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AMHERST ISLAND

P.O. Box 4, 5695 Front Road,
Stella, ON K0H 2S0.

March 2013

Response to the REA for the Amherst Island Windlectric Wind Energy Development

The Adverse Health Effects of Wind Turbine Noise

Introduction: Although not required by the REA process, a discussion of adverse health needs to be an important component of the siting of industrial wind turbines. Algonquin Power Company (APCo) realizes this and that it why they retained Intrinsik Environmental Sciences Inc. to present at the first and second public meetings on the expected adverse health effects.

The APAI/SaveAI formal response to the case made by Intrinsik has been made by our health consultant, Dr. Robert McMurtry. The Intrinsik presentation was based upon the paper: "Health effects and wind turbines: A review of the literature", by L D Knopper and C A Ollson, Environmental Health, 10, 78 (2011). Dr. McMurtry has written a 2-part critique of that paper, first a discussion of the points made in the paper and, secondly, a discussion of the errors of omission and of more recent research not available to the authors at the time of their writing.

This short report addresses a review frequently cited by wind energy developers in Ontario and by the Ministry of the Environment to further their cause by denying adverse health effects from wind turbine noise. It is the report published under the name of Dr. Arlene King, the Chief Medical Officer of Health for Ontario (The CMOH Report). There is in addition a critique of the preamble to the Health Canada Study: "Health Impacts and Exposure to Wind Turbine Noise: Research Design and Noise Exposure Assessment", written by Michaud et al. (2012).

The major problems with these studies are:

- The focus on direct adverse health effects as against the indirect effects that develop from annoyance, stress and sleep disturbance.
- Ignoring annoyance and sleep disturbance as adverse health effects.
- The mis-interpretation of the field studies from Sweden and The Netherlands.
- The neglect of the special characteristics of wind turbine noise, including the predominance of infrasound and low frequency noise.
- The absence of diagnosis.
- The omission of recent work on ILFN.

Recommendation: There is no doubt that this project, with so many homes close to the predicted 40 dBA noise contour, will cause significant adverse health impacts. The project

needs to be re-designed to account for the uncertainty in the sound power level of the turbines, for the uncertainty in the prediction of the noise at homes, for the lenient ground parameter allowed by the Ministry of the Environment, for the high probability of turbulent inflow noise and for the excess night-time noise expected in a stable atmosphere. A setback of 1.5 km is not unreasonable.

The CMOH Report

Conclusions: The CMOH report concludes as follows:

a) *Some people living near wind turbines report symptoms such as dizziness, headaches and sleep disturbance;*

This statement, along with the statements of all of the witnesses at the Chatham-Kent Environmental Review Tribunal (for the appellants, the proponent Suncor and the Ministry of the Environment) acknowledge that wind turbine noise at the level allowed by the Ontario noise guideline causes annoyance and sleep disturbance in a proportion of residents living in proximity to the turbines.

b) *The scientific evidence to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects.*

This statement is contrary to the position taken by the World Health Organization that annoyance and sleep disturbance are adverse health effects.

c) *The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health impacts, although some people may find it annoying. It has been suggested that annoyance may be a reaction to the characteristic "swishing" or fluctuating nature of wind turbine sound rather than to the intensity of the sound.*

The adverse health effects are indirect in character: annoyance, sleeplessness and disturbed sleep lead to stress, head-aches, inability to concentrate, depression, a sense of worthlessness and anger

The CMOH's report and the earlier report sponsored by the Canadian and American Wind Energy Authorities are skirting the issue. Claiming there are no direct health impacts when they know full well there are health impacts that are indirect in nature is a way to support the agenda of the provincial government and the wind industry.

d) *Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there*

is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects.

The new research contradicting these assertions is discussed in Dr. McMurtry's report and in the discussion of Michaud et al. below.

e) *Finally there are some statements concerning community engagement and fairness and equity that have no bearing on the problem of turbine noise.*

There are problems in the body of the report:

Level of Annoyance: Dr. King has misquoted from field studies of annoyance due to wind turbine noise. The field studies referred to are the work of Eva Pedersen and colleagues. The CMOH report includes the statement: "The sound was annoying only to a small percentage of the exposed people; approximately 4 to 10% were very annoyed at sound levels between 35 and 45 dBA."

