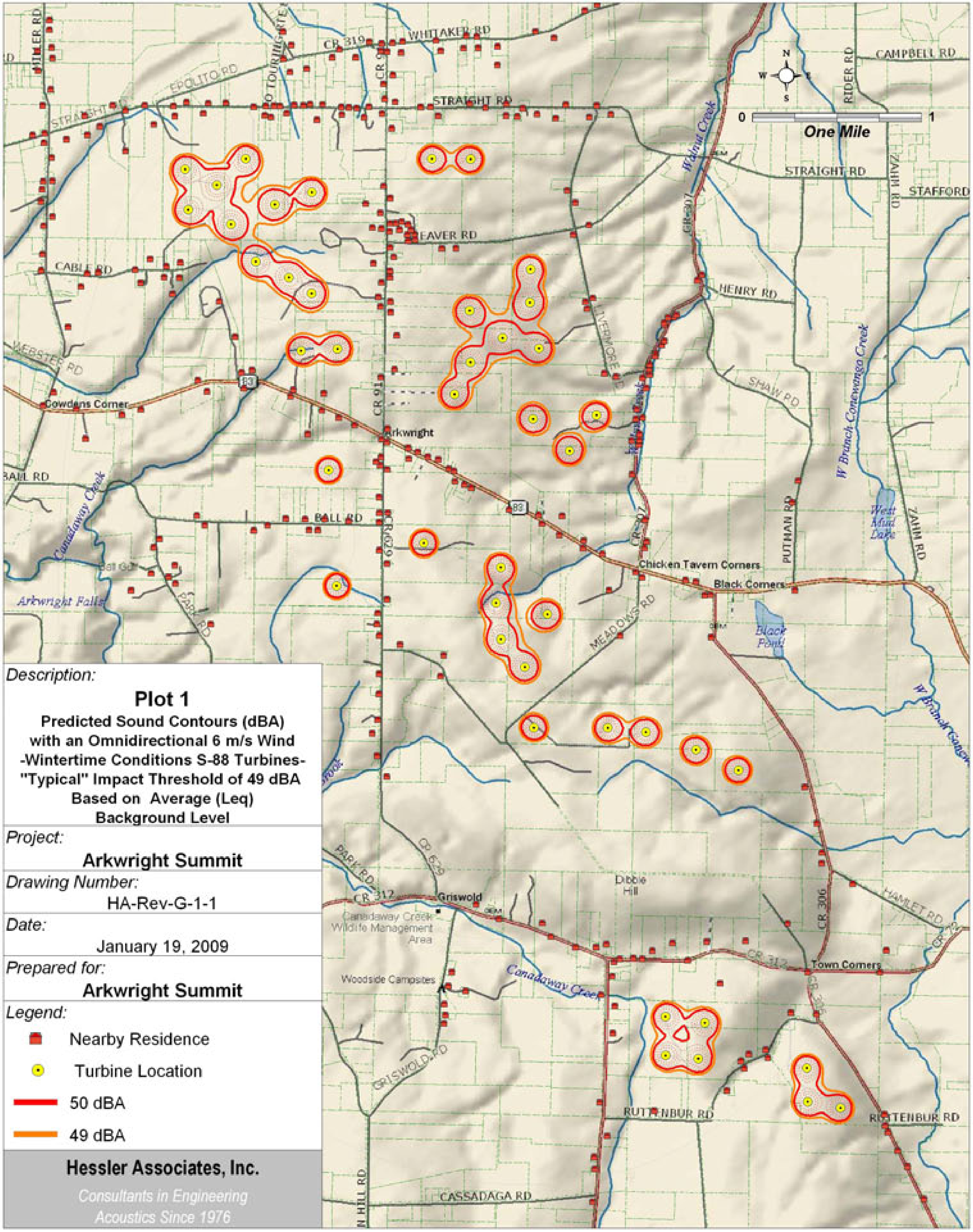
Acoustics Since 1976



Description:

Plot 1

Predicted Sound Contours (dBA)
with an Omnidirectional 6 m/s Wind
-Wintertime Conditions S-88 Turbines-
"Typical" Impact Threshold of 49 dBA
Based on Average (Leq)
Background Level

Project:

Arkwright Summit

Drawing Number:

HA-Rev-G-1-1

Date:

January 19, 2009

Prepared for:

Arkwright Summit

Legend:

