Oakfield Wind Project // Oakfield, Maine
Evergreen Wind Power II, LLC, applicant
Site Location and NRPA

Exhibits 1 - 30 Submitted by Rufus Brown as part of Powers Trust comments on the application, and referenced in Powers Trust appeal

Appellant Exhibit #	Description
#1	Memorandum from Jean Vissering Landscape Architecture, to DEP, Re: comments on Oakfield Wind Project (September 21, 2009)
#2	Jean Vissering resume
#3	ISO 9613-2, Acoustics - Attenuation of Sound During Propagation Outdoors, Part 2: General Method of Calculation (1996-12-15)
#4	Notes from conference call between W. Brown, D. Mills and others (3/5/09)
#5	"Some Limitations of Ray-Tracing Software for Predicting Community Noise from Industrial Facilities" Frank Brittain and Marlund Hale, from NOISE-CON (The Institute of Noise Control Engineering's Annual Conference), Dearborn, Michigan (July 28-30, 2008)
#6	Propagation Modeling Parameters for Wind Turbines, Kenneth Kaliski and Eddie Duncan, Sound & Vibration, December, 2008.
#7	"Accuracy of Model Predictions and the Effects of Atmospheric Stability on Wind Turbine Noise at the Maple Ridge Wind Power Facility, Lowville, NY-2007: Clifford Schneider (April 10, 2008)
#8	"Some Limitations and Errors in Current Turbine Noise Models" Ebbing Acoustics (July 16, 2009)
#9	Wind Turbine Acoustics, Harvey Hubbard and Kevin Shepard, NASA Technical Paper 3057, (December, 1990) pp. 19-29
#10	"Applied Acoustics Handbook" C.E. Ebbing, Carrier Corporation, (02/93) pp. 2-8 through 2-10
#11	"Sound Propagation from Wind Turbines" Mats Abom, PowerPoint presentation (2007)
#12	"Technical Assistance Bulletin #4, Noise" Maine State Planning Office, Maine Department of Environmental Protection, et al. (May, 2000)
#13	"The 'How To' Guide to Siting Wind Turbines To Prevent Health Risks from Sound" George Kamperman and Richard James (October 28, 2008)
#14	"Affidavit of Michael A. Nissenbaum, M.D., In Re: Record Hill Wind, LLC" with attached Exhibit D "Maine Medical Association, Resolution Re: Wind Energy and Public Health," (September 17, 2009) See also exhibit 26 below, which is a subsequent affidavit by Dr. Nissenbaum with additional attachments.

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#15	"Wind Turbine Syndrome, A Report on a Natural Experiment" pre-publication draft, Nina Pierpont M.D., PhD, (March 7, 2009)
#16	"Night Noise Guidelines For Europe" World Health Organization, Regional Office for Europe (2007) pp. 1 - 6
#17	"Guidelines for Community Noise" Birgitta Berglund, Thomas Lindvall, Dietrich Schwela, World Health Organization, Geneva (April, 1999) pp. 52 - 53
#18	Report by Dr. Christopher Hanning BSc, MB, BS, MRCS, LRCP, FRCA, MD, on Sleep disturbance and wind turbine noise, on behalf of, Stop Swinford Wind Farm Action Group (June, 2009)
#19	Order of the State of Vermont Public Service Board, In the Matter of Amended Petition of Deerfield Wind, LLC for a certificate of public good (April 16, 2009)
#20	Wind Turbine Impact Study, Dodge & Fond Du Lac Counties – Wisconsin, by Appraisal Group One (September 9, 2009)
#21A	"FOAA Response" emails between Dr. Dora Mills and various employees of DEP
#21B	Continuation of #21A
#22	Night Guidelines for Europe, World Health Organization, Europe, (2009) pp. I – XVIII and pp. 15 – 43
#23	"WindVOiCe, Wind Vigilance for Ontario Communities, A self-reporting survey: adverse health effects with industrial wind turbines and the need for vigilance" (September 24, 2009)
#24A	"Wind Turbine Syndrome, A Report on a Natural Experiment" Nina Pierpont, M.D. PhD at 112-121(2009) pp. 26 – 73
#24B	Continuation of #24A, pp. 74 – 125
#25	"An Analysis of the American/Canadian Wind Energy Association sponsored Wind Turbine Sound and Health Effects, An Expert Panel Review, December 2009" by The Society for Wind Vigilance (January, 2010)
#26	"Affidavit of Michael A. Nissenbaum, M.D., In Re: Evergreen Wind Power II, LLC" with attached Exhibits "Curriculum Vitae-Michael A. Nissenbaum, MD" Exhibit B "Mars Hill Wind Turbine Project, Health Effects-Preliminary Findings" PowerPoint presentation, Exhibit C "Industrial Wind Turbines and Health Effects in Mars Hill, Maine" (January 8, 2010)
#27	Letter from Richard James, E-Coustic Solutions, to Rufus Brown, Re: Comments on Oakfield Wind Project, (January 7, 2010), with attached email
#28	Letter from Richard James, E-Coustic Solutions, to Rufus Brown, Re: E-Coustic Solutions' Response to EnRad's Critique of Powers Trust Objections, Dec. 31, 2009, by Mr. Warren Brown (January 11, 2010), Under cover letter from Rufus Brown, dated January 12, 2010, with

	attached email from Catherine Lavella dated January 12, 2010.
#29	Memorandum from Philip Powers, Trustee, Martha A Powers Trust, to Rufus Brown, Re: Comments on Maine DEP's Draft Order Concerning First Wind's Oakfield Project (January 6, 2010)
#30	"First Wind Holdings, Inc, Strategic Analysis Review, by Global Markets and Companies (Nov, 2009)
#31	Letter from Philip A. Powers, to Mark Margerum, DEP, Re: Comments on Oakfield Wind Project (September 10, 2009)

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RUFUS E. BROWN
M. THOMASINE BURKE

September 28, 2009

VIA E-mail (Mark.T.Margerum@Maine.gov)

Mark Margerum
Project Manager, Oakfield Wind Project
Department of Environmental Protection
17 State House Station
Augusta, ME 04333-0017

Re: *Objections of the Trustees of Martha A. Powers Trust to Oakfield Wind Project*

Dear Mark:

As discussed on the telephone last week, I am sending this letter as the attorney for the Martha A. Powers Trust (the "Trust"), land owners adjacent to the Oakfield Wind Project (the "Project"), in opposition to the Application of Evergreen Wind Power. The Trust objects to the Application on 4 grounds: (1) visual impact, (2) noise (3) funding of the decommissioning costs and (4) reduction in land values. Each objection will be addressed below.

A. Objections as to Visual Impact

The Trust's property adjoins the Project boundaries and will be negatively impacted by it visually. Initially, no visual impact analysis was done in relation to Pleasant Lake (much of the lakeshore of which is owned by the Trust) based on the mistaken belief that Pleasant Lake was not a "scenic resource of state or national significance" as defined by 35-A M.R.S.A. §3451.9, enacted by Chapter 661, 123rd Legis. Second Reg. Sess. (the "Wind Power Act"). When the mistake was discovered, the Applicant submitted a Visual Impact Assessment Addendum dated June 30, 2009, addressing how the Project will impact visually Pleasant Lake. This assessment is incomplete, inaccurate, and inconsistent and does not fairly depict the extent of the visual impact of the Project on Pleasant Lake and does not give DEP adequate information to properly evaluate the visual impact.

The deficiencies of the Assessment Addendum has been addressed in a letter to you by Philip Powers, one of the Trustee's trustees and beneficiaries dated September 10, 2009, based on Mr. Power's lifetime familiarity with Pleasant Lake. In addition, the Trust requested the Assessment Addendum to be reviewed by Jean Vissering, a landscape architect with a special expertise in wind power visual impact assessments. Ms. Vissering's Report, dated September 21, 2009, is attached hereto as *Exhibit 1* and her resume is attached to this letter as *Exhibit 2*. Ms. Vissering concludes that the material submitted by the Applicant is insufficient to properly evaluate the visual impact of the Project on Pleasant Lake and raises several questions about the validity of what was submitted.

B. Objections as to Noise:

The *Sound Level Assessment* submitted by the Applicant in Section 5 of the Application was performed by Resource Systems Engineering ("RSE"), the same firm that provided a noise assessment in the Record Hill Wind Project. In fact the *Sound Level Assessment* is virtually identical to the one submitted in Record Hill. The Trust objects to the noise analysis of the Application on the same grounds that aggrieved parties in the Record Hill Wind Project objected to the Record Hill noise analysis, which is currently on appeal to the Board of Environmental Protection. Later this week, Richard James, a principal of E-Coustics, with extensive experience

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in wind power noise issues, will supplement the Trust's objections to noise, summarized below.

The Applicant represents that the Project will comply with quiet limits of 55 dba for daytime and 45 dba for nighttime noise at the project boundaries and protected locations as required by DEP's Chapter 375 §10.C.1.v. with hardly any cushion, see Table 3 at pg. 10 of the *Sound Level Assessment*, except for a 3 dba deviation allowance for accuracy uncertainties of the sound calculations and a 2 dba deviation for uncertainties concerning sound level estimates. Moreover, there are 10 locations where there were predictions that the sound limits will be exceeded, for which easements or a lease arrangement was obtained to exempt such locations from the sound limits. *Sound Level Assessment* at 10, Table 4. The Trust objects to the validity of these predictions as well as to the adverse health effects that will follow from the Project as proposed for the following reasons:

1. The Limitations of the Models Used to Measure Noise.

The *Sound Level Assessment* states that RSE's prediction model for sound propagation used Cadna/A (operating in ISO 9613-2, *Attenuation of Sound During Propagation Outdoors,* mode). *Sound Level Assessment* at 7-8. The problem with this prediction model is that ISO 9613-2 (*Exhibit 3*) was not designed for wind turbines, and it was not designed for sound sources at a height of a ridgeline, such as that proposed for the Project. These problems with using Cadna/A (operating in ISO 9613-2) were acknowledged by the DEP's own consultant, Warren Brown of EnRad Consulting, in an internal conference call last March on the subject of noise in wind power applications pending before the DEP. In the *Notes of March 5, 2009 DEP Conference Call* between Warren Brown, Dora Mills, Maine Center for Disease Control ("MCDC"), and others (*Exhibit 4*), Warren Brown stated that he "has issues with [the] model being used. Currently it's based on industrial noise, not wind power noise. ***We haven't been able***

to determine whether this model is accurate for wind turbines. " [Emphasis added.] Later in the Notes he states that RSE predicts compliance with 45 dba nighttime noise, "but [he] still [has] questions regarding the model – [it is] based on industrial noise." He states "wind turbine noise needs more investigation. 1. Need to be able to predict stable atmospheric conditions .... 2. Set up protocol for acoustic measurements with DEP staff member on site. ... Questions RSE's assumption – due to model. ... There is a period when turbines are loud. ***Not sure how to predict this yet. Need to figure out stable atmospheric conditions.*** " [Emphasis added.]

The concerns expressed by Warren Brown in the conference call are reflected in credible scientific literature on the subject. For example, Frank H. Brittain & Marlund E. Hale, in their article, "Some Limitations of Ray-Tracing Software for Predicting Community Noise from Industrial Facilities," NOISE-CON, Dearborn, Michigan (July 28-30, 2008) (*Exhibit 5*), state that ISO 9613 estimates the accuracy of A-weighted sound propagation noise for distances only up to 1 km, but it is routinely used for distances greater than that. A study by Kenneth Kaliski & Edward Duncan, "Propagation Modeling Parameters for Wind Turbines, "NOISE-CON, Reno, Nevada (October 22-24, 2007) (*Exhibit 6*), states that modeling of wind turbines in flat and relatively porous terrain may yield results that underestimate actual sound levels when using standard ISO 9613-2 algorithms, and that "wind turbines often operate with wind speeds that are higher than the ISO 9613-2 methodology recommends. The combination of higher wind speeds and high noise source may result in greater downward refraction."

The effect of "atmospheric stability" on the accuracy of sound assessments using the ISO 9613 algorithms that Warren Brown referred to is also the focus of a study by Clifford Schneider, "Accuracy of Model Predictions and the Effects of Atmospheric Stability on Wind Turbine Noise at Maple Ridge Wind Power Facility, Lowville, NY- 2007". *Exhibit 7.* Atmospheric stability occurs at night when the land cools and vertical air movement disappears, and where wind can be calm on the ground but continue to blow at hub-height. When this occurs, Schneider explains, "[w]ind turbine sounds are more noticeable, since there is little masking of background noise, and more importantly, because atmospheric stability can amplify noise levels significantly." Pg. 6. Schneider states that most wind assessments never mention atmospheric stability. Pg. 7. Schneider concludes that the developer's predicted noise levels using ISO 9613 were too low when compared against noise levels measured during the actual operation of the wind project. "Further the accuracy of the ISO 9613 protocol is a +/- 3 dBA, without considering reflected sounds, and it is not recommended for source levels higher than 30m" per ISO 9613 itself. Pg. 22. The same concern about atmospheric stability is expressed by Charles Ebbing in his article dated July 16, 2009, "Some Limitations and Errors in Current Turbine Noise Models" (July 2009)." *Exhibit 8*. *See also*, Kaliski & Duncan, *supra*, "Propagation Modeling Parameters for Wind Turbines" (*Exhibit 6*) at 6 (when noise comes from elevated turbines, i.e., from ridge mounted turbines, "sound waves may not significantly interact with the ground over distance.").

Given the limitations of the modeling, originally expressed repeatedly by Warren Brown of EnRad in a context where he could give candid expression of his concerns, and given the support in the literature of these limitations, RSE's sound predictions at protective locations as just barely meeting minimum sound level limitations cannot be accepted. If allowances were made by the DEP for the limitations of the sound propagation models by assuming that the noise generated by the turbines would carry further than predicted by those models, the nighttime noise limits specified by DEP Rule 375 would be exceeded for the Oakfield Project.

2. The Failure to Use Line Source Calculations.

In RSE's *Sound Level Assessment* wind turbines were treated as "point sources", *see* id. at

8, without calculations based on "line sources." The *Sound Level Assessment* states:

> Sound propagation in air can be compared to ripples on the surface of a pond. The ripples spread out uniformly in all directions of the pond surface decreasing in amplitude as they move further from the source. For every doubling of distance from a stationary hemispherical noise source, the sound level drops by 6 dBA.

Sound Level Assessment, at 2. "Line source" calculations measure sound propagation perpendicular to a row (line) of wind turbines, giving effect to the combined noise from the line that radiates in a cylindrical (directed) manner as opposed to a spherical (like a ripple in a pond) manner. The decay rate of a line source is *3 dB* for every doubling of distance, one half of the decay rate of a point source of *6 dBA* per doubling.

The Trust objects to the accuracy of the predictions in the *Sound Level Assessment* because, if a line source calculation were used, the DEP nighttime noise limits of 45 dBA would be exceeded for protected locations. *See*, the NASA study (*Exhibit 9*) at 27 and C.E. Ebbing, "Applied Acoustics Handbook" (*Exhibit 10)*) at 2-8 through 2-10, Kaliski & Duncan, *supra*, "Propagation Modeling" (*Exhibit 6)* at 6 and Mats Abon, "Sound Propagation From Wind Turbines" (*Exhibit 11*) at 10. There is clear scientific consensus on this issue. The NASA studies show that the line source and point source produce similar results only at distances that exceed the length of the line, *see Exhibit 9* at pg. 27. Many of the homes at Oakfield have a direct sight line to turbines. If the RSE *Sound Level Assessment* had used line source calculations, the DEP noise limits would be exceeded.

3. The Failure to Apply the SDR 5% Penalty.

The DEP regulations on sound level limits, Chapter 375, Section 10.D. 19 defines "Short Term Duration Repetitive Sounds" ("SDR") as a "sequence of repetitive sounds which occur

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more than once within an hour, each clearly discernible as an event and causing an increase in the sound level of at least 6 dBA on the fast meter response above the sound level observed immediately before and after the event, each typically less than 10 seconds in duration, and which are inherent to the process or operation of the development and are foreseeable." Section 10.C.1.d imposes a 5 dBA penalty when SDR is present for purposes of measuring sound level limits.

The Applicant's *Sound Level Assessment* did not take into account SDR. Id. at 11. The *Assessment* asserts at 11 that wind turbines only have increased sound levels of 2-4 dBA, rendering the 5 dBA penalty inapplicable. The Trust objects to the *Sound Level Assessment* on these grounds. The Applicant's assertion about the low level of repetitive sounds is based on a 1997 version of a British wind siting standard ETSU-R-97 that is now over 10 years old and is under critical attack by independent acoustical consultants in the UK and that many current studies show SDR sounds from wind turbines commonly in the range of 5-6 dBA and can frequently exceed 10-15 dBA . Ebbing Acoustics, "Some Limitations and Errors," *supra, Exhibit 8* at 3-4 (explaining how the interaction of coherent sound waves from multiple turbines working in synch can increase amplitude modulation by 12 dBA when only 4 turbines are involved), whereas in Oakfield there are many more turbines within line of sight to several protected locations.

4. *Failure to Consider the Health Effects of Nighttime Noise.*

The preamble to DEP's noise regulations, Chapter 375.10 states:

> The Board recognizes that the construction, operation and maintenance of developments may cause excessive noise that could degrade the health and welfare of nearby neighbors. It is the intent of the Board to require adequate provision for the control of excessive noise ...

The Maine State Planning Officer Technical Assistance Bulletin # 4 (*Exhibit 12)* states a similar concern, warning that "[p]rolonged noise exposure is a serious threat to human health, especially when resulting in sleep interruption and especially during the nighttime hours." The Applicant's *Sound Level Assessment* fails to account at all for the potential health effects of the Project Wind Project. In part this is explainable from RSE's use of flawed noise propagation modeling, as explained above. *See*, George Kamperman & Richard James, "The 'How To' Guide to Siting Wind Turbines To Prevent Health Risks From Sound" (*Exhibit 13*) at 1 ("The errors in the predicted sound levels can easily result in inadequate setback distances thus exposing the property owner to noise pollution and potential health risks.") In part it is due to the refusal of the wind power industry to take the issue of health effects from wind turbine noise seriously.

This is a serious problem according to Dr. Robert Nissenbaum. Dr. Nissenbaum has been examining the adverse health effects of the Mars Hill Project in a study that will soon be published in the New England Journal of Medicine. Affidavit of Michael A. Nissenbaum, M.D. (*Exhibit 14*, ¶3 and Exhibit B thereto) ("Dr. Nissenbaum Aff."). He opines, based on his experience with Mars Hill: "It is my opinion that the BEP should hold a public hearing to examine the potential health effects of the Record Hill Wind Project given the potential seriousness of the health issues, and to ensure that an appropriately corrected modeling process (compared to the flawed model that was in fact used) is implemented to best predict the sound emissions that can be expected from the Record Hill Wind Project." Dr. Nissenbaum Aff. at ¶4. He adds that "credible evidence of negative health effects from Industrial Wind Projects [is available] from Canada (in the form of the health/symptom survey from Ontario, Canada) by Robert McMurtry, M.D., [his] own preliminary but significant findings from Mars Hill, Maine and a draft of a potential landmark book 'Wind Turbine Syndrome' by Nina Pierpont, M.D. [*Exhibit 15*] Dr. Pierpont is an accomplished and well respected physician who is making significant contributions to the body of knowledge on the health impacts of wind turbines. Her basic premise about the existence of wind power syndrome has been well received by some of the foremost experts in the field of Otorhinolaryngology and Otology. [He] furthermore agree[s] with her statements and recommendations at pages 11-12 of an excerpt of her Draft Report"', namely minimum protective distances of up to 1 to 3.5 km (for mountainous terrains). Dr. Nissenbaum Aff. at ¶9.