After reviewing the original publications we find the following: The authors broke down the responses to turbine noise from the surveys (586 non-participants in the Netherlands and 1095 mostly non-participants in Sweden) into five categories: do not notice; notice but not annoyed; slightly annoyed; rather annoyed; and very annoyed. The survey population was grouped by the noise level at their homes: 30 to 35 dBA, 35 to 40 dBA etc.

The authors add together "rather annoyed" and "very annoyed" when determining annoyance from turbine noise. Figure 2 of the 2009 publication by Dr. Pedersen and colleagues shows very clearly that the fraction of respondents annoyed was 20% and 25% in the ranges 35 to 40 dBA and 40 to 45dBA respectively for the Dutch survey and was 9% and 29% for the two ranges in the Swedish survey. As in any survey, there is uncertainty; the authors put the uncertainty at about 5% in the above percentages.

For reference, the noise limit regulation for Ontario is 40 dBA for wind speeds up to 22 km/h with the possibility of rising to 51 dBA for wind speeds up to 36 km/h. Dr. King is quite correct in writing that annoyance due to transportation noise at the same level is very much smaller, about 3%.

I return to these field studies in the comment on Michaud et al. below.

Diagnosis: A major criticism of the CMOH report is that no attempt was made to meet with those in Ontario who are suffering adverse health impacts. It would have been very easy for Dr. King to have asked the local medical officers of health to talk with those in their communities who have registered complaints and to have visited their homes to experience the night-time

noise that causes the annoyance and sleep disturbance. After all, these medical officers are first and foremost doctors.

Actual Noise Levels: Another major criticism is that no attempt was made to investigate whether the real noise levels at the homes of those suffering were above or below the regulation noise limit. The Ministry of the Environment was being overwhelmed by complaints of excess turbine noise and reacted by claiming that there was no protocol for measuring noise levels at homes.

This is nonsense. Acoustics consultants have been performing noise audits in all sorts of situations and environments for years. Consultants have indeed performed noise audits of turbine noise. One audit performed by a very experienced company on behalf of a major developer showed noise levels at an Ontario home above the Ontario noise limit for all wind speeds above 10 km/h and at times 25 dBA above the 40 dBA limit. The CMOH report accepted this state of affairs.

There is now a compliance procedure and we have to see how firm the Ministry of the Environment will be with out-of-compliance turbines.

Mis-Information: In writing the report, Dr. King did not seem to know what the Ministry of the Environment is allowing in its regulations. For instance, in the report we read that a complete blade has been thrown 150 metres, a blade fragment 500 metres and sizeable ice fragments 100 metres. Later: The risk of injury is minimized with setbacks of 200 to 500 metres. However, Technical Bulletin Six issued by MOE on March 1, 2010 allows a setback of hub-height plus 10 metres (i.e. 110 metres) from public roads and a setback of hub-height (i.e. 100 metres) from property lines. A proponent can even apply to reduce the setback from a property line, over the objection of the neighbour.

Again, in the report we read that the minimum setback from a receptor is 550 metres. Until Technical Bulletin Six this was true. Now, a participating receptor is no longer subject to this minimum setback. This is regardless of the fact that the participating receptor may have a family and that the 550 metre setback was put in as a mild effort to avoid adverse health effects.

Yet again, we read in the report that setbacks now extend beyond 550 metres with an increased number of turbines, with an example of 950 metres for five 107 dBA turbines within a 3 km radius of the receptor. In fact, the MOE regulations that accompanied the Green Energy Act allow the developer to hire a consultant and use the old October 2008 noise and setback regulations, subject to the minimum 550 metres for non-participating receptors.

Health Canada Study

First, we welcome a Health Canada impact assessment of living in proximity to wind turbines. Here we would like to express concern regarding the apparent bias against there being adverse health effects shown by the authors, Michaud et al. (2012), in the assessment document. This is a further example of the official efforts to deflect attention away from those who are experiencing the ill effects.