- ■ Nearby Residence
- ● Turbine Location
- ━ 50 dBA
- ━ 49 dBA

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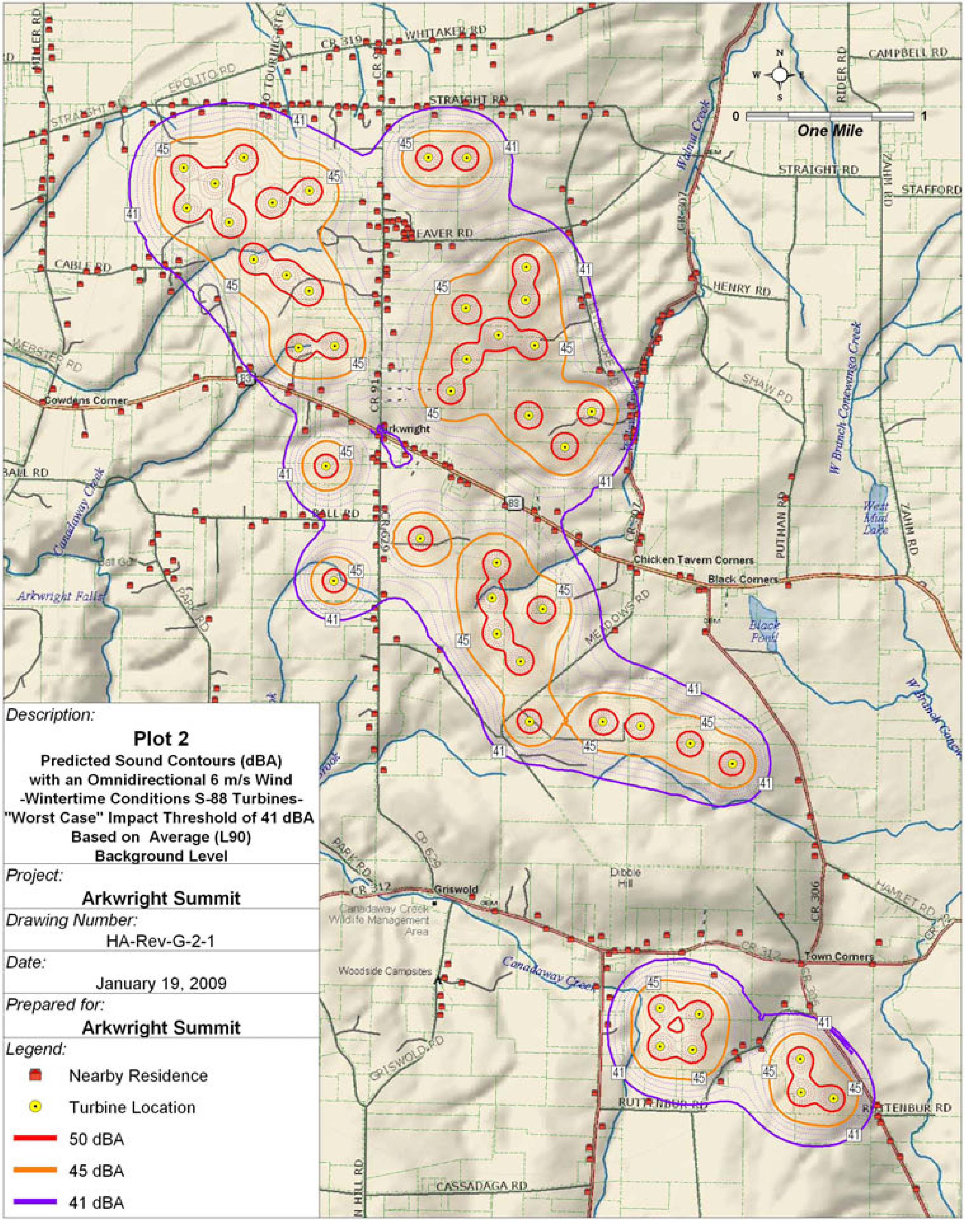


Description:

Plot 2

Predicted Sound Contours (dBA)
with an Omnidirectional 6 m/s Wind
-Wintertime Conditions S-88 Turbines-
"Worst Case" Impact Threshold of 41 dBA
Based on Average (L90)
Background Level

Project:

Arkwright Summit

Drawing Number:

HA-Rev-G-2-1

Date:

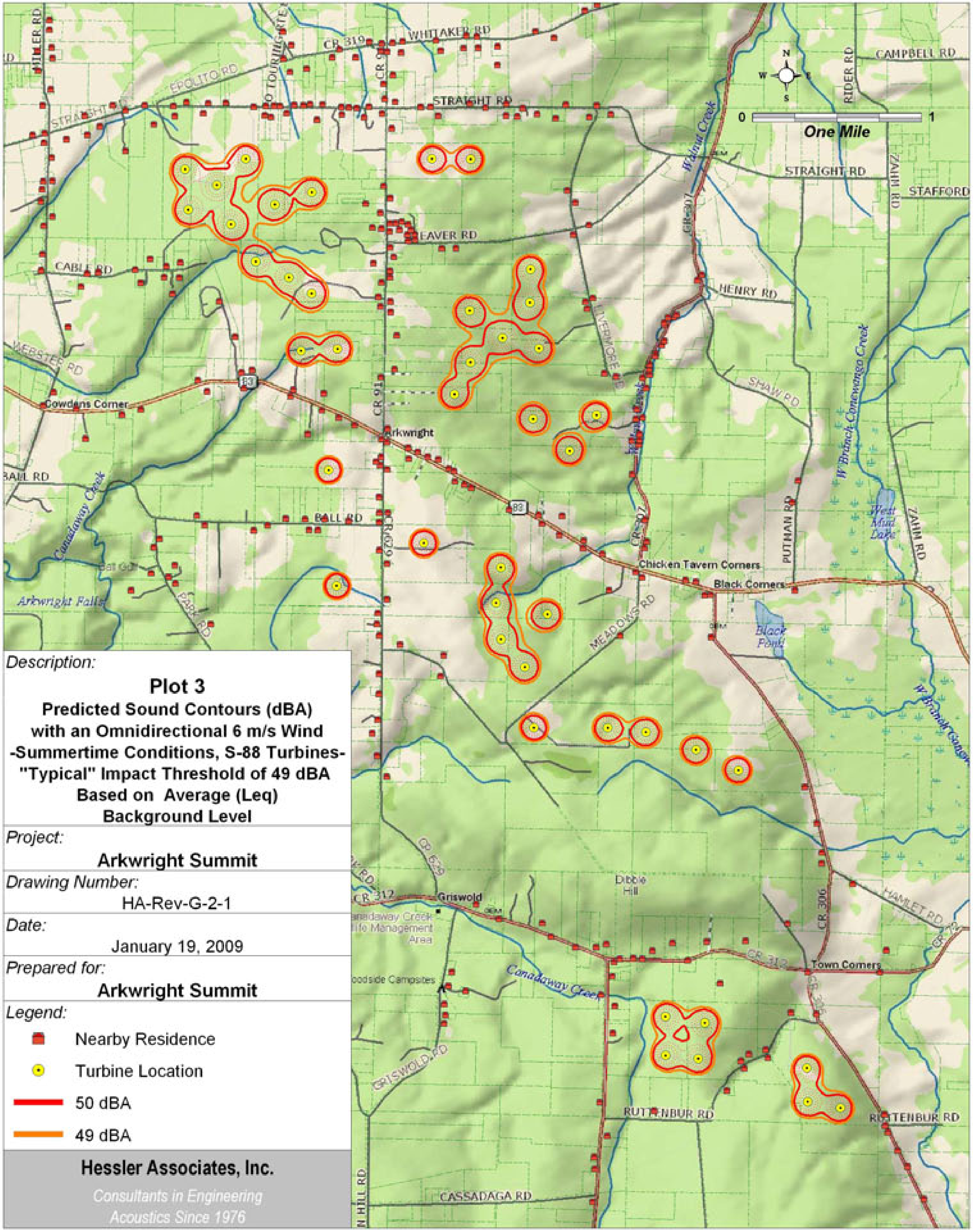
January 19, 2009

Prepared for:

