Evaluation of Environmental Noise Analysis for

"Dutch Hill Wind Power Project"

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January 11, 2007
Rev. 0

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1.0 Introduction

Two industrial wind turbine farms are proposed by parent UPC Wind Partners for the town of Cohocton, NY and will permanently alter the town. Large turbines create strong noise levels not only from wind through the blades but largely by the turbine mechanisms themselves. To capture the wind these turbines are to be installed on hill tops around the town and thus have significant potential to create a noise nuisance. Wind turbine noise added to the prevailing ambient background sound is an important environmental consideration when siting wind turbines since they are a permanent installation and may significantly impair resident's enjoyment of neighboring lands or even personal health. Also, relevant consideration of noise impacts and mitigation measures are a specific requirement of a NY State Environmental Quality Review (SEQR) procedure, required before approval of permits.

The purpose of this report is to evaluate, not to repeat the noise study, which was the province of UPC Wind Partners through their contractor Hessler Associates. There are many modern tools to evaluate and predict the effects of noise sources, well known to the scientific and engineering communities. Sounds, as a form of wave propagation have been thoroughly and meticulously studied and measured. There are therefore a host of instrumentation and analysis tools available. But these tools must be used correctly and carefully in order to avoid the "garbage in garbage out" syndrome and erroneous conclusions.

2.0 "Dutch Hill Wind Power Project"

UPC Wind Management has proposed two wind farms for Cohocton, the Cohocton Wind Power Project is first, the Dutch Hill Power Project is the second. Sixteen high power turbines of 2.5 MW nameplate rating are proposed for the hill crests predominantly south of the hamlet of Atlanta, NY.

2.1 Flawed Noise Analysis

The successful measurement and assessment of the complex noise potential of a large wind turbine farm project is a vital part of the environmental review and mitigation process and there are specific instructions in the Policy about excessive noise. According to NYS DEC Policy: (Ref 2):

> When a sound level evaluation indicates that receptors **may experience sound levels or characteristics that produce significant noise impacts or impairment of property use**, the Department is to require the permittee or applicant to **employ reasonable and necessary measures to either eliminate or mitigate adverse noise effects**.

The Hessler study should methodically and scientifically evaluate and predict the noise impact of the wind farm on the Atlanta community. Hessler admits this is their intent and they claim to follow the customary procedure- background ambient qualification followed by mathematical model predictions:

> The study essentially consisted of two phases: a background sound level survey and a computer modeling analysis of future turbine sound levels. The field survey of existing sound levels at the site was necessary to determine how much natural masking noise there might be - as a function of wind speed - at the nearest residences to the project. The relevance of this is that high levels of background noise due to wind induced natural sounds, such as tree rustle, would 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.

Ref 1, 1.0 Introduction

The Hessler study claims to adhere to the DEC Noise Policy but it is severely flawed and does not conform to the Policy:

a) All potential receptors that may be affected by unreasonable noise levels must be characterized, not just surrounding the 3 background measurement sites as was done by Hessler because unique acoustical features of the terrain may influence sound propagation. A statistically valid sample will need evaluation of the topography mixed with the residential density and proximity. These mathematical techniques are well established.
b) Measurements of background noise were completely inaccurate and do not provide a baseline for establishing noise contour maps.
c) Vegetation was not present for the short duration (15 April days) field measurements, and vegetative cover will likely have an important effect on elevated noise source propagation compared with ground level ambient. Wind strength increases with elevation above earth and it is frequently expected that the turbines will be operating just above cut-in while the land nearby is without wind or with very low wind and hence with quiet ambient.
d) Realistic computer modeling should conform to prevailing sound propagation results and include atmospheric refraction effects.

The Hessler noise study consists of two parts, identification of the ambient background noise and then computer modeling analysis of the expected turbine noise for various geographic noise boundaries (contours) surrounding the turbine farm. The background ambient determination is important because the new wind turbine noise emissions will be added to the ambient to provide a “limit of acceptance.” The DEC Noise Policy suggests a 3 dB(A) increase over ambient for “sensitive receptors” and a generally applicable limit of 6 dB(A) increase as acceptable under most circumstances. Therefore the computer modeling of noise contours around each turbine depends exclusively on obtaining reliable ambient background noise data. Inaccurate noise contours and inaccurate background noise limits will lead to serious errors in delineating setback requirements for turbine siting. The simple mathematics of sound assessment is shown in the graph, Fig. 1 below.

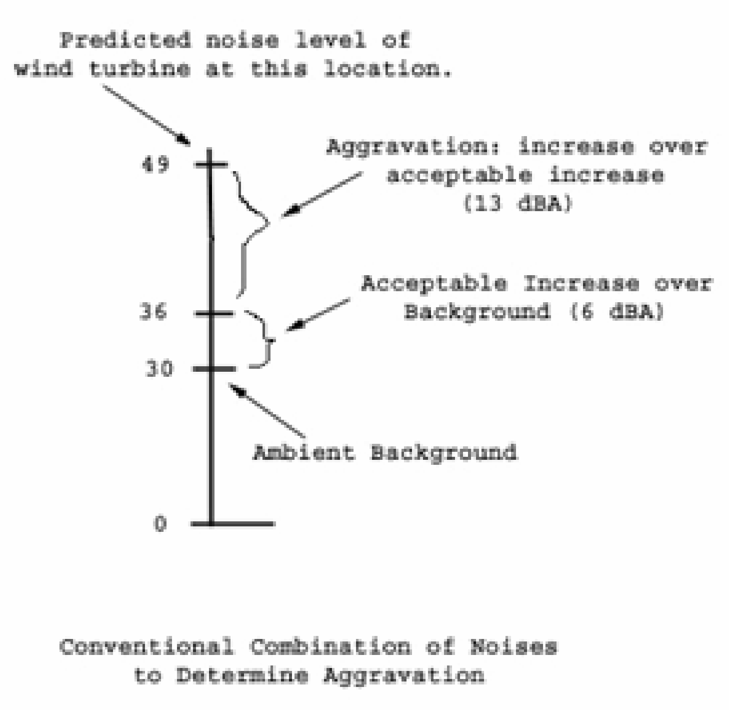


Fig. 1: Noise Aggravation Mathematics

Hessler agrees:

> The primary basis for evaluating potential project noise is the Program Policy *Assessing and Mitigating Noise Impacts* issued by the New York State Department of Environmental Conservation (NYCDEC), Feb. 2001. This assessment procedure is incremental in the sense that a simplified "first level noise impact evaluation" is initially carried out to determine if any residential receptors *may* experience a noticeable increase in sound level followed by a more in depth "second level noise impact evaluation" if any sensitive receptors are identified as being possibly affected. **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.**

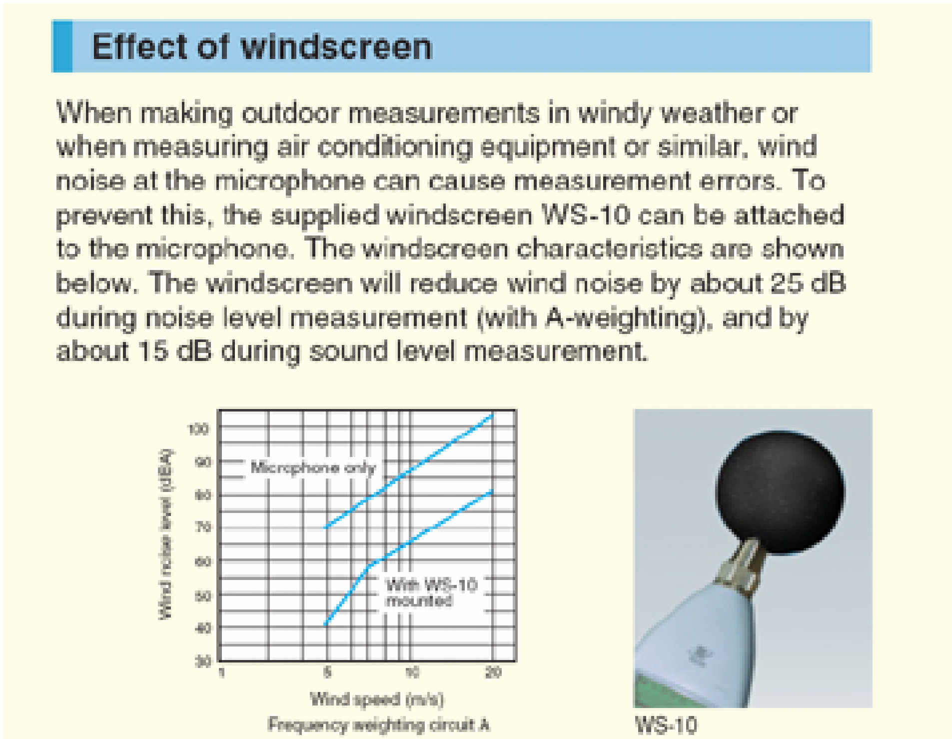
(emphasis added)

Analysis of the Hessler study reveals however that the background noise levels were not measured due to overwhelming contamination of measurements by the wind blowing through the meter's own microphone. To take background ambient sound measurements Hessler put an acoustical microphone on a tripod support at the measurement site. The microphone has a spherical wind screen attached and is connected to recording electronics. Fig. 2 is a photo excerpt from a typical setup used by Hessler, this one from their Noise Survey, Fig 2.2.3. Generally a wind screen should contain several "spikes" protruding out the top to prevent birds from alighting on the wind screen and creating large local "noise" errors from the bird's feet, but this is not evident here.


Fig. 2: Hessler’s Typical Background Sound Measurement Setup (Central Location)

It is well known that wind induced microphone noise is a large source of “masking error” in any windy measurement situation. The reader may recall news broadcasts where the reporter is trying to talk despite breezes causing “wind noise” that overcomes the reporter’s voice. It’s the same thing here, a breeze on the microphone, even with a wind screen, will cause significant errors due to this unwanted effect. Noise meter manufacturer data clearly show the error and it has been studied theoretically by van den Berg (Ref. 3), with good agreement between theory and instrumentation.

Rion, manufacturer of the model used by Hessler, provides wind-induced error curves for their instruments in varying wind conditions in their specification sheet (Fig. 3). And Fig. 4 shows a plot of wind speed vs. dBA error for the Rion as well as another manufacturer’s noise meter, plus two conditions for the van den Berg theoretical model. All are in good agreement. Also shown on the graph as vertical bars are the cut-in wind speed and cut-out wind speed for the Gamesa G87-2.0 MW turbine, expected to be similar to the proposed Clipper Windpower 2.5 MW turbines. It can be seen that at the cut-in wind speed of 9 mph the noise meter error is about 35 dBA. Unless the background noise being measured is above 35 dBA it won’t be registered as a true background sound because of the microphone error. Since wind itself is completely silent, it creates sound only when acting on some object causing it to react to the wind’s pressure. A 9 mph wind may create an “ambient” less than 35 dBA, depending on physical conditions around the measuring site – nearby woods and vegetation, structures, and terrain. At the turbine cut-out wind speed of 56 mph the microphone error has risen to an astonishing 80 dBA. Only loud background sounds can be now be registered, once again with no way of discerning any quieter ambient. Putting a microphone on a tripod with a wind screen simply does not give any kind of reliable background noise information if the wind is blowing!