Recently, on September 12, 2009, the Maine Medical Association ("MMA") adopted a resolution recognizing that "assessing the potential health impact of wind turbines has been difficult to measure but if present would be of significant concern" and urging the DEP to adopt procedures that "reflect scientific evidence regarding potential health effects, and to further explore such potential health effects" and to "avoid [ ] unreasonable noise … with development setbacks…." Dr. Nissenbaum Aff. at Exhibit D. This resolution passed, notwithstanding the previous objections of Dr. Dora Mills in a subcommittee considering a similar resolution. According to Dr. Nissenbaum, the "Maine CDC Director's refusal to recognize any potential negative health effects of wind power projects, and her public statements urging the rapid establishment of Industrial Wind Projects in Maine seem to be at odds with the caution expressed by the wider medical community, as indicated by the attached Maine Medical Association resolution. Nissenbaum Aff. at ¶11.[1]

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[1] The Maine CDC did not investigate the cluster of health complaints in Mars Hill for potential significance. Given that Mars Hill potentially represents a new negative health phenomenon resulting from the interaction of a ridge line source of Industrial Wind Turbines sited too close to human dwellings after faulty pre installation sound modeling, this represents a failure of the Maine CDC to comply with its mandate to investigate newly arising health issues to better understand them and propose solutions for mitigation and future prevention. As such, any statements

The need to take a more cautious approach to wind turbine siting because of the potential health effects is also supported by the *Night Noise Guidelines* in 2007*(Exhibit 16)* issued by World Health Organization ("WHO"), recommending sound levels during the nighttime at less than 30dBA during sleeping periods for children and below 32 dBA for adults. An earlier version of these Guidelines, published in 1999 *(Exhibit 17)*, concluded that even then WHO believed that "low frequency noise ... can disturb rest and sleep at low sound levels" and that the *"evidence on low frequency noise is sufficiently strong to warrant immediate concern."* See pg xii, xiii and 53. [Emphasis added.] *See also*, the discussion of the WHO Guidelines and other literature in George Kamperman & Richard James, "The 'How To' Guide", *supra, Exhibit 13*, , which recommends greater setbacks than DEP Chapter 375.10 based on the current state of scientific evidence on the health effects of low frequency sound. Nina Pierpont, M.D., PhD, in *Wind Turbine Syndrome, supra, Exhibit 15*, states at pg. 11 that "Kamperman and James have convinced me that single, one size fits all setback distances may not be protective and fair in all environments with all types of turbines. Even so, it is clear from this study and others that minimum protective distances need to be "greater than 1-1.5 km ... at which there were severely affected subjects in this study b) greater than 1.6 km ... at which there were affected subject in Dr. Harry's UK study and c) and, in mountainous terrain, greater than 2-3.5 km ... at which there were symptomatic subjects in Professor Robyn Phipp's New Zealand Study." Dr. Pierpont's work was among those studies referenced at the MMA meeting resulting in the resolution described above.

Further record support for the need to take seriously the potential health effects from wind

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emanating from the Maine CDC on this subject must be viewed as being based on incomplete information, at this point in time. Dr. Nissenbaum Aff. ¶3.

turbines can be found in Dr. Christopher Henning, "Sleep Disturbance and Wind Turbine Noise" (June 2009) (*Exhibit 18*) ("There can be no doubt that groups of industrial wind turbines ('wind farms') generate sufficient noise to disturb sleep and impair health of those living nearby.").

Based on the foregoing, the Trust urges the DEP to reject the Application or at least defer action on the Project until the BEP holds a hearing on wind power noise, including the health effects of wind power noise, requested by the aggrieved parties in the Record Hill case. In addition, the Trust urges DEP to require the Applicant to disclose what it represented to the 10 land owners who gave a lease or easements about the effects of the Project on their health. Those easements and the lease should not be allowed as exemptions to the DEP noise regulations unless an adequate health disclosure was made.

C. Objections to the Decommissioning Plan.

The Application, in Section 29, proposes to begin funding a decommissioning fund in an amount of $50,000 a year and then to evaluate the adequacy of the fund 15 years. This does not comply with the Wind Power Act, Section B-13. This provision requires "Decommissioning plans [to] include[ ] demonstration of *current and future financial capacity that would be* ***unaffected by the applicant's future financial condition*** to fully fund any necessary costs commensurate with the project's scale, location and other relevant considerations, including, but not limited to, those associated with site restoration and turbine removal." [Emphasis added.] This statutory requirement was recommended in a paper submitted to the Governor's Task Force on October 30, 2007 (See "Meeting Summaries" at the Governor's Task Force Website) titled "State Siting Process For Grid Scale Wind Energy Facilities: Issues and Options." Issue A-6, states: "Because a wind power project ... has real and potential effects on the natural environment, it is important to ensure that the project facility is properly decommissioned ...."

The paper then proposed the following option:

> Develop a standardized state decommissioning policy,
> to be implemented regarding wind power, under which,
> as a condition of project approval, the applicant would establish
> a fully funded decommissioning account ... that would be
> unaffected by the applicant's future financial condition.
> [Emphasis added.]

The Wind Power Act, like the proposal that the Wind Power Act adopted, thus requires a *pre-funded* decommissioning fund, not one established in the future that might be "affected by the applicant's future financial condition." By definition, any funding requirement in the future would be affected by the applicant's future financial condition. Not only is the requirement for pre-funding obvious from the wording of the Wind Power Act, but it makes eminent sense, as evidenced by the Decision of April 16, 2009 by the Vermont Public Service Board *In the Matter of Amended Petition of Deerfield Wind, LLC* at pgs 91-92, see *Exhibit 19,* requiring a Letter of Credit for the estimated decommissioning fund to be posted prior to construction.

The Deerfield decision also disallowed a deduction for scrap metal salvaged as part of the decommissioning because "[s]crap value is vulnerable to market place volatility and thus should not be considered a viable funding source for decommissioning the Project." *Id.* at 91. The Applicant in this case deducts an enormous amount for scrap metal, $17.5 million against total decommissioning cost of $18.4 million. The Applicant should not be allowed any deduction for scrap and certainly not scrap at 95% of the cost. In addition, the Applicant should be required disclose how the $17.5 million for estimated for scrap value was calculated.

D. Objections as to Affect on Property Values

The fourth ground that the Trust objects to is that the Project will reduce the property value of Trust property without compensation. A study published just weeks ago, *Wind Turbine*

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Impact Study, by Appraisal Group One (September 9, 2009), *Exhibit 20*, showed that the value of property bordering a wind project reduces the value of unimproved land by 43%. The Applicant's private project should not be allowed at such a dramatic impact on bordering property without compensation.

For all of these reasons, the Trust urges DEP to deny the Application for the Project or at least defer approval of the Application all the previously described issues have been satisfactorily resolved.

Sincerely yours,

Rufus E. Brown

REB/

cc. Alex Powers
Philip Powers

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Jean Vissering Landscape Architecture

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MEMORANDUM

September 21, 2009

To: Department of Environmental Protection

Re: Oakfield Wind Project, Aroostook County
(MDEP#L-24572-24-A-N: IL-24572-TF-B-N)

I was requested by the Trustees of the Martha A. Powers Trust to review the application of First Wind for the Proposed Oakfield Wind Project and to comment in particular on the aesthetic impacts of the proposed project. I have considerable experience in preparing visual impact assessments and have evaluated many wind energy projects in New England and elsewhere. I provided testimony in both the Redington/Black Nubble Wind Project (on behalf of the Appalachian Trail Conservancy) and in the Kibby Wind Project (on behalf of TransCanada). In both cases the LURC agreed with my assessment. I believe that there are many good sites for wind energy projects, but that in some cases there are scenic resources that may be unreasonably affected. I also believe there are useful approaches for making this determination, some of which are addressed below. Please see my attached resume.

Having reviewed the report prepared by Landworks in this case, I do not believe it is possible to draw conclusions based upon the evidence presented. I should be clear that I have not visited the site, but I believe that a visual assessment should offer sufficient information in the form of both photographic representations and descriptive text to give the reader/reviewer a reasonable sense of the character of the surrounding area, the particular scenic resources that will be affected and the extent to which the project would affect these resources and interfere with existing scenic and aesthetic uses. While a site visit is critical to making an informed decision about the case, a well documented assessment should provide sufficient evidence that a DEP Project Manager and/or others reviewing the evidence would be well informed about the existing scenic and aesthetic uses and how the project may impact these uses.

I have outlined below some specific issues and concerns which I believe need to be addressed in order to ensure an adequate review of the project.

- Section 1.1 Existing Conditions and Context of Pleasant Lake contains only four photographs and very little text describing the visual features of the area. Understanding the existing resource is critical to evaluating aesthetic impacts. Pleasant Lake was singled out as having some important scenic and natural values and it would be useful to understand what these are. (Note that high scenic quality does not necessarily mean that a wind energy project is inappropriate; rather that determination needs to be made based upon a number of factors discussed below.)

- Examining a map of the area, I note that the Oakfield Hills (including Sam Drew Mountain) appear to be one of only two named landforms within a five mile radius around the lake. This suggests the possibility that the Oakfield Hills may be important visual features within views of and from the Lake. If it is viewed as the only major landform it could serve as a focal point. This should be discussed in the evaluation. Mt. Chase is mentioned and noted in the discussion but it appears to be about 14 miles away rather than in the near to mid middleground as are the Oakfield Hills.
- The character of Pleasant Lake is very briefly described in the next section (1.2 Visual Impacts to Great Ponds within the Viewshed). It is described here as "typical of many similar lakes in this region of Maine," but that was apparently not the conclusion of the Resource Inventory. The discussion here needs greater depth. All sites are visually distinct in some way and it is necessary to provide a detailed discussion of the particular attributes of the surrounding landscape and to describe the areas from which the project ridge is visible. Among the features which appear notable from the aerial photographs is the lack of development along a large portion of the eastern two-thirds of the lake. This in itself may provide a distinct visual character and should be noted.
- Visibility is minimally discussed. Given the Lake's status as a Great Pond, a viewshed analysis map illustrating visibility especially from the Lake itself is warranted. I note that the DEP requirements emphasize line-of-sight analysis but these are not particularly useful for assessing the visual impacts of wind energy projects. Viewshed Maps are generally required in most other review processes for wind energy projects. Vermont requires an analysis with a 10-mile radius, New York a 5 mile radius, and a 15-mile radius was required in an evaluation I prepared in New Hampshire (and used in two other cases in Maine). In this particular case, a 5 mile radius should be acceptable.
- The discussion of how many turbines are visible from where is confusing in the report. There is a focus on the boat launch area from which apparently 4 turbines would be visible but little discussion of how many turbines would be visible from other parts of the Lake. Visibility does not necessarily imply unreasonable aesthetic impacts, but is one factor that needs to be addressed.

  On page 4 the following statement is made: "Boaters will be able to see portions of the Oakfield Wind Project as it has been proposed, and the visibility will most likely be of 5 of the closest turbines, 1-1 ½ to 2 miles distant depending on the vantage point. The turbines appear in a compact group and will only be visible over one small section of the shoreline…" Without a viewshed analysis map, the extent of visibility is difficult to determine. Further discussion is needed about the over all visibility, the number of turbines visible in viewpoints around the lake, and their distance from the viewer.
- There is no discussion of views of the project from areas other than the Lake. Although the Lake appears to be the scenic resource that has triggered the requirement for a professional visual assessment, Chapter 315 appears does not appear to limit the assessment only to the Lake.

- Lighting is not discussed. Given the apparent natural values of the more remote and undeveloped portions of the Lake, the impacts of night-time hazard lighting would be important to evaluate.
- There is no discussion of associated infrastructure and its potential for visibility from sensitive viewing areas. This would include project roads, associated clearing, collector and transmission lines and the substation.
- The following statement on page 5 is irrelevant: "Boaters and those fishing from boats can choose locations where, if they do not want to experience the turbines they will not be visible, particularly along the north shore." The project will be part of the experience of the lake and needs to be evaluated as such. The project will be visible from about 2/3 of the Lake and the emphasis should be on where they <u>will</u> be visible and what their impacts will be from those vantage points.
- Two simulations have been provided although the cover photograph is not identified in terms of the viewing location or its characteristics. When a sensitive resource is involved especially given the size of the Lake and it's proximity to the project, several photographic simulations would be expected from the most scenic viewpoints around the Lake and area.
- The simulation in Exhibit 1 appears to be two stitched together photographs. This does not accurately represent the appearance of the project. While a panorama view can be used, they must also show the simulation as a single full frame taken at 50mm (34 digital). The best approach is to illustrate a single frame view as well as a panorama view.
- A factor not discussed in the section on viewer expectations is the fact that so much of the Lake shoreline is held in trust and therefore will remain undeveloped. I would expect this characteristic to affect the expectations of users and to be relevant to the evaluation.
- DEP's criteria for determination are somewhat awkward in reviewing wind energy projects, though they can work well with traditional kinds of development such as housing developments. When evaluated in terms of form, line, color and texture, wind energy projects tend to be generally incompatible and also to have significant contrast in scale. This does not, in my opinion, mean wind energy projects are necessarily incompatible, but the discussions regarding these "landscape compatibility" and "scale contrast" are likely to be the same for nearly every wind project you review providing no meaningful basis for a decision. Spatial dominance *does* provide a useful evaluative measure, but it needs to be based upon a thorough understanding of how the project is viewed in relation to particular scenic resources in the area.
- The framework below is one I've used in other projects and, in my opinion, provides more useful evaluative criteria. Each is a potential red flag, but only when a project has *significant* concerns in at least several of the categories is it likely to unreasonably interfere with the existing and aesthetic uses of the area. Nearly all wind energy projects are likely to raise some red flags.

  In each category I have provided a general definition along with indented notes as to how Pleasant Lake might relate to each category. Since I have not visited the Lake, my site specific comments are limited to what I have read in the applicant's report or observed on maps and are not intended to draw conclusions regarding the

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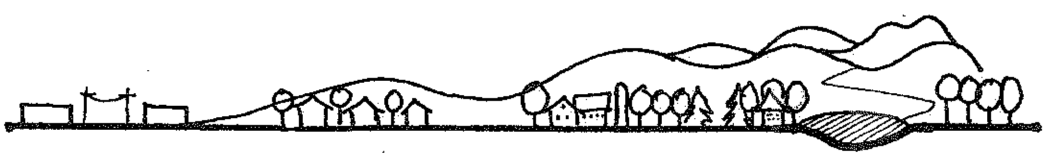
visual impacts. A thorough description of the characteristics of the site and surrounding area as well as the characteristics of the particular project including associated infrastructure are important background information.

EVALUATING AESTHETIC IMPACTS OF WIND ENERGY PROJECTS	
Documented Significance	▪ Notation of a particular scenic resource in public documents indicates a clear consensus of the broad value of the resource. Descriptions of the resource can provide further guidance as to the particular resource values. Resources may be documented as having local, state or national significance. o Pleasant Lake is documented as Management Class 1 Lake having "Significant" scenic values. Class 1 Lakes are considered "high value, least accessible undeveloped lakes."
Scenic Quality/ Focal Point	▪ Scenic Quality can be identified using standard professional methodologies. Factors such as diversity of form, line, color and texture in the natural environment; intactness of natural and cultural resource patterns, and the presence of clear and compelling focal points can enhance scenic quality. Focal points in the landscape are often critical visual elements and important to consider in terms of how a proposed project may degrade or interfere with the enjoyment of the focal point. o Pleasant Lake is identified as having Significant but not Outstanding Scenic Quality o Project ridge is one of only three hills in the surrounding area and is the largest and potentially most prominent of the three.
Viewer Expectations	▪ Factors that might affect viewer expectations could include a designated or noted overlook focused on a scenic view, or the protection of a landscape expressly to provide a natural setting. o Approximately a third of Lake Pleasant is developed with camps, but the eastern two thirds has been protected from development and is in permanent trust; this may be valuable to those seeking a more remote experience.
Uniqueness of Resource	▪ When a setting provides a unique experience that is rarely available elsewhere, consideration should be given as to how the project might affect the unique attributes. o Lack of development on portion of the Pleasant Lake *may* be unusual and contribute to the distinctive qualities of the lake.
Duration of View	▪ Views experienced over a long duration may exacerbate impacts in comparison to a quick glimpse. Proximity and prominence also factor into this (see below). o Project would be visible along the length of the lake except in areas close to the northern shore.
Proximity to Project	▪ Generally ½ mile is considered to be the foreground where details can be perceived such as leaves on trees. Due to their size and location, wind turbines tend to be most visually notable up to 3 miles away. Up to 5-6 miles away they may affect highly scenic views especially if numerous turbines occupy the view but will occupy an increasingly

	small part of the overall view (except possibly very large wind projects). Beyond that distance they are likely to both appear relatively small and occupy a small part of the view. Lighting at this distance will become much less noticeable as well. o Closest turbine visible at approximately 1 mile from the lake. o It appears that approximately 5 turbines are visible at distances of 2 miles or less (this needs to be confirmed).
Spatial Dominance	▪ Prominence of the project ridgeline in views around the lake, duration of view, proximity, and the overall size of the project (number of turbines in the view) will contribute to the spatial dominance of the proposed project. Sensitivity of the viewing location (e.g. designated campsite, known scenic viewing area) and expectation of the user may also play a role. o Project recedes away from the lake, but at least 5 turbines are located in relatively close proximity. o Up to 7 turbines would be visible (not clear from report). o Ridge is a somewhat prominent landform in the surrounding area (need more info). o Project is visible from a large portion of the lake. o Undeveloped portions of the lake may lead to expectations of a more natural experience.



Increasing Scenic Quality →

Concluding Remarks

DEP is currently reviewing a number of wind projects throughout the state. While some wind projects will not be required to submit evidence of aesthetic impacts, where resources of identified state or national significance are involved, it will be important to establish review criteria that provide a good baseline for understanding the specific characteristics of the scenic resources in the surrounding area and how the particular characteristics of the proposed project may affect them. I believe that higher standards of evidence will be needed in order to provide a meaningful review of wind energy projects.

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Jean Vissering Landscape Architecture

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RESUME

EDUCATION

Master of Landscape Architecture - 1975, North Carolina State University, Raleigh, NC, American Society of Landscape Architects Book Award.

Bachelor of Science in Landscape Architecture - 1972, University of Massachusetts, Amherst, MA. Cum Laude. Honors Thesis on Pedestrian Environments.

PROFESSIONAL EXPERIENCE

Professional Consulting: Visual Resource Planning and Visual Impact Assessment Projects

- Visual Impact Assessment for Granite Reliable Wind Park in Coos County, NH now under review by the NH Siting Evaluation Committee, on behalf of Noble Environmental Energy.
- Visual assessment of the Deerfield Wind Project on behalf of Iberdrola. The project is proposed within the Green Mountain National Forest and is currently under review by the Vermont Public Service Board and the GMNF.
- Visual Impact Assessment of the proposed Kibby Wind Energy Project in the Boundary Mountains of Maine on behalf of TransCanada (Approved by Maine LURC).
- Visual Impact Assessment of the proposed Redington and Black Nubble Wind projects on behalf of the Appalachian Trail Conservancy (Maine LURC concurred with my findings).
- Visual impact assessment of a proposed subdivision adjacent to Interstate 91 in Windsor Vermont District for the District #2 Environmental Commission.
- Appointed as member of the National Academy of Science Wind Energy Committee which produced a report, *Environmental Impacts of Wind-Energy Projects* (National Research Council of the National Academies 2007).
- Visual Impact assessment of a small wind turbine in Huntington for the Foundation for a Sustainable Future. The turbine would provide power for demonstrating sustainable agricultural practices.
- Aesthetic review under §248 of the Vermont Electric Coop (VELCO) Northwest Reliability Project for the Addison County Regional Planning Commission.
- Preliminary assessment of a proposed wind energy project in the vicinity of Jordanville and Cherry Valley, NY for Otsego 2000.
- Assisted the Bennington Regional Commission and the Town of Manchester in a public information and review process by providing information regarding the aesthetic effects of the proposed Little Equinox Wind Energy Project.