Arkwright Summit

Legend:

- 🟥 Nearby Residence
- ● Turbine Location
- — 50 dBA
- — 45 dBA
- — 41 dBA



Description:

Plot 3

Predicted Sound Contours (dBA)
with an Omnidirectional 6 m/s Wind
-Summertime Conditions, S-88 Turbines-
"Typical" Impact Threshold of 49 dBA
Based on Average (Leq)
Background Level

Project:

Arkwright Summit

Drawing Number:

HA-Rev-G-2-1

Date:

January 19, 2009

Prepared for:

Arkwright Summit

Legend:

🟥 Nearby Residence

● Turbine Location

▬ 50 dBA

▬ 49 dBA

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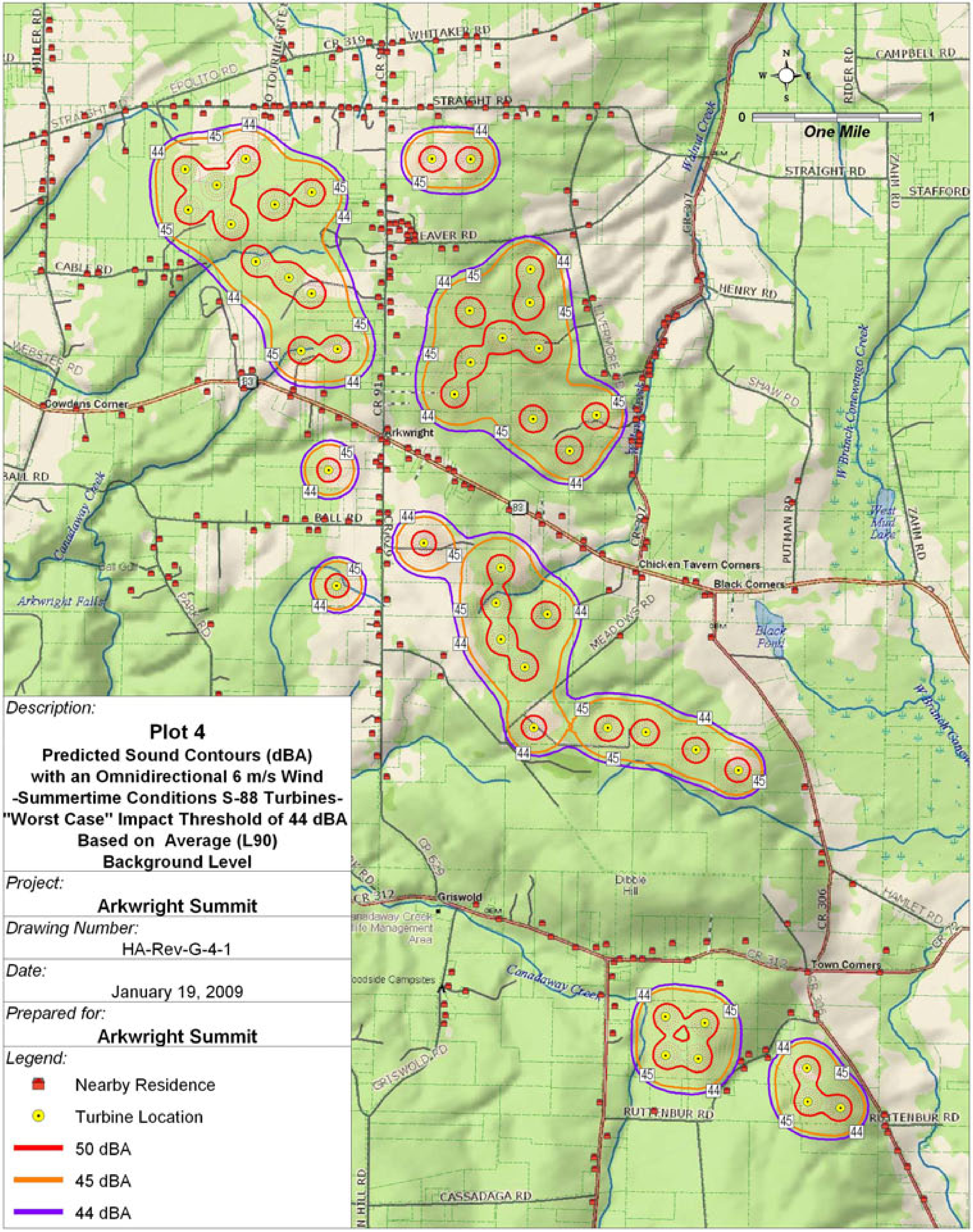

Description:

Plot 4
Predicted Sound Contours (dBA)
with an Omnidirectional 6 m/s Wind
-Summertime Conditions S-88 Turbines-
"Worst Case" Impact Threshold of 44 dBA
Based on Average (L90)
Background Level

Project:

Arkwright Summit

Drawing Number:

HA-Rev-G-4-1

Date:

January 19, 2009

Prepared for:

Arkwright Summit

Legend:

■	Nearby Residence
●	Turbine Location
▬	50 dBA
▬	45 dBA
▬	44 dBA

First International Meeting
on
Wind Turbine Noise: Perspectives for Control
Berlin 17th and 18th October 2005

How the "mythology" of infrasound and low frequency noise related to wind turbines might have developed

Geoff Leventhall
Noise Consultant   150 Craddocks Avenue
Ashtead   Surrey   KT21 1NL UK
geoff@activenoise.co.uk

Summary Objections based on infrasound and low frequency noise, often raised against wind farm developments, arise largely from a misunderstanding of these topics by the general public, for whom the problem has developed through media and related exaggerations. There was a period, about 30 years ago, when each time infrasound and low frequency noise were given publicity, more and more of the "facts" were lost in a cloud of increasing embellishment.