Impact on Sleep: On page 3, Michaud et al. write: *"There are studies which report that this sound may be exceeded at some residences, suggesting the potential for WTN to disturb sleep among sensitive individuals (Pedersen and Waye, 2004; Pedersen et al., 2009; Krogh, 2011; Harry, 2007; Shepherd, 2011; Pierpont, 2009)[1]. Some studies have been criticized for having poor methodology and some did not find impacts on sleep (Pedersen and Waye, 2007; Knopper and Ollson, 2011)."*

Pedersen and Waye could not have criticized these studies published 2 to 4 years after their 2007 publication. Knopper and Ollson make no reference to Krogh et al. (2011), Harry (2007) or Shepherd (2011). Nowhere in Knopper and Ollson is there mention of studies that find no impacts on sleep. To the contrary, in their conclusion they write:

"In the peer-reviewed studies, wind turbine annoyance and some reported health effects (e.g., sleep disturbance) have been statistically associated with wind turbine noise especially when found at sound pressure levels greater than 40 dBA, but found to be more strongly related to subjective factors like visual impact, attitude to wind turbines in general and sensitivity to noise."[2]

Earlier in the paper, Knopper and Ollson write:

"Sleep interruption, however, was associated with sound level and annoyance (OR and 95%CI > 1)." There follows some hypothesising concerning cognitive stress theory. This has been dealt with by Dr. McMurtry in his report.

Michaud et al. do not make reference to the peer-reviewed editorial in the 8th of March 2012 edition of the prestigious British Medical Journal. In this editorial the authors, Hanning and Evans (2012), write:

"Shortly after wind turbines began to be erected close to housing, complaints emerged of adverse effects on health. Sleep disturbance was the main complaint (Krogh et al., 2011). Such

[1] Note: A more recent reference is Frey and Hadden (2012).
[2] The topic of subjective factors is dealt with below.

reports have been dismissed as being subjective and anecdotal, but experts contend that the quantity, consistency, and ubiquity of the complaints constitute epidemiological evidence of a strong link between wind turbine noise, ill-health, and disruption of sleep."

Later, they write:

"A laboratory study has shown that low frequency noise is considerably more annoying than higher frequency noise and is harmful to health – it can cause nausea, headaches, disturbed sleep, and cognitive and psychological impairment (Møller and C. Pedersen, 2011). A cochlear mechanism has been proposed that outlines how infrasound, previously disregarded because it is below the auditory threshold, could affect humans and contribute to adverse health effects (Salt and Kaltenbach, 2011)."

Field Studies: Michaud et al. write, on page 3: *"To date there have been no field studies that have included objective health measures in their study design (that) could lend support to some of the self-reported claims derived from questionnaires."*

While strictly true in the sense that medical diagnostic tools have not been used, it is wrong to dismiss the large-scale field work undertaken by Eva Pedersen and her colleagues. The World Health Organization includes annoyance as an adverse health effect and that is what these field studies investigated.

Pedersen et al. (2009) presented the results of a 2007 field study in the Netherlands and related it to an earlier Swedish study. From a list of almost 18,000 addresses of residents living in proximity to turbines almost 2000 were selected for the field study. The response rate was 37%. All turbines were 500 kW or larger; however, this cut-off is small in comparison to the 2.3 MW and larger turbines that are now being installed. The surveys were constructed to hide the purpose of the field study[3]. The respondents were grouped according to the predicted turbine noise level at their home: <30, 30-35, 35-40, 40-45 and >45 dBA for a wind speed at 10 m of 8 m/s. For reference, the Ontario noise limit at 8 m/s is 45 dBA[4].

[3] The title of the survey (translated into English) was *"Study of the Perception of the Living Environment".* The purpose of the survey was:
"To provide knowledge of the perception of wind turbines by people living close to wind farms;
To evaluate human responses to audio and visual exposures from wind turbines and to give insight in(to) possibilities to mitigate the local impact of wind farms."

[4] However, the reality in Ontario is that the noise limit of 40 dBA at a wind speed of 6 m/s will determine the setback. See the 2008 Ontario Ministry of the Environment wind turbine noise guidelines.

Figure 1 shows, for those without economic benefit, the dependence of the fraction of respondents annoyed as a function of the predicted noise level at their homes. The five noise bands correspond to <30, 30-35, 35-40, 40-45 and >45 dBA.