Effect of windscreen

When making outdoor measurements in windy weather or when measuring air conditioning equipment or similar, wind noise at the microphone can cause measurement errors. To prevent this, the supplied windscreen WS-10 can be attached to the microphone. The windscreen characteristics are shown below. The windscreen will reduce wind noise by about 25 dB during noise level measurement (with A-weighting), and by about 15 dB during sound level measurement.

Fig 3: Excerpt from Rion NL Series Specification Sheet

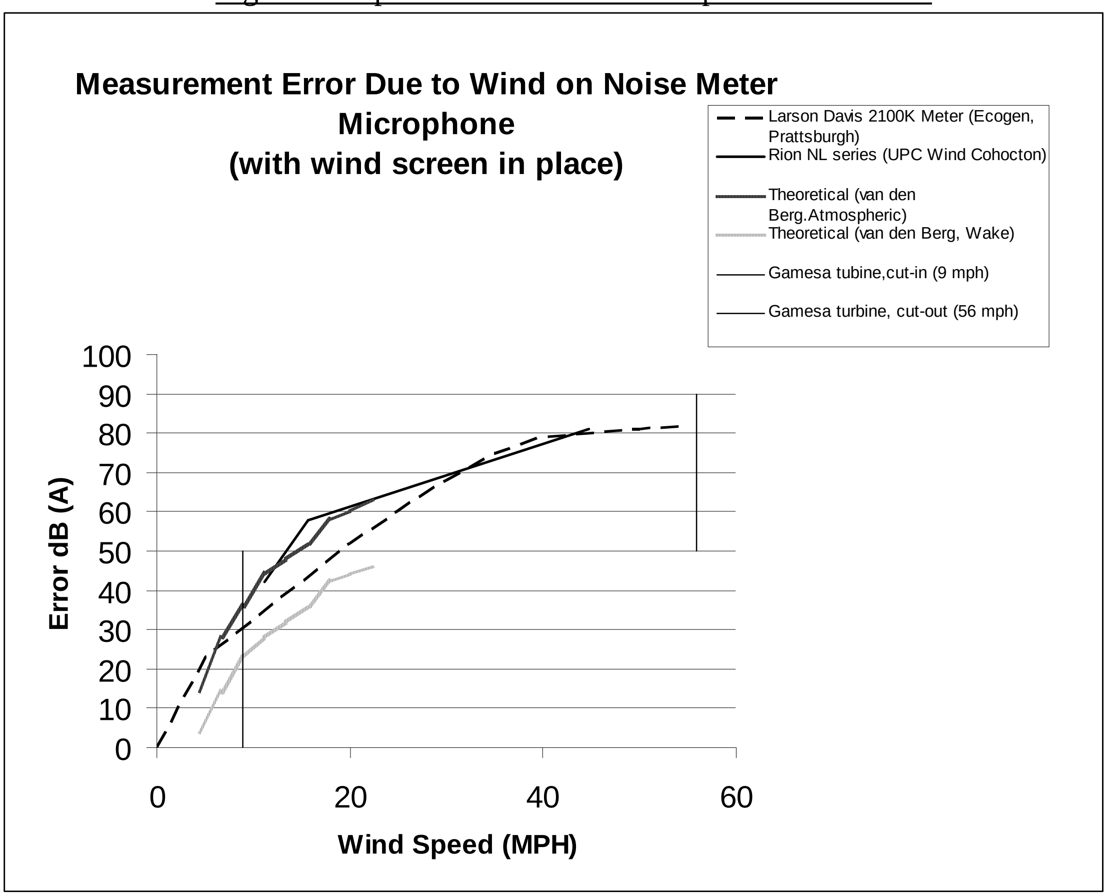


Fig 4: Noise Meter Microphone Error (Bolton)

Hessler states that the “microphones were protected from rain and self-induced wind noise by waterproof double windscreens.” (Appendix I, section 2.3 “Instrumentation and Survey Duration”) but this is merely to keep rain out and reduce the error from the “no windscreen” condition in Fig. 3.

Figure 5 shows a rough plot of the microphone error (Fig. 3) superimposed over the measured noise data that Hessler provides from raw hourly data. Of note, this data was taken during very light wind conditions and during this sample period the turbines would only be operating only 28 hours of the 336 hr. measurement period, or for only 8% of the period. Nevertheless the microphone error clearly contaminates the supposed “background” measurement, even for these light-wind conditions.

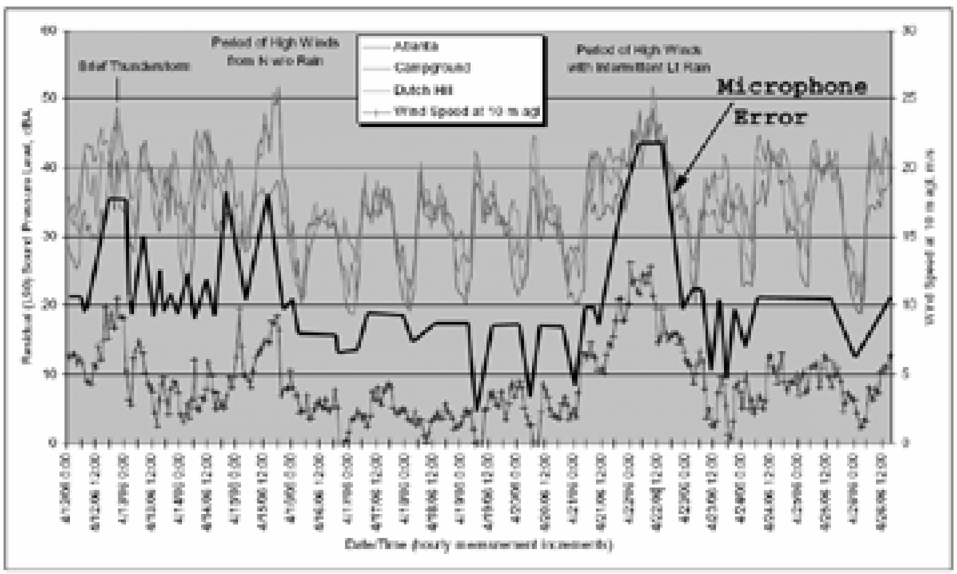


Figure 2.5.1 *Hourly Residual Sound Levels at All Positions vs. Wind Speed (11/17 to 12/8/05)*

Fig. 5: Graph of Microphone Measurement Error Superimposed over Field Data

I recently (8-23-06) called Rion’s US distributor, Scanteck and spoke at length with their Rick Peppin about wind screens and microphone noise error. He is aware of wind noise errors and says only a large windscreen, costing $1,800 and therefore seldom purchased, will effectively reduce this error, though it is not calibrated and therefore of limited use. It was his opinion one should measure background noises without the wind blowing at all, to give the most conservative noise figure

Rion publishes a graph showing that increasing the wind screen foam diameter helps the situation but does adequately correct it in windy situations, see Fig. 6 below (Ref. 4) .The type of wind screen that is required when making measurements in rural areas is shown in Fig. 7, taken from Ref. 5 and is 12” in diameter, much larger than that shown in Hessler’s photograph (Fig. 2, sic). Yet another and similar type of low-noise windscreen is made by Delta of Denmark, Fig. 8 below.

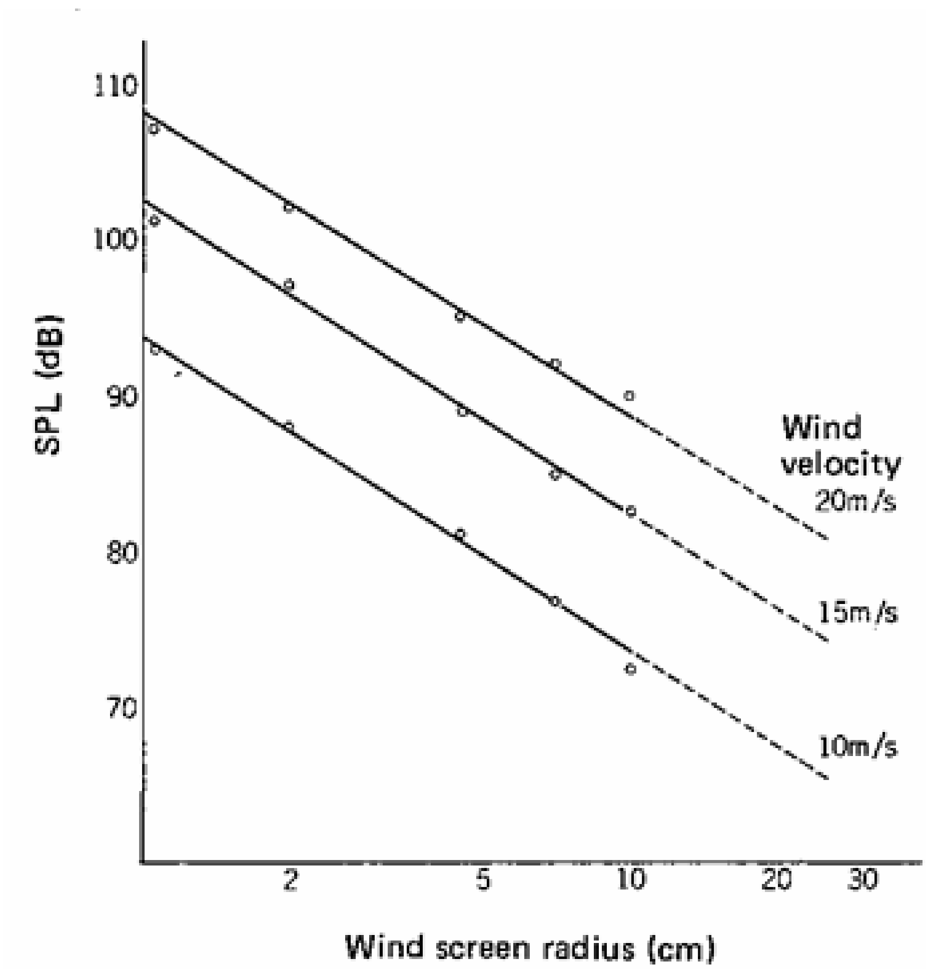


Fig 6: Relation between wind screen size and wind noise (Ref. 7)

A study "Noise Immission from Wind Turbines" (Ref. 6) evaluated some methods of correcting erroneous noise meter measurements:

> "The project has dealt with practical ways to reduce the influence of background noise caused by wind acting on the measuring microphone."