- Scenic evaluation methodology and protection strategies for the Town of Huntington's Conservation Commission to be used as a tool for prioritizing conservation efforts.
- Visual assessment for the proposed Glebe Mountain wind project on behalf of the Town of Londonderry.
- Presentation to Scenic America's Board of Directors and Affiliates of the visual issues involved in wind energy development at their annual meeting in Washington, D.C.
- Prepared the report, *Wind Energy and Vermont's Scenic Landscape*, for the Vermont Public Service Department summarizing discussions among stakeholders concerning the visual impacts of wind energy. The guidelines are intended for use by the PSB, prospective developers, and by local and regional planning organizations.
- Visual assessment methodology for the Public Service Board, published as a brochure: *Siting a Wind Turbine on Your Property;* designed to encourage the sensitive siting of small wind turbines to protect scenic views.
- *Open Space Plan Views and Vistas Study* for the City of Montpelier's Conservation Commission. The Study recommended priorities for green space and open space protection.
- Review of numerous projects for aesthetic impacts under Vermont's Land Use Law, Act 250. Examples include Old Stone House Subdivision in South Burlington, a proposed RV park in Sharon, a wind turbine in Middlebury, Pittsford Post Office, a proposed gas station in Hartland, the Sheffield Quarry, and a Bell Atlantic Communications Tower in Sharon.
- "Scenic Resource Evaluation Process": a team project to develop guidelines for Vermont Agency of Natural Resources' review of Act 250 projects.

Professional Consulting: Design and Planning Projects

- Work with the Trust for Public Land to facilitate discussions with stakeholders for the development and conservation of Sabin's Pasture, a 100 acre parcel in Montpelier. Development alternatives illustrated compact neighborhood design of up to 300 mixed use and affordable housing units, recreation paths and storm water retention areas.
- Design of a ceremonial garden the Center for Victims of Violent Crimes to honor those who have been affected by violent crimes. The garden is under construction and is located on State property near the State House in Montpelier.
- Design for rehabilitation of the existing City Hall Plaza in Montpelier
- Street Tree Plan for Route 2 in Plainfield, VT
- Design for Martin Bridge Park for the Town of Marshfield; park focus includes trails, parking and handicapped access to a historic covered bridge.
- Currently working with the Town of East Montpelier to enhance the village center in coordination with AOT (pro bono)
- Elm Court Park: a small pocket park developed by the Trust for Public Land and the City of Montpelier. The park demonstrates ecological approaches to design and contains a butterfly garden.
- Turntable Park, Stonecutters Way, Montpelier: design for restoration of an historic turntable, along with accommodation of recreational and theatrical use of a small park. (Designed in collaboration with the Office of Robert White).
- Design and construction supervision for numerous residential and institutional projects.

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- Randolph Family Housing and Templeton Court, landscape design for low-income housing projects in Randolph and White River Junction, VT.
- Plainfield Common, a public riverside park and small formalized parking area in the village center of Plainfield; this project involved extensive public involvement
- Streetscape Master Plan for Chelsea village: village plantings and hardscape improvements for the village center's greens and streets, as well as for several parks and public areas.
- Street tree inventory and plan for the City of Montpelier.
- Conservation and development plans for landholdings in various towns including Hardwick and Calais. Plans provide for the protection of important resources including scenic values, agricultural lands, wetlands, and valuable forestland while identifying appropriate areas for development.

Teaching Experience

- **2000-present:** Landscape Design courses at Studio Place Arts in Barre.

- **1982 -1997: <u>Lecturer</u> (University of Vermont, School of Natural Resources and Department of Plant and Soil Science)**
  I taught a variety of courses depending on the semester and year. Courses included *Park and Recreation Design* (Recreation Management); *Landscape Design Studio,* and *Colloquium in Ecological Landscape Design* (Plant and Soil Science), and *Visual Resource Planning and Management* (Natural Resources graduate level), and *Environmental Aesthetics and Planning* (Natural Resources). I also organized a seminar and lecture series for Shelburne Farms and for Plant and Soil Science focusing on topics in Sustainable and Ecological Landscape Design. I assisted graduate students in Natural Resources Planning and served on several graduate committees.

- **1996: Faculty (Vermont Design Institute)**
  Faculty facilitator for a summer workshop on finding patterns in rural landscapes and historic town centers which could be used as a planning and design tool.

- **1995: <u>Lecturer</u> (Norwich University, Department of Architecture)**
  Course in Landscape Design, the first to be taught in the school.

Additional Experience

- **1981 - 1982: <u>State Lands Planner</u> (Agency of Natural Resources, Department of Forests, Parks and Recreation)**
  Preparation and Coordination of all land management plans for the Department of Forests, Parks, and Recreation; review of plans under Act 250 and Act 248 for aesthetic impacts; provided design services and related expertise to other Agency departments and to municipalities.

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- **1978 - 1981: <u>Park Planner</u> (VT. Dept. of Forests, Parks and Recreation)**
  Design of state park facilities including site analysis, working drawings, grading plans, construction details, planting plans, and supervision of construction. Reviewed plans under Act 250 for aesthetic impacts. Instrumental in organizing a new state lands management unit.

PUBLICATIONS AND ILLUSTRATIONS

Environmental Impacts of Wind-Energy Projects, National Research Council of the National Academies, May 2007

Sabin's Pasture: A Vision for Development and Conservation, Central Vermont Community Land Trust, March 2003.

Siting a Wind Turbine on Your Property: Putting Two Good Things Together, Small Wind Technology & Vermont's Scenic Landscape, Public Service Board, December 2002

Wind Energy and Vermont's Scenic Landscape: A Discussion Based on the Woodbury Stakeholder Workshops, Vermont Public Service Department, August 2002.

Scenic Resource Evaluation Process, Vermont Agency of Natural Resources, July 1, 1990. Guidelines to be used by the Agency of Natural Resources in reviewing visual impacts of development projects under Act 250 in areas of regional and statewide scenic significance.

"Impact Assessment of Timber Harvesting Activity in Vermont: Final Report-March 1990": a research project conducted by the University of Vermont on behalf of the Vermont Department of Forests, Parks, and Recreation. My focus was the visual impacts of timber harvesting.

"Landscapes, Scenic Corridors and Visual Resources": a chapter of the 1989 Vermont Recreation Plan which outlines a five year plan for protecting and enhancing scenic resources in Vermont.

"Healing Springs Nature Trail Guide": Guide for a nature trail at Shaftsbury State Park including text, illustrations (I also designed the trail and bridges).

"The View from the Sidewalk": a walking tour emphasizing the interconnections of environment and culture that shaped the cityscape of Raleigh, North Carolina, text and illustrations. Published by the Raleigh Chamber of Commerce.

Illustrations for other books, guides and newsletters.

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INTERNATIONAL STANDARD

ISO 9613-2

First edition
1996-12-15

Acoustics — Attenuation of sound during propagation outdoors —

Part 2:
General method of calculation

Acoustique — Atténuation du son lors de sa propagation à l'air libre —
Partie 2: Méthode générale de calcul

Reference number
ISO 9613-2:1996(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9613-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 9613 consists of the following parts, under the general title *Acoustics — Attenuation of sound during propagation outdoors:*

— *Part 1: Calculation of the absorption of sound by the atmosphere*

— *Part 2: General method of calculation*

Part 1 is a detailed treatment restricted to the attenuation by atmospheric absorption processes. Part 2 is a more approximate and empirical treatment of a wider subject — the attenuation by all physical mechanisms.

Annexes A and B of this part of ISO 9613 are for information only.

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Introduction

The ISO 1996 series of standards specifies methods for the description of noise outdoors in community environments. Other standards, on the other hand, specify methods for determining the sound power levels emitted by various noise sources, such as machinery and specified equipment (ISO 3740 series), or industrial plants (ISO 8297). This part of ISO 9613 is intended to bridge the gap between these two types of standard, to enable noise levels in the community to be predicted from sources of known sound emission. The method described in this part of ISO 9613 is general in the sense that it may be applied to a wide variety of noise sources, and covers most of the major mechanisms of attenuation. There are, however, constraints on its use, which arise principally from the description of environmental noise in the ISO 1996 series of standards.

Acoustics — Attenuation of sound during propagation outdoors —

Part 2:
General method of calculation

1 Scope

This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level (as described in parts 1 to 3 of ISO 1996) under meteorological conditions favourable to propagation from sources of known sound emission.

These conditions are for downwind propagation, as specified in 5.4.3.3 of ISO 1996-2:1987 or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night. Inversion conditions over water surfaces are not covered and may result in higher sound pressure levels than predicted from this part of ISO 9613.

The method also predicts a long-term average A-weighted sound pressure level as specified in ISO 1996-1 and ISO 1996-2. The long-term average A-weighted sound pressure level encompasses levels for a wide variety of meteorological conditions.

The method specified in this part of ISO 9613 consists specifically of octave-band algorithms (with nominal midband frequencies from 63 Hz to 8 kHz) for calculating the attenuation of sound which originates from a point sound source, or an assembly of point sources. The source (or sources) may be moving or stationary. Specific terms are provided in the algorithms for the following physical effects:

— geometrical divergence;
— atmospheric absorption;
— ground effect;
— reflection from surfaces;
— screening by obstacles.

Additional information concerning propagation through housing, foliage and industrial sites is given in annex A.

This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources. It does not apply to sound from aircraft in flight, or to blast waves from mining, military or similar operations.

To apply the method of this part of ISO 9613, several parameters need to be known with respect to the geometry of the source and of the environment, the ground surface characteristics, and the source strength in terms of octave-band sound power levels for directions relevant to the propagation.

NOTE 1 If only A-weighted sound power levels of the sources are known, the attenuation terms for 500 Hz may be used to estimate the resulting attenuation.

The accuracy of the method and the limitations to its use in practice are described in clause 9.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9613. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9613 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1996-1:1982, *Acoustics — Description and measurement of environmental noise — Part 1: Basic quantities and procedures.*

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ISO 1996-2:1987, *Acoustics — Description and measurement of environmental noise — Part 2: Acquisition of data pertinent to land use.*

ISO 1996-3:1987, *Acoustics — Description and measurement of environmental noise — Part 3: Application to noise limits.*

ISO 9613-1:1993, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere.*

IEC 651:1979, *Sound level meters*, and Amendment 1:1993.

3 Definitions

For the purposes of this part of ISO 9613, the definitions given in ISO 1996-1 and the following definitions apply. (See table 1 for symbols and units.)

3.1 equivalent continuous A-weighted sound pressure level, L_{AT}: Sound pressure level, in decibels, defined by equation (1):

$$L_{AT} = 10 \lg \left\{ \left[(1/T) \int_0^T p_A^2(t)\, dt \right] \Big/ p_0^2 \right\} \ \text{dB} \qquad \ldots (1)$$

where

$p_A(t)$ is the instantaneous A-weighted sound pressure, in pascals;

p_0 is the reference sound pressure ($= 20 \times 10^{-6}$ Pa);

T is a specified time interval, in seconds.

The A-frequency weighting is that specified for sound level meters in IEC 651.

NOTE 2 The time interval T should be long enough to average the effects of varying meteorological parameters. Two different situations are considered in this part of ISO 9613, namely short-term downwind and long-term overall averages.

Table 1 — Symbols and units

Symbol	Definition	Unit
A	octave-band attenuation	dB
C_{met}	meteorological correction	dB
d	distance from point source to receiver (see figure 3)	m
d_p	distance from point source to receiver projected onto the ground plane (see figure 1)	m
$d_{s,o}$	distance between source and point of reflection on the reflecting obstacle (see figure 8)	m
$d_{o,r}$	distance between point of reflection on the reflecting obstacle and receiver (see figure 8)	m
d_{ss}	distance from source to (first) diffraction edge (see figures 6 and 7)	m
d_{sr}	distance from (second) diffraction edge to receiver (see figures 6 and 7)	m
D_I	directivity index of the point sound source	—
D_z	screening attenuation	—
e	distance between the first and second diffraction edge (see figure 7)	m
G	ground factor	—
h	mean height of source and receiver	m
h_s	height of point source above ground (see figure 1)	m
h_r	height of receiver above ground (see figure 1)	m
h_m	mean height of the propagation path above the ground (see figure 3)	m
H_{max}	largest dimension of the sources	m
l_{min}	minimum dimension (length or height) of the reflecting plane (see figure 8)	m
L	sound pressure level	dB
α	atmospheric attenuation coefficient	dB/km
β	angle of incidence	rad
ρ	sound reflection coefficient	—

3.2 equivalent continuous downwind octave-band sound pressure level, L_{fT}(DW): Sound pressure level, in decibels, defined by equation (2):

$$L_{fT}(\mathrm{DW}) = 10 \lg \left\{ \left[(1/T) \int_0^T p_f^{\,2}(t)\,\mathrm{d}t \right] \Big/ p_0^{\,2} \right\} \quad \mathrm{dB} \qquad \ldots (2)$$

where $p_f(t)$ is the instantaneous octave-band sound pressure downwind, in pascals, and the subscript f represents a nominal midband frequency of an octave-band filter.

NOTE 3 The electrical characteristics of the octave-band filters should comply at least with the class 2 requirements of IEC 1260.

3.3 insertion loss (of a barrier): Difference, in decibels, between the sound pressure levels at a receiver in a specified position under two conditions:

a) with the barrier removed, and

b) with the barrier present (inserted),

and no other significant changes that affect the propagation of sound.

4 Source description

The equations to be used are for the attenuation of sound from point sources. Extended noise sources, therefore, such as road and rail traffic or an industrial site (which may include several installations or plants, together with traffic moving on the site) shall be represented by a set of sections (cells), each having a certain sound power and directivity. Attenuation calculated for sound from a representative point within a section is used to represent the attenuation of sound from the entire section. A line source may be divided into line sections, an area source into area sections, each represented by a point source at its centre.

However, a group of point sources may be described by an equivalent point sound source situated in the middle of the group, in particular if

a) the sources have approximately the same strength and height above the local ground plane,

b) the same propagation conditions exist from the sources to the point of reception, and

c) the distance d from the single equivalent point source to the receiver exceeds twice the largest dimension H_{max} of the sources ($d > 2H_{max}$).

If the distance d is smaller ($d \leq 2H_{max}$), or if the propagation conditions for the component point sources are different (e.g. due to screening), the total sound source shall be divided into its component point sources.

NOTE 4 In addition to the real sources described above, image sources will be introduced to describe the reflection of sound from walls and ceilings (but not by the ground), as described in 7.5.

5 Meteorological conditions

Downwind propagation conditions for the method specified in this part of ISO 9613 are as specified in 5.4.3.3 of ISO 1996-2:1987, namely

— wind direction within an angle of ± 45° of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver, and

— wind speed between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground.

The equations for calculating the average downwind sound pressure level L_{AT}(DW) in this part of ISO 9613, including the equations for attenuation given in clause 7, are the average for meteorological conditions within these limits. The term average here means the average over a short time interval, as defined in 3.1.

These equations also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights.

6 Basic equations

The equivalent continuous downwind octave-band sound pressure level at a receiver location, L_{fT}(DW), shall be calculated for each point source, and its image sources, and for the eight octave bands with nominal midband frequencies from 63 Hz to 8 kHz, from equation (3):

$$L_{fT}(\mathrm{DW}) = L_W + D_c - A \qquad \ldots (3)$$

where

L_W is the octave-band sound power level, in decibels, produced by the point sound source relative to a reference sound power of one picowatt (1 pW);

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D_c is the directivity correction, in decibels, that describes the extent by which the equivalent continuous sound pressure level from the point sound source deviates in a specified direction from the level of an omnidirectional point sound source producing sound power level L_W; D_c equals the directivity index D_I of the point sound source plus an index D_Ω that accounts for sound propagation into solid angles less than 4π steradians; for an omnidirectional point sound source radiating into free space, $D_c = 0$ dB;

A is the octave-band attenuation, in decibels, that occurs during propagation from the point sound source to the receiver.

NOTES

5 The letter symbol A (in italic type) signifies attenuation in this part of ISO 9613 except in subscripts, where it designates the A-frequency weighting (in roman type).

6 Sound power levels in equation (3) may be determined from measurements, for example as described in the ISO 3740 series (for machinery) or in ISO 8297 (for industrial plants).

The attenuation term A in equation (3) is given by equation (4):

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc} \qquad \ldots (4)$$

where

A_{div} is the attenuation due to geometrical divergence (see 7.1);

A_{atm} is the attenuation due to atmospheric absorption (see 7.2);

A_{gr} is the attenuation due to the ground effect (see 7.3);

A_{bar} is the attenuation due to a barrier (see 7.4);

A_{misc} is the attenuation due to miscellaneous other effects (see annex A).

General methods for calculating the first four terms in equation (4) are specified in this part of ISO 9613. Information on three contributions to the last term, A_{misc} (the attenuation due to propagation through foliage, industrial sites and areas of houses), is given in annex A.

The equivalent continuous A-weighted downwind sound pressure level shall be obtained by summing the contributing time-mean-square sound pressures calculated according to equations (3) and (4) for each point sound source, for each of their image sources, and for each octave band, as specified by equation (5):

$$L_{AT}(DW) = 10 \lg \left\{ \sum_{i=1}^{n} \left[\sum_{j=1}^{8} 10^{0.1\left[L_{fT}(ij) + A_f(j)\right]} \right] \right\} \text{ dB} \qquad \ldots (5)$$

where

n is the number of contributions i (sources and paths);

j is an index indicating the eight standard octave-band midband frequencies from 63 Hz to 8 kHz;

A_f denotes the standard A-weighting (see IEC 651).

The long-term average A-weighted sound pressure level $L_{AT}(LT)$ shall be calculated according to

$$L_{AT}(LT) = L_{AT}(DW) - C_{met} \qquad \ldots (6)$$

where C_{met} is the meteorological correction described in clause 8.

The calculation and significance of the various terms in equations (1) to (6) are explained in the following clauses. For a more detailed treatment of the attenuation terms, see the literature references given in annex B.

7 Calculation of the attenuation terms

7.1 Geometrical divergence (A_{div})

The geometrical divergence accounts for spherical spreading in the free field from a point sound source, making the attenuation, in decibels, equal to

$$A_{div} = \left[20 \lg(d/d_0) + 11\right] \text{ dB} \qquad \ldots (7)$$

where

d is the distance from the source to receiver, in metres;

d_0 is the reference distance (= 1 m).

NOTE 7 The constant in equation (7) relates the sound power level to the sound pressure level at a reference distance d_0 which is 1 m from an omnidirectional point sound source.

7.2 Atmospheric absorption (A_{atm})

The attenuation due to atmospheric absorption A_{atm}, in decibels, during propagation through a distance d, in metres, is given by equation (8):

$$A_{atm} = \alpha d / 1\,000 \quad \ldots (8)$$

where α is the atmospheric attenuation coefficient, in decibels per kilometre, for each octave band at the midband frequency (see table 2).

For values of α at atmospheric conditions not covered in table 2, see ISO 9613-1.

NOTES

8 The atmospheric attenuation coefficient depends strongly on the frequency of the sound, the ambient temperature and relative humidity of the air, but only weakly on the ambient pressure.

9 For calculation of environmental noise levels, the atmospheric attenuation coefficient should be based on average values determined by the range of ambient weather which is relevant to the locality.

7.3 Ground effect (A_{gr})

7.3.1 General method of calculation

Ground attenuation, A_{gr}, is mainly the result of sound reflected by the ground surface interfering with the sound propagating directly from source to receiver. The downward-curving propagation path (downwind) ensures that this attenuation is determined primarily by the ground surfaces near the source and near the receiver. This method of calculating the ground effect is applicable only to ground which is approximately flat, either horizontally or with a constant slope. Three distinct regions for ground attenuation are specified (see figure 1):

a) the source region, stretching over a distance from the source towards the receiver of $30h_s$, with a maximum distance of d_p (h_s is the source height, and d_p the distance from source to receiver, as projected on the ground plane);

b) the receiver region, stretching over a distance from the receiver back towards the source of $30h_r$, with a maximum distance of d_p (h_r is the receiver height);

c) a middle region, stretching over the distance between the source and receiver regions. If $d_p < (30h_s + 30h_r)$, the source and receiver regions will overlap, and there is no middle region.

According to this scheme, the ground attenuation does not increase with the size of the middle region, but is mostly dependent on the properties of source and receiver regions.

The acoustical properties of each ground region are taken into account through a ground factor G. Three categories of reflecting surface are specified as follows.