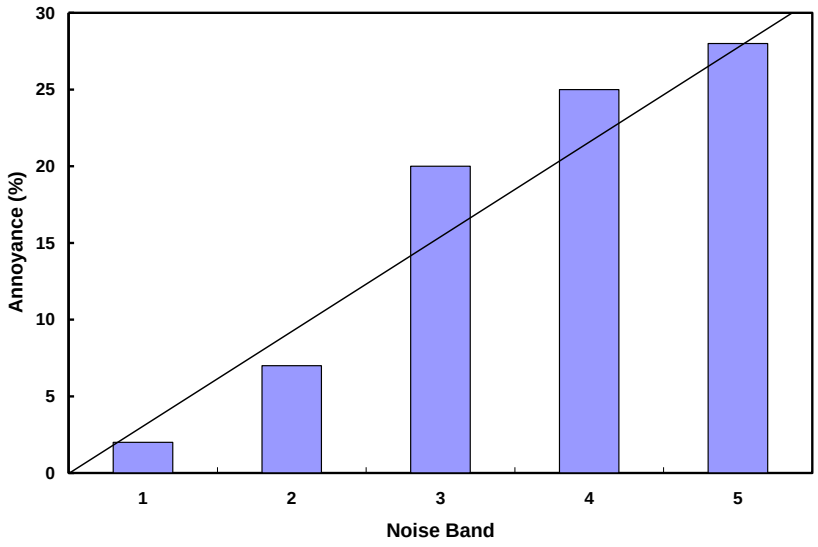

Figure 1. Dependence of Those Annoyed upon the Sound Pressure Level

The clear picture that emerges is that annoyance of residents is linearly related to the noise at the residence. That is, turbine noise causes annoyance which is acknowledged to be an adverse health effect. The results fully support the extensive evidence of Harry, Krogh et al., Pierpont, McMurtry, Frey and Hadden, and others.

World Health Organization Night Noise Guidelines: On page 4 Michaud et al. acknowledge that the WHO's Night Noise Guidelines are based on transportation noise sources. They then go on to state, without attribution, that *"current science shows that the same levels are applicable to noise emitted from wind turbines."* We know of no such current science. On the contrary, what we do know is that at the same sound pressure level wind turbine noise is significantly more annoying than traffic noise. Miedema and Vos (2004), in their field study of the response to traffic noise, found 2 to 4% annoyed at the 40 dBA sound pressure level. This compares to between 20 and 25% annoyed by wind turbine noise at the same 40 dBA sound pressure level (Pedersen et al., 2009).

Causal Relation – Noise and Visual Impact: Michaud et al. downplay the correlation between annoyance and wind turbine noise in the work of Pedersen and colleagues. Knopper and Ollson

(2011) have used the same approach. Both attribute the annoyance to visual intrusion and attitude to the visual intrusion. Figure 2 gives the lie to the conclusion that it is visual impact attitude that causes the annoyance[5]. It is based upon the data set published by Pedersen et al. (2009). It shows the dependence of those with a negative visual impact attitude on their level of annoyance. The data set includes only those without economic benefit.

Much has been made of this negative attitude to wind turbines and their visual impact on residents who are having the turbines shoe-horned among them. There is indeed a negative attitude and who can blame them. The turbines are an intrusion into a rural or semi-rural area, they cause property values to plummet and they have an impact on wild-life. However the large field studies conducted by Pedersen and colleagues provide no support for this attitude causing annoyance, sleep deprivation and consequent adverse health effects.