This paper traces some of the history of interest in infrasound and low frequency noise, showing how the misunderstandings have arisen, how they have been used in the past to cause confusion in international politics and are used currently by objectors to wind turbine developments.

Introduction Infrasound and low frequency noise are often raised in objections to the development of wind farms. It is necessary to understand how the concerns might have arisen, so that objectors can be shown that their anxieties are likely to be without foundation. In the UK there has been misrepresentation of the facts of infrasound and low frequency noise, both by objectors and also by some of the noise consultants who support the objectors. It is necessary to re-educate the public in order to remove the misconceptions which have developed.

In the definitions of infrasound and low frequency noise, infrasound is often considered as sound at frequencies below 20 Hz. However, from the subjective point of view, there is no reason for terminating a continuous process of hearing at this arbitrary frequency, so that from about 10Hz to 100Hz could be taken as the low frequency range. It may also be argued that there is no reason for terminating at 100 Hz, and the range is sometimes extended to about 200Hz. But we have to stop somewhere.

Atmospheric infrasound This is a well established discipline, studying frequencies from about one cycle in 1000 seconds up to, say, 2Hz. (Bedard and George, 2000) These infrasounds are caused by weather variations, meteorites, distant explosions, waves on the seashore, practically any occurrence which puts energy into the atmosphere over a relatively short period of time and any process with a low repetition rate, including pressure pulses from wind turbines. The attenuation with distance is very low. Monitoring of atmospheric infrasound is an essential part of ensuring the success of the Nuclear Test Ban Treaty.

Of course, it is important to realise that our evolution has been in the presence of naturally occurring atmospheric infrasound.

The American Space Programme Early work on low frequency noise and its subjective effects was stimulated by the American space programme. It was known that very large launch vehicles produce their maximum noise energy in the low frequency region. Furthermore, as the vehicle accelerates, the crew compartment is subjected to boundary layer turbulence noise for about two minutes after lift off. Experiments were carried out in low frequency noise chambers on short term subjective tolerance to bands of noise at levels of 140dB to 150dB in the range up to 100Hz (Mohr et al., 1965). It was concluded that subjects who were experienced in noise exposure, and who were wearing ear protection, could tolerate both broadband and discrete frequency noise in the range 1Hz to 100Hz at sound pressure levels up to 150dB. Later work suggests that, for 24 hour exposure, levels of 120-130dB are tolerable below 20Hz (von Gierke, 1973; von Gierke and Nixon, 1976). These limits were set to prevent direct physiological damage. It was not suggested that the exposure is pleasant, or even subjectively acceptable for anybody except those whose work requires them to be exposed to the noise.

Work was also in progress in the UK (Hood and Leventhall, 1971; Yeowart et al., 1969) and France (Gavreau, 1968; Gavreau et al., 1966) from the 1960's and in Japan and Scandinavia from the 1970's (Møller, 1980; Yamada, 1980). Japan and Scandinavia are now the main centres for work on infrasound and low frequency noise. A review of studies of low frequency noise has been given by Leventhall (Leventhall et al., 2003)

Origins of the Mythology The early American work was published in the middle 1960's and did not attract attention from the public, but a few years later *infrasound* entered upon its mythological phase, echoes of which still occur, currently in relation to wind turbines. The main name associated with the early phase is that of Gavreau from CNRS Marseille, whose work was in progress at the same time as that of the American space programme. (Gavreau, 1968; Gavreau et al., 1966). Infrasound from a defective industrial fan led to investigations of infrasonic problems and the design of high intensity low frequency sound sources. Gavreau made some misleading statements, which led to confusion of harmful effects of very high levels at higher frequencies with the effects of infrasound. (Note: According to the definition above, most of the sources developed by Gavreau and his colleagues were not infrasonic.) For example from the 1968 paper on "Infrasound", which was published in a "popular science" journal:

> *Infrasounds are not difficult to study but they are potentially harmful. For example one of my colleagues, R Levavasseur, who designed a powerful emitter known as the 'Levavasseur whistle' is now a victim of his own inventiveness. One of his larger whistles emitting at 2600Hz had an acoustic power of 1kW…..This proved sufficient to make him a life-long invalid.*

Of course, 2600Hz is not infrasound, but the misleading implication is that infrasound caused injury to Levavasseur. A point source of sound power 1kW will produce a sound level of about 140dB at 1m, which is an very undesirable exposure at 2600Hz.

Gavreau's progress Gavreau initially energised his sources in a laboratory, exposing himself and his co-workers to very high levels of noise at relatively high frequencies. For example at 196Hz from a pneumatic "whistle" and 37Hz from a larger whistle. Exposure to the 196Hz source at a level of 160dB [1] led to irritation of internal organs, so that Gavreau and his colleague felt ill for some time following a five minute exposure, which is not surprising. Again from the 1968 paper:

> *…after the test we became aware of a painful 'resonance' within our bodies – everything inside us seemed to vibrate when we spoke or moved. What had happened was that this sound at 160 decibels….. acting directly on the body produced intense friction between internal organs, resulting in severe irritation of the nerve endings. Presumably if the test had lasted longer than five minutes, internal haemorrhage would have occurred.*

196 Hz is not infrasound, but the unpleasant effects are described in a paper which is described as on "Infrasound". Internal haemorrhage is often quoted as an effect of exposure to any infrasound.