Table 2 — Atmospheric attenuation coefficient α for octave bands of noise

Temperature	Relative humidity	Atmospheric attenuation coefficient α, dB/km							
		Nominal midband frequency, Hz							
°C	%	63	125	250	500	1 000	2 000	4 000	8 000
10	70	0,1	0,4	1,0	1,9	3,7	9,7	32,8	117
20	70	0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6
30	70	0,1	0,3	1,0	3,1	7,4	12,7	23,1	59,3
15	20	0,3	0,6	1,2	2,7	8,2	28,2	88,8	202
15	50	0,1	0,5	1,2	2,2	4,2	10,8	36,2	129
15	80	0,1	0,3	1,1	2,4	4,1	8,3	23,7	82,8

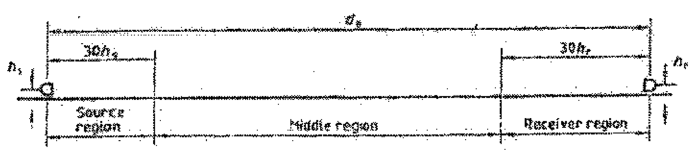

Figure 1 — Three distinct regions for determination of ground attenuation

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a) **Hard ground**, which includes paving, water, ice, concrete and all other ground surfaces having a low porosity. Tamped ground, for example, as often occurs around industrial sites, can be considered hard. For hard ground $G = 0$.

NOTE 10 It should be recalled that inversion conditions over water are not covered by this part of ISO 9613.

b) **Porous ground**, which includes ground covered by grass, trees or other vegetation, and all other ground surfaces suitable for the growth of vegetation, such as farming land. For porous ground $G = 1$.

c) **Mixed ground**: if the surface consists of both hard and porous ground, then G takes on values ranging from 0 to 1, the value being the fraction of the region that is porous.

To calculate the ground attenuation for a specific octave band, first calculate the component attenuations A_s for the source region specified by the ground factor G_s (for that region), A_r for the receiver region specified by the ground factor G_r, and A_m for the middle region specified by the ground factor G_m, using the expressions in table 3. (Alternatively, the functions a', b', c' and d' in table 3 may be obtained directly from the curves in figure 2.) The total ground attenuation for that octave band shall be obtained from equation (9):

$$A_{gr} = A_s + A_r + A_m \qquad \ldots (9)$$

NOTE 11 In regions with buildings, the influence of the ground on sound propagation may be changed (see A.3).

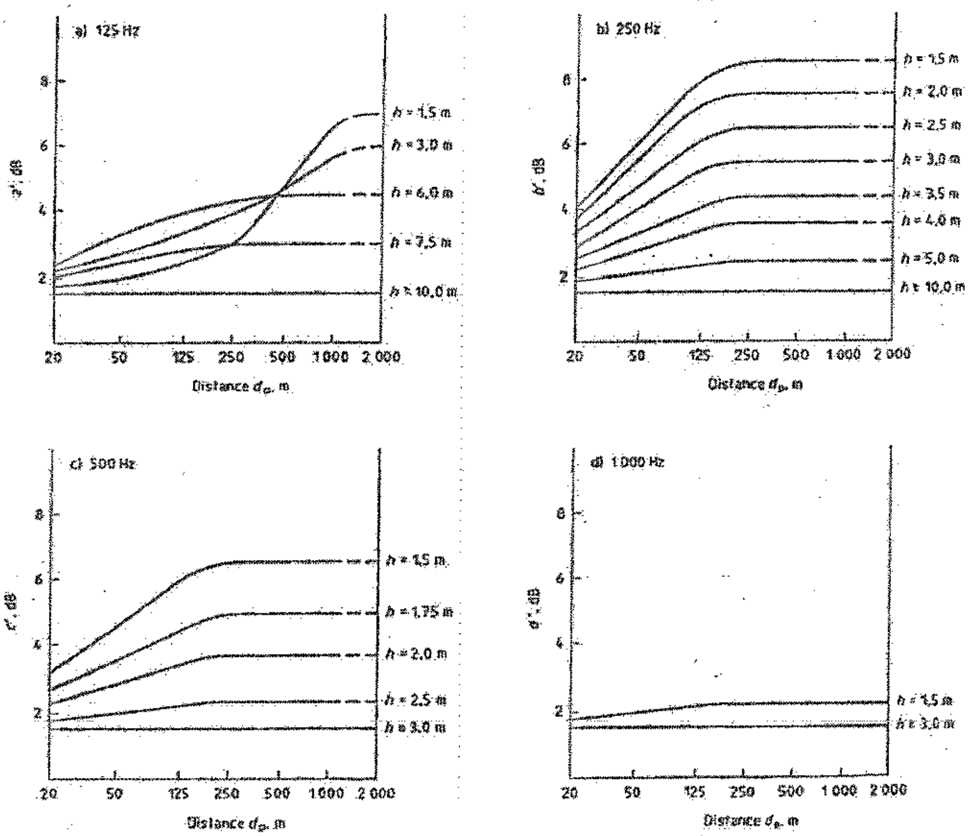

Figure 2 — Functions a', b', c' and d' representing the influence of the source-to-receiver distance d_p and the source or receiver height h, respectively, on the ground attenuation A_{gr} (computed from equations in table 3)

Table 3 — Expressions to be used for calculating ground attenuation contributions A_s, A_r and A_m in octave bands

Nominal midband frequency Hz	A_s or A_r [1] dB	A_m dB
63	$-1,5$	$-3q$ [2]
125	$-1,5 + G \times a'(h)$	$-3q(1 - G_m)$
250	$-1,5 + G \times b'(h)$	
500	$-1,5 + G \times c'(h)$	
1 000	$-1,5 + G \times d'(h)$	
2 000	$-1,5(1 - G)$	
4 000	$-1,5(1 - G)$	
8 000	$-1,5(1 - G)$	

NOTES

$$a'(h) = 1,5 + 3,0 \times e^{-0,12(h-5)^2}\left(1 - e^{-d_p/50}\right) + 5,7 \times e^{-0,09h^2}\left(1 - e^{-2,8 \times 10^{-6} \times d_p^2}\right)$$

$$b'(h) = 1,5 + 8,6 \times e^{-0,09h^2}\left(1 - e^{-d_p/50}\right)$$

$$c'(h) = 1,5 + 14,0 \times e^{-0,46h^2}\left(1 - e^{-d_p/50}\right)$$

$$d'(h) = 1,5 + 5,0 \times e^{-0,9h^2}\left(1 - e^{-d_p/50}\right)$$

1) For calculating A_s, take $G = G_s$ and $h = h_s$. For calculating A_r, take $G = G_r$ and $h = h_r$. See 7.3.1 for values of G for various ground surfaces.

2) $q = 0$ when $d_p \leq 30(h_s + h_r)$

$$q = 1 - \frac{30(h_s + h_r)}{d_p} \quad \text{when } d_p > 30(h_s + h_r)$$

where d_p is the source-to-receiver distance, in metres, projected onto the ground planes.

7.3.2 Alternative method of calculation for A-weighted sound pressure levels

Under the following specific conditions

— only the A-weighted sound pressure level at the receiver position is of interest,

— the sound propagation occurs over porous ground or mixed ground most of which is porous (see 7.3.1),

— the sound is not a pure tone,

and for ground surfaces of any shape, the ground attenuation may be calculated from equation (10):

$$A_{gr} = 4,8 - (2h_m/d)\left[17 + (300/d)\right] \geq 0 \text{ dB} \quad \ldots (10)$$

where

h_m is the mean height of the propagation path above the ground, in metres;

d is the distance from the source to receiver, in metres.

The mean height h_m may be evaluated by the method shown in figure 3. Negative values for A_{gr} from equation (10) shall be replaced by zeros.

NOTE 12 For short distances d, equation (10) predicts no attenuation and equation (9) may be more accurate.

When the ground attenuation is calculated using equation (10), the directivity correction D_c in equation (3) shall include a term D_Ω, in decibels, to account for the apparent increase in sound power level of the source due to reflections from the ground near the source.

$$D_\Omega = 10 \lg \left\{1 + \left[d_p^2 + (h_s - h_r)^2\right] \Big/ \left[d_p^2 + (h_s + h_r)^2\right]\right\} \text{ dB} \quad \ldots (11)$$

where

h_s is the height of the source above the ground, in metres;

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h_r is the height of the receiver above the ground, in metres;

d_p is the source-to-receiver distance projected onto the ground plane, in metres.

7.4 Screening (A_{bar})

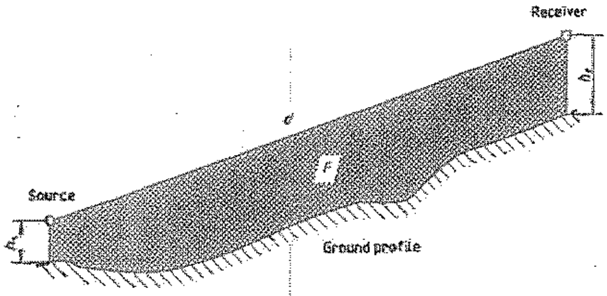
An object shall be taken into account as a screening obstacle (often called a barrier) if it meets the following requirements:

— the surface density is at least 10 kg/m²;

— the object has a closed surface without large cracks or gaps (consequently process installations in chemical plants, for example, are ignored);

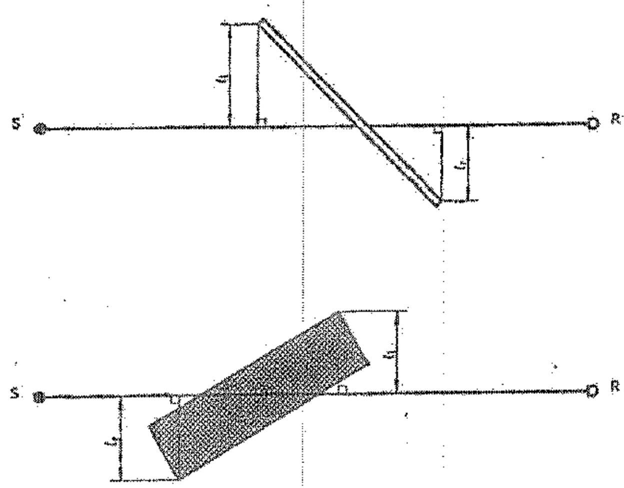
— the horizontal dimension of the object normal to the source-receiver line is larger than the acoustic wavelength λ at the nominal midband frequency for the octave band of interest; in other words $l_l + l_r > \lambda$ (see figure 4).

Each object that fulfils these requirements shall be represented by a barrier with vertical edges. The top edge of the barrier is a straight line that may be sloping.



$h_m = F/d$, where F is the area

Figure 3 — Method for evaluating the mean height h_m



NOTE — An object is only considered to be a screening obstacle when its horizontal dimension perpendicular to the source-receiver line SR is larger than the wavelength: $(l_l + l_r) > \lambda$

Figure 4 — Plan view of two obstacles between the source (S) and the receiver (R)

For the purposes of this part of ISO 9613, the attenuation by a barrier, A_{bar}, shall be given by the insertion loss. Diffraction over the top edge and around a vertical edge of a barrier may both be important. (See figure 5.) For downwind sound propagation, the effect of diffraction (in decibels) over the top edge shall be calculated by

$$A_{bar} = D_z - A_{gr} > 0 \qquad \ldots (12)$$

and for diffraction around a vertical edge by

$$A_{bar} = D_z > 0 \qquad \ldots (13)$$

where

- D_z is the barrier attenuation for each octave band [see equation (14)];
- A_{gr} is the ground attenuation **in the absence of the barrier** (i.e. with the screening obstacle removed) (see 7.3).

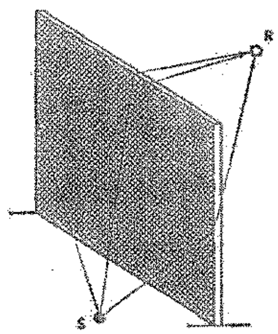


Figure 5 — Different sound propagation paths at a barrier

NOTES

13 When A_{bar} as defined by equation (12) is substituted in equation (4) to find the total attenuation A, the two A_{gr} terms in equation (4) will cancel. The barrier attenuation D_z in equation (12) then includes the effect of the ground in the presence of the barrier.

14 For large distances and high barriers, the insertion loss calculated by equation (12) is not sufficiently confirmed by measurements.

15 In calculation of the insertion loss for multisource industrial plants by high buildings (more than 10 m above the ground), and also for high-noise sources within the plant, equation (13) should be used in both cases for determining the long-term average sound pressure level [using equation (6)].

16 For sound from a depressed highway, there may be attenuation in addition to that indicated by equation (12) along a ground surface outside the depression, due to that ground surface.

To calculate the barrier attenuation D_z, assume that only one significant sound-propagation path exists from the sound source to the receiver. If this assumption is not valid, separate calculations are required for other propagation paths (as illustrated in figure 5) and the contributions from the various paths to the squared sound pressure at the receiver are summed.

The barrier attenuation D_z, in decibels, shall be calculated for this path by equation (14):

$$D_z = 10 \lg\left[3 + (C_2/\lambda) C_3 z K_{met}\right] \text{ dB} \qquad \ldots (14)$$

where

- C_2 is equal to 20, and includes the effect of ground reflections; if in special cases ground reflections are taken into account separately by image sources, $C_2 = 40$;
- C_3 is equal to 1 for single diffraction (see figure 6);

$$C_3 = \left[1 + (5\lambda/e)^2\right] \Big/ \left[(1/3) + (5\lambda/e)^2\right] \qquad \ldots (15)$$

for double diffraction (see figure 7);

- λ is the wavelength of sound at the nominal midband frequency of the octave band, in metres;
- z is the difference between the pathlengths of diffracted and direct sound, as calculated by equations (16) and (17), in metres;
- K_{met} is the correction factor for meteorological effects, given by equation (18);
- e is the distance between the two diffraction edges in the case of double diffraction (see figure 7).

For single diffraction, as shown in figure 6, the pathlength difference z shall be calculated by means of equation (16):

$$z = \left[(d_{ss} + d_{sr})^2 + a^2\right]^{1/2} - d \qquad \ldots (16)$$

where

- d_{ss} is the distance from the source to the (first) diffraction edge, in metres;
- d_{sr} is the distance from the (second) diffraction edge to the receiver, in metres;
- a is the component distance parallel to the barrier edge between source and receiver, in metres.

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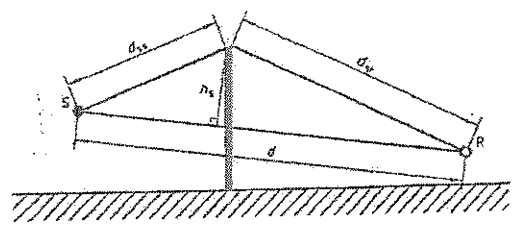


Figure 6 — Geometrical quantities for determining the pathlength difference for single diffraction

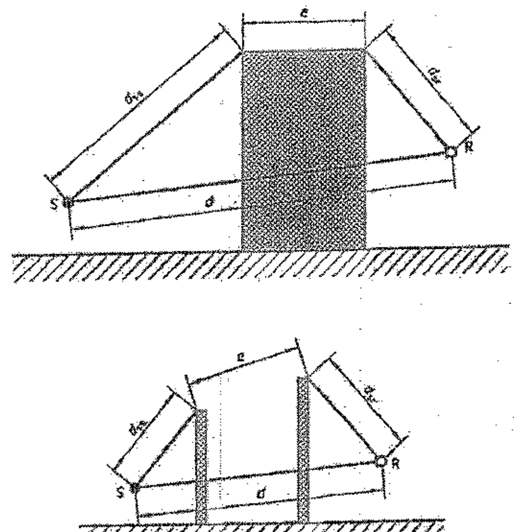


Figure 7 — Geometrical quantities for determining the pathlength difference for double diffraction

If the line of sight between the source S and receiver R passes above the top edge of the barrier, z is given a negative sign.

For double diffraction, as shown in figure 7, the pathlength difference z shall be calculated by

$$z = \left[\left(d_{ss} + d_{sr} + e \right)^2 + a^2 \right]^{1/2} - d \qquad \ldots (17)$$

The correction factor K_{met} for meteorological conditions in equation (14) shall be calculated using equation (18):

$$K_{met} = \exp\left[- (1/2000) \sqrt{d_{ss} d_{sr} d / (2z)} \right] \quad \text{for } z > 0$$

$$\ldots (18)$$

$$K_{met} = 1 \quad \text{for } z \leq 0$$

For lateral diffraction around obstacles, it shall be assumed that $K_{met} = 1$ (see figure 5).

NOTES

17 For source-to-receiver distances less than 100 m, the calculation using equation (14) shows that K_{met} may be assumed equal to 1, to an accuracy of 1 dB.

18 Equation (15) provides a continuous transition from the case of single diffraction ($e = 0$) where $C_3 = 1$, to that of a well-separated double diffraction ($e \gg \lambda$) where $C_3 = 3$.

19 A barrier may be less effective than calculated by equations (12) to (18) as a result of reflections from other acoustically hard surfaces near the sound path from the source to the receiver or by multiple reflections between an acoustically hard barrier and the source.

The barrier attenuation D_z, in any octave band, should not be taken to be greater than 20 dB in the case of single diffraction (i.e. thin barriers) and 25 dB in the case of double diffraction (i.e. thick barriers).

The barrier attenuation for two barriers is calculated using equation (14) for double diffraction, as indicated in the lower part of figure 7. The barrier attenuation for more than two barriers may also be calculated approximately using equation (14), by choosing the two most effective barriers, neglecting the effects of the others.

7.5 Reflections

Reflections are considered here in terms of image sources. These reflections are from outdoor ceilings and more or less vertical surfaces, such as the façades of buildings, which can increase the sound pressure levels at the receiver. The effect of reflections from the ground are not included because they enter into the calculation of A_{gr}.

The reflections from an obstacle shall be calculated for all octave bands for which all the following requirements are met:

— a specular reflection can be constructed, as shown in figure 8;

— the magnitude of the sound reflection coefficient for the surface of the obstacle is greater than 0,2;

— the surface is large enough for the nominal midband wavelength λ (in metres) for the octave band under consideration to obey the relationship

$$1/\lambda > \left[2/(l_{min}\cos\beta)^2\right]\left[d_{s,o}d_{o,r}/(d_{s,o}+d_{o,r})\right] \quad \ldots (19)$$

where

λ is the wavelength of sound (in metres) at the nominal midband frequency f (in hertz) of the octave band $\left(\lambda = \dfrac{340\ \text{m/s}}{f}\right)$;

$d_{s,o}$ is the distance between the source and the point of reflection on the obstacle;

$d_{o,r}$ is the distance between the point of reflection on the obstacle and the receiver;

β is the angle of incidence, in radians (see figure 8);

l_{min} is the minimum dimension (length or height) of the reflecting surface (see figure 8).

If any of these conditions is not met for a given octave band, then reflections shall be neglected.

The real source and source image are handled separately. The sound power level of the source image $L_{W,im}$ shall be calculated from

$$L_{W,im} = L_W + 10\lg(\rho)\,\text{dB} + D_{Ir} \quad \ldots (20)$$

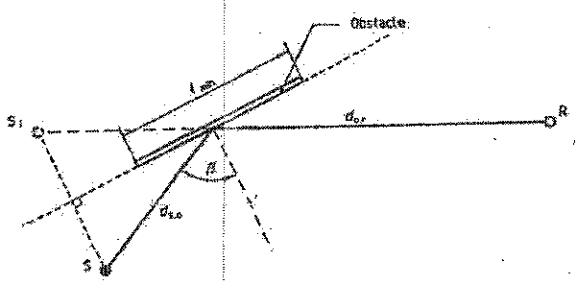
where

ρ is the sound reflection coefficient at angle β on the surface of the obstacle ($\geq 0{,}2$) (see figure 8);

D_{Ir} is the directivity index of the source in the direction of the receiver image.

If specific data for the sound reflection coefficient are not available, the value may be estimated using table 4.

For the sound source image, the attenuation terms of equation (4), as well as ρ and D_{Ir} in equation (20), shall be determined according to the propagation path of the reflected sound.



NOTE — A path $d_{s,o} + d_{o,r}$ connecting the source S and receiver R by reflection from the obstacle exists in which β, the angle of incidence, is equal to the angle of reflection. The reflected sound appears to come from the source image S_i.