The report identifies four methods to eliminate microphone error:

> 3.1.1 Reduction of Wind Induced Microphone Noise
>
> **Wind induced microphone noise is a major problem in wind turbine noise measurement during strong wind.** Four techniques for reducing this so-called pseudo noise were tested in the project.
>
> - *Two microphone cross correlation*. Noise signals from two identical microphones positioned some distance apart were analyzed applying correlation technique to suppress wind induced noise components, which are uncorrelated in the two signals[4]
> - *Mounting the microphone on a vertical reflecting board.* The board reduces wind velocity at the microphone, screens the noise from any source behind the board, and causes pressure doubling (+6 dB) for sources in front of the board.

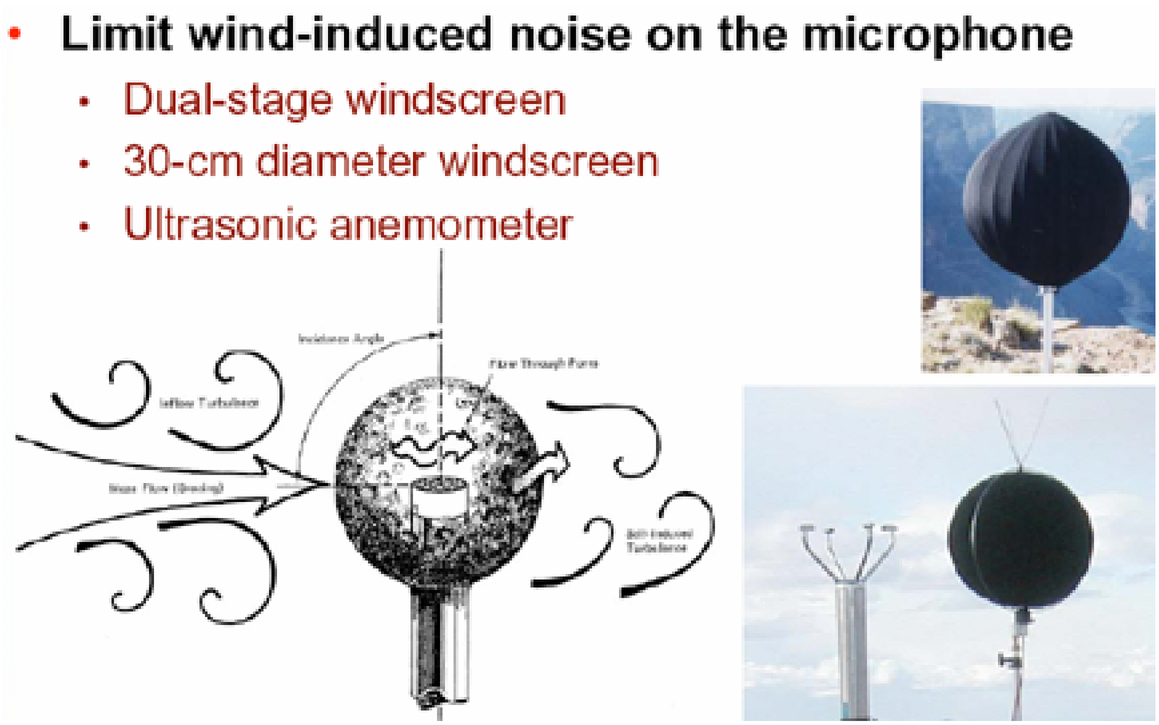


Fig. 7: Wind Screen for Limiting Wind-Induced Microphone Noise

Fig. 8: Secondary Noise Shield from Delta Co., Denmark

- *Directional microphone with supplementary wind shield*. A directional microphone reduces noise from directions other than that of its axis. Wind noise sensitivity of the directional microphone was reduced by mounting a supplementary wind shield.
- *Large secondary wind screen.* An extra wind screen used simultaneously with the normal wind screen reduces wind noise. The attenuation of the acoustic signal when transmitted through the secondary wind screen was measured in an anechoic room and the wind induced noise was measured in the field.

The reduction of wind-induced noise turned out to be more or less the same no matter which of the methods is used…"

(emphasis added)

None of these correction methods was employed by Hessler. As a reputed "expert" consulting company Hessler should have certainly known about the obvious problems with ambient sound measurement and should have used corrective measures such as listed above.

2.2 Vegetation

The Hessler noise study was conducted for a brief period in April, when vegetation is lacking. Hessler attempts to justify this:

> 3.6 SEASONAL INFLUENCES ON POTENTIAL NOISE IMPACTS
>
> Experience in conducting ambient sound level surveys at all times of year indicates that, as might be intuitively obvious, background levels are lowest in winter when the leaves are off the trees.

It would however seem "intuitively obvious" from my own experience living in quiet rural setting that ambient noises in the summer can be much less than the winter, absorbing road noises and other distant sounds. And since the wind turbines are elevated and directly radiating, their noise will be more easily heard against a much lower background due to summer vegetation. From the DEC Noise Policy, in direct contradiction to Hessler:

> A. Environmental Setting and Effects on Noise Levels
>
> 4. Time of Year - **Summer time noises have the greatest potential for causing annoyance** because of open windows, outside activities, etc. During the winter people tend to spend more time indoors and have the windows closed.

(emphasis added)

2.3 Background Measurement Sample Size

The proposed 16 turbine locations may well affect over 60 residences (Appendix K, Plot 1, Ref. 1) for the 20 year life of the wind farm. All potential receptors that may be affected by unreasonable noise levels must be characterized, not just surrounding the 3 background measurement sites as was done by Hessler because unique acoustical features of the terrain may influence sound propagation. A detailed geographic and demographic breakdown with ranking needs to be done to justify the number of sample sites required and how they conform to the ranking criteria. The techniques of zone mapping are well established and used elsewhere, for example see *Natural Soundscape Monitoring in*

Yellowstone National Park (Ref. 7, p. 6) or *Draft Guidelines for the Measurement and Assessment of Low-Level Ambient Noise,* (Ref. 8 Section 2.2).

The only comment Hessler makes about its site selection is:

> As illustrated in Figure 2.2.1 below, three monitoring positions, designated as North, Central and South, were selected to measure background sound levels at key locations representative of the nearest potentially sensitive receptors.
>
> (2.2 of Ref 1, *sic*)

The large number of possible affected residents dictates a legitimate selection methodology to ensure environmental protection is afforded all affected residents.

2.4 Wind Variation With Height

Hessler claims that the wind turbines only operate when the prevailing winds are generating noises to mask the turbine noise. This claim has two errors. It is only true that noises will mask each other only if they are of essentially the same type. Hessler assumes that since the turbines noises are essentially "white"[1] that they will statistically combine with the prevailing ambient under windy conditions and that the ambient is also a "white" noise. This is only partially true and an oversimplification. If the white noises have periodic components, such as modulation or tonal components then the noises will not mask each other, which will be discussed further in Section 4.4.

Also for masking to work the assumption must be made that the wind at the turbine height is the same as the wind at the receptor/resident. Generally wind increases with elevation so in most wind situations the turbines will experience higher winds than the terrain below, exposing residents to the noise. Hessler's comparisons using 10M (30 ft) wind height data to substantiate their claim has been shown to be totally inadequate and understate the actual winds at the blades by up to 260%. (Ref. 9). It is simply not credible to assume that the wind speeds at the rotors match the ground wind speeds, they will be substantially higher.

2.4 Noise Predictive Modeling

Hessler discusses the noise modeling software and its application in their section 3.3 "Noise Modeling Methodology". They use the Cadna/A v 3.5 software and provide a project contour map of results in Plot 1. There are three noise contours drawn, 55, 50 and 44 dBA. However this contour map is not a reasonable nor accurate predictor since Cadna/A software does not include well known refraction effects that will often "focus" distant sounds and cause them to be at elevated dB levels much more distant than Cadna/A predicts.

[1] From Wikepedia: White noise is a random signal (or process) with a flat power spectral density. In other words, the signal's power spectral density has equal power in any band, at any centre frequency, having a given bandwidth. White noise is considered analogous to white light which contains all frequencies.

> Long range propagation including atmospheric refraction is not part of the standards used for (normal, "standard") noise calculations**. It is known that atmospheric refraction may cause sound to be refracted downwards again and contributing strongly to the level at long distances**. The atmosphere in the standards existing is just homogeneous above height.
>
> However, there is also in Europe and in Germany some discussion going on about "atmospheric noise". Recently a study group has been set up here to look for possible solutions. This could end in new standards or in amendments of existing ones. The problem is that nobody knows the layer structure and the properties of the atmosphere vs. height. That's the situation right now.

H. Metzen, DataKustik, Ref. 10

Yet these effects are fundamental to sound propagation and are well developed and known. For example “Mechanical Radiation” (Ref. 11) includes a complete derivation from the governing differential equation for sound propagation in a refractive medium – air and water - which reduces as it should to the familiar Snell’s law of optics. Indeed there are strong similarities in all wave propagation mathematics, whether the wave is an electromagnetic transverse wave (i.e. radio and/or light radiation) or a molecular compression wave (sound). Waves can be treated as “rays” and exhibit diffraction, refraction and coherence effects and have been thoroughly studied for 200 years now.

Refraction occurs from the change in sound propagation velocity due to atmospheric variability. One source is wind shear, the progressive increase in wind speed above ground and which occurs frequently. From *Mechanical Radiation* (Ref. 11 *sic*):

> Its practical importance in sound propagation in a windy atmosphere is obvious: **elevated sound sources are decidedly advantageous in transmitting to windward.**

(emphasis added)

A graphical depiction is shown below, Fig 7-30 from *Wind Turbine Acoustics*, (NASA, Ref. 13). This example is for wind propagated through a wind farm grid of low power wind turbines (100 KW, 31 generators/row, 5 rows). Note the very long sound propagation distance of about 8,500 ft at 40 dB. The much larger Dutch Hill project has several rough linear and row clusters which will similarly act together and create a similar propagation field. In downwind conditions it is reasonable to expect that certain regions would experience noise levels far in excess of Hessler’s primitive Cadna/A predictions. Hessler claims to show wind-blown propagation effects on their Plot 1 (Ref. 1 *sic*) but these are not due to refraction and do not show anything resembling the expected multi-turbine propagation effect of the NASA analysis. See Fig. 9 below, an enlarged section of Plot 1, which purports to show omni-directional propagation for light winds, but obviously understates the true impact.

Another refraction is from temperature effects. Sound speed changes with temperature and there is usually a temperature gradient above earth, sometimes inverted by radiation cooling. The complex interaction of these refractive effects with the wind gradient effect may cause a tunneling or cylindrical “focusing” of the sound at great distances from the turbine. By studying historical meteorological data and through local interviews a predictive model can be constructed to reasonably predict the frequency occurrence and propagation distances with some statistical confidence.

