

REVIEW OF NOISE STUDIES AND RELATED MATERIAL SUBMITTED REGARDING KENT BREEZE WIND

Date: January 17, 2011

Introduction

This review was conducted on behalf of the Appellant for their Appeal for Renewable Energy Approval issued to Kent Breeze Corp. and MacLeod Windmill Project Inc.. The EBR Registry Number is: 011-1039

The review will address a number of topics. Those topics include:

- An Overview summarizing deficiencies in the Noise Assessment Report by Hatch
- Description of wind turbine noise as a source of environmental noise exposure for humans
- Specific issues with the Noise Assessment report produced regarding Kent Breeze Wind
- Evidence that the Kent Breeze Wind farm noise will exceed the permitted levels
- Comments on the Ontario Chief Medical Officer of Health Report (attached) specifically regarding comments about wind turbine noise and sound.

Overview

This review identified a number of deficiencies in the report and information presented by Hatch regarding the potential for excessive noise exposure on adjoining properties. Most are concerned with the assumptions and methodology Hatch used in constructing the computer model of sound propagation. They fall into the following three categories.

First, the Hatch model included the tolerances for instrumentation error of the IEC 61400-11 test procedures of 0.9 dB but did not include the tolerances for the ISO 9613-2 modeling procedure of ± 3 dB. If the Hatch model had included this tolerance the results shown on the contour maps and tables of their report would be 3 dB higher than stated.

A second, and equally significant fault is that the predicted sound levels underestimate the sound levels that will be received on the properties and at homes adjacent to the wind turbine utility under nighttime stable atmospheric conditions. The Sound Power data used in the sound propagation models does not represent the noise produced by wind turbines during nighttime operations with high wind shear and stable atmospheric conditions. The IEC 61400.11 test standard collects data under neutral atmospheric conditions that do not cause these louder "thumping" or "whooshing" type of noise emissions.

MOE's 2008 Noise Guidelines for Wind Farms requires in section 6.2.3 Adjustment to Wind Turbine Generator Acoustic Emissions for Wind Speed Profile that:

"The wind speed profile on site of the Wind Farm may have an effect on the manufacturer's wind turbine acoustic emission data and, consequently, on the sound levels predicted at a Point of Reception. Therefore, the wind turbine generator acoustic emission levels must be consistent with the wind speed profile of the project area." (emphasis added)

"To address this issue, the assessment must use manufacturer's acoustic emission data adjusted for the average summer night time wind speed profile, representative of the site." (emphasis added)

In "Effects of the wind profile at night on wind turbine sound" G.P. van den Berg states:

"...measurements show that the wind speed at hub height at night is up to 2.6 times higher than expected, causing a higher rotational speed of the wind turbines and consequentially up to 15 dB higher sound levels, relative to the same reference wind speed in daytime. Moreover, especially at high rotational speeds the turbines produce a 'thumping', impulsive sound, increasing annoyance further. It is concluded that prediction of noise immission at night from (tall) wind turbines is underestimated when measurement data are used (implicitly) assuming a wind profile valid in daytime."¹

The "thumping" referred to in the Van den Berg paper occurs in synchronization with blade rotation (about one "thump" or "whoosh" per second assuming the hub is rotating at 20 rpm). "Thumping" does not refer to the blade "swish" of 1-3 dBA present when the turbine is operating in a neutral atmosphere. This "swish" is included as part of the wind turbine sound power ratings provided by the manufacturer. MOE does not permit a penalty for this type of swish. Since the noise from the swish is accounted for in the IEC 61400-11 sound power levels that may be a reasonable decision. The "thumping" of concern is the much louder noise that is not accounted for in the manufacturer's test data. This occurs typically at night under a stable atmosphere where there is high wind shear. This "thumping" can modulate by 5 to 10 dBA or more and is a result of increased sound power emissions from the wind turbine's blades.

Based on this reviewer's experience the nighttime noise is increased by at least 5 dBA over what is observed for similar hub level wind speeds during the day under a neutral atmosphere. If the increased sound power caused by the nighttime atmospheric conditions had been added to the manufacturer's sound power for neutral atmospheric conditions the predicted values would be 5 dBA or more higher than what is shown in the Hatch report tables and contour map.

Third, the sound propagation modeling software used for the sound models is a general purpose model designed for modeling noise from common urban noise sources like industrial plants, roads, and railways. The ISO Standard limits use of the methods to noise sources that are no more than 30 meters above the receiving locations. A wind turbine with a hub height of 80 meters exceeds this ISO limitation by 50 meters. The Hatch report did not disclose this limitation or make any effort to account for the errors that may accrue from the noise source exceeding the source height limits. Cadna/A is based on the ISO standard and thus limitations to the standard apply equally to the Cadna/A model.

The result of these three failings is that the Hatch model does not address the types of audible noise from wind turbines that occurs as a result of the summer night time wind speed profile. The model does not represent the nighttime high wind shear conditions that people find most objectionable. If the model had correctly addressed tolerances and the need to increase the IEC61400-11 sound power levels to account for increased sound emissions at night the contour map and tables would be at least eight (8) dBA higher. This increase would have expanded the boundary of the 40 dBA threshold to include many of the homes around the perimeter of the Kent Breeze project. As a rule of thumb, assuming that the increased sound power for nighttime operation results in a 5 dBA increase and the 3 dB ISO tolerances are included, all receiving properties that have sound level projections between 32 and 40 dBA will exceed 40 dBA. Properly modeled this project would not comply with MOE's 40 dBA limit at receiving properties.

¹ Van den Berg, G.P., "Effects of the wind profile at night on wind turbine sound" Journal of Sound and Vibration, 2003

Description of wind turbine noise

It is common for people to look at wind turbines as a separate type of noise source. However, some of the problems associated with them are easier to understand if we view wind turbines as a special case of very large exposed-blade industrial fan. For example, if we take a look at the spectrum from a fan, as shown in Figure 1, there are certain characteristics that all fans have in common. There is maximum energy at the blade passage frequency, tones above the blade passage frequency, and broadband noise. The harmonics of that tone have somewhat lower energy content. The broadband spectrum starts above the range where the tones no longer dominate. The energy is highest at the blade passage frequency and drops off as frequency increases.