Figure 8 — Specular reflection from an obstacle

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Table 4 — Estimates of the sound reflection coefficient ρ

Object	ρ
Flat hard walls	1
Walls of building with windows and small additions or bay	0,8
Factory walls with 50 % of the surface consisting of openings, installations or pipes	0,4
Cylinders with hard surfaces (tanks, silos)	$\frac{D \sin(\phi/2)}{2d_{sc}}$ *) where D is the diameter of the cylinder; d_{sc} is the distance from the source to the centre C of the cylinder; ϕ is the supplement of the angle between lines SC and CR.
Open installations (pipes, towers, etc.)	0

*) This expression applies only if the distance d_{sc} from the source S to cylinder C is much smaller than the distance d_{cr} from the cylinder to receiver; see figure 9.

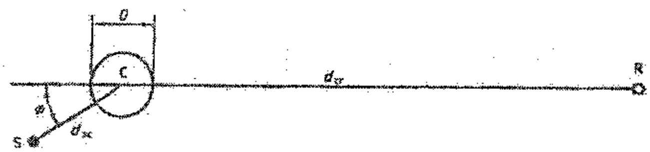

Figure 9 — Estimation of sound reflection coefficient for a cylinder

8 Meteorological correction (C_{met})

Use of equation (3) leads directly to an equivalent continuous A-weighted sound pressure level L_{AT} at the receiver for meteorological conditions which are favourable for propagation from the sound source to that receiver, as described in clause 5. This may be the appropriate condition for meeting a specific community noise limit, i.e. a level which is seldom exceeded (see ISO 1996-3). Often, however, a long-term average A-weighted sound pressure level L_{AT}(LT) is required, where the time interval T is several months or a year. Such a period will normally include a variety of meteorological conditions, both favourable and unfavourable to propagation. A value for L_{AT}(LT) may be obtained in this situation from that calculated for L_{AT}(DW) via equation (3), by using the meteorological correction C_{met} in equation (6).

A value (in decibels) for C_{met} in equation (6) may be calculated using equations (21) and (22) for the case of a point sound source with an output which is effectively constant with time:

$$C_{met} = 0 \quad \ldots (21)$$

if $d_p \leq 10(h_s + h_r)$

$$C_{met} = C_0 \left[1 - 10(h_s + h_r)/d_p\right] \quad \ldots (22)$$

if $d_p > 10(h_s + h_r)$

where

h_s is the source height, in metres;

h_r is the receiver height, in metres;

d_p is the distance between the source and receiver projected to the horizontal ground plane, in metres;

C_0 is a factor, in decibels, which depends on local meteorological statistics for wind speed and direction, and temperature gradients.

The effects of meteorological conditions on sound propagation are small for short distances d_p, and for longer distances at greater source and receiver heights. Equations (21) and (22) account approximately for these factors, as shown in figure 10.

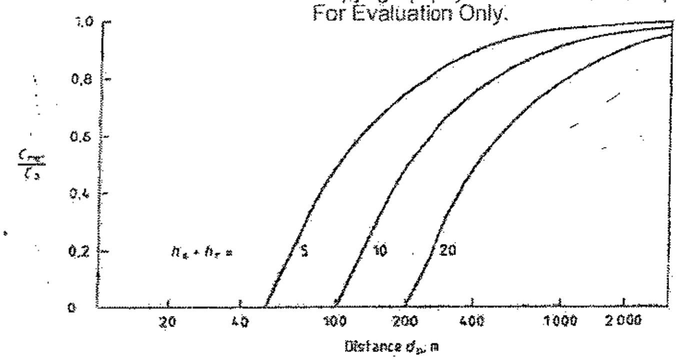

Figure 10 — Meteorological correction C_{met}

NOTES

20 A value for C_0 in equations (21) and (22) may be estimated from an elementary analysis of the local meteorological statistics. For example, if the meteorological conditions favourable to propagation described in clause 5 are found to occur for 50 % of the time period of interest, and the attenuation during the other 50 % is higher by 10 dB or more, then the sound energy which arrives for meteorological conditions unfavourable to propagation may be neglected, and C_0 will be approximately + 3 dB.

21 The meteorological conditions for evaluating C_0 may be established by the local authorities.

22 Experience indicates that values of C_0 in practice are limited to the range from zero to approximately + 5 dB, and values in excess of 2 dB are exceptional. Thus only very elementary statistics of the local meteorology are needed for a ± 1 dB accuracy in C_0.

For a source that is composed of several component point sources, h_s in equations (21) and (22) represents the predominant source height, and d_p the distance from the centre of that source to the receiver.

9 Accuracy and limitations of the method

The attenuation of sound propagating outdoors between a fixed source and receiver fluctuates due to variations in the meteorological conditions along the propagation path. Restricting attention to moderate downwind conditions of propagation, as specified in clause 5, limits the effect of variable meteorological conditions on attenuation to reasonable values.

There is information to support the method of calculation given in clauses 4 to 8 (see annex B) for broad-band noise sources. The agreement between calculated and measured values of the average A-weighted sound pressure level for downwind propagation, L_{AT}(DW), supports the estimated accuracy of calculation shown in table 5. These estimates of accuracy are restricted to the range of conditions specified for the validity of the equations in clauses 3 to 8 and are independent of uncertainties in sound power determination.

NOTE 24 The estimates of accuracy in table 5 are for downwind conditions averaged over independent situations (as specified in clause 5). They should not necessarily be expected to agree with the variation in measurements made at a given site on a given day. The latter can be expected to be considerably larger than the values in table 5.

The estimated errors in calculating the average downwind octave-band sound pressure levels, as well as pure-tone sound pressure levels, under the same conditions, may be somewhat larger than the estimated errors given for A-weighted sound pressure levels of broad-band sources in table 5.

In table 5, an estimate of accuracy is not provided in this part of ISO 9613 for distances d greater than the 1 000 m upper limit.

Throughout this part of ISO 9613 the meteorological conditions under consideration are limited to only two cases:

a) moderate downwind conditions of propagation, or their equivalent, as defined in clause 5;

b) a variety of meteorological conditions as they exist over months or years.

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The use of equations (1) to (5) and (7) to (20) (and therefore also table 5) is limited to case a): meteorological conditions only. Case b) is relevant only to the use of equations (6), (21) and (22). There are also a substantial number of limitations (non-meteorological) in the use of individual equations. Equation (9) is, for example, limited to approximately flat terrain. These specific limitations are described in the text accompanying the relevant equation.

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

Height, h [a]	Distance, d [a]	
	$0 < d < 100$ m	100 m $< d < 1\ 000$ m
$0 < h < 5$ m	± 3 dB	± 3 dB
5 m $< h < 30$ m	± 1 dB	± 3 dB

[a] 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.

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Annex A
(informative)

Additional types of attenuation (A_{misc})

The term A_{misc} in equation (4) covers contributions to the attenuation from miscellaneous effects not accessible by the general methods of calculating the attenuation specified in clause 7. These contributions include

- A_{fol}, the attenuation of sound during propagation through foliage,
- A_{site}, the attenuation during propagation through an industrial site, and
- A_{hous}, the attenuation during propagation through a built-up region of houses,

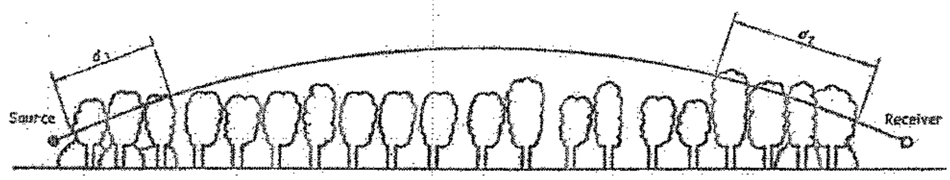
which are all considered in this annex.

For calculating these additional contributions to the attenuation, the curved downwind propagation path may be approximated by an arc of a circle of radius 5 km, as shown in figure A.1.

A.1 Foliage (A_{fol})

The foliage of trees and shrubs provides a small amount of attenuation, but only if it is sufficiently dense to completely block the view along the propagation path, i.e. when it is impossible to see a short distance through the foliage. The attenuation may be by vegetation close to the source, or close to the receiver, or by both situations, as illustrated in figure A.1. Alternatively, the path for the distances d_1 and d_2 may be taken as falling along lines at propagation angles of 15° to the ground.

The first line in table A.1 gives the attenuation to be expected from dense foliage if the total path length through the foliage is between 10 m and 20 m, and the second line if it is between 20 m and 200 m. For path lengths greater than 200 m through dense foliage, the attenuation for 200 m should be used.



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

Figure A.1 — Attenuation due to propagation through foliage increases linearly with propagation distance d_f through the foliage

Table A.1 — Attenuation of an octave band of noise due to propagation a distance d_f through dense foliage

Propagation distance d_f m	Nominal midband frequency Hz 63	125	250	500	1 000	2 000	4 000	8 000
$10 \leq d_f \leq 20$	Attenuation, dB: 0	0	1	1	1	1	2	3
$20 \leq d_f \leq 200$	Attenuation, dB/m: 0,02	0,03	0,04	0,05	0,06	0,08	0,09	0,12

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A.2 Industrial sites (A_{site})

At industrial sites, an attenuation can occur due to scattering from installations (and other objects), which may be described as A_{site}, unless accounted for under A_{bar}, or the sound source radiation specification. The term installations includes miscellaneous pipes, valves, boxes, structural elements, etc.

As the value of A_{site} depends strongly on the type of site, it is recommended that it is determined by measurements. However, for an estimate of this attenuation, the values in table A.2 may be used. The attenuation increases linearly with the length of the curved path d_s through the installations (see figure A.2), with a maximum of 10 dB.

A.3 Housing (A_{hous})

A.3.1 When either the source or receiver, or both are situated in a built-up region of houses, an attenuation will occur due to screening by the houses. However, this effect may largely be compensated by propagation between houses and by reflections from other houses in the vicinity. This combined effect of screening and reflections that constitutes A_{hous} can be calculated for a specific situation, at least in principle, by applying the procedures for both A_{bar} and reflections described in 7.4 and 7.5. Because the value of A_{hous} is very situation-dependent, such a calculation may be justified in practice. A more useful alternative, particularly for the case of multiple reflections where the accuracy of calculation suffers, may be to measure the effect, either in the field or by modelling.

A.3.2 An approximate value for the A-weighted attenuation A_{hous}, which should not exceed 10 dB, may also be estimated as follows. There are two separate contributions

$$A_{hous} = A_{hous,1} + A_{hous,2} \qquad \text{... (A.1)}$$

A.3.3 An average value for $A_{hous,1}$ (in decibels) may be calculated using the equation

$$A_{hous,1} = 0{,}1Bd_b \quad \text{dB} \qquad \text{... (A.2)}$$

where

B is the density of the buildings along that path, given by the total plan area of the houses divided by the total ground area (including that covered by the houses);

d_b is the length of the sound path, in metres, through the built-up region of houses, determined by a procedure analogous to that shown in figure A.1.

The path length d_b may include a portion d_1 near the source and a portion d_2 near the receiver, as indicated in figure A.1.

The value of A_{hous} shall be set equal to zero in the case of a small source with a direct, unobstructed line of sight to the receiver down a corridor gap between housing structures.

NOTE 25 The A-weighted sound pressure level at specific individual positions in a region of houses may differ by up to 10 dB from the average value predicted using equations (A.1) and (A.2).

Table A.2 — Attenuation coefficient of an octave band of noise during propagation through installations at industrial plants

Nominal midband frequency, Hz	63	125	250	500	1 000	2 000	4 000	8 000
A_{site}, dB/m	0	0,015	0,025	0,025	0,02	0,02	0,015	0,015

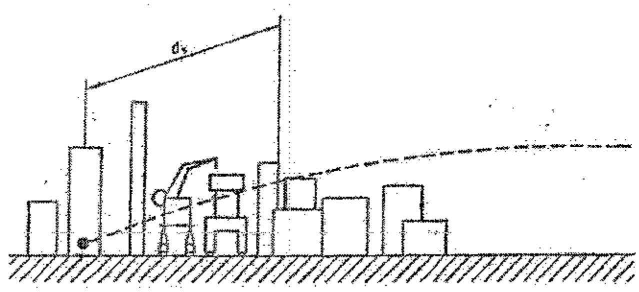

Figure A.2 — The attenuation A_{site} increases linearly with the propagation distance d_s through the installations at industrial plants

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A.3.4 If there are well-defined rows of buildings near a road, a railway, or a similar corridor, an additional term $A_{hous,2}$ may be included (provided this term is less than the insertion loss of a barrier at the same position with the mean height of the buildings):

$$A_{hous,2} = -10 \lg[1-(p/100)] \text{ dB} \qquad \ldots \text{(A.3)}$$

where p (the percentage of the length of the façades relative to the total length of the road or railway in the vicinity) is $\leqslant 90$ %.

A.3.5 In a built-up region of houses, the value of $A_{hous,1}$ [as calculated by equation (A.2)] interacts as follows with the value for A_{gr}, the attenuation due to the ground [as calculated by equation (9) or equation (10)].

Let $A_{gr,b}$ be the ground attenuation in the built-up region, and $A_{gr,0}$ be the ground attenuation if the houses were removed [i.e. as calculated by equation (9) or equation (10)]. For propagation through the built-up region in general, $A_{gr,b}$ is assumed to be zero in equation (4). If, however, the value of $A_{gr,0}$ is greater than that of A_{hous}, then the influence of A_{hous} is ignored and only the value of $A_{gr,0}$ is included in equation (4).

The interaction above is essentially to allow for a range of housing density B. For low-density housing, the value of A_{gr} is dominant, while for high-density housing A_{hous} dominates.

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Annex B
(informative)

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Following are my comments in red on the 3/5/09 conference call between Warren Brown, Dora Mills, DEP high level staff (Andrew Fisk, director of BLWQ review division, Jim Cassida, wind power specialist,) RHW case manager Beth Callahan, and Rollins case manager Becky Maddox (who confirmed by email that she took the notes). I transcribed the notes for legibility.

The call begins with Warren:
Wind turbine noise has been researched in Europe (Denmark, Belgium, Germany) over the past 25 years. Regulations have been adopted overseas by each country. **In the US - slow response to turbine noise. Industrial noise started being addressed in 60's-70's. We haven't addressed wind turbine noise yet.**
Kamperman and James have extensively studied turbine noise, and continue their investigations. They are the authors of "Simple Guidelines for Siting Turbines to Eliminate Health Risks" which clearly explains turbine noise and how to deal with it properly. Maine DEP has been given this information. They have chosen to ignore it.

Internet - Wind turbine experts, studies in Europe, conclusions drawn - people have access to this information. How true, if people have access to it, so do the wind developers and government regulatory agencies - so why are they in denial?

(Dr. Nina) Pierpont - studies in US recently done. Medical research conducted. (Scientific study). Science behind wind turbine noise - low frequency energy causes a rumbling. At unknown distance - get some of that rumbling noise, especially with windows open at night in rural areas.
Dr. Pierpont's work goes well beyond "that rumbling noise". See manuscript of her book Wind Turbine Syndrome attached for a clear explanation of what turbines do to people.

Dora Mills:
Just because you can hear it doesn't mean it has adverse health effects.
Such a simplistic and childish statement. Shows no empathy or curiosity (like real doctors have).
With regard to low frequency inaudible turbine noise. "Just because you CAN'T hear it doesn't mean it DOES NOT have adverse health effects.

Warren:
A-weighted measurements established by OSHA for industrial noise - different altogether than wind turbines. A-weighted is based on hearing protection.

L-90 (the level exceeded 90% of the time) - allow this to be adjustable to the existing sound level of the area. Raises base line up.
European studies - UK=43 dBC or L-90 +5
Australia = 35 dBA

Europe captures low frequency noise the same as the US does.
Maine's rules are very conservative in US - 45 dBA in Maine.
But, as a community we have not taken account for the low frequency spectrum. Other

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countries use dBA as well, not dBC. But, Maine needs to think about low frequency. Well put, Warren.

Dora Mills:

1. Went through Pierpont's studies. Its not scientific - a group of anecdotes does not equal scientific study. Pierpont's work is peer reviewed and builds on earlier studies. The wind industry has marginalized Dr. Pierpont because her work threatens their ability to put turbines wherever they want. She coined the phrase Wind Turbine Syndrome, which is becoming part of the lexicon.
2. CO - DOE studies - noise not related to medical issues. I think she meant CA - DOE (Canada and Dept. of Energy)
3. Canada - a couple of articles in journals - can have annoyances, but not necessarily health effects.
4. **Europe - "annoyance" = "adverse health effects".** World Health Organization (WHO) - studies done in urban areas, not rural. Our point exactly - why does she disregard her own findings?
5. U Mass Amherst 1995. Info from around W.E.(western Europe?) Info in Netherlands = 30-35 dBA
6. Maine - looked at Standards. Reviewed peoples issues in Mars Hill. Are our regs protective enough? **Not a lot of evidence of adverse health effects, even at Mars Hill, but subjective.** Anecdotal issues with noise only. Mars Hill WHO issues - need to stengthen these.
   Many residents at Mars Hill have been complaining about turbine noise since the day the first turbine became operational. An objective observer might infer that they have something to complain about. A public nuisance suit is the only avenue left to them, since DEP refuses to enforce its own variance limits. Turbines should not have to make people physically ill to be termed a nuisance. Mars Hill people complain of illness caused by exposure to turbine noise, which goes well beyond nuisance.

Andrew Fisk:
DEP awarded Mars Hill a 5 decibel variance (for 50 dBA), but we would not do that again.

Warren Brown:
Can't regulate indoor noise. Annoyance based on WHO - Warren says not credible.

Maine's noise levels based on 10% of population will be annoyed.

Has issues with model being used. Currently its based on industrial noise, not wind turbine noise. We haven't been able to determine whether this model is accurate for wind turbines. So why are they approving wind turbine projects as if the model was reliable? Why not simply compute the noise prediction by hand, instead of using a "black box" with numerous ways to tweak the results.

Dora Mills:

Maine Medical Association meeting coming up. Lewiston Sun journal need answers. Angus King will speak at the meeting as well.

We are moving forward with mistakes made at Mars Hill with variance, and siting. They are not doing anything differently at Rollins or Record Hill Wind. There have been no changes made to the parameters in the CADNA model according to descriptions in the noise studies submitted by RSE on both projects.

WHO issue - many decades of experiences in Europe - **their standards are close to what ours are - measured in dBA** This is false. WHO most recent noise guidelines are 30 dBA outside homes at night, not 45 dBA.

Warren Brown:
Lots of studies done in Denmark and the Netherlands show annoyance is an issue.

Dora Mills:
States there is no evidence for state wide moratorium. **There are lots of health benefits to wind turbines.** There is no evidence to support this statement.

WHO issue - many yrs of experience with wind turbines - no evidence of adverse health effects. This is a false statement.

Andrew Fisk:
Mars Hll Issue - we have learned a lot from this project and will not allow variances, have changed siting, etc... How has siting been changed? Lisa and Gary Hodgkins house is closer to the Record Hill Wind turbines than many of the homes at Mars Hill.

Warren Brown:
Reviews are ready to send out. Meaning his peer reviews, ignore most of the warnings made here.
Based on models - in compliance with predictive model for 45 dBA nighttime noise, but, still questions
regarding the model - based on industrial noise.

1990 Hubbard paper done for NASA on nighttime noise. (RSE noise studies are) based on point source, but turbines are not point sources or line sources - they are in between.

Stable Atmospheric Conditions - wind speed is stratified as change elevation - may vary a lot - causing air turbulence and swishing and popping noise. This is the condition that occurs most nights at Roxbury Pond - dead quiet at pond level, but wind sufficient for turbine operation above the ridge.

Wind turbine noise needs more investigation.

1. Need to be able to predict stable atmospheric conditions (has friend in Air Force who is a meteorologist - will contact him).

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2. Setup protocol for acoustic measurements with DEP staff member on site. May be able to get readings within a month or so - but not sure at this point.

Questioning RSE's assumptions - due to the model.

Convinced that we can use dBA and don't need to use dBC.

Sound pressure levels may need to be tested to make sure they are in compliance with noise values.

Need to collect more data at Mars Hill - looked at the wrong model. Weather should not be too much of an issue this time of year.

Stability based on - seasons, atmospheric conditions.