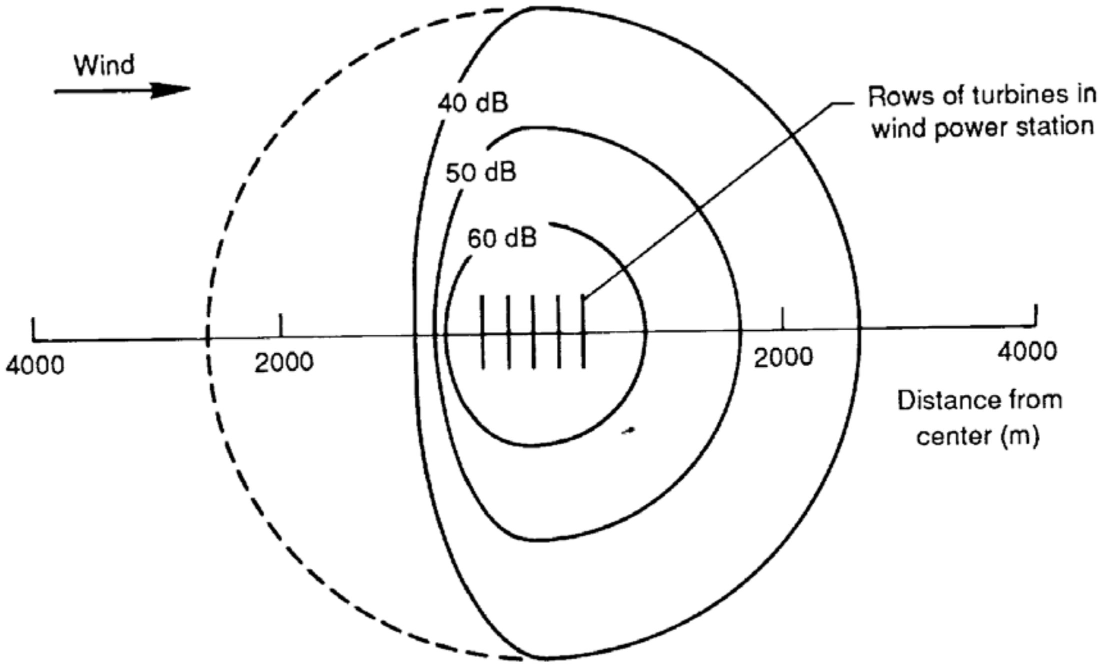


Figure 7-30. Calculated contours of sound pressure level around a five-row example array for the one-third-octave band at 1000 Hz (α = 0.54 dB/100 m) [Shepherd and Hubbard 1986]

A comprehensive theoretical study "Modeling of Noise from Wind Turbines" was done by W. J. Zhu in 2004, (Ref. 13). This study includes some refraction and reflection effects due to hilly terrain. It shows conclusively the danger of not including refractive/reflective effects in models. Zhu uses simple assumptions for sound propagating from a turbine down into a valley under different conditions and finds a 6 dB increase in noise is predicted for many frequencies, see Fig. 10 below.

In at least one study, "Environmental Noise Assessment Pubnico Point Wind Farm" (Ref. 14) software that accounts for wind gradient propagation confirmed this increase.

> The results of the assessment, using the predictive mathematics of ISO 9613-2, suggest a sound level of 49 dBA would be expected at the d'Entremont residence based on a sound power level determined at a wind speed of about 9 m/s.

The original Pubnico Point noise prediction was also made using Cadna/A and was predicted to be 49 dBA. However using a different software model that included the prediction of downwind effects the noise prediction increased 6 dBA, or a doubling of perceived sound! This was confirmed in the field measurements:

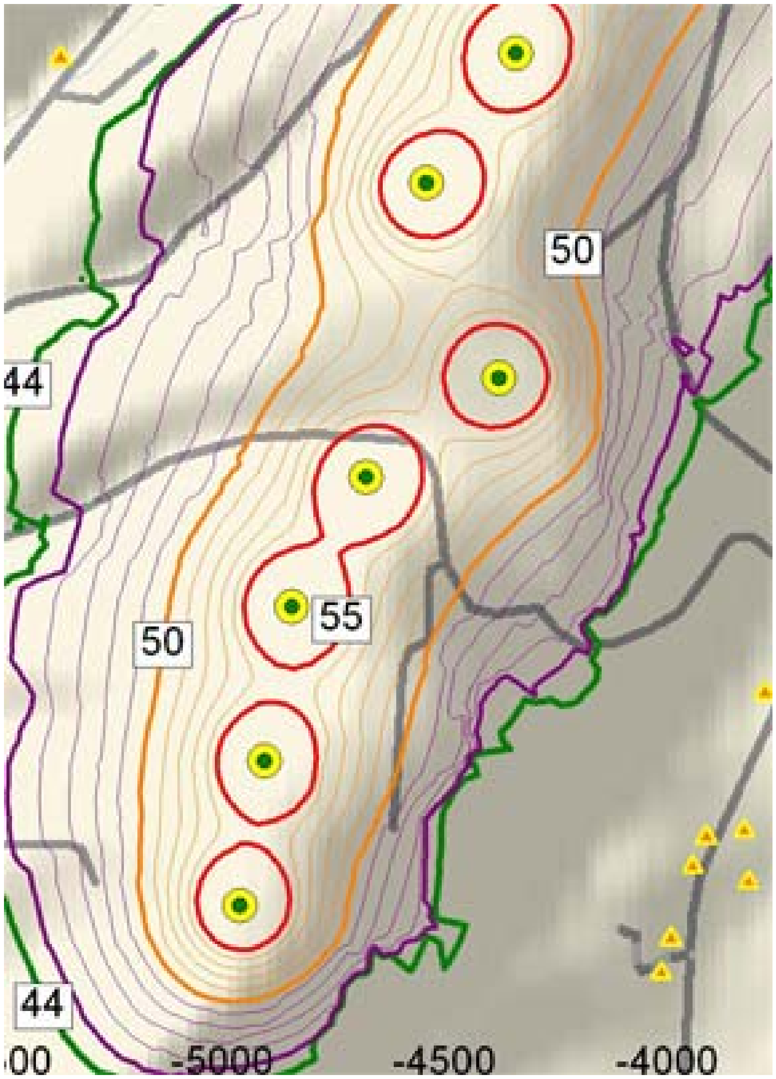


Fig. 9: Enlarged View of Plot 1, Hessler Predicted Noise Contours with Low Omnidirectional Wind

> …effects of wind and atmospheric conditions using the methods of the CONCAWE6 noise assessment protocol was thus undertaken. **This protocol allows for predictions under specific wind speeds or atmospheric conditions. The predictions indicate that the predicted 49 dBA level could be as high as 54 dBA** at the d'Entremont residence when winds (including winds as light as 5 m/s) are from the south, or as low as 42 dBA with winds from the north. This is consistent with the automatic sound level monitor results, and demonstrates that even with an impact that is acceptable under Interpretation, there can be periods and conditions when the sound level impact is higher.

(emphasis added)
Ref. 14, *sic*

Even for this brief Pubnico study period of 5 days, it was noted that other atmospheric effects can result in a nearly 400% increase in sound perception beyond predictions. These will be discussed further in section 4.4:

However, under certain wind and atmospheric conditions when background sound would be expected to be low, **the measured sound levels were found to exceed the criteria and expected background sound by up to 13 dB**.

(emphasis added)

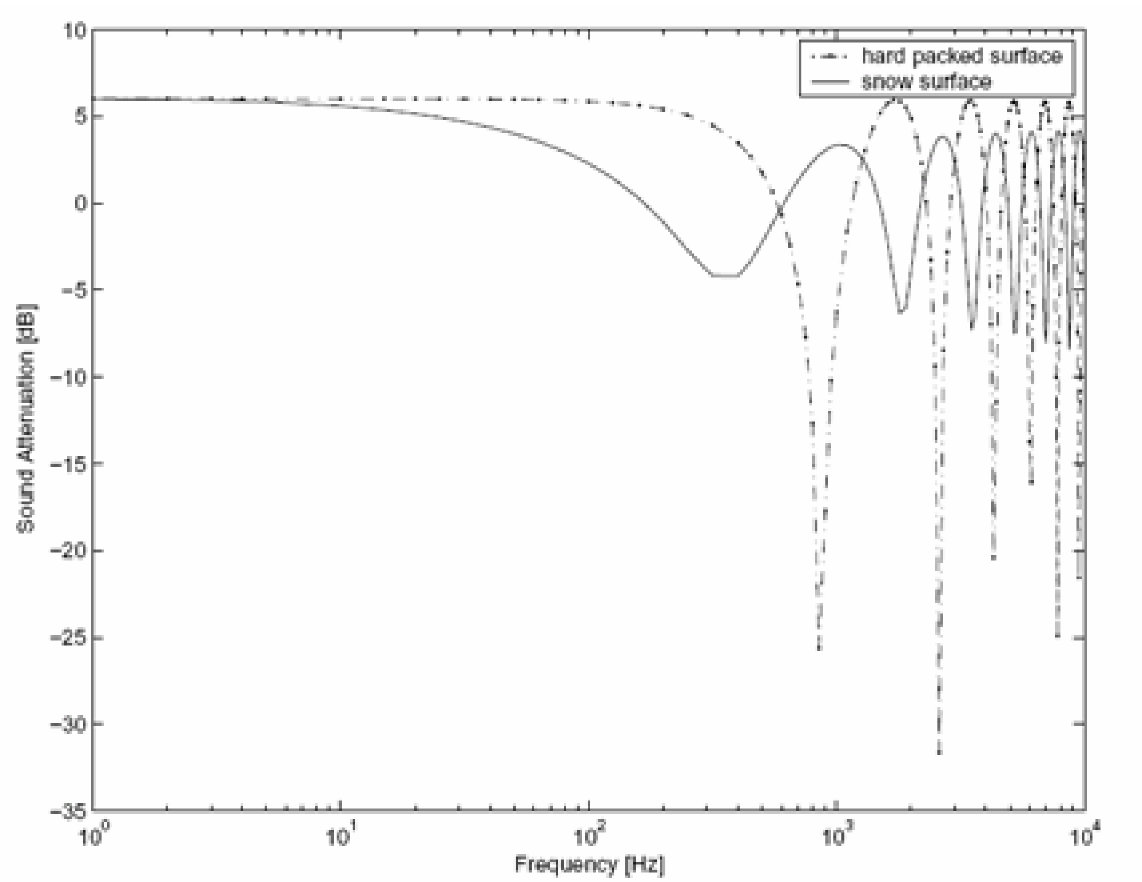


Fig. 10: Predicted Sound Absorption With Refraction and Terrain (Zhu *sic*, Ref. 13)

Hessler uses the conventional "-6 dBA/distance doubling" noise attenuation factor for computing propagation distances. This is the expected geometrical result due to simple spherical spreading of the sound. It is the same attenuation result that would be obtained for other sources of spherical radiation such as for a light bulb. However it has been shown that when atmospheric refractive ("focusing") effects are present that the sound attenuation is only about 3 dBA/doubling. See van den Berg (Ref. 9 *sic*) , and NASA (Ref. 12 *sic*). Hence the sound propagates much further before significant attenuation.

3.0 Associated Noise Studies from other Regions and Agencies

In the study of complex phenomena or in the manufacture of electrically operated equipment it is common for analysts and manufacturers to use information, studies and standards developed in other countries as a guide. The beneficial sharing builds the knowledge base, prevents undesirable effects and enhances public comfort and safety.