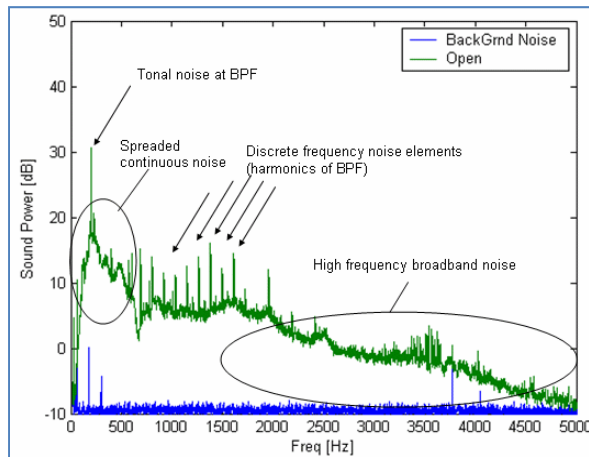


Figure 1-Typical Fan Noise Spectrum

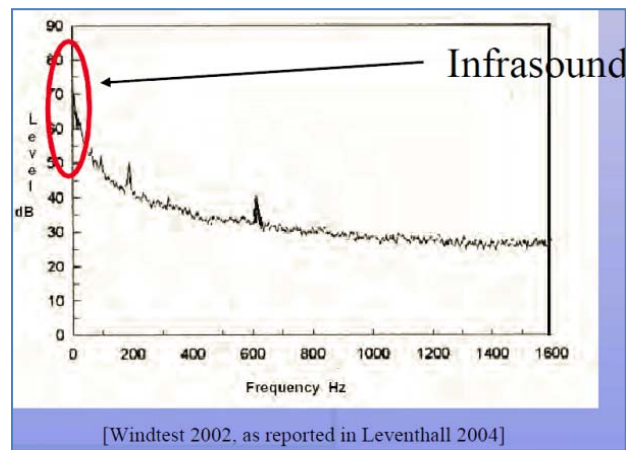


Figure 2-Vestas V-52 Spectrum (From NREL)

In Figure 2, the wind turbine spectrum for a Vestas V-52 shows some of the same spectral characteristics. It does not show the tones and harmonics at the blade passage frequency (BPF) because for industrial scale upwind turbines this is usually between 1 and 2 Hz and the harmonics occur below 10 Hz. Because this is a difficult range of frequencies to measure, especially in field test situations, most information about the spectral characteristics do not show the infrasound range (0-20Hz) sound pressure levels (SPL). This is further obscured by the practice of wind industry acoustical consultants to present data using of A-weighting (dBA). The practice masks the spectrum shape by creating a visual impression of minimal low-frequency sound content. Even when octave band (1/1 or 1/3) SPLs are presented the reports normally ignore frequencies below 31.5 or 63 Hz. The wind industry and its consultants often conclude that there is little or no infra or low frequency

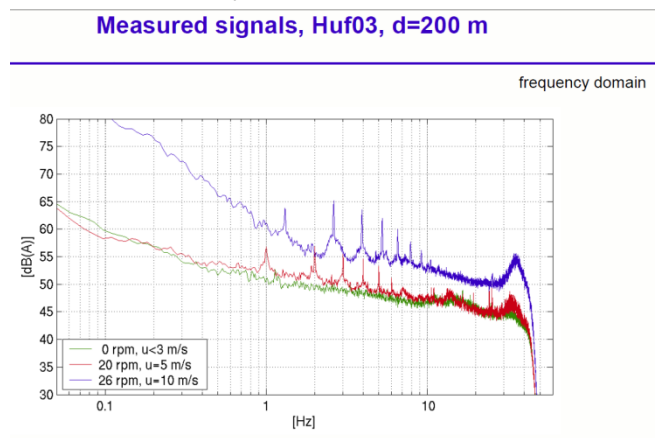


Figure 3-Wind Turbine Infrasound

content. If that is true, then the customary reporting practices are understandable. But, if those assumptions are not accurate, then these practices mask a potential source of significant problems.

The graphic to the left (Figure 3) is expanded in the lower frequency range to show a wind turbine's spectrum for the frequency range of 0-10 Hz. Now the tones and harmonics are clearer. Also, note the correlation of the frequency of the tones to rotational speed. This graph is from a study conducted by the Federal Institute for Geosciences and Natural

Resources, Hannover, Germany, titled: “The Inaudible Noise of Wind Turbines” presented at the Infrasound work shop in 2005 (Tahiti).

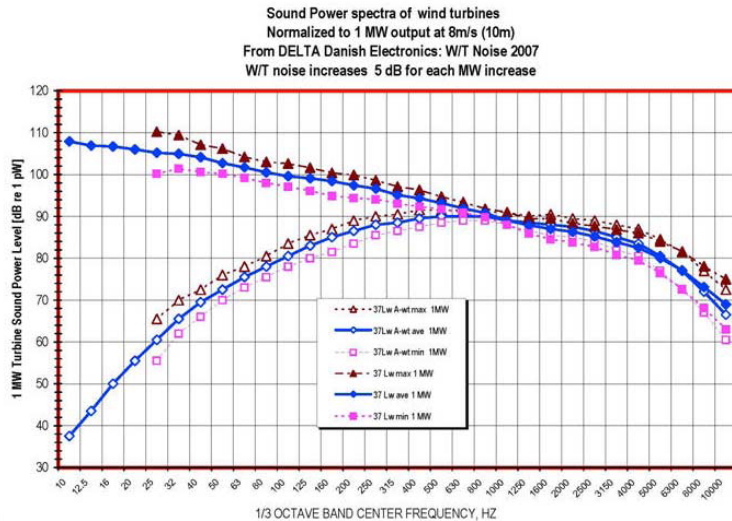


Figure 4-Sound Power Level of 37 Turbines Normalized to 1MW

industrial scale wind turbines have similar high sound pressure levels and tones in these lowest frequencies.