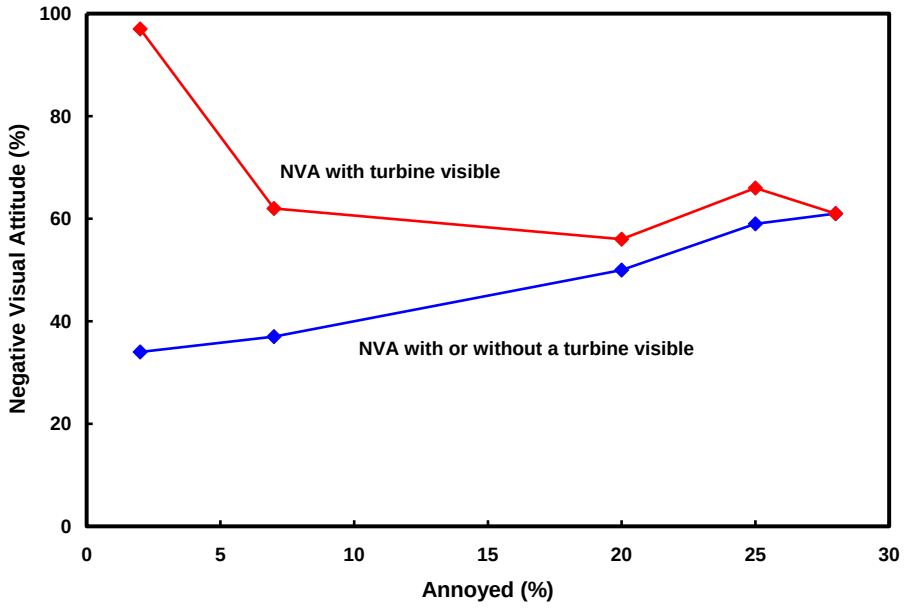

Figure 2. The Relation between Negative Visual Attitude (NVA) and Annoyance.

It is the noise that causes the annoyance. As noted above, the turbine noise is significantly more annoying than noise at the same sound pressure level arising from road, rail and air traffic. The reason is that the turbine noise is incessant, is amplitude modulated, is predominantly low frequency as the higher frequency components are absorbed in the atmosphere, is enhanced by the blades turning in turbulent air (from atmospheric or wake turbulence), and is under-estimated by current prediction algorithms. The problem of low

[5] See the Appendix for the basis for Figure 2.

frequency noise will only get worse as the turbines get larger. Møller and Pedersen (2011) demonstrate a downward shift in frequency of one-third octave on going from less than 2 MW turbines to larger turbines in the range 2.3 to 3.6 MW. Low frequency noise can penetrate into homes and be amplified by resonance effects.

Wind Turbine Noise: The last paragraph on page 4 notes that up-wind turbines have overcome many of the noise problems of the previous generation, leaving the impression that low frequency sound and infrasound is not such a problem anymore. The modern wind turbines are most certainly not without problems. The amplitude modulation remains. This is clear from the work of van den Berg (2005) and the "Salford Report" published by the British Wind Energy Association (Moorhouse, 2007). It was acknowledged by the Ontario Ministry of the Environment in the 2008 noise regulations. Leventhall (2006), a frequent consultant to wind energy developers, has written: *"A time-varying sound is more annoying than a steady sound of the same average level and this is accounted for by reducing the permitted level of wind turbine noise"*. Unfortunately this reduction has not happened. The consensus is that amplitude modulation is of the order of 5 dBA.

Wind turbine noise does contain infrasound which propagates with insignificant absorption by the atmosphere. On average this infrasound is below the threshold of audibility. However, Bray and James (2011) have demonstrated that the infrasound output is highly variable on the short timescale with peaks above the audibility threshold[6]; Salt and Hullar (2010) and Salt and Kaltenbach (2011) have demonstrated an alternate pathway (outer hair cells) for perception of infrasound, significantly below the threshold for audibility.

Madsen (2008) has compared calculation of turbine noise for up-wind blade and down-wind blade turbines. He confirms with his model that up-wind blade turbines are quieter. However, when comparing actual measurements with the calculated sound pressure levels for an up-wind turbine, the measurements were 40 dBA higher in the frequency range 10 to 40 Hz. This he attributed to turbulent inflow aerodynamic noise. In Europe this low frequency noise source is acknowledged as a problem but is not as yet included in calculations of turbine noise at receptors.

Modern wind turbines can have tower heights of 100 metres and blade diameters of over 100 metres. Yet ISO-9613 and its derivatives are still used to calculate the noise at homes and other receptors. ISO-9613 is quite specific in having been designed for traffic and industrial noise and being limited to noise sources at and below 30 metres above ground level. It has no allowance

[6] The ear perceives sound on the short time scale; it does not average over 10 minutes.

for possible cylindrical spreading of turbine sound beyond several hundred metres; this does occur when certain atmospheric conditions promote refraction of the sound.

Wind turbine noise remains very much a problem. We are pleased to note that both the sound power levels of the turbines and the sound pressure levels at up to 5 km will be tested. Testing of the transmission of sound through walls with windows partially open is important but by having the noise source indoors rather than the other way will miss the importance of resonance effects in establishing large low frequency vibration and sound in the home.

It is interesting that the parallel is drawn with the noise produced in buildings by heating, ventilation, and air-conditioning systems. One of two consistent causes of the "sick-building syndrome" was identified with the infrasound and low frequency sound generated by these systems (Niven et al., 2000[7]; Schwartz, 2008). Of particular significance is the recent historical review (James, 2011)[8] in which he draws the parallel between the adverse health effects caused by poorly designed and installed heating and ventilation systems and those being caused now by living in proximity to wind turbines. There were sound commercial reasons for developers to solve the sick-building syndrome; they were losing clients as companies were moving their operations and personnel out of the sick buildings.