There is a period when turbines are loud. Not sure how to predict this yet. Need to figure out stable atmospheric conditions first. Another term for stable atmosphere is temperature inversion. As the ground and water cools after the sun goes down by radiating heat into space. cooler, denser air descends and settles at the surface. This is the typical pattern at Roxbury Pond.

NEXT STEPS - 3 OPTIONS

1. Need to calibrate model being used and determine compliance with Mars Hill. Then need to apply it to Rollins and Record Hill. Need to look at worst case predictions.
2. or - Data mining existing data from Mars Hill. Nordex model exists (a type of turbine that is programmable to react to remote noise or wind monitoring equipment and curtail operation)
3. or - 4 models for turbines - he's not familiar with them but would find someone who is. Would use these models at Rollins, Roxbury (Nordex model is one Rick mentioned in his first report).

Jim Cassida:
If choose option 3 - Nordex model - can we put it back on applicant to run the data? Warren says that will work.

Compare outcome with the Nordex model with existing one used.

Warren Brown:
Nordex is a 2000 + model that considers turbine noise, but not sure if it is a good model to use. Not sure how widely it is used. In his earliest testimony Rick James suggested using Nordex turbines due to their remote control capabilitites. He also spoke to Warren Brown about them in one of several phone conversations in which he attempted to educate Warren about turbine noise issues.

Will clarify next step with model. Will be in touch with Jim tomorrow afternoon.

The importance of the statements made by Brown and Mills in this phone conference cannot be overemphasized. Mills shows her disregard for the suffering of people living near turbines, ignoring the vast body of anecdotal information and many scientific studies about people suffering from turbines, and saying the health benefits of turbines trump any concerns about "annoyance". In interviews she has said that not only should there be no moratorium to study the problem of turbine noise, we should build wind projects more quickly because Mainers are dying premature deaths from respiratory disease from emissions from coal plants.

Brown's statements, rebutting Mills, show he is aware of low frequency noise causing problems and that turbine noise is most problematic when stable atmospheric conditions (such as are typical at Roxbury Pond most nights) also known temperature inversions, exist. He states the CADNA model is not designed for wind turbine noise, and is concerned about its fitness for this purpose.

Simple calculations of "decay rates" based on the known distance between turbines and homes are included in my testimony which show that even using a single turbine as a point source (6 dBA per doubling of distance) turbine noise will exceed Maine's 45 dBA limit, without including the 5 dBA penalty for SDR noise.

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Dora Mills
Warren Brown
Andy Fisk
Becky Hadley
Beth Callahan
Jim Cassida

Wind power - conference call 3/5/09

Warren:

20+ yrs in Europe -> wind turbine noise has been being researched over the years. { Denmark Belgium Germany }

Regulations adopted overseas by each particular country. In US -> slow response to wind turbine noise. Industrial noise started being addressed in 60's - 70's, but we haven't addressed wind turbine noise yet.

Internet -

wind turbine experts, studies in Europe, conclusions drawn. - people have access to this info.

Dr. Pierpont -> studies in US. recently done. medical research conducted. (scientific study)

Science behind wind turbine noise -> low freq. energy causes a rumbling.

At unknown distance -> get some of that rumbling noise, especially w/ windows open at night in rural areas.

☆ Low-freq. rumble created by turbines.

France
↳ Took lowest 10% of sound that occurs at night →
(L-90) ☆ Acoustic sound at night can be
(L-90+2) twice what it is, based on A-weighted sound
↳ France said no to turbines! (Measured at property line.)

Acoustic energy can damage hearing!

Dora Mills:
☆ Just because you can hear it doesn't mean it has adverse health effects!

Warren:
A-weighted measurements established by OSHA for indust. noise → Different altogether than wind turbines.

A-weighted is based around hearing protection!

L-90 → allow this to be adjustable to the existing sound level of the area. (Raises base-line up!)

European ~~Standards~~:
UK = 43 dBa or L-90+5
Australia = 35 dBa

☆ Europe captures lower freq. noise the same as US does.
☆ Maine's rules are very conservative in US.
↳ 45 dBa in ME!

↳ But, as a community we have not taken account for the ~~low~~ -freq. spectrum!

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The other countries use dBA as well, not dBC.

→ But, ME needs to think about low freq.

Dora Mills:

① Went thru Dr. Pierpoint's studies. She says it's not scientific (group of anecdotes ≠ scientific study!)

② CO - DOE studies → ~~noise~~ not ~~related~~ to medical issues.

③ Canada → a couple articles in Journals
↳ can have annoyances, but not necessarily health effects.

④ Europe - Annoyance = adverse health effect (WHO)
- World Health Organization -
↳ studies done in Urban areas, not rural!

⑤ UMASS Amherst ~~[illegible]~~ - 1995
- info from around N.E.
- info in Netherlands = 30-35 dBA.

⑥ ME - looked at Std's.
→ Reviewed people's issues in Mars Hill.
★ ↳ Are our reg. protective enough?

Not a lot of evidence of adverse health effects, even at Mars Hill, but subjective!

////

Anecdotal issues w/ noise only!

Mars Hill → need to strengthen these!
WHO issues

Maine DEP
Appealed Mars Hill a 5 decibel variance (for 50 dBa) but we wouldn't do that again.

Warren: 45 dBa will still penetrate their houses! (low-freq noise) → noise can get inside and resonate → consequently, noise can be louder inside than outside!

- can't regulate indoor noise!

Annoyance based on WHO → Warren says not credible!

☆ ME's noise levels based on:
↳ 10% of pop. will be annoyed by noise.

Warren → Has issue w/
Model being used → currently its based on industrial [redacted] noise, not wind turbine noise!
↳ we haven't been able to determine that this model is accurate for wind turbines.

Dora Mills:
ME Med. Assoc. Mtg → coming up.
Lewiston Sun Journal needs answers

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- Angus King will speak at the mtg as well.
- we are moving forward w/ mistakes made at Mars Hill (variance, siting).
- WHO issue -> many decades of experiences in Europe -> their std's are close to what ours are. (measured in dBa!)

Warren:

Lots of studies done in Denmark/Netherlands -> show annoyance is an issue!

Dora Mills:

States there is no evidence for State-wide moritorium! Lots of health benefits to wind turbines!

(1) WHO issue -> Many yrs of experience w/ wind turbines -> no evidence of adverse health effects!

Andy: (2) Mars Hill issue - we have learned a lot from this project and will not allow variance, have changed siting, etc...

Warren:

Reviews are ready to send out!
Based on models ⇒ in compliance w/ predictive model for 45 dBa night time noise, but, still questions regarding the model! → Based on industrial noise.

1990 - Hudson paper done for NASA on nighttime noise,
↳ based on point source, but turbines are not point sources or line sources → they are in between!

Stable atmospheric conditions:
↳ Wind speed is stratified as change elevation → may vary a lot → causing air turbulence + swooshing, + popping noise. Very

↳ Wind turbine noise needs more investigation!
(1) need to be able to predict stable atmospheric conditions
↳ has friend in air force who is meteorologist → will contact him!!
(2) setup protocol for acoustic measurements w/ DEP staff member on-site.

↳ may be able to get reading w/in month or so, but not sure at this moment.

→ Questioning RSE's assumptions, due to the model.

→ He's convinced that we can use dBa! and don't need to use dBc.

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Sound pressure levels may need to tested to make sure they are in compliance w/ noise rules.

↳ need to collect more data (for Mars Hill)
↳ looked at the wrong model!

Weather shouldn't be too much of an issue this time of year.

Stability based on:
- Seasons
- Atmospheric conditions

There is a period when turbines are loud, but not sure how to predict this yet.
↳ Needs to figure out stable atmospheric conditions first!

3 options -
Next Steps!

① Need to calibrate model being used and determine compliance w/ Mars Hill.
↳ Then need to apply it to Rollins + Record Hill. (Need to look at worst-case predictions).

- or -

③ If don't go back to Mars Hill →
↳ 4 models for turbines → he's not familiar w/ them but would find someone who is.
↳ would use these models for Rollins + Roxbury (Nordes model).

- or -

② Data-mining existing data from Mars Hill

Nordes model
↳ exists

Jim:
If chose option 3 -> Nordes model -> can we put it back on applicant to run the data?
↳ Warren says that would work.

Compare outcome w/ the Nordes model w/ existing one used.

Warren:
Nordes is a 2000+ model that considers wind turbine noise, but not sure if it is a good model to use. Not sure how widely its used.

☆ Will clarify next step w/ model. Will be in touch w/ Jim tomorrow afternoon!

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Some Limitations of Ray-Tracing Software for Predicting Community Noise from Industrial Facilities

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ABSTRACT

Ray-tracing software has proven to be a valuable and powerful tool to predict community noise from industrial facilities. Accurate predictions are necessary to select the noise reductions needed to meet regulations and/or project noise limits, and then to determine individual equipment noise limits, select add-on noise controls, and confirm the plant will comply with its noise limits. Although ray-tracing and similar image-source software packages have proven to be powerful, they have many limitations. To use ray-tracing software effectively to model community or in-plant noise, the user needs to understand those limitations. How the software handles barriers is considered the most significant limitation. Further, ray tracing does not adequately predict levels when the wavelength of sound is comparable to dimensions of objects in the transmission path, when diffuse reflections occur, or when sound is scattered and transmitted by equipment and piping. The empirical methodology (ISO 9613-2) used to predict outdoor propagation, including ground effects, also imposes limitations. This paper identifies and discusses many of the more important limitations of ray-tracing software for predicting community noise. Examples are given. Commercially available software is identified, but no attempt is made to compare available packages.

1. Background - What is Ray-Tracing Software?

Ray-based acoustical modeling assumes that sound acts like rays of light, which are used to find receivers and intervening objects and then predict or calculate the sound pressure level (SPL). SPLs can be predicted in the community or close to the source, at isolated receivers or as contours. Outdoor propagation from a point source is computed by summing multiple attenuations with distance, using some standard, usually ISO 9613, Part 2[1]. Everything else, including tracing sound rays and defining finite-sized sources, is handled by the ray-tracing software. The accuracy of output predictions depends on how the user chooses to model the situation, and how the software treats the input data. Accurate predictions are needed to select the noise reductions needed to meet regulations and/or project noise limits; then to determine individual equipment noise limits and select add-on noise controls; and finally to confirm that the plant will comply with applicable noise limits.

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The advantages of ray-tracing software include the ability to manage data of very large projects, screening by multiple barriers and finite-sized sources, and multiple reflections by screens and objects. Ray-tracing software allows the user to define line and area sources, which can be used to model buildings. Software breaks or partitions finite-sized sources into many point sources – automatically for ray-tracing software and typically from user-selected options for image source software. These advantages lead to more precise modeling of sources and propagation paths, and thus more accurate predictions. The price of this power is complexity, and a long and steep learning curve. Ray-tracing software is far more complex than it first appears to be. Effective use of this software requires significantly greater expertise than acoustical modeling using a spreadsheet. The following are some commercial ray (many reflections) and image source (usually one reflection) modeling software packages: CadnaA (DataKustik), IMMI (Wölfel), Mithra (01dB-Stell), SoundPLAN (Braunstein + Berndt GmbH), and SMP9613 (Power Acoustics, Inc.).

2. Assumptions and Omissions

There are a number of assumptions and omissions the authors have made because of space constraints. This paper cannot include every aspect of the limitations of ray-tracing software or the many outdoor sound propagation methodologies and standards. Only limitations of ISO 9613-2 are discussed. No other outdoor sound propagation standards or methodologies are referenced. The paper also does not cover atmospheric effects *per se*, but only where needed to explain a limitation.

The following terminology applies to this paper. When "9613" is used, it means ISO 9613, Part 2 or its equivalent, ISO 9613-2. "Ray-tracing software" refers to commercial software packages. "Ray tracing" means either 9613 and/or commercial ray-tracing software.

Because the paper's topic is limitations, there is no attempt to describe 9613 or ray-tracing software, except to explain a limitation. Very limited guidance on how to use ray tracing is given. Input, output, database functions, and graphics are excluded. Topics discussed apply generally to ray-tracing packages and image software (e.g., SMP9613) used in outdoor community noise predictions. This paper is limited to the authors' experience with ray-tracing software and its application, and is not intended to imply a complete knowledge of all available software. The authors make no attempt to compare differences or peculiarities of specific ray-tracing software packages. The inherent complexity and user learning curve have been discussed previously by the authors[2]. Attenborough[3] and Witte and Ouwerkerk[4] provide helpful evaluations of 9613.

3. What Does Ray-Tracing Software Predict?

On one hand, the answer to this question seems obvious – it predicts or calculates the sound pressure level (SPL) in the community at isolated receivers or as contours. ISO 9613-2 is an empirically based engineering method, in which octave-band attenuations include both geometrical spreading and other attenuations. For each point source, the SPL is computed from the sound power level (PWL) as follows:

$$\text{SPL}\big|_d = \text{SPL at a distance } d \text{ from a point source} = \text{PWL} - \text{Attenuations} + \text{Directivity}. \quad (1)$$

The distance (*d*) from a source to a receiver can be one meter to at least a thousand meters. Directivity is input to the software by the user. Propagation over water[5] is specifically excluded by 9613.

On the other hand, the answer is not obvious. According to 9613, various attenuations – one at a time in octave bands – are combined for a long-term average (say, one year) under downwind atmospheric conditions favorable to propagation of sound. Wilson[6] indicates downwind propagation is equivalent to propagation in a moderate thermal inversion, both of which result in a downward refracting atmosphere. Yet these conditions are seldom constant. A long-term average would include many different atmospheric conditions and ground covers. Thus, a SPL calculated according to 9613 is not applicable to any one atmospheric condition or ground cover. Daigle and Stinson[7] demonstrate that 9613 calculations are not applicable to propagation over newly fallen snow.

Geometrical divergence is calculated using spherical spreading (-6 dB/doubling of distance) from a point source, which corresponds to cylindrical spreading (-3 dB/doubling of distance) from a line source (or a line of closely spaced point sources). This implicitly assumes a neutral atmosphere. However, for propagation downwind or in a moderate inversion, the actual rate of divergence (in absence of atmospheric absorption) is often much less than nominal spherical or cylindrical divergence[8,9]. Lower rates of actual divergence (attenuation) result in much higher noise levels than are predicted by ray-tracing software.

ISO 9613-2 implicitly assumes that wind blows from each source to each receiver, as shown in Figure 1. Although each receiver cannot be downwind simultaneously, this assumption is useful in designing a facility to meet a not-to-exceed community noise limit, as shown in Figure 1a. As suggested by Figures 1b and c, actual levels can be lower than predicted, because each receiver cannot be downwind of each source at the same time.

4. Modeling Accuracy

ISO 9613-2 method estimates the accuracy of the A-weighted SPL it predicts as ±3 dB for distances up to 1 km. No estimated accuracy beyond 1 km is given. This estimate of accuracy is only for the long-term downwind average, and does not apply where there are reflections, screening, or other noted exclusions. The estimated accuracy excludes uncertainties in the PWL of sources. The accuracy for any octave band and tones is "somewhat" less than ±3 dB, but no estimate of accuracy is given. However, 9613 and ray-tracing software are routinely used for distances beyond 1 km. Melding ray tracing with 9613 raises issues about the resulting predictions, because 9613 calculations do not apply to any one atmospheric condition; do not address wind speed and direction, or ground cover; and exclude propagation over water. In some software packages, the user can choose settings (such as search angle, number of reflections, and overall accuracy tolerance) that affect the resultant accuracy and compute speed. Further, accuracy depends on how a plant is modeled.

5. Barriers

Ray tracing has great advantages when calculating insertion loss (IL) of barriers, which can be buildings, tanks, large equipment, cooling towers, hilly terrain, and sound walls. Sometimes 9613 and ray-tracing software calculate erroneously high ILs, and lower than realistic SPLs. However, its treatment of barriers is also considered the most significant limitation of 9613.

The so-called "speed-bump" effect[10] can be a problem. When strictly applied, 9613's formulation gives a significant IL from a speed bump around a plant, which is obviously incorrect. This is caused by two effects: First, 9613 calculates a barrier IL even though in the real world wave length effects result in an IL of essentially zero (see Section 8); and second, the calculated diffraction of a straight ray (assumed by 9613 and used by ray-tracing software) when it passes over but close to a barrier (bright zone or negative path length difference). ISO 9613-2 gives a smooth transition between the bright and shadow zones. Older versions of ray-tracing software often calculated the speed-bump effect, but many now have included special features (sometimes with a numerical switch) to eliminate this effect.

ISO 9613-2 uses straight-ray barrier diffraction, and assumes each receiver is downwind of each source. Downwind (and in a moderate inversion) rays of sound tend to arc over the top of objects on the ground with reduced or no attenuation, as shown in Figure 2. Curved rays (downwind or in a moderate inversion) tend to produce actual ILs lower than predicted, and thus higher actual SPLs than predicted. For example, if a source, barrier, and receiver have the same height (grazing barrier incidence) and they are separated by 1 km from each other, 9613 calculates an IL of 4.8 dB, which is unrealistic. When a barrier is close to either the source or the receiver, 9613's formulation works well. When the barrier is located at a larger distance from either, the predicted ILs are normally unrealistically high. Serious doubts arise in predicting the IL for a barrier not close to either. Brittain and Parzych[11] use curved rays (in a modification of SMP9613) to show the effects of distance from a residential barrier. They show the IL of A-weighted levels behind a 4-m high barrier protecting residences from a distant refinery unit can be up to 3 dB and 9 dB lower than predicted by 9613 at 30 m and 100 m from the barrier, respectively. Beyond 50 m, this residential barrier provides essentially no IL.

Only one top diffraction and two end diffractions are calculated. ISO 9613-2 can correctly compute all diffractions only of one barrier, whose top is a straight edge. A critical issue with multiple barriers is the number and location of diffraction paths around the ends of barriers. Adding barriers increases the number of possible paths around the ends of various combinations of barriers, none of which is handled by 9613. For long barriers and many multiple barriers, end diffractions are often negligible, so the limit of two end diffractions may not pose a problem. For tall multiple barriers, end diffractions can be the dominant transmission path as shown in Figure 3; ray tracing does not identify or calculate the dominant ray in Figure 3. Some ray-tracing software may have implemented provisions for end diffractions of multiple barriers similar to what is done for top diffractions, but it is doubtful that more the two end diffractions are calculated. Diffraction by an end and then the top of another barrier is also not calculated by 9613, which is a limitation.

Figure 4 gives examples of two "pathological" barrier configurations that are not handled correctly by either 9613 or ray-tracing software. In each example (and by Figure 3), there are more than two end diffractions, but only two are calculated by 9613. Figure 4a shows two very different barrier heights, a vertical edge, and three source-receiver paths. Figure 4b has a high narrow barrier behind a long low barrier.

Parzych[10] also points out deficiencies in 9613's formulation of ground effects for a ray diffracted over the top of a barrier, and recommends a more accurate formulation. ISO 9613-2 sets the barrier IL to the greater of either the barrier attenuation or the ground attenuation. It appears that only SMP9613 software offers the option to use the more accurate formulation. Ground effects for end diffractions are not included in 9613, and it is not known whether or how ray-tracing software handles ground effects for end diffractions.

6. Finite-Sized Source Effects

The size and shape of a large, finite-sized, or volume source affects both the actual and the predicted community noise level – beyond the obvious dependence of computed PWL on the size of the conformal surface.

A finite-sized or volume source in the shape of a box has a predicted and actual community noise level 4 dB lower than a point source at the same distance – when each source has the same octave-band PWL[12,2]. In general, ray tracing correctly and automatically calculates noise radiated by large finite-sized sources. Users of ray-tracing software sometimes assume that contributions from a point source and a finite-sized source at a distant receiver should be identical, and erroneously apply a correction to make them equal. This can be readily demonstrated using any ray-tracing software. For example, each of five faces of the large source in the shape of a cube sitting on the ground, as shown in Figure 5, has directivity. The front surface (facing the receiver) has a directivity of 0 dB; the two side surfaces and top have a directivity of -5 dB; and the rear surface has a directivity of -20 dB[13,14]. If both the point and volume source has a PWL of 100 dBA, the PWL of each identical face of the cube would be 93 dBA. Assuming reflections from hard ground, no atmospheric absorption, and the distance from each face of the volume and the point source essentially the same, the point source yields a predicted level of 61 dBA at the receiver, while the level from the cube is predicted to be 57 dBA. This difference in A-weighted SPL at a distant receiver is a limitation, which can unnecessarily increase costs of noise control.