Wind turbine noise is distinctively annoying

There have been several studies, primarily conducted in European countries with a long history of wind turbines, showing that at the same sound pressure (decibel) level or less, wind turbine noise is experienced as more annoying than airport, truck traffic or railroad noise^{3,4}. There are several reasons why people respond more negatively to wind turbine noise that are directly a result of the dynamic modulations of the noise, both audible and inaudible, more than the absolute level of the sounds received.

Amplitude Modulation (Audible Blade Swish)

It is not clear which characteristic of wind turbines makes them more annoying than other common sounds in the community. Whether it is the distinctive rhythmic, impulsive or modulating character of wind turbine noise (all synonyms for “thump” or “whoosh” or “beating” sounds); its characteristic low frequency energy (both audible and inaudible, and also impulsive); the adverse health effects of chronic exposure to wind turbine noise (especially at night); in-phase modulation among several turbines in a wind farm (this can triple the impulse sound level when impulses of three or more turbines become synchronized); or some combination of all of these factors that best explains the increased annoyance is not fully understood. One or more of these characteristics are

Are the sound emission characteristics similar or different for different models and makes of wind turbines? Figure 4 shows the general spectrum shape of 37 modern upwind turbines representing the type and sizes being located in the Kent Breeze Wind Project. This graph shows the sound power data after normalizing the data for each turbine to 1 MW of power output.² It is clear that there is little deviation in spectral shape between any of the various models that is not related to power produced. However, as seen in the A-weighted

curves of the same data, the use of A-weighting masks the low frequency energy content. All modern upwind

² DELTA, Danish Electronics, Light & Acoustics, “EFP-06 Project, Low Frequency Noise from Large Wind Turbines, Summary and Conclusions on Measurements and Methods,” April 30, 2008
³ E. Pedersen and K. Persson Waye, “Perception and annoyance due to wind turbine noise: a dose–response relationship,” J. Acoust. Soc. Am. 116, 3460–3470 (2004).
⁴ Vandenberg, G., Pedersen, E., Bouma, J., Bakker, R. “WINDFARM perception Visual and acoustic impact of wind turbine farms on residents” Final Report, June 3, 2008.

likely present depending on atmospheric and topographic conditions, (especially at night)⁵ as is the individual susceptibility of each person to them.

Nevertheless, reports based on surveys of those living near wind farms consistently find that, compared to surveys of those living near other sources of industrial noise, annoyance is significantly higher for comparable sound levels among wind utility footprint residents. In most cases, where relationships between sound level and annoyance have been determined, annoyance starts at sound levels 10 dBA or more below the sound level that would cause equivalent annoyance from the other common community noise sources. Whereas one would expect that people would be annoyed by 45 dBA nighttime sound levels outside their homes in an urban area, rural residents are equally annoyed by wind turbines when the sound levels are 35 dBA. Given that wind turbine utilities are often permitted to cause sound levels of 40 or higher at the outside of homes adjacent to or inside the footprint of wind utilities the negative reactions to wind turbines from many of those people is understandable. Their reactions provide objective evidence from currently operating wind utilities that a substantial number of people who live near the Kent Breeze project will complain that the noise level they experience is both causing nighttime sleep disturbance and creating other problems once operation commences.^{6 7}

Although there remain differences in opinions about what causes the amplitude modulation of audible wind turbine noise most of the explanations involve high wind shears and/or turbulence as it moves into turbine's blades⁸. There are a number of explanations that have been presented to explain this noise. For example, eddies in the wind, high wind shear gradients (e.g. different wind speeds at the higher reach of the blades compared to the lower reach), slightly different wind directions across the plane of the blades, and interaction among turbines, have each been identified as causes of modulating wind turbine noise from modern upwind turbines.⁹

Consultants for wind utility developers often claim that wind turbine sound **immissions** inside and adjacent to the project footprint estimated by the sound propagation model's represent "worst-case" conditions. The IEC 61400-11 test procedures used to derive this data states that the turbine's reported sound power levels represent the turbine's sound emissions at or above its nominal operating wind speeds under standardized weather and wind conditions. These weather conditions require a neutral atmosphere where the wind shear fits the assumptions of the power law for winds at 10 meters and the hub level. This condition is often associated with a warm, sunny afternoon. That is reasonable given that the purpose of these tests is to produce standardized data to permit a prospective buyer of turbines to compare the sound emissions from various makes and models. This needs to be understood as being similar to the standardized gasoline mileage tests for new vehicles. One does not get the mileage posted on the vehicle sticker since each person's driving habits are different. The same is true for wind turbines and the environments in which they operate. The IEC test data does not account for the increased noise from turbulence or other weather conditions that cause higher sound emissions. A review of the IEC 61400-11, Wind Turbine

⁵ G.P. Van den Berg, "The beat is getting stronger: The effect of atmospheric stability on low frequency modulated sound on wind turbines," Noise notes 4(4), 15-40 (2005) and "The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise" Thesis (2006)

⁶ Kamperman and James (2008); James (2009b); Minnesota Department of Health (2009), pp. 19-20.

⁷ Bajdek, Christopher J. (2007). *Communicating the Noise Effects of Wind Farms to Stakeholders*, Proceedings of NOISE-CON (Reno, Nevada), available at http://www.hmmh.com/cmsdocuments/Bajdek_NC07.pdf

⁸ Van den Berg (2006, pp. 35-36); Oerlemans/Schepers (2009).

⁹ Bowdler, "Why Turbine Noise Annoys – Amplitude Modulation and other things," Where Now with Wind Turbines, Environmental Protection U.K. Conference, Sept. 9, 2010 Birmingham, U.K.