Summary: We believe that the authors of the background paper for the Federal Health Wind Turbine Impact Assessment have biased the document so as to mitigate what is already known about the adverse health effects associated with living in proximity to wind turbines. They have:

- Wrongly implied poor methodology for the sleep studies and that there are studies showing no impact on sleep;
- Denied the importance of the field studies of Pedersen et al. which demonstrate a clear dependence of annoyance upon turbine noise;
- Mistakenly applied the World Health Organization's Night Noise Guidelines for traffic noise to wind turbine noise;
- Wrongly attributed the annoyance from living in proximity to wind turbines to an attitude to the visual aspect of the turbines;

[7] To quote from the conclusion*: "In conclusion, this study has shown consistent relations between dust particulates and noise to symptoms compatible with the sick building syndrome. Other factors are inconsistently associated and vary between buildings."*

[8] This peer-reviewed paper should be required reading for all those involved in the design and siting of wind turbines: manufacturers, regulators, developers and their consultants.

- Left the impression that the turbine noise problem was solved by the change from down-wind to upwind placement of the turbine blades.

Appendix: The purpose of this appendix is to question the contention that annoyance is caused by the attitude to the visual impact of wind turbines. It is based upon the data base assembled by Pedersen et al. (2009). The table shows a sub-set of the data base. The first row is the predicted sound pressure level at the home, based upon the ISO 9613-2 methodology and checked against other models. The second row shows the percentage of respondents with economic benefits from the turbines. Additionally it is reported that these respondents had some control over the turbines, including one report of being able to shut down the turbine when annoyed. The third row shows the percentage of respondents for whom the turbines were visible. The next two rows show the percentages annoyed, for the whole sample and for those without economic benefit. Again, following Pedersen et al. the number annoyed includes those rather annoyed and those very annoyed. The final three rows are those with a negative attitude towards the look of the turbines (negative visible attitude). First, for the whole sample, then for those without economic benefit assuming that those with economic benefit do not have a negative attitude. To derive this number we divided the percentage for the complete sample by the fraction without benefit. The final row is based upon the assumption that those without a view of the turbines will not have a negative visual attitude! The reality will be somewhere between the final two rows.

Predicted SPL (dBA)	<30	30-35	35-40	40-45	>45
Economic Benefit (EB) (%)	2	3	10	34	67
Wind Turbine Visible (%)	35	60	90	89	100
Annoyed (%)	2	7	18	18	12
Annoyed (%) No EB	2	7	20	25	28
NVA (%)	33	36	45	39	20
NVA (%) No EB, estimated	34	37	50	59	61
NVA (%) No EB, turbine visible, est.	97 (?)	62	56	66	61

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Credentials

Career: PhD (Leeds, 1964); Post-doctoral Fellow (Cornell 1964 – 67, Sussex 1967 – 69); Faculty at Queen's University (1969 – 2002); presently retired.

Service: Many national and international committees, including the International Committees for the Conference Series on Phonon Physics[9]; Co-Editor and then Editor of the (International) Journal of Low Temperature Physics (1978 – 1992); a 2-year term as an Associate Editor of the Canadian Journal of Physics; 3-year term as a member of a grant selection committee for the Natural Sciences and Engineering Research Council.

Wind Turbine Noise: Presentations made to community groups; Member of the Ministry of the Environment Stakeholder Focus Group on Wind Turbine Noise Regulations; Member of the Society for Wind Vigilance; Invited talk given at the International World Wind Energy Conference held in June 2008 in Kingston, Ontario and paper accepted for the conference proceedings; Invited talk and paper presented on wind turbine noise at the annual conference of the Canadian Acoustics Association in October 2009; Invited talk presented at the International Symposium on The Global Wind Industry and Adverse Health Effects in October 2010, with the paper published in Bulletin of Science, Technology and Society 31, 256 (2011).

John Harrison, Vice President,
Association to Protect Amherst Island,
PO Box #4, 5695, Front Road,
Stella, ON K0H 2S0
harrisjp@physics.queensu.ca

[9] Phonons are very high frequency sound waves.