When the SPL of a very large uniformly radiating volume source is predicted at 1 m from the center of a face (in the absence of contaminating sources), the SPL will be about 3 dB higher than the SPL used by ray-tracing to compute the PWL[2,15]. This is caused by pressure fluctuations[16] where particle velocities are parallel to the surface. The effect decreases exponentially with distance from the surface, and does not propagate to the far field. This is sometimes called the evanescent field. As the source size decreases, the magnitude of this effect decreases, and it disappears (as expected) for a point source. A correction can be computed to account for the source size effect. This limitation results in over predicting SPL.

Noise radiated by a finite-sized source can be strongly limited by radiation efficiency when the source dimensions approach or are lower than the wavelength of sound. For example, a pipeline radiates little noise at lower frequencies, because of decreased radiation efficiency – even when there is considerable low frequency energy. Ray-tracing software calculates noise radiated by finite-sized sources independent of source dimensions, and dependent only on the PWL. Thus, a 1-m and a 20-m cube radiate the same acoustic energy if the PWLs are identical. However, when PWL is measured/computed on a hemisphere, the measurements automatically include any and all effects of radiation efficiency. Thus, predicted levels are accurate, because measurement/calculation of PWL makes up for deficiencies in ray tracing – as long as the measured and predicted sources are roughly the same shape and size and directivity is neglected.

7. Specular And Diffuse Reflections

Both ray tracing and 9613 include reflections from building walls, large equipment, barriers and other flat surfaces. This works well and reflections will be specular as long as the surface is smooth and both of its dimensions are large compared to the wavelength of sound in the octave band of interest. The limiting octave band can be calculated using 9613, and is calculated by ray-tracing software. For the octave band whose center wavelength is just below the limiting octave band, the reflection is taken by 9613 as zero, which results in a step function in reflected sound between two octave bands. In reality, there will be appreciable reflected sound in some lower octave bands, and no step function in reflected sound for the frequency. For close-to-grazing incidence (of a ray of sound incident on the reflecting surface), the reflected energy calculated by 9613 becomes negligible. Again, there may be appreciable reflection of sound at grazing incidence, contributing to an actual SPL higher than is predicted.

Irregularities on the reflecting surface and clutter near the surface, including piping, structure, equipment, stairwells, etc., substantially affect reflections by scattering sound and causing diffuse reflections. A diffuse reflection can be viewed as a reflection at each point on the surface radiates in all directions, rather than in one direction for specular reflections. Irregular surfaces and clutter near a surface cause wavelength-dependent scattering of incident energy, and transform much of it into diffuse reflections. The balance between diffuse and specular reflections is difficult to predict or measure. As diffuse reflections increase, less energy is reflected specularly. Some incident sound energy is absorbed, which is an option in ray-tracing software. The importance of diffuse reflections is illustrated by the need to include both diffuse and specular reflections when predicting indoor propagation – even when the walls are nominally smooth[17]. Complex-shaped equipment also generates diffuse reflections. The inability of ray tracing to calculate scattering and diffuse reflections is a limitation. As an example of diffuse reflections, the walls of an HRSG (heat recovery steam generator, which extracts waste energy from a combustion turbine exhaust), are heavily cluttered as shown in Figure 6. The "thickness" of this surface clutter affects low-frequency reflections (say, below roughly one quarter of the wavelength of the octave band of interest).

As the dimensions of an object decreases compared to the wavelength, the amount of scattering increases. This is illustrated by the frequency response of a microphone and preamp. As the diameter decreases, the scattering is shifted to higher frequencies. The extent of scattering and diffuse reflections affects the predicted noise level, and is wavelength dependent. The inability of ray tracing to calculate wavelength-dependent phenomena is a limitation of ray-tracing.

8. Other Wavelength Effects and Difficult Geometries

Much of acoustics involves wavelength effects. Wavelength effects depend on wavelengths of sound, which are often temperature dependent, and not on frequency, which is not temperature dependent. For example, a fan has a constant frequency blade tone, but a tuned silencer must be designed to attenuate the temperature-dependent wavelength of the blade tone.

Ray-tracing software calculates levels using the empirical formulations of 9613, which includes wavelength effects to a very limited extent, except the empirical formulations for barrier IL and ground effects. Figure 7 shows five configurations where wavelength effects are likely to have a major effect in predicted community noise levels. First, an important wavelength-dependent limitation arises when the distance between a source and any reflecting surface, or any gap or opening on a transmission path, is small compared to the wavelength of sound in the octave band of interest. All configurations in Figure 7 have narrow gaps, slots or passages where wavelength dependent phenomena can be dominant, and wavelength-dependent software is needed to accurately predict. Further, when the equipment in Figures 7a to c have irregular surfaces (as usually happens), diffuse reflections also occur. Figures 7d and e have a narrow slit or gap, which 9613 will calculate by excluding all wavelength effects Ray tracing will compute each of these configurations, but frequency-dependent accuracy is adversely affected in an unknown way. Second, diffraction of a short barrier will exhibit wavelength effects. If the barrier is short compared to the wavelength in the octave band of interest, it will have reduced diffraction and IL. As the wavelength increases (low frequencies), this effect also increases.

A related limitation arises with multiple reflecting surfaces. Ray-tracing software cannot model many configurations with multiple reflecting surfaces moderately close to a source or on a transmission path(s), because 9613 only has only provisions to model vertical, reflecting surfaces (barriers or building walls). There are no provisions in 9613 for horizontal or oblique reflecting surfaces. Because applicable configurations cannot be adequately defined, examples are given in Figures 7a to c, which have multiple reflecting surfaces that are not vertical. Some ray-tracing software packages include a special (not from 9613) provision for modeling horizontal and/or oblique reflecting surfaces (3D reflectors in CadnaA and floating horizontal barriers in SoundPLAN), but these appear to have no or at most one reflection. Ray-tracing software cannot model the multiple reflecting surfaces of Figure 7a to c.

9. Ground Effects and Ground Reflections

Sound levels at the receiver, which include ground effects, can vary widely, over a few minutes or many months, due to atmospheric effects, particularly wind speed and direction. There are other limitations in 9613 the user needs to consider. Ground effects arise from interactions between the direct path (straight ray between source and receiver through the air) and the reflected path (straight ray between source and receiver reflected by the ground). Frequency-dependent ground effects in 9613 are complicated and use empirical formulations to approximate a long-term average attenuation from ground effects. ISO 9613-2 calculates ground effects using three regions between the source and the receiver, i.e., source, receiver, and middle region. The ground factor G is zero for a hard surface, and 1 for a soft or porous surface. The user must choose the ground factor for each region. In modeling ground that falls away sharply from the source, Ray[18] suggests setting $G = 0$ to account for a ground plane that has no reflections.

Large source-receiver distance and low or high source heights raise questions about accuracy of ground attenuation in 9613. Both the size of the source region (30 times the source height) and the attenuation in it are questionable. For example, for a 100-m-high stack, a source region of 3,000 m is nonsense, particularly for receivers close to the source. Very low height sources are also problematic, and the source region goes to zero for a point source resting on the ground. Ray[18] indicates a minimum source height of 1.5 m should be used. When the source height is less than 1.5 m over soft ground, the attenuation predicted using $G = 1$ is unreasonably high. As a work around, Ray[18] suggests using hard ground in cases where the source height is less than 1.5 m.

Ground effects in 9613-2 implicitly assume a low angle of incidence of the reflected ray to the ground. For larger angles of incidence (say, beyond 15 degrees), 9613 is silent, and ray-tracing software uses ground effects for such reflections, which introduce inaccuracies of unknown magnitude in predicted noise levels at receiver locations.

10. Transmission And Reflections From Pipe Racks And Equipment

Most process, power, and LNG (liquefied natural gas) plants have complex banks of rotating equipment, piping, pipe racks, air coolers, vessels, and tanks, which are usually densely packed as shown in Figure 8. The density often effectively blocks the line of sight, and heights often reach 10 to 50 m.

Depending on the location relative to sources and a receiver, pipe racks, piping, and banks of densely packed equipment dramatically affect propagation. Incident sound is heavily scattered, reflected diffusely, and transmitted. Further, equipment and piping are often sufficiently dense that the tops and edges of pipe racks and banks of equipment diffract sound, and act like porous barriers. Transmitted sound and diffuse reflections are wavelength dependent. The longer the path through the equipment and piping, the greater these effects. Modeling a pipe rack as a barrier usually gives erroneous results, because a barrier has only specular reflections and no transmission. Reflection or backscattering causes sound to be propagated in the opposite direction. Even when not densely packed, equipment and piping significantly affect sound propagation. Banks of equipment and piping often affect ground effects. No specular reflection or transmission is calculated by ray-tracing software, and 9613 has no empirical provisions for scattering by densely packed equipment and piping.

Little information is available to quantify reflection, transmission, and diffraction (sometimes called screening) by densely packed equipment and piping. Middleton and Seebold[19] give combined attenuations of pipe racks and equipment measured in a refinery, which was not operating. Relocatable noise sources were used. EEMUA[20] gives two plots of wavelength dependent screening (minimal and significant) by refinery equipment.

11. Conclusions

There is an apparent dichotomy. This paper identifies many important limitations of ray tracing. On the other hand, ray tracing has been used successfully to design facilities for many years. Until prediction technology, including Nord2000[21] for outdoor propagation, that significantly reduces these limitations becomes commercially available and feasible for large projects, there is no choice but to continue to use ray tracing. Spreadsheets and software that do not compute reflections have even greater limitations. However, ray-tracing software needs to be used with great discretion. By understanding its limitations, ray tracing can be used much more effectively. After identifying limitations that have a major effect on predicted levels at the controlling receiver, case-by-case evaluations and accommodations can be made. Without an awareness or understanding of the prediction method's limitations, the noise control engineer will obtain predicted levels, but is not likely to have the ability to evaluate their accuracy and significance. Except for errors in noise source data, the largest limitations in predictions of a long-term average downwind community noise level come from how the software handles barriers, multiple reflecting surfaces, pipe racks and banks of equipment, ground effects, and diffuse reflections. Further, most community noise from a plant usually comes from a handful of dominant sources. Knowing the expected dominant sources and the most significant limitations, the noise control engineer has a place to start evaluating the impact of limitations of ray tracing predictions on noise control, including costs and project decisions. Since the cost of reducing one dB from a predicted community noise level can significantly exceed $ one million, limitations of 9613 and ray-tracing software can greatly affect cost. Now – gentlemen and lady, it's time to start your engines.

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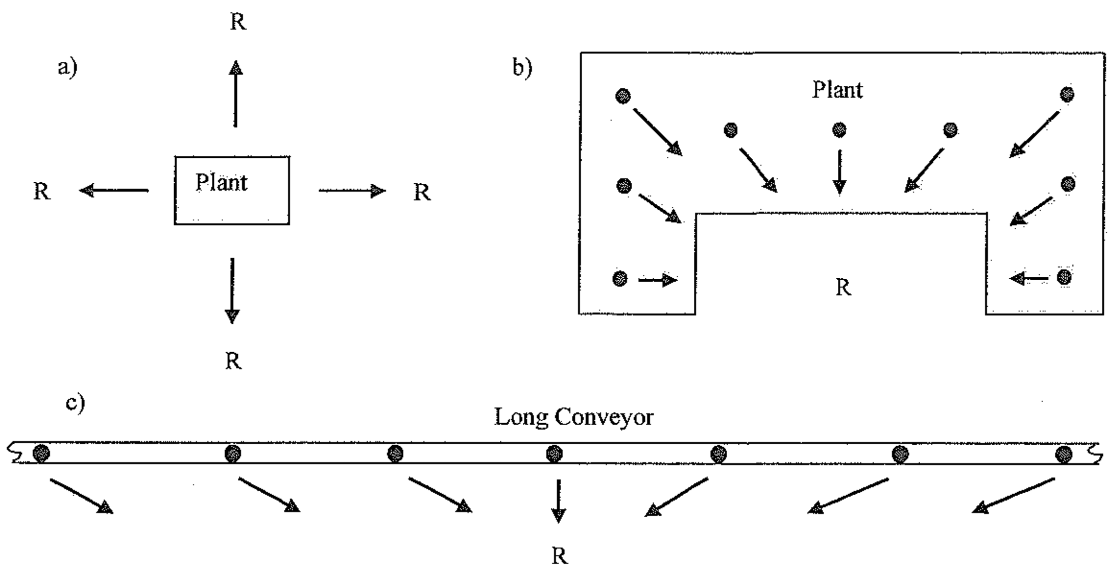

Figure 1: Three examples of ISO 9613-2's implicit assumption that wind blows from each source to each receiver. None of thee cases are physically possible. (a) Industrial plant where the downwind assumption makes sense for design. (b) Industrial plant where predicted long-tem average levels can be unrealistically high. (c) Long conveyor plant where predicted long-tem average levels can be unrealistically high.

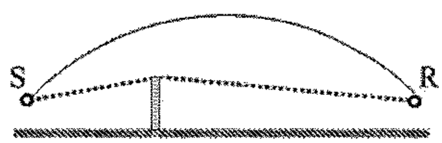

Figure 2: Long distance downwind arcing sound ray and diffracting 9613 straight ray.

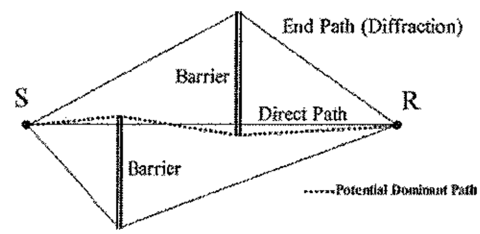

Figure 3: Offset barriers' potentially dominant path with direct path and 9613 end paths

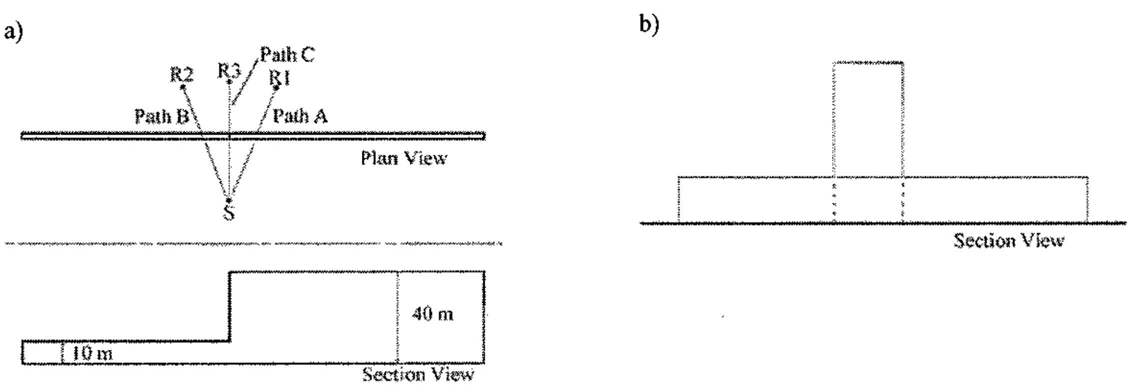

Figure 4: Sketches of pathological barrier examples which have more than two diffracting ends. (a) A barrier with a significant height change and three receivers with different source shielding. (b) A tall narrow barrier located a short distance behind a long lower barrier.

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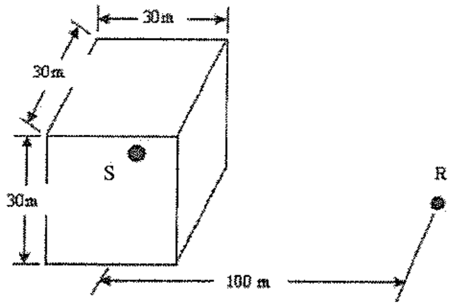

Figure 5: A cubic shaped finite-sized source that indicates how the boiler can be modeled as a point source or volume source. Due to directivity, the finite-sized source contributes about 4 dB less to A-weighted level at the receiver than the point.

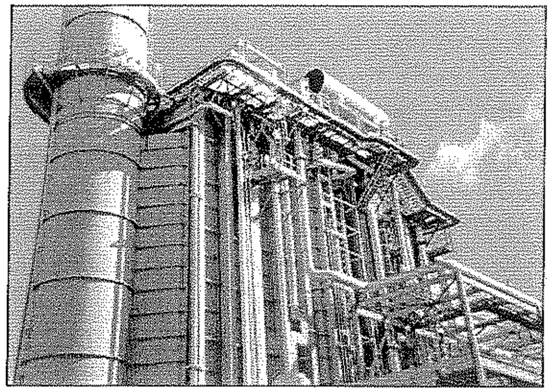

Figure 6: Heat recovery steam generator showing surface clutter in the form of structure, piping, and platforms that scatter and diffusely reflect much of the incident acoustic energy.

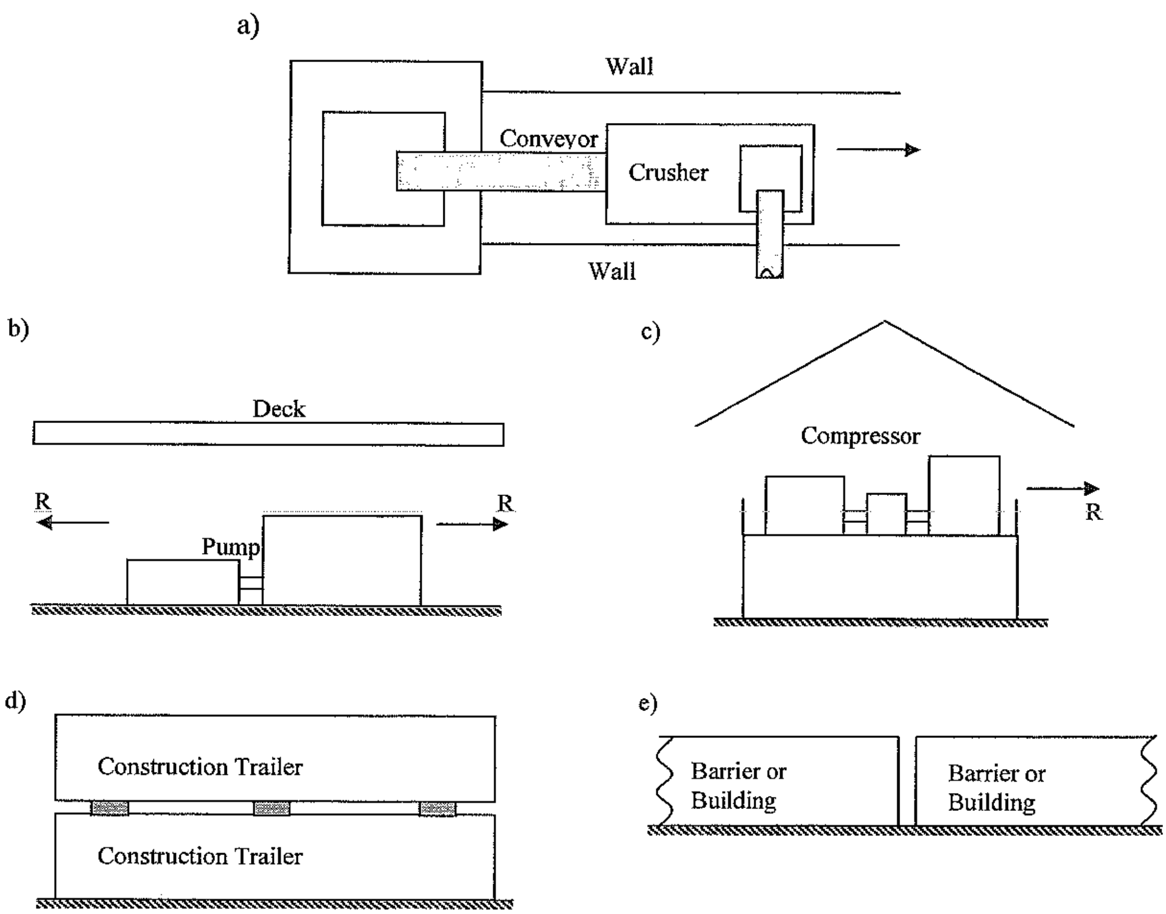

Figure 7: Configurations where wavelength effects at lower frequencies cannot be accurately computed by ray tracing (all), or ray-tracing software cannot model, because ray-tracing software do not support non-vertical surfaces need (b and c). (a) Conveyor and hoppers with vertical concrete walls. (b) Pump with concrete deck above. (c) Compressor shed with roofs and partial walls. (d) Stacked construction trailers with narrow slit. (e) Two building or barriers with a narrow slit.