The 37Hz whistle was run at a low level, but sufficient to cause the lightweight walls of the laboratory to vibrate. (Some of Gavreau's earlier work had been in the development of pneumatic high intensity ultrasonic sources, so that he merely had to scale up the size).

Gavreau generated 7Hz with a tube of length 24m, driven by either a loudspeaker or a motor- driven piston. He suggested that 7Hz was particularly "dangerous" because the frequency coincided with alpha rhythms of the brain. He also used a tube to generate 3.5Hz, but further details were not given.

However, from the 1968 paper:

> *The effects of low frequency sound and infrasound are noxious. However, we found one exception: the intense vibration of the nasal cavities produced by our*

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[1] 160dB is about 2000Pa, or 1/50 of an atmosphere, which is in the non-linear region.

> *whistle (340Hz, 155 decibels) had favourable effects! In one case, a subject recovered a sense of smell which he had lost some years back and was able to breathe more easily.*

Infrasound and the public By present standards, Gavreau's work was irresponsible, both in the manner in which it was carried out and in the manner in which it was described. Today, the experiments on people could lead to prosecution for negligence. Much of the paper with title of 'Infrasound' is not about infrasound. However, the work was picked up by the media and embellished further, including a statement that 7Hz was fatal. There was manipulation, sometimes willing manipulation, of scientists by the media, which was happy to describe all the sources developed by Gavreau as infrasound sources and to attribute all the adverse effects to infrasound, although they were actually due to high levels at frequencies above the infrasonic range.

The misunderstanding between infrasound and low frequency noise continues to the present day. A recent newspaper article on low frequency noise from wind turbines (Miller, 24 January 2004), opens with:

Onshore wind farms are a health hazard to people living near them because of the low-frequency noise that they emit, according to new medical studies.

A French translation of this article for use by objectors' groups opens with

De nouvelles études médicales indiquent que les éoliennes terrestres représentent un risque pour la santé des gens habitant à proximité, à cause de l'émission d'infrasons.

The translation of *low frequency noise* into *infrasons* continues through the article.

This is not a trivial misrepresentation because, following on from Gavreau, infrasound has been connected with many misfortunes, being blamed for problems for which some other explanation had not yet been found (e.g., brain tumours, cot deaths of babies, road accidents). A selection of some UK press headlines from the early years is:

The Silent Sound Menaces Drivers - Daily Mirror, 19th October 1969
Does Infrasound Make Drivers Drunk? - New Scientist,16th March 1972
Brain Tumours 'caused by noise' - The Times, 29th September 1973
Crowd Control by Light and Sound - The Guardian, 3rd October 1973
Danger in Unheard Car Sounds - The Observer, 21st April 1974
The Silent Killer All Around Us - Evening News, 25th May 1974
Noise is the Invisible Danger - Care on the Road (ROSPA) August 1974

Absurd statements were made in the book 'Supernature' by Lyall Watson, first published in 1973 as 'A Natural History of the Supernatural' and which has, unfortunately, had a number of reprints and large sales. This book includes an extreme instance of the incredible nonsense which has been published about infrasound. It states that the technician who gave the first trial blast of Gavreau's whistle "fell down dead on the spot". A post mortem showed that "all his internal organs had been mashed into an amorphous jelly by the vibrations". It continues that, in a controlled experiment, all the windows were broken within a half mile of the test site and further, that two infrasonic generators "focused on a point even five miles away produce a resonance that can knock a building down as effectively as a major earthquake".

One can detect a transition from Gavreau and his colleague feeling ill after exposure to the high level of 196Hz to "fell down dead on the spot" and a further transition from laboratory walls vibrating to "can knock a building down", transitions which resulted from repeated media exaggerations over a period of five or six years.

Perhaps the singer David Bowie had read "Supernature". On the 20th September 1977, the London Evening News published an interview with him, giving his views on life, including the following:

"He also expresses fears about America's new Neutron Bomb. 'It was developed along the lines of the French sound bomb which is capable of

destroying an area 25 miles around by low frequency vibration'. According to Bowie, plans for such a bomb are readily available in France and any minor power can get their hands on a copy. Low frequency sounds can be very dangerous. The 'sensurround' effect that accompanied the film 'Earthquake' was achieved by a noise level of nine cycles per second. Three cycles per second lower is stomach bleeding level. Any lower than that and you explode".

We cannot blame the public for their anxiety about infrasound and low frequency noise when they have been exposed to statements like these. Public concern over infrasound was one of the stimuli for a growth in complaints about low frequency noise during the 1970's and 1980's and has continuing effects. It appears that concerns over infrasound and low frequency noise have found a place deep in the national psyche of a number of countries and lie waiting for a trigger to bring them to the surface. Earlier triggers have been gas pipelines and government establishments. A current trigger is wind turbines.

Infrasonic weapons The media follow-up of Gavreau's work led to interest in infrasonic weapons, although these have not been produced, as it is not possible to generate directional infrasound of high enough level to be effective at a distance. For example, to produce 150dB (1000W/m^2) at 100m distance requires a point source power of about 60MW. At 20Hz, which has a wavelength of about 17m, an efficient directional reflector, which must have dimensions of several wavelengths, is not feasible. However, during the cold war, the Conference of the Committee on Disarmament (see: www.unog.ch) , which commenced its work in Geneva in about 1960, and is believed to be still sitting, was presented with a paper from the Hungarian Peoples' Republic (Anon, 1978) which discussed infrasonic weapons and concluded:

> *"…..infrasound can become the basis of one of the dangerous types of new weapons of mass destruction…….*
> *All this leads to the unequivocal conclusion that the scope of the agreement on the prohibition of the development and manufacture of new types of weapons of mass destruction must also be extended to the military use of infrasound weapons of mass destruction……"*

An example of an infrasonic weapon was given as a jet engine attached to a long tube – reminiscent of Gavreau's 24m tube, as shown in Fig 1. Of course, the physics is at fault, because the rapid flow of the exhaust gas from the engine will prevent the development of resonance (Leventhall, 1998).