For example with consumer electrical equipment it will often bear a Underwriter's Laboratory (UL) label certification of design and manufacturing safety for U.S. products and also a Canadian Standard's Association (CSA) certification for products sold in Canada since the electrical supply is identical, though the safety measurements and standards are slightly different.

Likewise for wind turbine noise, the noise emanations are similar, turbines are manufactured internationally, and noise measurement methods and reporting units are identical. It is therefore useful to assess other analyses to survey their conclusions, rationale and compare these to the Hessler analysis.

Several other reports identify rural, country ambient sounds as about 30 dBA, or frequently quieter, and that quieter noise levels in the 30 dBA range should be used as opposed to urban environments that frequently allow 50 dBA limits. For example, wind turbines in Europe are more widely established and noise studies there indicate that in terrain similar to many areas of the Dutch Hill Wind Power Project site low noise backgrounds are to be expected. The wind turbines noises are therefore much more objectionable, and that setbacks up to 1 mile, or more, are needed.

3.1 Federal EPA Noise Study

Early in the EPA's founding, circa 1971, it conducted a comprehensive analysis of noise pollution (Ref. 15). Modern urbanization has significantly increased noise pollution in urban areas due to the post-WW II presence of passenger jets and the proliferation of expressways and automobiles. This study includes a variety of sound assessment methods, measurements of noises, receptor acceptance levels and statistical analysis of data. Today the EPA findings are the general underpinning of the NYS DEC's Noise Policy.

From the EPA study, pertinent to wind farm siting in New York's rural areas:

> 3.1 Variation of Outdoor Noise Environment with Location
>
> The range of daytime outdoor noise levels at the 18 locations is presented in Figure 7. The locations are listed from top to bottom of the figure in descending order of their daytime residual noise levels (Lg0). The noisiest location which is outside of a 3rd floor apartment overlooking an 8-lane freeway is at the top of the list with its daytime residual noise level of 77 dB(A). **The rural farm is next to the bottom of the list with its daytime residual noise level of 33 dB(A)**. This difference of 44 dB in the residual noise levels of these two locations constitutes a large range in noise climate. Its magnitude clearly implies that all citizens do not enjoy the same "quality" in their noise environment. In fact, the owner of the 3rd floor apartment near the freeway has trouble keeping the apartment rented for more than a month to any one tenant. His problem is not surprising since the outdoor noise level is sufficiently high to render normal speech communication difficult indoors even when the windows are closed.

(emphasis added)

From the EPA daytime noise graph below (their Fig. 7) we see clearly that a daytime "farm in valley" noise level is less than 40 dBA, half the time. At night, from the EPA's Fig 9 table the "farm in valley" is now quieter than 33 dBA half the night and is only above 36 dBA for 10% of the night. The details of the “farm in valley” location are not explicit and it is unknown how closely this site may mimic a Cohocton Wind Power Project site. Perhaps parts of the siting area are even quieter at certain times (winter?), like the “Grand Canyon (North Rim)” location, showing a mean of 20 dBA?

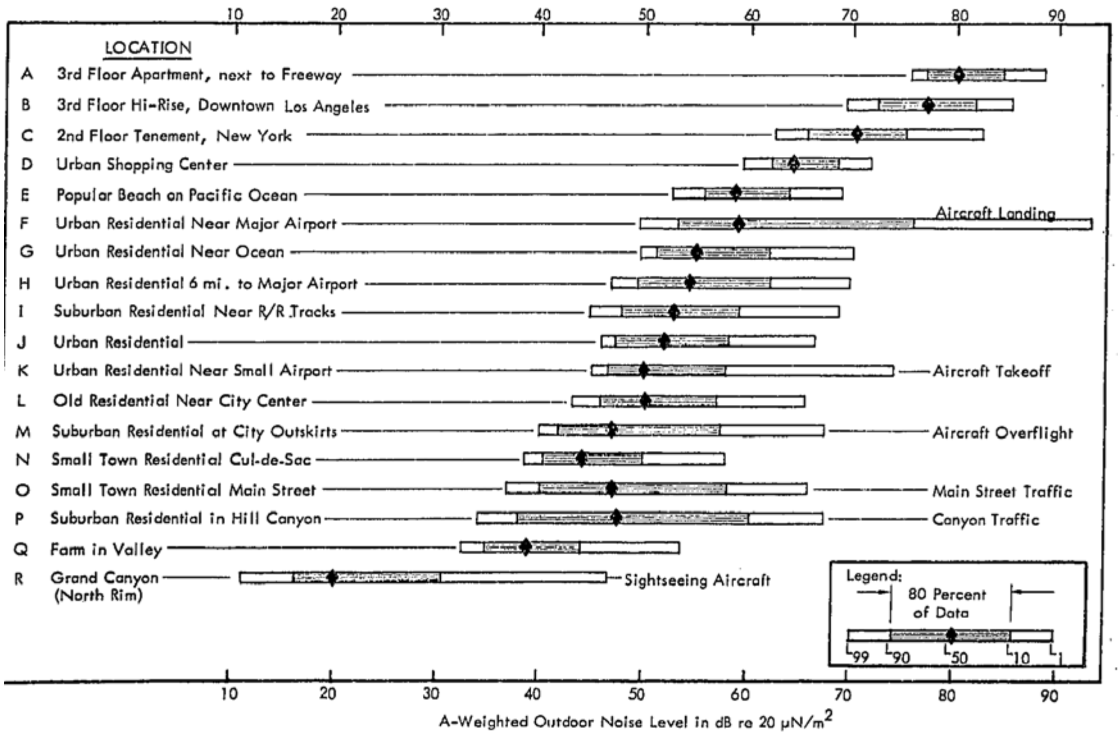


Fig. 7 of EPA Report, Daytime Noise Measurements

3.2 Canadian Requirements

The Ontario Canada Ministry of the Environment has evaluated noise requirement for siting of wind turbines in Ontario Canada (Ref. 17). They publish a graph for various environments with a weighted increase for increasing winds. See Fig. 11 below. The project sponsor identifies predicted noise emissions at a location and compares it with the values in the graph to flag nonconformance. For rural settings the noise limit is 40 dBA over a range of turbine speeds rising to 52 dBA only in higher winds.

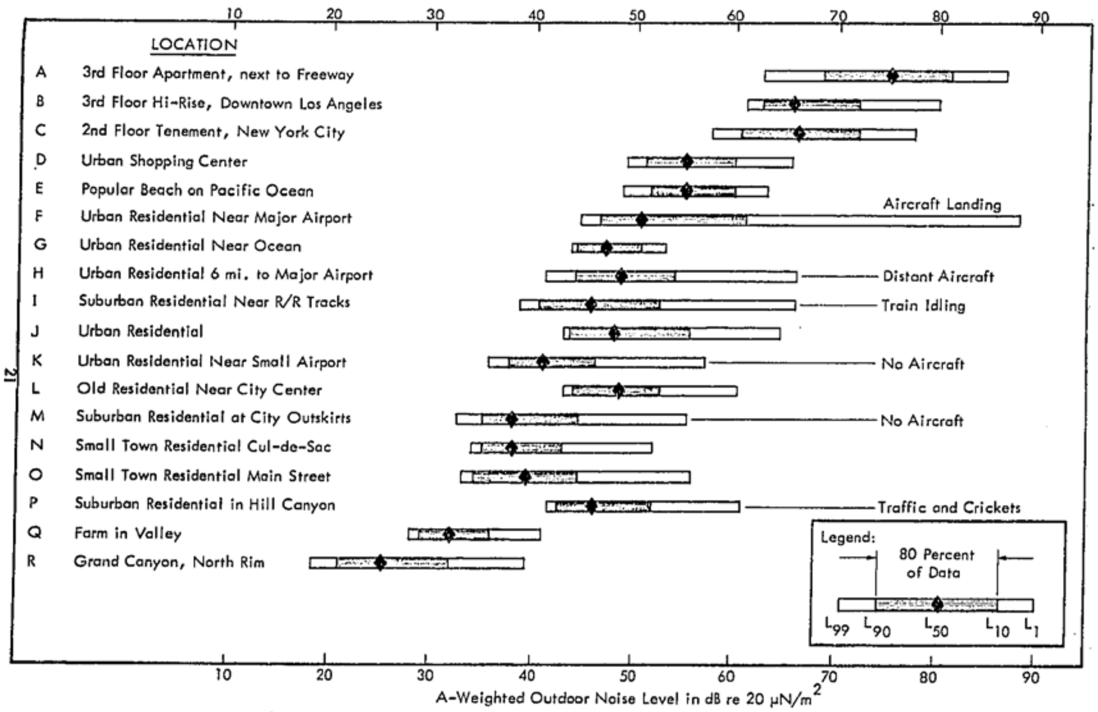
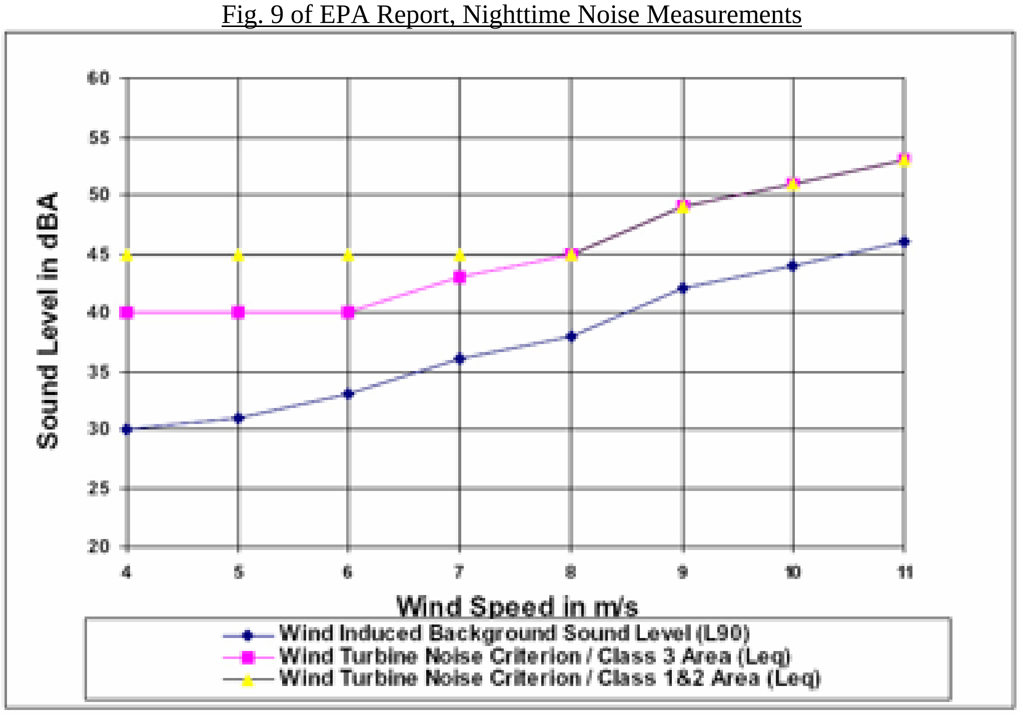


Figure 9. Nighttime Outdoor Noise Levels Found in 18 Locations Ranging Between the Wilderness and the Downtown City, with Significant Intruding Sources Noted. Data are Arithmetic Averages of the 9 Hourly Values in the Nighttime Period (10:00 p.m. - 7:00 a.m.) of the Levels Which are Exceeded 99, 90, 50, 10 and 1 Percent of the Time

<u>Fig. 9 of EPA Report, Nighttime Noise Measurements</u>



"Class 3 Area" means a rural area with an acoustical environment that is dominated by natural sounds having little or no road traffic, such as the following:

i. a small community with less than 1000 population;
ii. agricultural area;
iii. a rural recreational area such as a cottage or a resort area; or a wilderness area.