Systems-Part 11: Acoustic Noise Measurement Techniques' assumptions in the body and appendices (esp. Appendix A) show that the IEC test data reported to turbine manufacturers is not 'worst case' for real world operations. Weather can introduce additional deviations from model results along its propagation path. ANSI standards for outdoor noise caution that turbulence in the air can increase the downwind sound levels by several decibels. It should be clear that any assertions by the acoustical modeler that the models represent "worst case" sound level estimates rely on careful phrasing or ignorance of the underlying standards and methods.

Impulsive sound was considered more problematic for older turbines that had rotors mounted downwind from the tower¹⁰. The sound was reduced by mounting the rotor upwind of the tower, common now on all modern turbines¹¹. Initially, many presumed that the change from downwind to upwind turbine blades would eliminate amplitude modulated sounds (whooshes and thumps) being received on adjacent properties. However, in a landmark study by G. P. van den Berg¹², it was shown that the impulsive swishing sound increases with size because larger modern turbines have blades located at higher elevations where they are subject to higher levels of wind shear during times of ground level "atmospheric stability." This results in sound fluctuating 5 dBA or more between beats under moderate conditions and 10 dBA or more during periods of higher turbulence or wind shear¹³.

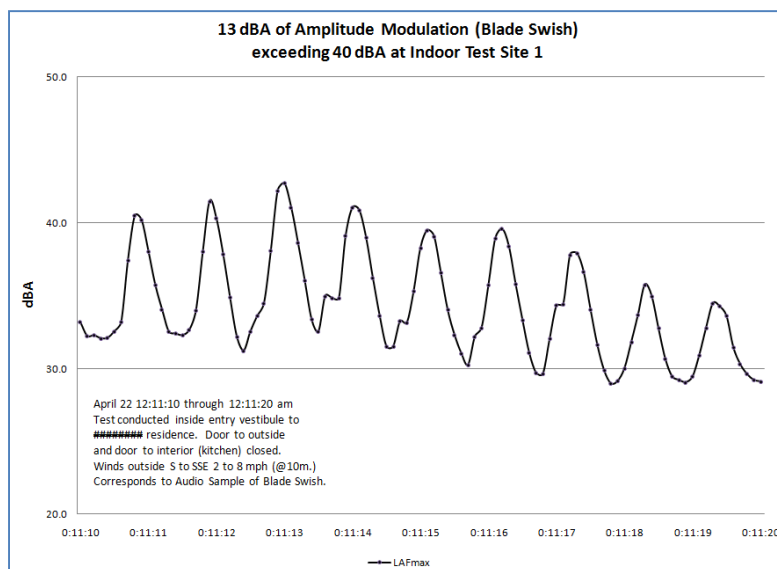


Figure 5-Audible Blade Swish inside home from New York Wind Utility

with a window partly open.

To compensate for the added annoyance of fluctuating or impulsive sound, the sound power levels of the turbine must be increased above what is reported for neutral atmospheric conditions under IEC 61400-11. The impact of this increased annoyance from short term fluctuations in sound levels

This author has confirmed night time amplitude modulation (blade thumping) at every wind project he has investigated. During periods of high turbulence or wind shear levels the sound levels produced by blade "thump" have been as high as 10-13 dBA. Figure 5's graph shows the rise and fall of the A-weighted sound levels from blade swish measured inside a closed entry vestibule to a home. This test site is approximately 1500 feet from two (2) turbines with sound emission characteristics similar to the turbines proposed for the Kent Breeze Wind project. It should be noted that other tests measured sound levels exceeding 40 dBA inside the home in the rooms facing the turbines

¹⁰ Rogers (2006, p. 10)

¹¹ *Id.*, pp. 13, 16; Van den Berg (2006), p. 36.

¹² Van den Berg (2006, p. 36)

¹³ *Id.*,

is cited in the Minnesota Department of Public Health report of 2009.¹⁴ The evidence collected by this reviewer as demonstrated in Figure 5 shows that this increase in noise emissions is generally applicable. It is the days and nights when the amplitude modulation is at its worst that cause complaints. It is not the 1-3 dB swishes of a summer afternoon, but the 6-9 dB whooshes of a late evening or the 10 -14 dB thumps during warm season night time weather with high turbulence or wind shear that matter. These conditions are common in warm weather months and at any time when significant vertical and horizontal turbulence and wind shear may occur.

Frequency of Conditions that Cause Blade Swish

The phenomenon of wind shear coupled with ground level atmospheric stability refers to the boundary that forms between calm air at ground level and winds above the boundary at a higher altitude. *"A high wind shear at night is very common and must be regarded a standard feature of the night time atmosphere in the temperate zone and over land."*¹⁵ A paper presented at the 2009 Institute of Noise Control Engineers, Noise-Con 2009 conference in Ottawa, Canada on background noise assessment in New York's rural areas noted: *"Stable conditions occurred in 67% of nights and in 30% of those nights, wind velocities represented worst-case conditions where ground level winds were less than 2 m/s and hub-height winds were greater than wind turbine cut-in speed, 4 m/s."*¹⁶

Based on a full year of measurements every half-hour at a wind farm in Germany, Van den Berg found:

*"the wind velocity at 10 m[eters] follows the popular notion that wind picks up after sunrise and abates after sundown. This is obviously a 'near-ground' notion as the reverse is true at altitudes above 80 m. . . . after sunrise low altitude winds are coupled to high altitude winds due to the vertical air movements caused by the developing thermal turbulence. As a result low altitude winds are accelerated by high altitude winds that in turn are slowed down. At sunset this process is reversed."*¹⁷

In other words, when ground-level wind speed calms after sunset, wind speed at typical hub height for large wind turbines (80 meters, or 262 feet) commonly increases or at least stays the same. As a result, turbines can be expected to produce noise while there is no masking effect from wind-related noise at the ground where people live. *"The contrast between wind turbine and ambient sound levels is therefore at night more pronounced."*¹⁸ The blade angle is calculated for the average wind speed (at the hub) but the wind speeds at the top and bottom can require different settings to avoid producing noise. As the turbine's blades sweep from top to bottom under such conditions the blade encounters different wind velocities that do not match the blade's angle of attack resulting in rhythmic swishing noise from the parts of the rotation where blade angle mismatches occur¹⁹. Such calm or stable atmosphere at near-ground altitude accompanied by wind shear near turbine hub height occurred in the Van den Berg measurements 47% of the time over the course a year on average, and most