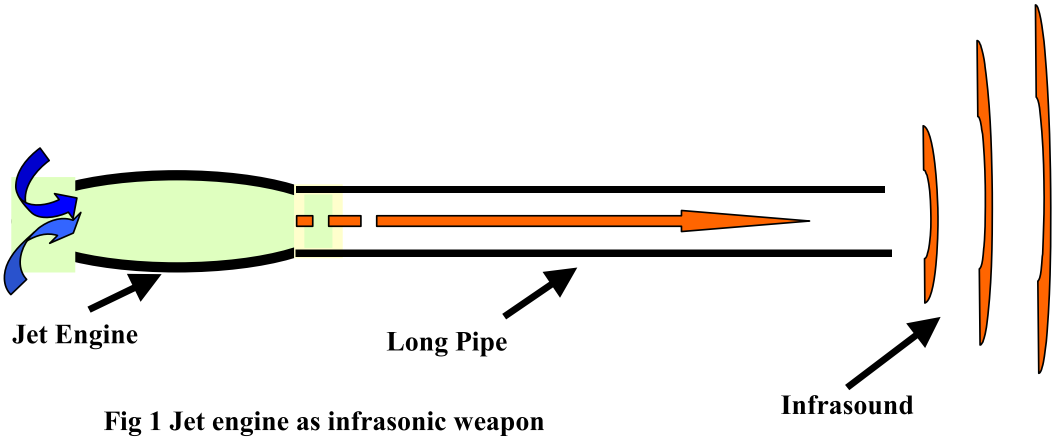
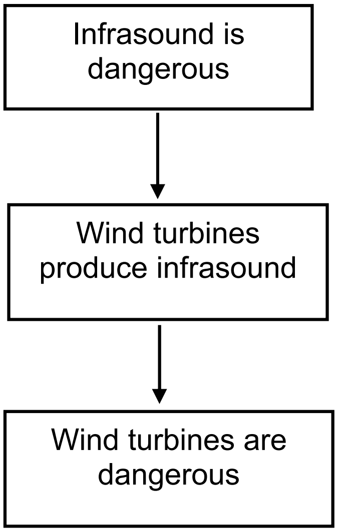


Fig 1 Jet engine as infrasonic weapon

However, after taking advice, the Western powers concluded that infrasonic weapons were a political distraction from the main points of the disarmament negotiations.

In relation to wind turbines, the concept that "infrasound is dangerous" has been absorbed into the minds of objectors, who take a one dimensional view of infrasound. That is, they consider only that it may be present from wind turbines and ignore the very low levels. So we have the relation:



Which objectors are pleased to believe and which they make use of in planning applications.

A recent example is from the leaflet from an objectors' group which stated:
"wind turbines still create noise pollution, notably 'infra sound' - inaudible frequencies which nevertheless cause stress-related illness ..."

The wind farm developers referred this statement, and others, to the UK Advertising Standards Authority, which ruled that it was misleading.

What infrasound do we hear? The audibility of infrasound for subjects exposed in infrasonic chambers, has been measured reliably down to 4Hz, Fig 2, is based on work by Watanabe and Møller from 4Hz and on ISO 226 from 20Hz (ISO:226, 2003; Watanabe and Møller, 1990b). The median threshold at 4Hz is 107dB, at 10Hz is 97dB and at 20Hz is 79dB. The standard deviation of the threshold measurements is about 6dB, so that a very small number of people may have 12dB or more greater sensitivity than the median.