<u>Fig. 11: Ontario Canada Turbine Noise Acceptance Chart</u>

3.3 United Kingdom

The UK Noise Association has extensively studied turbine noise issues. From *Location, Location, Location, An investigation into wind farms and noise by the Noise Association,* by John Stewart (Ref. 18):

> Wind Farm Noise – the impact on areas of low background noise:
> Mid Wales -a land of hills and valleys. A place where the wind blows frequently and the population tends to be thinly spread. Ideal for wind farms. And, not surprisingly, many are planned. **The best place very often for the turbines to catch the wind is close to the top of a hill**. It means that the wind turbines can be at their most productive. But it also means that the **noise may cascade down the surrounding valleys**. To makes matters worse, many of the scattered hamlets within the valleys snuggle into corners protected by the hills and the mountains where the background noise level is very low indeed. **You only need to visit these areas to hear the 'swish, swish, swish' of the turbines – particularly downwind – over a mile away from the wind farm.**
>
> (emphasis added)

The description of Mid Wales above describes parts of scenic Atlanta. The prevailing (urban) UK national guidelines for noise limits are (from Stewart)

> • Daytime noise levels outside the properties nearest the turbines should not exceed 35-40 dB(A) or 5dB(A) above the prevailing background, whichever is the greater.
> • Night noise limits outside the nearest property should not exceed 43 dB(A) or 5dB(A) above the prevailing background, whichever is the greater.

But in areas like Mid Wales, the guidelines are deemed by the UK Noise Association to give noise levels **too high**. Likewise, a lower noise threshold limit, in the 35 dBA range is to be anticipated for the Dutch Hill project.

Further corroboration pertaining to Scotland siting comes from Dick Bowdler, "a noise and acoustic consultant for more than 30 years and most of my current work is dealing with the assessment of environmental noise as it affects residential properties. I work equally for those potentially creating noise and those affected by it. I have been a supporter of wind energy and other forms of renewable energy for some 35 years." (Ref. 18) Continuing, he says:

> In practice, in most rural areas, my rule of thumb is that **the nearest turbine needs to be at least 1¼ miles from any house**. However, these are areas where the background noise level can be 20 dBA at night. You suggest that **your background noise level could be 30-32dB. This seems a likely figure if you have 350 houses in the area**, though I suspect it could be a bit lower than this. On this basis, noise from the wind farm should not exceed 35dBA. **If the developers are suggesting that 55 decibels is acceptable, this is quite outrageous.** 55dBA is more than four times as loud as your background noise.
>
> Most of the Scottish wind farms that have recently been approved have no housing closer than about 1 mile, except where the house belongs to the landowner of the wind farm site. There are a few applications with houses as close as about 2000 feet but these have all either been turned down or withdrawn by the developer.
>
> I am not familiar with the GE turbines, but I suspect that they have a sound power level of about 105dBA. In this case, the noise level would be between 45 and 50 dBA at 1400 feet in neutral weather conditions and if the nearest turbines were in full view.
>
> (emphasis added)

3.4 Sweden

The Swedish Environmental Protection Agency (SEPA) published a report "Noise Annoyance from Wind Turbines – a review" (Ref. 19). This report "reviews the present knowledge on perception and annoyance of noise from wind turbines in residential areas as well as in recreational areas."

The study relates information useful for two criteria: perception and objection.
Each receptor location, turbine location, vegetation and terrain may have a marked impact on turbine noise perception. This is particularly important in geographies having many undulating hills. From the study:

> Topographical conditions at site have importance for the degrees to which the noises from wind turbines are masked by the wind. **Dwellings that are positioned within deep valleys or are sheltered from the wind in other ways may be exposed to low levels of background noise, even though the wind is strong at the position of the wind turbine** [Hayes 1996]. The noise from the turbine may on these conditions be perceived at lower sound pressure levels then expected. Current recommendation state that measures and sound propagation calculations should be based on a wind speed of 8 m/s at 10 meter above the ground, down wind conditions, creating a "worst case" scenario.

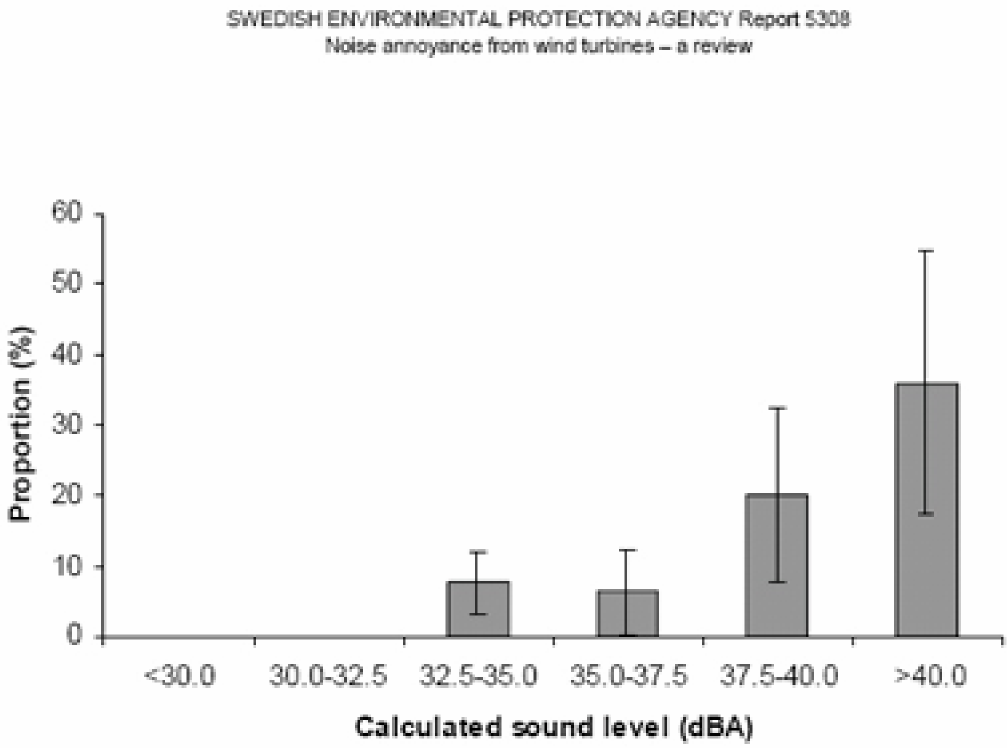
(Emphasis added)

Also this study categorized the objection to noise by a well composed, statistically valid survey of a variety of residents near a moderate-power (600 KW/unit) wind turbine installation. The study setup parameters are given below, followed by Fig. 12, a "chart of annoyance" from the report summarizing the results.

> The Swedish study was performed in Laholm during May-June 2000. The areas chosen comprised in total 16 wind turbines thereof 14 had a power of 600 kW. The study base comprised one randomly selected subject between the ages of 18 and 75 in each household living within a calculated wind turbine sound pressure level of 25 to 40 dBA (n=518).
> The annoyance was measured using a questionnaire. The purpose of the study was masked and among questions on living conditions in the countryside, questions directly related to wind turbines were included. Annoyance from several outdoor sources was asked for regarding the degree of annoyance both outdoor and indoor. Annoyance was measured with a 5-graded verbal scale ranging from "do not notice" to "very annoyed". The same scale was used for measuring annoyance from wind turbines specifically (noise, shadows, reflections, changed view and psycho-acoustical characters). The respondents' attitude of the impact of wind turbines on the landscape scenery and the attitude to wind power in general were also measured with a 5-graded verbal scale, ranging from "very positive" to "very negative". Questions regarding living conditions, health, sensitivity to noise and employment were also included. A total of 356 respondents answered the questionnaire, which gave a total response-rate of 69%.
> For each respondent calculated A-weighted sound pressure level as well as distance and direction to the nearest wind turbine were obtained. Sound pressure levels (dBA) were calculated at 2.5-decibel intervals for each household. The calculations were done in accordance with [Naturvårdsveket 2001] and reflect downwind conditions. Data of distance between the dwelling of the respondent and the nearest wind turbine, as well as the direction, was obtained from maps.
> The correlation between noise annoyance from wind turbines and sound pressure level was statistically significant (rs=0.399; n=341; p<0.001). **The annoyance increased with increasing sound pressure level at sound pressure levels exceeding 35 dBA**. No respondent stated them selves very annoyed at sound pressure levels below 32.5 dBA (Fig. 1). **At sound pressure**

levels in the range of 37.5 to 40.0 dBA, 20% were very annoyed and above 40 dBA 36%. The confidence intervals were though wide; see Figure 1.

(emphasis added)
Noise Annoyance from Wind Turbines – a review (Ref. 19, *sic*)



The proportions very annoyed by noise outdoors from wind turbines (95%CI) at different A-weighted sound pressure levels [Pedersen and Persson Waye 2002].

Fig. 12: Chart of Very Annoyed Respondents

Note that about 40% of the participants find turbine sounds above 40 dBA “very objectionable”. Even 32.5-35 dBA are “very objectionable” to 10 % of respondents. This study should serve as a direct warning that residents will strongly object to the Dutch Hill Wind Power Project, if sited as planned. After turbine farms are operational, with finality and permanence, resident “receptors” will have no recourse for any mitigation other than to physically move away. What price will they receive for their real estate when prospective buyers find that the seller is moving because they can’t stand the noise?

Also of interest from the Swedish EPA study are comments relating to wilderness areas pertaining to much of the Cohocton project area:

“3.3 Perception of noise from wind turbines in wilderness recreational areas

The special soundscape of wilderness recreational areas has been described by a number of authors, e.g. [Miller 2001, Dickinson 2002]. **The soundscape differs from site to site and can be very quiet in remote areas, especially when vegetation is sparse** (as in the Swedish bare

> mountain region). In a comparison between different outdoor settings in USA, it was found that the sound pressure level in a suburban area at nighttime was above 40 **dBA**, along a river in Grand Canyon 30-40 dBA and **at a remote trail in the same park 10-20 dBA** [Miller, 2002]. **The effect of intruding sound should be judged in relation to the natural ambient soundscape. The sound pressure level of the intruding sound must be compared to the sound pressure levels of the background noise**. The durability of audibility is another variable of importance for understanding visitors' reactions to noise [Miller 2001].
>
> No studies on noise from wind turbines in wilderness areas have to my knowledge been carried out, but the effect of noise from other sources has been discussed in a few articles. A larger study on noise annoyance from aircraft over-flights on wilderness recreationists was performed in three wilderness areas in USA [Fidell et al 1996].