¹⁴ Van den Berg (2006), p. 106; Minnesota Department of Public Health (2009), p. 21. See also Pedersen, "Wind turbine noise, annoyance and self-reported health and well being in different living environments," 2007, p. 24)

¹⁵ Van den Berg (2006, p. 104). See also Cummings (2009)

¹⁶ Schneider, C. "Measuring background noise with an attended, mobile survey during nights with stable atmospheric conditions" Noise-Con 2009

¹⁷ (Van den Berg 2006, p. 90)

¹⁸ *Id.*, p. 60

¹⁹ *Id.*, p. 61. Cf. also Minnesota Department of Public Health (2009), pp. 12-13 and Fig. 5.

often at night²⁰.

Infra and Low Frequency Sounds

The level of annoyance produced by wind turbine noise also increases substantially for **low frequency sound**, once it exceeds a person's threshold of perception. Annoyance increases more rapidly than the more readily audible mid-frequency sounds. Sound measured as dBA is biased toward 1,000 Hz, the center of the most audible frequency range of sound pressure. Low frequency sound is in the range below 200 Hz and is more appropriately measured as dBC or using instrumentation that can provide 1/3 octave band resolution of the spectrum sound pressure levels. Sound below 20 Hz, termed infrasound, is generally presumed to not be audible to most people. See Leventhall (2003, pp. 31-37); Minnesota Department of Public Health (2009, p. 10); Kamperman and James (2008, pp. 23-24). However, if these criteria are applied to the most sensitive people, the thresholds drop approximately 6-12 dB. Since the wind turbine sounds are a complex mix of tones, all within the same critical band, they will be audible at levels lower than what is required for a single pure tone. The combination of people with extra sensitivity and the presence of a complex set of tones in the range from 0 to 20 Hz puts the infrasound sound pressure levels measured on receiving properties and inside homes within the threshold of perception for a subset of the population.

For many years it has been presumed that only infra and low frequency sounds that reached the threshold of audibility for people posed any health risks. Many acoustical engineers were taught that if you cannot hear a sound, it cannot harm you. Recent research has shown that the human body is more sensitive to infra and low frequency noise (ILFN) and that the organs of balance (vestibular systems) respond at levels of sound significantly lower than the thresholds of audibility.²¹

Dr. Nina Pierpont has conducted a peer reviewed study of the effects of infra and low frequency sound on the organs of balance that establishes the causal link between wind turbine ILFN and medical pathologies. The new research is not from the traditional fields that have provided guidance for acoustical engineers and others when assessing compatibility of new noise sources and existing communities. A recent peer reviewed paper by Dr. Alec Salt, reported that the cochlea responds to infrasound at levels 40 dB below the threshold of audibility.²² These studies show how the body responds to extremely low levels of energy not as an auditory response, but instead as a vestibular response.

In a personal communication, this reviewer asked Dr. Salt the question: "Does infrasound from wind turbines affect the inner ear?" Dr. Salt responded:

"There is controversy whether prolonged exposure to the sounds generated by wind turbines adversely affects human health. The un-weighted spectrum of wind turbine noise slowly rises with decreasing frequency, with greatest output in the 1-2 Hz range. As human hearing is insensitive to infrasound (needing over 120 dB SPL to detect 2 Hz) it is claimed that infrasound generated by wind turbines is below threshold and therefore cannot affect people. The inner hair cells (IHC) of the cochlea, through which hearing is mediated, are velocity-sensitive

²⁰ Van den Berg 2006, p. 96

²¹ Alves-Pereira, Marianna and Nuno A. A. Branco (2007a). *Vibroacoustic disease: Biological effects of infrasound and low-frequency noise explained by mechanotransduction cellular signalling*, 93 PROGRESS IN BIOPHYSICS AND MOLECULAR BIOLOGY 256–279, available at <http://www.ncbi.nlm.nih.gov/pubmed/17014895>< and, Alves-Pereira, Marianna and Nuno A. A. Branco (2007b). *Public health and noise exposure: the importance of low frequency noise*, Institute of Acoustics, Proceedings of INTER-NOISE 2007,

²² Salt, Alec, "Responses of the ear to low frequency sounds, infrasound and wind turbines", Hearing Research, 2010. This work was supported by research grant RO1 DC01368 from NIDCD/NIH

and insensitive to low frequency sounds. The outer hair cells (OHC), in contrast, are displacement-sensitive and respond to infrasonic frequencies at levels up to 40 dB below those that are heard."

"A review found the G-weighted noise levels generated by wind turbines with upwind rotors to be approximately 70 dBG. This is substantially below the threshold for hearing infrasound which is 95 dB G but is above the calculated level for OHC stimulation of 60 dB G. This suggests that most wind turbines will be producing an unheard stimulation of OHC. Whether this is conveyed to the brain by type II afferent fibers or influences other aspects of sound perception is not known. Listeners find the so-called amplitude modulation of higher frequency sounds (described as blade "swish" or "thump") highly annoying. This could represent either a modulation of audible sounds (as detected by a sound level meter) or a biological modulation caused by variation of OHC gain as operating point is biased by the infrasound. Cochlear responses to infrasound also depend on audible input, with audible tones suppressing cochlear microphonic responses to infrasound in animals. These findings demonstrate that the response of the inner ear to infrasound is complex and needs to be understood in more detail before it can be concluded that the ear cannot be affected by wind turbine noise."