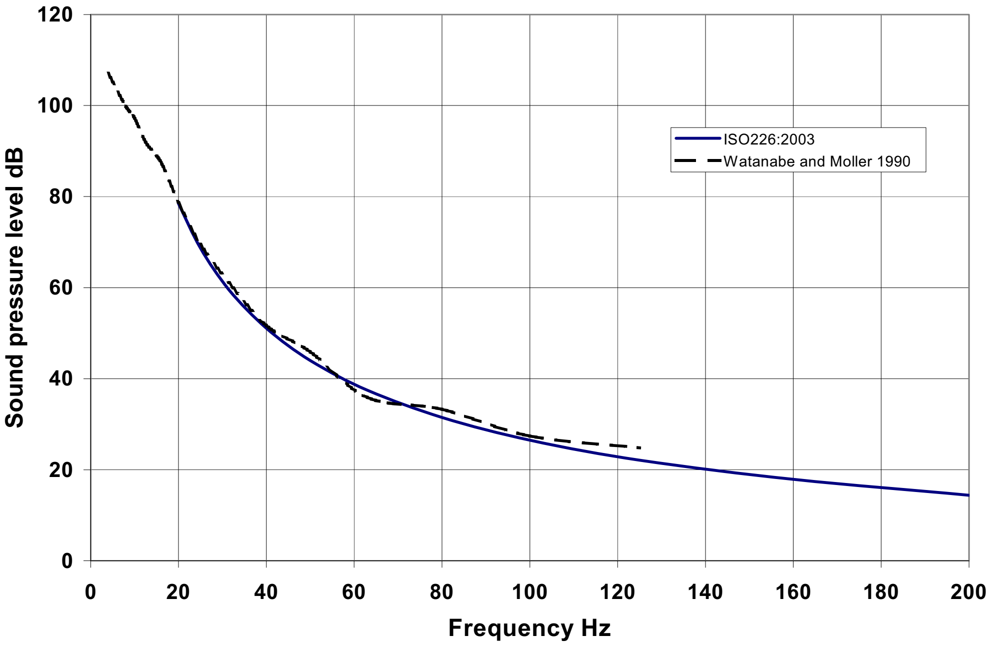


Fig 2. Low frequency threshold

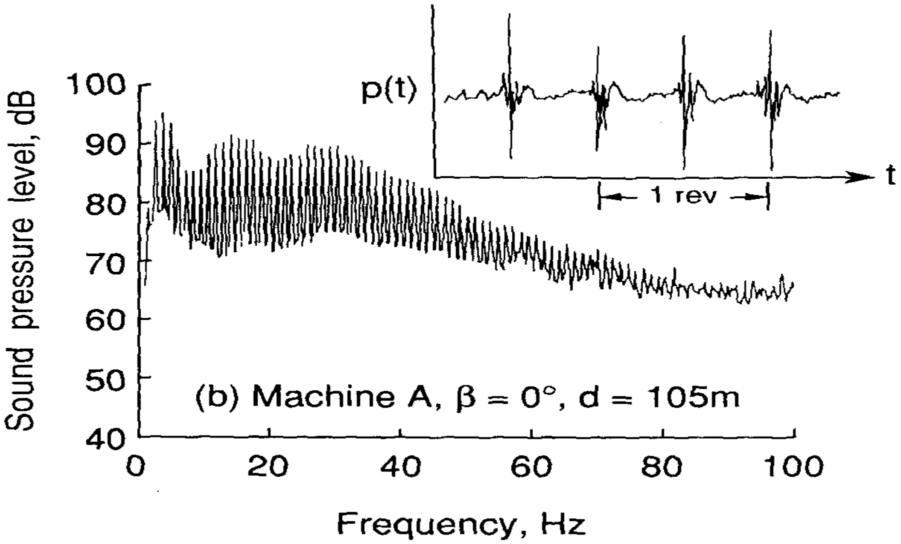
Part of the mythology is that infrasound can be felt but not heard. However, the ear is the most sensitive receptor in the body, as has been shown by threshold measurements on both normal hearing subjects and profoundly deaf subjects, which were carried out down to 8Hz (Yamada et al., 1983). If you can't hear it you can't feel it.

Gavreau (1968) used loud music to show that 7Hz infrasound could be masked by higher frequencies. Initially the sound was throbbing unpleasantly, but

> *'This musical experiment proved that this infrasound acted through the ears and not directly on the body. Furthermore, any kind of strong audible sound, by reducing the sensitivity of the ear, rendered this infrasound perfectly harmless'.*

Gavreau did not give the level of the 7Hz, but it is likely to have been at least 110 - 120dB.

Infrasound and wind turbines As is well known, earlier downwind turbines produced pulses at levels which caused vibration effects in light-weight buildings,



MOD-1 Downwind 1.5MW to 2MW 61m diameter rotor BPF ~ 1Hz

Fig 3 Infrasound from early downwind turbine

occurring twice a revolution from a two bladed turbine, as shown in Fig 3. (Shepherd and Hubbard, 1991)

Any slow train of pulses will analyse as infrasound. For example, pulses occurring once a second, as in Fig 3, will analyse as infrasound with a harmonic series at 1Hz intervals. But it was actually the peak pressure from the pulses which caused transient effects in the buildings, such as rattling of loose components, not the emission of a continuous infrasonic wave. These effects were heard as separate events.

Modern up-wind turbines produce pulses which also analyse as infrasound, but at low levels, typically 50 to 70dB, well below the hearing threshold. Infrasound can be neglected in the assessment of the noise of modern wind turbines (Jakobsen, 2004)

Low frequency noise

There is an easy transition from infrasound to low frequency noise and much of the publicity about infrasound applies equally to low frequency noise. Sometimes the terms are used interchangeably. However, audible low frequency noise does have annoying characteristics which are not shown in conventional environmental noise measures, such as the A-weighting. This has been recognised by the World Health Organisation, which makes a number of references to low frequency noise in its publication on Community Noise (Berglund et al., 2000) with statements such as:

It should be noted that low frequency noise, for example, from ventilation systems can disturb rest and sleep even at low sound levels

For noise with a large proportion of low frequency sounds a still lower guideline (than 30dBA) *is recommended*

When prominent low frequency components are present, noise measures based on A-weighting are inappropriate

Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting

It should be noted that a large proportion of low frequency components in a noise may increase considerably the adverse effects on health

The evidence on low frequency noise is sufficiently strong to warrant immediate concern

An example of the difference between responses to low frequency noise/infrasound and other noises is in the growth of annoyance, illustrated in Fig. 4.

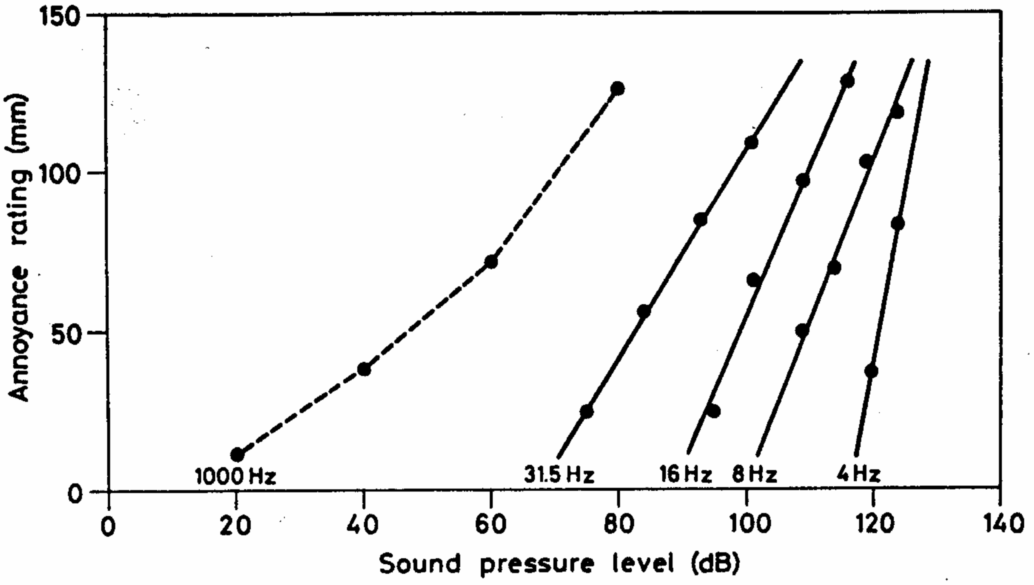


Fig 4 Growth of annoyance at low frequencies

Although low frequency tones require a higher level for the on-set of perception, their annoyance rating increases more rapidly with level. At 4Hz the range of annoyance is covered in a rise of about 10dB, compared with about 50dB at 1000Hz. Annoyance does not normally commence until the tone is 5 to 10dB above its threshold.