(emphasis added)
Noise Annoyance from Wind Turbines – a review (Ref. 19, *sic*)

There is an additional noise component to wind turbine noise not generally studied but possibly very important, a definite noise modulation effect:

> When listening to a wind turbine, **one may distinguish broadband noise and a beating noise**. Broadband noise is characterized by a continuous distribution of sound pressure. **The beating noise is amplitude modulated, i.e. the sound pressure level rises and falls with time.** This noise is of interest for this review, **as it seems to be more annoying than a non-modulated noise at the same sound pressure level**. Only a few studies have however explicitly compared noises with and without modulations.
> ..
> Modulated noise from wind turbines has the beat of the rotor blades' pace. The amplitude modulation has in experimental studies found to be most apparent in the 1 and 2 kHz octave band with amplitude of ± 2-3 dB [Dunbabin 1996]. Theories have been put forward regarding the source and extent of the amplitude modulation. One possible mechanism is the interaction of the blade with disturbed airflow around the tower, another the directionality of radiation from the blades as they rotate. Finally it is possible that variation in noise levels occur due to the atmospheric wind profile, which would result in a slight variation in angel of attack as the blade rotates [Dunbabin 1996]. In summery**, the modulation in the noise from wind turbines is not yet fully explained** and will probably not be reduced in the near future **and is therefore a factor of importance when discussing noise annoyance from wind turbines**.
> ….
> The new turbines erected today often have variable rotor speed. This means that the modulation frequency will be low at low wind speed, typically **0.5 Hz** at 4 m/s and higher at high wind speed, typically **1.0 Hz** at 20 m/s. This is still in the span were **modulations could easily be detected**.

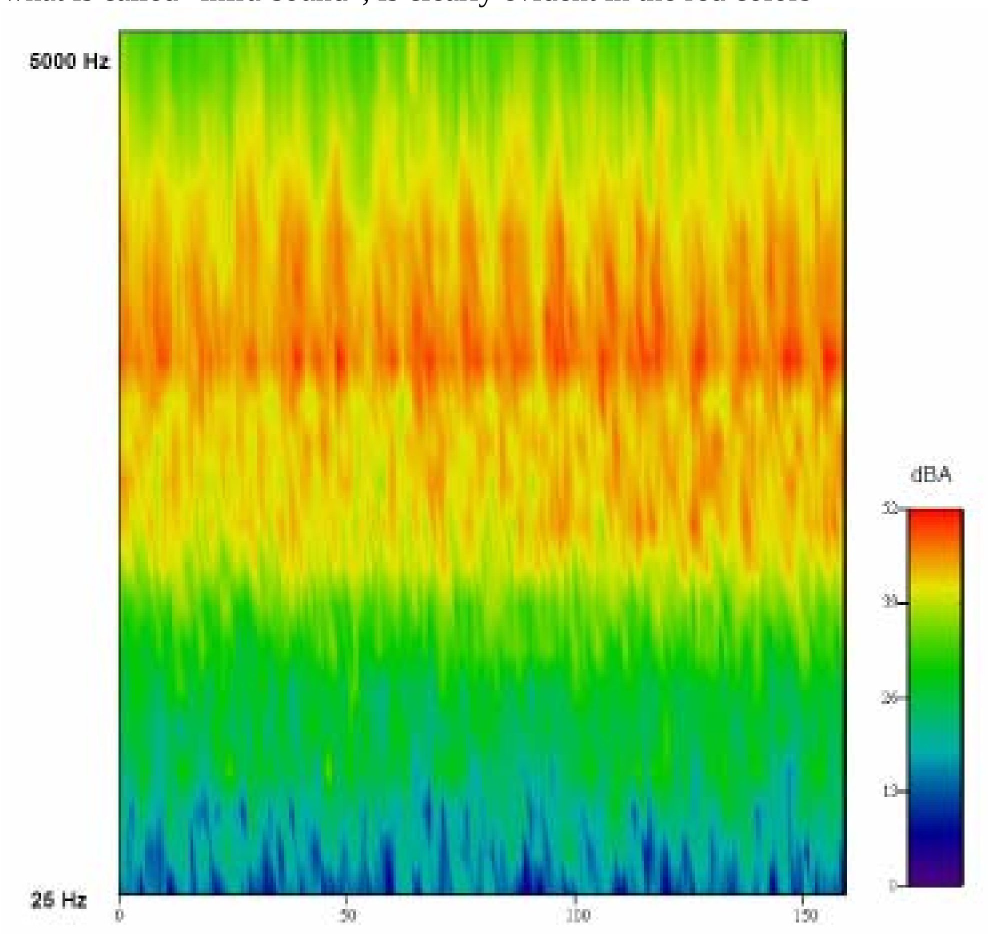
(emphasis added)
Noise Annoyance from Wind Turbines – a review (Ref. 19, *sic*)

Modulation has been recorded at the Pubnico Point Wind Farm (Ref. 14, *sic*). The farm is composed of 17 generators of 1.8 MW capacity (Vestas) arranged in a grid pattern. The generators operate at 16 rpm across their operating range. The three blades therefore give 48 pressure pulses (due to passage by the tower support) or 0.8 Hz, within the human modulation response range. This modulation will propagate long distances and there may be cumulative out-of-phase frequency multiplication across the farm 0.8 Hz x 17 = 13.6 Hz. If some blades operate synchronously the amplitude will give approximately a 4x boost to the sound pressure level. The impulses were detected in the Pubnico study at a strong modulation level of 5 dB (roughly a 2x loudness perception modulation) indicating the possible presence of these coherence effects.

> The three-bladed wind turbines, rotating at about 16 rpm, have a blade pass frequency of about 0.8 Hz. Thus, over 20 seconds, about 16 ‘swoosh’ sounds would be expected, and can be seen in Figure 4a. The influence of the ‘swoosh’ is clearest at midband frequencies, centered at about 1000 Hz, where the amplitude modulates by about 5 dB.

(Ref. 14, *sic*)

The Fig. 4a referred to is a 2-D sound spectrum showing the modulation graphically and is shown below as Fig. 13. Time is on the horizontal axis and sound frequency on the vertical axis. The colors represent the loudness intensity. The “swish” modulation, which is <u>not</u> what is called “infra-sound”, is clearly evident in the red colors



<u>Fig. 13: Sample Spectrum of Noise Modulation (Pubnico Point, *sic*)</u>

Strong modulation due to coherence has been noted in at least one other comprehensive study done near a German-Dutch wind farm:

> A second effect that adds to the sound annoyance is that **the sound has an impulsive character**. The primary factor for this is the well known swishing sound caused by the pressure fluctuation when a wing passes the turbine mast. For a single turbine these 1 – 2 dB broad band sound pressure fluctuations would not classify as impulsive. When several

turbines operate nearly synchronously the pulses however may occur in phase: two equal pulses give a doubling in pulse height (+3 dB), three a tripling (+5 dB).

(emphasis added)

Wind turbines at night: acoustical practice and sound research (Ref. 9, *sic*)

A follow-up discussion of the Swedish study is in *Perception and annoyance due to wind turbine noise—a dose–response relationship* by Pedersen and Waye, published in 2004 (Ref. 20):

Already, turbines are being erected near densely populated areas. Preliminary interviews conducted among 12 respondents living within 800 m of a wind turbine, and a register study of the nature of complaints to local health and environments authorities, indicated that **the main disturbances from wind turbines were due to noise, shadows, reflections from rotor blades, and spoiled views**.

Furthermore, **noise from wind turbines comprises modulations with a frequency that corresponds to the blade passage frequency** ~Hubbard *et al.*, 1983! **and is usually poorly masked by ambient noise in rural areas** ~Arlinger and Gustafsson, 1988!.

The aims of this study were to evaluate the prevalence of annoyance due to wind turbine noise and to study dose–response relationships. The intention was also to look at interrelationships between noise annoyance and sound characteristics, as well as the influence of subjective variables such
as attitude and noise sensitivity.

(emphasis added)

As noted this was a moderate-impact study in comparison to the farm proposed for the Dutch Hill project. The Swedish turbines are a modest 600-660 kw so the overall individual turbine noise level is lower and the combinational increases have a lower effect on receptors. The study is relevant nevertheless because it focuses specifically on community reaction to wind farms.

Five areas totaling 22 km^2 comprising in total 16 wind turbines and 627 households were chosen within a total area of 30 km^2 (Table I) Subjective responses were obtained through questionnaires delivered at each household and collected a week later in May and June 2000. The response rate was 68.4%. A-weighted SPL's due to wind turbines were calculated for each respondent's dwelling. Comparisons were made of the extent of annoyance between respondents living at different A-weighted SPL's.

Most people live in privately owned detached houses in the countryside or in small villages. The wind turbines are visible from many directions.

The report concludes that there is a <u>much</u> higher annoyance with wind turbines than that associated with other forms of noise such as from aircraft, road traffic or railways (See graph, Fig. 14). The onset of annoyance begins a SPL of 32 dBA sharply increasing to 35% of respondents at 41 dBA. A noise level of 50 dBA as proposed by Cohocton local law would clearly be outrageous to many residents. In trying to explain the differences Pedersen says:

For wind turbine noise **the main annoyance reaction is formed when spending time outdoors.**

(emphasis added)

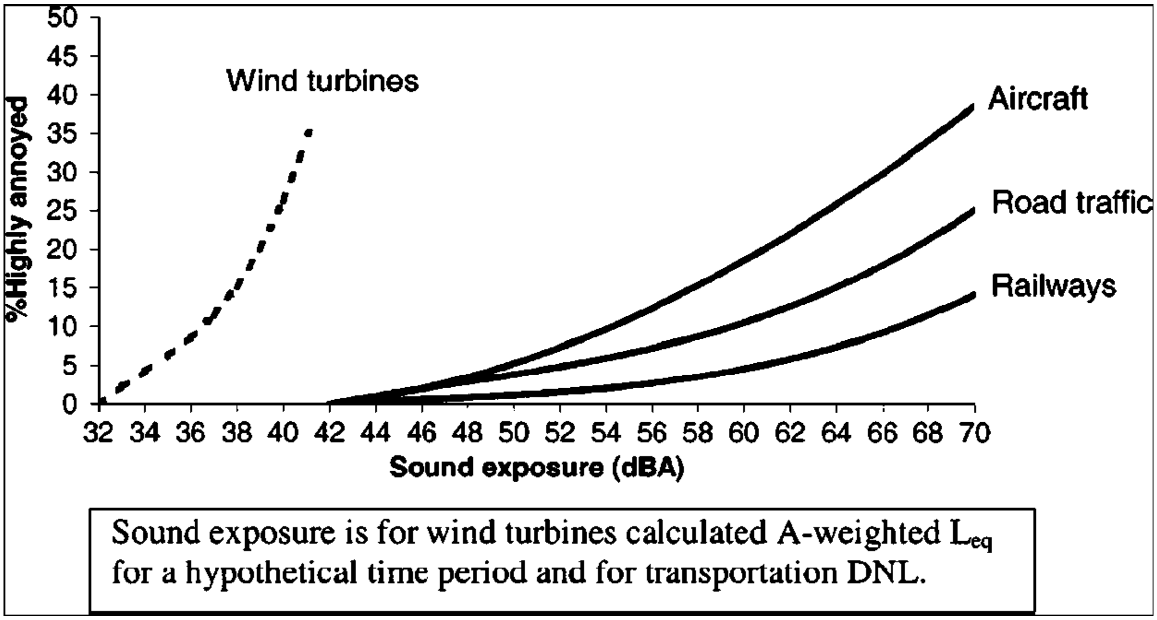


Fig. 14 : High Annoyance from Wind Turbines (Pederson 2004, Ref. 20)

Also:

> Another factor that could be of importance for explaining the seemingly different dose–response relationships is that **the wind turbine study was performed in a rural environment, where a low background level allows perception of noise sources even if the A-weighted SPL are low**. Wind turbine **noise was perceived by about 85% of the respondents even when the calculated A-weighted SPL were as low as 35.0–37.5 dB.** This **could be due to the presence of amplitude modulation in the noise, making it easy to detect and difficult to mask by ambient noise**. This is also confirmed by the fact that the aerodynamic sounds were perceived at a longer distance than machinery noise.