During the summer of 2009, this reviewer conducted a study of homes in Ontario where people had reported adverse health effects that they associated with the operation of wind turbines in their communities²³. The study involved collecting sound level data at the homes and properties of these people, many of who had abandoned their homes due to their problems. This study found that sound levels in the 1/3 octave bands below 20 Hz were often above 60 dB and in many cases above 70 dB. Since the shape of the spectrum for wind turbine sound emissions is greatest at the blade passage frequency which was below the threshold for the instruments used it can be assumed that the sound pressure levels in the range of 0 to 10 Hz exceeded 70 dBA. Given the statement by Dr. Salt that vestibular responses would start at levels of 60 dBG or higher this data supports the supposition that there is a link between the dynamically modulated infra sound and reported adverse health effects. These examples demonstrate that there is evidence to suspect a link between the presence of modulated wind turbine infra and low frequency noise (ILFN) and the reported adverse health effects.

Problems related to inaudible low frequency and infra sound have been encountered before. Acoustical engineers in the Heating, Cooling and Air Conditioning (ASHRAE) field have suspected since the 1980's and confirmed in the late 1990's that dynamically modulated, but inaudible, low frequency sound from poor HVAC designs or installations can cause a host of symptoms in workers in large open offices²⁴. The ASHRAE handbook devotes considerable attention to the design of systems to avoid these problems and has developed methods to rate building interiors (RC Mark II) to assess them for these low frequency problems²⁵. The report on Ontario by this reviewer includes an Appendix that provides more detail on this aspect of how inaudible infra and low frequency sound can cause adverse health effects.

When infra and low frequency sound is in the less-audible or inaudible range, it is often felt rather than heard. Unlike the A-weighted component, the low-frequency component of wind turbine noise "*can penetrate the home's walls and roof with very little low frequency noise reduction.*"²⁶ Further, as discussed in the 1990 NASA study the inside of homes receiving this energy can resonate and cause an increase of the low frequency energy over and above what was outside the home. Acoustic

23 James, R. R., "Comments Related to EBR-010-6708 and -010-6516" Comment ID 123842, 2009

24 Persson Waye, Kirsten, Rylander, R., Benton, S., Leventhall, H. G., Effects of Performance and Work Quality Due to Low Frequency Ventilation Noise, Journal of Sound and Vibration, (1997) 2005(4), 467-474.

25 The study also showed that NC curves are not able to predict rumble. This use of NC curves was disproved in the 1997 Persson Waye, Leventhall study. Use of the RC Mark II procedures is more appropriate for this use.

²⁶ Kamperman and James (2008), p. 3.

modeling for low frequency sound emissions of ten 2.5 MW turbines indicated “that the one mile low frequency results are only 6.3 dB below the 1,000 foot one turbine example.²⁷” This makes the infra and low frequency sound immissions from wind turbines a potential problem over an even larger area than the audible sounds, such as blade swish and other wind turbine noises in the mid to high frequency range.

The acoustical consultant that does not practice in that field may not be as aware of the problems of amplitude modulated, in-audible low frequency sound identified by the ASHRAE engineers. Many have not integrated these new understandings of how infra and low frequency sound can affect the vestibular organs into their work on community noise. These levels were only a few years ago considered too low to cause any physical response.

Specific Issues with the Hatch Noise Assessment Report

Problems with Cadna/A (Limitations on Use of ISO 9613-2 Algorithms)

As discussed earlier in this review the sound propagation modeling presented by Hatch and used as the basis for conclusions about the impact of the Kent Breeze Wind project on nearby properties and residences underestimates the sound levels that will be received on the properties and homes adjacent to the wind turbine utility. The sound propagation modeling software used for the sound models (Cadna/A and others) are general-purpose commercial packages for use in modeling noise from noise sources like industrial plants, roads, and railways, not wind turbines. Although this does not completely preclude the use of the Cadna/A software package, it does call into question the implied assertion by Hatch in representing the sound levels to a tenth of a decimal precision that the predicted values can be assumed to be precise. We need to apply reasonable safety factors and give consideration to the known tolerances and limits to the accuracy of the procedures in our conclusions. Further, it must be understood that there are other computational methods and algorithms that can be used to model wind turbines other than the ISO method that produce different results.

Hatch included the 0.9 decibel tolerance associated with instrumentation error from the IEC 61400 –

Table 5 — Estimated accuracy for broadband noise of $L_{A,T}(DW)$ calculated using equations (1) to (10)

Height, h ^{*)}	Distance, d ^{*)}	
	$0 < d < 100$ m	100 m $< d < 1$ 000 m
$0 < h < 5$ m	± 3 dB	± 3 dB
5 m $< h < 30$ m	± 1 dB	± 3 dB

^{*)} h is the mean height of the source and receiver.
 d is the distance between the source and receiver.

NOTE — These estimates have been made from situations where there are no effects due to reflection or attenuation due to screening.

11 test protocol for measuring the sound power produced by wind turbines. However, Hatch does not include the three (3) dB tolerance associated with

errors when applying the ISO-methodology (See Table 5 from the ISO standard on previous page).

If Hatch had included the three (3) dB tolerance for the ISO methodology, the results of the models for daytime and nighttime operating modes would have shown many of the homes proximate to the project being exposed to sound levels over 40 dBA. ISO 9613-2, Table 5, Section 9, "Accuracy and limits of the method" (Figure 1), shows the tolerance as plus/minus 3 dB for predictions. This applies when the noise source is at a height greater than 5m and less than 30 m above the receiver and the receiver is within 1000 m. of the noise source. Inspection of Table 5 shows that the ISO

²⁷ *Id.*, p. 12

standard is limited to receivers within 1000 m also limits it to situations where the noise source is no more than 30 m above the receiver.

It essential to include the three (3) dB tolerance in the predictions. Further, the predicted values should be viewed as estimates, not precise values.

Use of Sound Power Data Representing Sound Emissions in a Neutral Atmosphere

Sound power levels must represent the conditions that cause the intrusive blade swish that is commonly associated with nighttime sleep disturbance and complaints. The manufacturer’s reported power levels represents a standardized value for ‘typical’ conditions of a neutral atmosphere with a moderate wind shear gradient. The Hatch report made no attempt to address this deficiency.