The concerns of the WHO on low frequency noise require us to look carefully at low frequency noise from wind turbines. In general, there is not a problem, although the mythology is that wind turbine noise has a substantial low frequency component.

This may be a misunderstanding of the "swish – swish - swish", at about once a second, which is typical of wind turbines. However, the swish is a modulation of a higher frequency, typically in the 500Hz to 1000Hz range, and does not contain low frequencies or infrasound. An analogy is with an amplitude modulated radio wave, which contains only the carrier and side bands, not the modulation frequency.

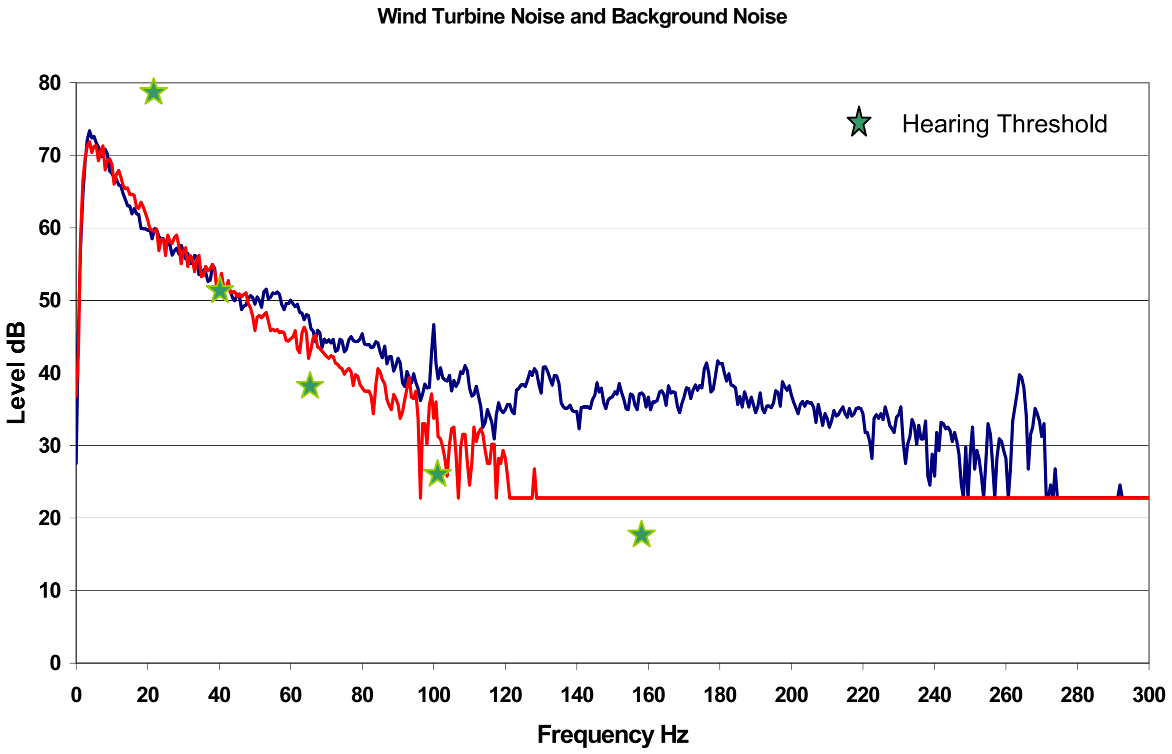


Fig 5 Wind turbine noise ▬ and background noise ▬
65m distance. wind speed at hub ~ 15m/s

All wind turbines produce low frequencies, mainly mechanical noise, which has been reduced to low levels in modern turbines, but there are also circumstances in which turbines produce increased levels of low frequency noise. This is mainly when the inflow air to the turbine is very turbulent and there are interactions between the blade and the turbulence.

Fig 5 shows the infrasonic and low frequency noise at 65m from a 1.5MW wind turbine on a windy day. The following should be noted.

- The fall off below about 5Hz is an instrument effect. The background noise actually increases down to the frequencies of atmospheric pressure variations .
- Frequencies below 40Hz cannot be distinguished from background noise due to wind.
- The wind turbine noise and background noise separate above about 40Hz and both rise above the median hearing threshold.
- The measurements were taken at 65m. Levels are likely to be about 15dB lower at normal separation distances

.

On the occasions, such as turbulent inflow conditions, when low frequency noise is produced by wind turbines, it may not be perceived as a noise, but rather as an unidentified adverse component in the environment, which disappears if the turbines stop, or if the inflow conditions change. This is because we are not accustomed to listening to low levels of broad band low frequency noise and, initially, do not always recognise it as a "noise", but more as a "disturbance" in the environment.

Conclusions. Specialists in noise from wind turbines have work to do in educating the public on infrasound and low frequency noise. Specifically,

- Infrasound is not a problem,
- Low frequency noise may be audible under certain conditions,
- The regular 'swish' is not low frequency noise.

Advice to objector groups in this connection could be that, by dissipating their energy on objections to infrasound and low frequency noise, they are losing credibility and, perhaps, not giving sufficient attention to other factors.

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