(emphasis added)

There may be a combinatorial effect associated with blade flicker and/or aesthetic degradation:

> Data obtained in this study also suggest that visual and/or aesthetic interference influenced noise annoyance.

Pressure waves created by the blades as they pass by the support tower propagate long distances and are a modulation of sound intensity, not a "noise" *per se* but a loudness variance. This is apparently the main objection to wind turbine "noise":

> The high prevalence of noise annoyance could also be due to the intrusive characteristics of the aerodynamic sound. The verbal descriptors of sound characteristics related to the aerodynamic sounds of swishing, whistling, pulsating/throbbing, and resounding were—in agreement with this hypothesis—**also reported to be most annoying.**

(emphasis added)

3.5 Australia

The Australian findings and requirements mimic those around the world and are much lower than Hessler's conclusions. From *Environmental Noise Guidelines: Wind Farms* (Ref. 21):

> The impact of a given noise is also closely linked to the amount it exceeds the background noise. For example, **the same noise in a quiet rural area will generally have a greater adverse impact than in a busy urban area because of the masking effect of high ambient noise environments.** If the noise generated does not exceed the background noise by more than 5 dB(A) the impact will be marginal and acceptable.
>
> 2.2 Noise criteria - new wind farm development
> The predicted equivalent noise level (LAeq,10), adjusted for tonality in accordance with these guidelines, **should not exceed 35 dB(A),** or the background noise (LA90,10) by more than 5 dB(A) whichever is the greater, at all relevant receivers for each integer wind speed from cut-in to rated power of the WTG.
>
> The background noise should be as determined by the data collection and regression analysis procedure recommended under these guidelines (Section 3). It should be read from the resultant graph at the relevant integer wind speed.

(emphasis added)

3.6 NASA

Noises carry greater distances from elevated noise sources like wind turbines and this has been reported by NASA in a study *Wind Turbine Acoustic* by Hubbard and Shepherd (Ref. 12, *sic*) From the Introduction:

> Wind turbine generators… are producing electricity both singly and in wind power stations that encompass hundreds of machines. Many installations are in uninhabited areas far from established residences, and therefore there are no apparent environmental impacts in terms of noise. There is, however, **the potential for situations in which the radiated noise can be heard by residents of adjacent neighborhoods, particularly those neighborhoods with low ambient noise levels**. …

(emphasis added)

This report contains detailed noise analyses of various wind turbine styles – upwind rotors vs. downwind rotors, blade shape, rotational speed etc. And it includes a detailed sound propagation analysis. Sound "bends" (refracts) in the atmosphere much like light refracts in striking a lens. A graph of the effect, from the report, is shown in Fig. 15 below.

The "Shadow" zone in the figure may explain the observed "quietness" experienced by observers when taken to stand near wind farm turbines such as the Fenner, NY wind farm. The noises are masked unless the observer is 2-4x the tower height distance. And it underscores the necessity of comprehensive and accurate engineering studies of complex phenomena. Merely relying on anecdotal "I don't hear anything" knee jerk responses to a turbine visit is misleading and hardly equivalent to living year round as a saturated "receptor".

Recall from the Mid Wales description above that turbine sounds carry one mile. The sounds carry further for a “line” of turbines and many wind farms are arranged in linear and row clusters. As mentioned earlier this situation sounds diminish at about ½ the normal rate assumed for spherical spreading, or -3 dB/doubling of distance rather than -6 dB/doubling and this is discussed as well in the NASA report.

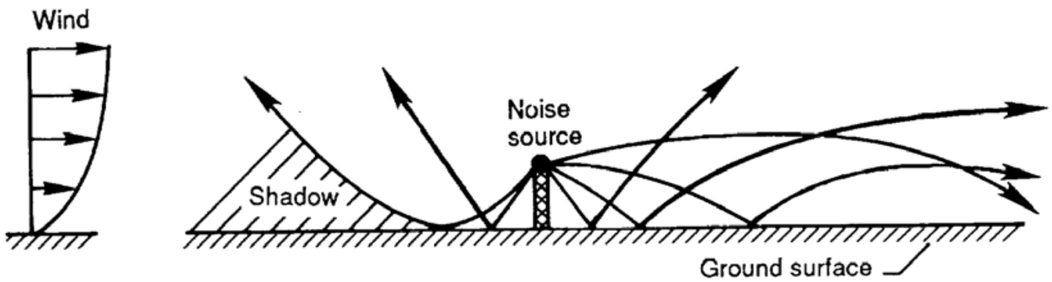


Figure 7-20. Effects of wind-induced refraction on acoustic rays radiating from an elevated point source [Shepherd and Hubbard 1985]

Fig. 15: Sound Refraction Effects (NASA Fig 7-20)

3.7 W.H.O. Sound Levels for Night Sleeping

The World Health Organization (Ref. 22) has begun conducting comprehensive analysis of the health impairment due to night time noises and disturbance to sleep. Though targeting the effects from aircraft and highway noises the conclusions can be associated with wind turbines since those studies are as yet not started.

The WHO’s actual conclusions should serve as a guide and warning, that sleep disturbance is not merely an annoyance and an ‘anti-wind turbine’ sentiment, but a genuine health hazard.

> Conclusions:
> 8. **There was unanimous agreement that disturbed sleep had serious health** effects – solidevidence existed in sleep medicine, the insomnia model would be used as a proxy and itscauses and effects described on the final document.
> 9. The analysis of the evidence suggested **that Lnight outdoor>42 dB(A) induced sleep disturbances.**
> 18. The NOAEL for Myocardial Infarction was Lday = 60–65 dB outdoors **and Lnight outdoors = 50 – 55 dB** for road traffic**.** [2] (emphasis added)

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[2] As the report discusses there is an association between long term noise exposure and heart attack (myocardial infrarction or MI):

> **Sufficient evidence existed for an association between community noise and ischaemic heart diseases;** limited/sufficient evidence existed for an association between community noise and hypertension. Most information came from road traffic noise studies but there was normally little information regarding night noise in particular. But **night time values could be extrapolated from day time results.** **(footnote cont next p)**

4.0 Conclusion

New York's SEQR laws require a thorough analysis of environmental impacts of large projects, including construction noises. Mitigation measures are to be imposed if feasible, or the project revised to eliminate environmental pollution as much as possible.

An accurate and comprehensive noise analysis is crucial for delineating turbine setbacks to mitigate noise pollution. But clearly the Hessler study is critically flawed. The study must be repeated with far better analysis in terms of a) reasonably accurate background levels and a valid sampling methodology b) inclusion of non-vegetated measurements and c) reasonable computer modeling to show noise contours accounting for likely atmospheric and modulation effects.

These requirements must be satisfied to conform to the noise policy and SEQR rules:

> In circumstances where noise effects cannot readily be reduced to a level of no significance by project design or operational features in the application, the applicant **must evaluate alternatives and mitigation measures in an environmental impact statement to avoid or reduce impacts to the maximum extent practicable** per the requirements of the State Environmental Quality Review Act.

The Hessler report itself identifies some 60 or more homes that likely will be exposed to noise disturbance due to the wind farm. Many sites may be found to be unsuitable for use due to unacceptably high noise intrusion that will <u>require</u> higher setbacks, with 1 mile an expected outcome from a genuine study. Mitigation suggestions from the DEC Noise Policy do include "increasing the setback distance" and residents have a right not to be subjected to adverse noise pollution. It is entirely likely that other turbine locations must be sought, or the scale of the wind farm must be reduced.

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Richard H. Bolton , CV in Appendix 1

> Below 60 dB(A) for Lday there was no noticeable increase in MI risk to be detected. Therefore for the time-being, Lday = 60 dB(A) could be set as the NOAEL ("no observed adverse effect level") for road traffic noise and myocardial infarction (Babisch, 2002). For noise levels greater than 60 dB(A), the MI risk increased continuously, and was greater than 1.2 for noise levels of 70 dB(A).
> *Discussion*
> **Normally CVD effects manifested themselves after 10 years living in a noisy area**.
> (emphasis added)

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Appendix 1

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I graduated from the University of Rochester in 1975 with a B.S. in Physics and subsequently took graduate courses in optics there.

From 1975 to my retirement in 1998 I was a Project Engineer at Eastman Kodak and receive 5 US Patents. Always working in new product research, engineering and development I was often involved in "due diligence" engineering analysis for new product proposals throughout the corporation. This involved considerations of manufacturability, reliability, ergonomics, customer acceptance, and design methodology. My work was cross-disciplinary because of my physics background and my exposure within Kodak to many other scientists and engineers. I often worked in engineering disciplines of optical design, mechanical design, systems design, and product software.

From 1976 to 1986 I had the position of Adjunct Faculty, Rochester Institute of Technology, Physics Laboratory.

From 2005 to present I have been a Technician at Hobart and William Smith Colleges' Physics Department, where I am responsible for laboratory setup, physics equipment parts manufacture, and devising new demonstrations.

I am President of Bare Hill Software Company that develops engineering software for Macintosh and Microsoft personal computers. In that capacity I served as consultant engineer to Eastman Kodak, Corning Glass, and Xerox on various equipment projects.

I am President of the Environmental Compliance Alliance founded to promote public and government agency awareness of New York State and Federal environmental regulations, and promoting agency compliance with those regulations.

In my professional experience I have learned to examine and analyze technical reports, especially with regard to methodological, technical and statistical errors. I recently consulted on a wind turbine project slated for Clinton County in upstate NY. My noise analysis is being used in a proceeding there.

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