Evidence of wind farm noise exceeding certificate of approval levels

A spreadsheet model was developed for three of the properties near the wind project that applies the tolerances as they should be applied. Residences number 12, 61, and 249 were selected as representatives of other properties for comparison to the sound levels reported by Hatch. These models are attached as appendix materials for review.

Evidence of Kent Breeze Exceeding Certificate Approval Level of 40 dBA				
Residence	Nearest turbine (m)	Hatch Study Reported dBA (w/o ISO tolerance)	E-CS Study dBA (w/ 3dB ISO tolerance)	Sound Level that reflects the 3 dB tolerance and 5 dBA increase in Turbine Sound Power Level for Night Blade Thump
012	580-M-5	39.1	41.6	46.6
061	1553 (K-1)	31.8	35.5	40.5
249	825 (K-1)	35.9	38.8	43.8
Number of receiving properties at 40 dBA or higher*	N/A	1 (number 19)	40 (including number 19)	114 (including number 19)
* Determined by adding 3 and 8 dB to the sound levels reported in Table 6.1 of the Hatch report				

It is worth noting that the Hatch report used the location of homes as the receiving locations instead of the property line at the point nearest to the turbine(s). If the property line had been selected as the receiving location it would increase the number of properties that would exceed the 40 dBA threshold. Use of property lines as the enforcement boundary is customary for noise pollution. It avoids granting a de facto noise easement to the noise emitter giving them the right to cause noise pollution on some or all of the receiving property.

Comments on the Ontario Chief Medical Officer of Health Report

The Health Report issued by the Ontario Chief Medical Officer does not represent a complete and unbiased review of information on how infra and low frequency sounds that are inaudible can affect the health of people exposed to the complex, modulated sounds emitted by wind turbines in the lowest frequency ranges. As discussed earlier in this

review there have been other situations where inaudible levels of low frequency sound have caused adverse health effects. The most prominent case being that of office spaces for knowledge workers where inaudible modulated "rumble" created in the HVAC duct systems affected worker performance and health. In addition, the review did not include the findings of recent research of Dr. Salt.

The MOH document has been critically reviewed by members of the Society for Wind Vigilance. Its findings are incorporated into its document: "An Analysis of the Chief Medical Officer of Health (CMOH) of Ontario's "The Potential Health Impacts of Wind Turbines May 2010."" This document is attached.

Conclusion

It is the opinion of this reviewer, based on his personal experience and the review described in this document that a properly conducted study would identify many more homes in the vicinity of the wind turbines where the receiving properties will have sound levels that exceed 40 dBA. When adjusted for known tolerances of algorithms and measurements used to construct the model and the increased sound power emitted by wind turbines at night under conditions of high wind shear, a common situation during the warm season over 100 receiving properties will exceed the sound levels permitted by the MOE.

End of Review

Richard R. James, INCE
For E-Coustic Solutions



January 16, 2011

**Appendix
Model Spreadsheets**

Predicted dBA, dBC, and dBZ Average (Leq) and Maximum (Lmax) Sound Pressure Levels (Residence #249)															
Receiver Elevation to Tower Hub (m.)		83		1/1 Octave Band Center Frequency (Hz) with Un-weighted Sound Pressure Levels (dB(Z) Leq)								From 1/1 Octave Band SPL's			
Octave Band Center Frequency (Hz)				63	125	250	500	1000	2000	4000	8000	dB(Z) Leq	dB(C) Leq	dB(A) Leq	
Sound Power (Lw) ==> GE 2.5 xl @ 8 m/s V10				112.0	108.5	107.2	102.4	102.5	93.0	85.4	71.1	115.0	114.6	105.9	
ISO9613-2 Accuracy Tolerance (U.L.)				3	3	3	3	3	3	3	3	3	3	3	
IEC 61400-11 Meas. Tolerance				0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Single Turbine Lw + Tolerances ==>		GE 2.5 xl @ 8 m/s V10		115.9	112.4	111.1	106.3	106.4	96.9	89.3	75.0	118.9	118.5	109.8	
Lw	Turbines at specified distances from receiver		1	115.9	112.4	111.1	106.3	106.4	96.9	89.3	75.0	119	119	110	
Air Absorption Coefficient (Alpha) db/m @ 10C 70%RH															
MOE Absorption Coefficients				0.0001	0.0004	0.0010	0.0019	0.0037	0.0097	0.0328	0.1170	---	---	---	
Turbine No:	Distance to tower base (ft)	Distance to tower base (m)	Distance to hub (m)	63	125	250	500	1000	2000	4000	8000	dB(Z) Leq	dB(C) Leq	dB(A) Leq	Distance to tower hub (m.)
K-1	2706	825	829	46	43	41	35	34	19	-7	-91	49	49	38	829
K-3	9699	2956	2957	35	31	28	20	15	-12	-88	-351	37	37	23	2957
K-4	9473	2887	2889	35	31	28	21	15	-11	-86	-343	37	37	23	2889
K-5	7894	2406	2408	37	33	30	23	19	-5	-68	-285	39	39	26	2408
M-1	10376	3163	3164	35	30	27	19	14	-15	-95	-376	37	36	22	3164
M-3	14661	4469	4469	31	27	23	14	6	-30	-141	-532	33	33	17	4469
M-4	14210	4331	4332	32	27	23	14	7	-29	-137	-516	33	33	18	4332
M-5	15338	4675	4676	31	26	22	13	5	-33	-148	-556	33	32	17	4676
Cummulative Effect of Listed Turbines as Long Term Average Leq SPL's												dB(Z) Leq	dB(C) Leq	dB(A) Leq	
Turbines Only (w/o AM or Turb.):				48	44	42	36	34	20	3	3	50	50	38.8	%HA
Turbines Plus Background (w/o AM or Turb.):				48	44	42	36	34	20	5	5	50	50	38.8	

Predicted dBA, dBC, and dBZ Average (Leq) and Maximum (Lmax) Sound Pressure Levels (Residence #61)																		
Receiver Elevation to Tower Hub (m.)		83		1/1 Octave Band Center Frequency (Hz) with Un-weighted Sound Pressure Levels (dB(Z) Leq)										From 1/1 Octave Band SPL's				
Octave Band Center Frequency (Hz)				8	16	32	63	125	250	500	1000	2000	4000	8000	dB(Z) Leq	dB(C) Leq	dB(A) Leq	
Sound Power (Lw) ==> GE 2.5 xl @ 8 m/s V10				125.0	125.0	125.0	112.0	108.5	107.2	102.4	102.5	93.0	85.4	71.1	129.9	123.8	105.9	
ISO9613-2 Accuracy Tolerance (U.L.)				3	3	3	3	3	3	3	3	3	3	3	3	3	3	
IEC 61400-11 Meas. Tolerance				0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Single Turbine Lw + Tolerances ==>		GE 2.5 xl @ 8 m/s V10		128.9	128.9	128.9	115.9	112.4	111.1	106.3	106.4	96.9	89.3	75.0	133.8	127.7	109.8	
LW	Turbines at specified distances from receiver		1	128.9	128.9	128.9	115.9	112.4	111.1	106.3	106.4	96.9	89.3	75.0	134	128	110	
Air Absorption Coefficient (Alpha) db/m @ 10C 70%RH																		
MOE Absorption Coefficients							0.0001	0.0004	0.0010	0.0019	0.0037	0.0097	0.0328	0.1170	---	---	---	
Turbine No:	Distance to tower base (ft)	Distance to tower base (m)	Distance to hub (m)	8	16	32	63	125	250	500	1000	2000	4000	8000	dB(Z) Leq	dB(C) Leq	dB(A) Leq	Distance to tower hub (m.)
K-1	5088	1551	1553	54	54	54	41	37	35	29	26	7	-36	-182	59	53	31	1553
K-3	10948	3337	3338	47	47	47	34	30	26	18	13	-17	-102	-397	52	46	22	3338
K-4	9715	2961	2962	48	48	48	35	31	28	20	15	-12	-88	-352	53	47	23	2962
K-5	7709	2350	2351	50	50	50	37	33	30	23	19	-4	-66	-279	55	49	26	2351
M-1	6939	2115	2117	51	51	51	38	34	31	25	21	-1	-58	-250	56	50	27	2117
M-3	9868	3008	3009	48	48	48	35	31	28	20	15	-13	-90	-358	53	47	23	3009
M-4	8481	2585	2586	50	50	50	36	32	29	22	18	-7	-75	-307	55	48	25	2586
M-5	8018	2444	2445	50	50	50	37	33	30	23	19	-6	-70	-290	55	49	26	2445
Cumulative Effect of Listed Turbines as Long Term Average Leq SPL's														dB(Z) Leq	dB(C) Leq	dB(A) Leq		
Turbines Only (w/o AM or Turb.):				60	60	60	46	42	39	33	29	9	3	3	64	58	35.5	%HA
Turbines Plus Background (w/o AM or Turb.):				60	60	60	46	42	39	33	29	10	5	5	64	58	35.5	

Predicted dBA, dBC, and dBZ Average (Leq) and Maximum (Lmax) Sound Pressure Levels (Residence #012)																		
Receiver Elevation to Tower Hub (m.)		83		1/1 Octave Band Center Frequency (Hz) with Un-weighted Sound Pressure Levels (dB(Z) Leq)										From 1/1 Octave Band SPL's				
Octave Band Center Frequency (Hz)				8	16	32	63	125	250	500	1000	2000	4000	8000	dB(Z) Leq	dB(C) Leq	dB(A) Leq	
Sound Power (Lw)==> GE 2.5 xl @ 8 m/s V10				125.0	125.0	125.0	112.0	108.5	107.2	102.4	97.5	93.0	85.4	71.1	129.9	123.7	104.3	
ISO9613-2 Accuracy Tolerance (U.L.)				3	3	3	3	3	3	3	3	3	3	3	3	3	3	
IEC 61400-11 Meas. Tolerance				0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Single Turbine Lw + Tolerances==> GE 2.5 xl @ 8 m/s V10				128.9	128.9	128.9	115.9	112.4	111.1	106.3	101.4	96.9	89.3	75.0	133.8	127.6	108.2	
Air Absorption Coefficient (Alpha) db/m @ 10C 70%RH																		
MOE Absorption Coefficients							0.0001	0.0004	0.0010	0.0019	0.0037	0.0097	0.0328	0.1170	---	---	---	
Turbine No:	Distance to tower base (ft)	Distance to tower base (m)	Distance to hub (m)	8	16	32	63	125	250	500	1000	2000	4000	8000	dB(Z) Leq	dB(C) Leq	dB(A) Leq	Distance to tower hub (m.)
K-1	8562	2610	2611	50	50	50	36	32	29	22	12	-8	-76	-310	54	48	24	2611
K-3	13986	4263	4264	45	45	45	32	27	23	15	2	-28	-134	-507	50	44	18	4264
K-4	11132	3393	3394	47	47	47	34	29	26	18	7	-18	-104	-404	52	46	21	3394
K-5	8753	2668	2669	49	49	49	36	32	29	22	12	-9	-78	-317	54	48	24	2669
M-1	7136	2175	2177	51	51	51	38	34	31	24	16	-2	-60	-257	56	50	26	2177
M-3	6565	2001	2003	52	52	52	39	35	32	25	17	0	-53	-236	57	51	27	2003
M-4	4091	1247	1250	56	56	56	43	39	37	31	24	12	-25	-144	61	55	33	1250
M-5	1902	580	586	63	63	63	49	46	44	39	33	25	4	-60	67	61	40	586
Cummulative Effect of Listed Turbines as Long Term Average Leq SPL's														dB(Z) Leq	dB(C) Leq	dB(A) Leq		
Turbines Only (w/o AM or Turb.):				64	64	64	51	47	46	40	34	25	6	3	69	63	41.6	%HA
Turbines Plus Background (w/o AM or Turb.):				64	64	64	51	47	46	40	34	25	7	5	69	63	41.6	