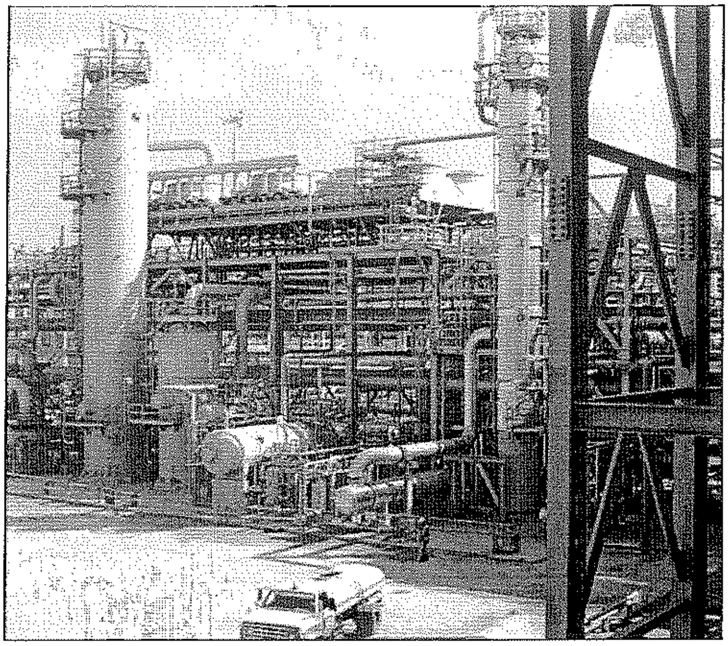

Figure 8: Very large pipe rack with air coolers on the top that scatters, diffusely reflects, transmits, and diffracts incident sound.

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Propagation Modeling Parameters for Wind Power Projects

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Noise modeling of wind turbines can be problematic in that they generate sound over a large area, from a high elevation, and make the most noise in very high wind conditions. For ISO 9613, these factors directly relate to how ground attenuation and meteorology are accounted for.

To study how ground attenuation and wind speed affect the accuracy of propagation modeling for wind turbines, data were gathered at an existing industrial-scale wind farm, and propagation modeling was conducted using Cadna A modeling software by Datakustik, GmbH for the same site under the same operating conditions in which monitoring was carried out. By adjusting the type of ground attenuation used in the model and the meteorological conditions, the best combinations for modeling propagation for wind turbines were determined with comparisons to the monitored data.

Standards Background

ISO 9613-2 (1996)[1,2] provides two methods for calculating ground effect (A_{gr}). The first method, known as spectral ground attenuation, divides the ground area between the source and the receiver into three regions: a source region, a receiver region, and a middle region. The source region extends from the source toward the receiver at a distance equal to 30 times the height of the source. For a tall wind turbine, this can be up to 2 to 3 km. The receiver region extends from the receiver toward the source at a distance equal to 30 times the height of the receiver. If the source and receiver regions do not overlap, the distance between the two regions is defined as the middle region. The ISO standard goes on to define ground attenuation for each octave band utilizing a ground factor (G) for each region depending on how reflective or absorptive it is. For reflective, hard ground, G=0; and porous, absorptive ground suitable for vegetation, G=1. If the ground is a mixture of the two, G equals the fraction of the ground that is absorptive. The ISO standard states that "This method of calculating the ground effect is applicable only to ground that is approximately flat, either horizontally or with a constant slope."

The second method provided in ISO 9613-2, known as nonspectral ground attenuation, is for modeling A-weighted sound pressure level over absorptive or mostly absorptive ground; but the ground does not need to be flat. Using the alternative method also requires an additional factor (D_Ω) be added to the modeled sound power level to account for reflections from the ground near the source.

To show the effect of using spectral vs. nonspectral ground attenuation for a source at a reasonable wind turbine hub height of 80 m, the ground attenuation (A_{gr}) was calculated using both methods for a source height of 80 m and 1 m over a range of distances from 0 to 3.5 km with the ground factor, G, set to zero. In a third scenario, G was set to 1, and an 80-m source height was used. In each example, the receiver height was set at 1 meter. The results for spectral ground attenuation are shown in Figure 1, and nonspectral ground attenuation results are shown in Figure 2.

As shown in the graphs, over soft, porous, spectral ground, attenuation for an 80-meter source is approximately 2 dB less than a 1-meter source. For nonspectral ground attenuation, an 80-m source height actually has negative ground attenuation over the first 750 m due to reflections from the ground.

ISO 9613-2 is only valid for moderate nighttime inversions or downwind conditions. The valid range of wind speeds is 1 to 5 m/s at 3 to 11 m high. For wind turbines, it may be more accurate to consider adjustments such as those presented by CONCAWE[3] or HARMONOISE.[4] These adjustments account for propagation at various wind speed, wind directions, and atmospheric stability. The CONCAWE meteorological adjustments are built into Cadna A and were used in this study.

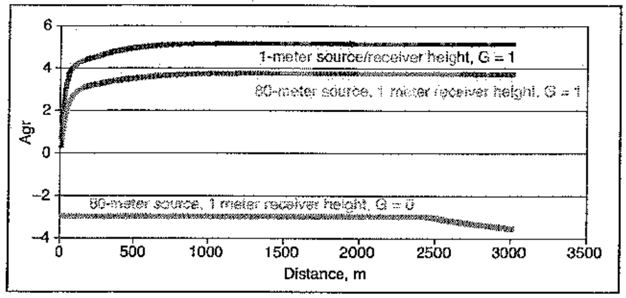

Figure 1. Spectral ground attenuation (A_{gr}) over distance for an 80-m and 1-m-high source; 1-m-high receiver and ground factor set to 1 (soft) and 0 (hard).

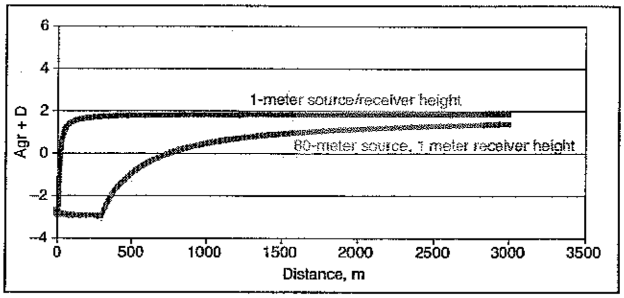

Figure 2. Nonspectral ground attenuation (A_{gr}) over distance for an 80-m and 1 m source and 1-m receiver height. Nonspectral ground attenuation is not a function of ground hardness.

Figure 3. Rural 100-MW wind farm used to study ground attenuation and meteorological modeling factors.

Wind Farm Background

The wind farm in this study is situated on nearly 8 square miles of flat farm land. There are a total of 67 wind turbines that are capable of producing about 100 megawatts of electricity. Each turbine hub is 80 m tall, and the rotation path of the three blades is 80 m in diameter. The turbines are roughly 1,000 ft apart, but there is a wide variation for individual pairs. An image of the terrain and some of the turbines is shown in Figure 3, and Figure 4 shows the layout of the wind farm.

Sound Monitoring

Two sound level meters were set up at 120 m and 610 m from the northern edge of the wind farm. Each sound level meter was an IEC Type I Cesva SC310 fitted with windscreens. The sound level meter at 120 m was placed flat on a 1-m-square ground board,

Based on a paper presented at Noise-Con 2007, Institute of Noise Control Engineering, Reno, NV, October, 2007.

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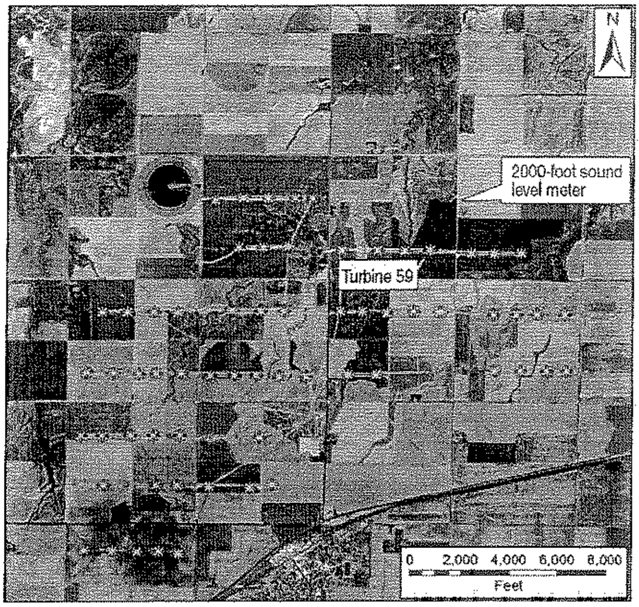

Figure 4. Map of wind farm used for study ; asterisks = wind turbines.

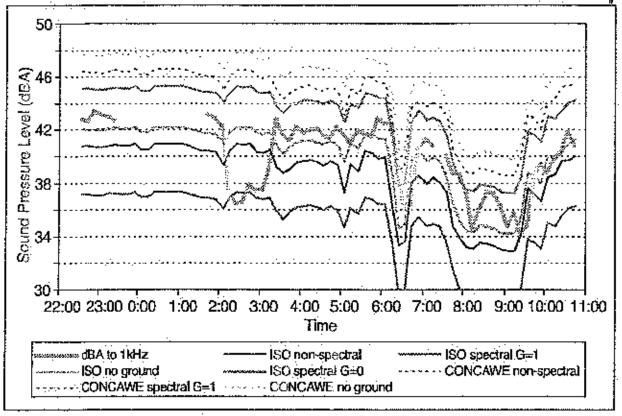

Figure 5. Comparison of monitored sound levels over time at 610 m (shown in orange) with modeled sound levels under various combinations of ground attenuation and meteorological factors.

while the meter at 610 m was mounted on a stake at approximately 1 m off the ground.

The measurement period was at night from approximately 10 p.m. to 10 a.m. Each meter logged 1-minute equivalent average sound levels in 1/3-octave bands. In addition, recordings of WAV files were made at certain points.

At the same time, spot measurements of wind speed and direction at hub height, blade rotational frequency, and energy output for each wind turbine were made at 10-minute intervals.

Since we could not obtain background sound levels, we assumed that much of the localized noise from wind passing through the surrounding wheat field would be at and above 2,000 Hz. This was confirmed by listening to and analyzing the WAV file recordings. Therefore, to isolate the wind turbine sound, we created a virtual low-pass filter eliminating sound at frequencies above 2 kHz. In addition, assuming that the wind turbines operated within a narrow range of sound power over any one 10-minute period, we used the 90th-percentile, 1-minute equivalent average sound level for each 10-minute period for comparison to modeled results. This minimized the localized effects of noise from wind gusts.

Sound Monitoring

The Cadna A sound propagation model made by Datakustik GmbH was used to model sound levels from the wind farm. Cadna A can use several standards of modeling, including ISO 9613 with or without CONCAWE meteorological adjustments.

A model run was conducted for every 10-minute period of turbine operation during the monitoring period. This was done by running Cadna A for the following scenarios:

- Standard meteorology with spectral ground attenuation and G=1.
- Standard meteorology with spectral ground attenuation and G=0.
- Standard meteorology with nonspectral ground attenuation.
- Standard meteorology with no ground attenuation.
- CONCAWE adjustments for D/E stability with winds from the south at greater than 3 m/s and spectral ground attenuation, assuming G=1.
- CONCAWE adjustments for D/E stability with winds from the south at greater than 3 m/s and nonspectral ground attenuation.
- CONCAWE adjustments for D/E stability with winds from the south at greater than 3 m/s and no ground attenuation.

For each scenario, a "protocol" was run that listed the ISO 9613-2 attenuation and propagation factors by frequency between each turbine and receivers at 120 m and 610 m from the northern end of the wind farm; that is, the receivers represented by the sound monitoring locations. These attenuation factors were then put into a spreadsheet model that looked up the manufacturer sound power level for each turbine for each 10-minute period based on actual measured wind speeds at each turbine. The spreadsheet model then calculated the sound level from each turbine by subtracting the attenuation factors from the sound power levels and then combining each turbine to get an overall sound pressure level at the 610-m receiver.

Results

A comparison of the modeled results to monitored sound levels over time is shown in Figure 5. The orange line toward the middle is the actual monitored sound levels. As shown, these monitored levels ranged from about 34 dBA to 43 dBA. Except for the period between 2:00 and 3:00 a.m., the sound levels were highly correlated with wind speed.

We conducted further regression analyses to determine which method achieved the best fit to the modeled data. The results are shown in Figures 6 and 7. Starting with Figure 6a, we found that the CONCAWE meteorology combined with spectral ground attenuation had a coefficient close to 1.0 and, on average, underestimated sound levels by only 1%. The CONCAWE meteorology along with the nonspectral ground attenuation consistently overestimated monitored sound levels. The ISO meteorology with nonspectral ground attenuation yielded a good fit. The coefficient of 0.957 indicates that average modeled levels underestimated monitored levels by about 4%. On the opposite end of the scale, the ISO meteorology along with spectral ground attenuation and G=1 significantly underestimated modeled sound levels by an average of 13%.

Starting with Figure 7a, the CONCAWE meteorology with no ground attenuation overestimated monitored sound levels by approximately 13%, while the ISO meteorology with no ground attenuation provided the best fit of all the runs, with a coefficient of 0.9924. Finally, the ISO meteorology with spectral ground attenuation and G=0 yields moderately accurate results but overestimates by approximately 3%. All trend lines were statistically significant with probabilities greater than 99%.

Discussion and Conclusions

The results of the study indicate the modeling of wind turbines in flat and relatively porous terrain may yield results that underestimate actual sound levels when using the standard ISO 9613-2 algorithms with spectral ground attenuation and G=1. We found that the best fit between modeled and monitored sound levels for this case occurs when using ISO meteorology and no ground attenuation. The second-best model fit was with the CONCAWE adjustments for wind direction and speed along with spectral ground attenuation and G=1. Using the ISO methodology with nonspectral ground attenuation also yielded good results.

While the ISO 9613-2 methodology specifically recommends spectral ground attenuation for flat or constant-slope terrain with G=1, in this case, it underestimated the sound levels. This may be due to the height of the hub (80 m) as compared with typical noise

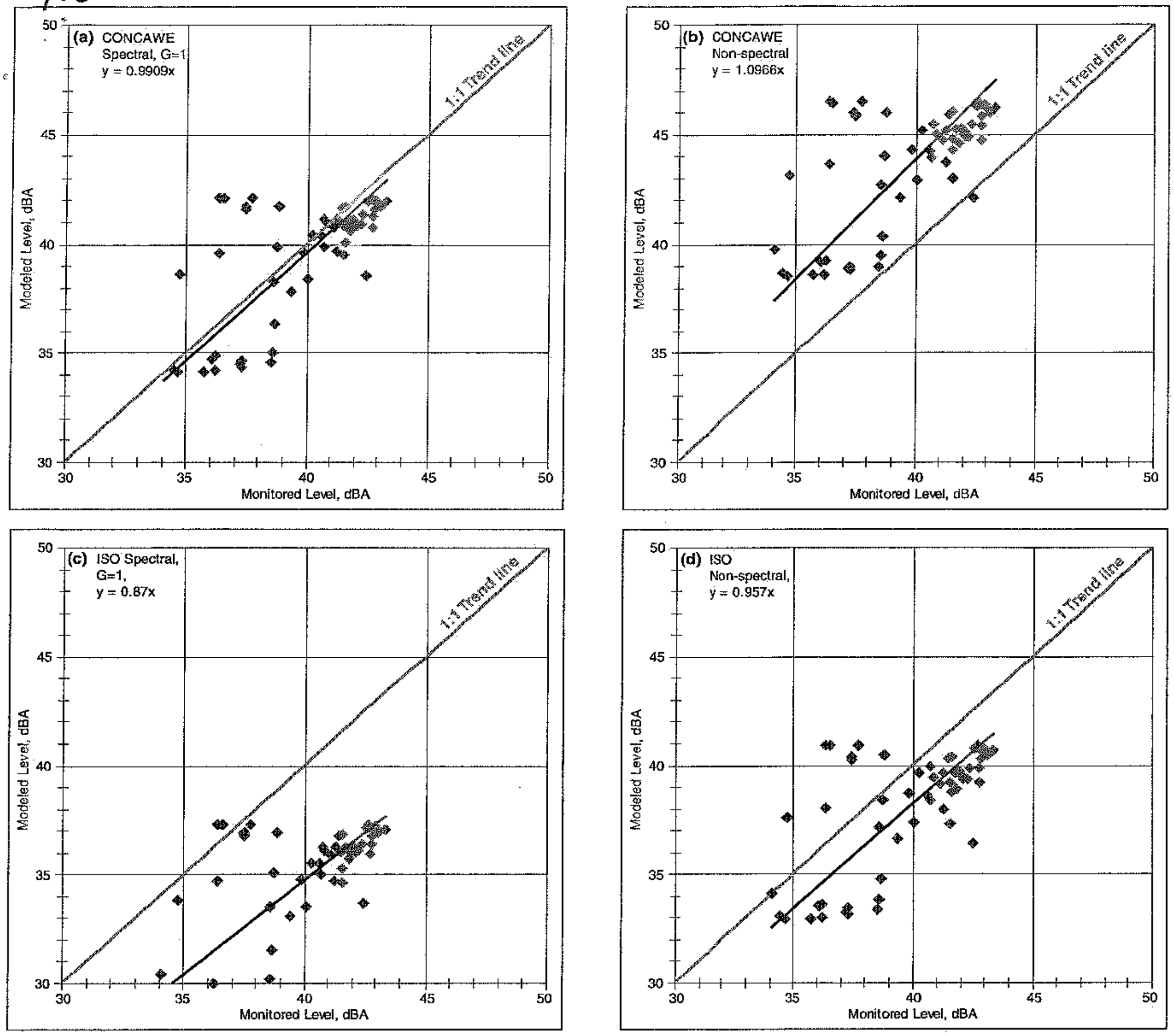

Figure 6a-d. Comparison of modeled and monitored sound levels for four meteorological and ground attenuation combinations. Regression coefficients are shown in the upper left-hand corner. Regression trendline shown in black; 1:1 trendline, indicating a match between monitored and modeled sound levels, is shown in red. N = 60.

sources. That is, the sound waves may not significantly interact with the ground over that distance. It may also be due to the fact that sound from wind turbines comes not from a single point – we assumed a single point at hub height – but is more likely to be similar to a circular area source. Finally, wind turbines often operate with wind speeds that are higher than ISO 9613-2 recommends. The combination of higher wind speeds and an elevated noise source may result in greater downward refraction.

To be more representative, a larger dataset should be obtained. Some improvements to the methodology and study would include:

- Improved accounting for background sound levels.
- Measurements of ground impedance so that the ISO 9613-2 G factor can be better estimated.
- Monitoring over a larger range of wind speeds.
- Using ground boards for the measurement microphone to minimize self-induced wind noise.
- Using larger wind screens.
- Measuring at distances greater than 610 m.
- Applying the methodology to other ground types and terrain.

Care should be taken in applying this methodology in other projects that are not similar. Overall, the ISO 9613-2 methodology is appropriate for propagation modeling of wind turbines, but modeling parameters should be adjusted appropriately to account for this source's unique characteristics.

Acknowledgments

We acknowledge gratefully the project spon[redacted], Iberdrola, its project manager, Krista Jo Gordon, and the wind farm operator, enXco, for funding and cooperation. We also thank all those who attended Noise-Con 2007 and Acoustics '08 who provided valuable feedback on our methodology and many suggestions for further study.

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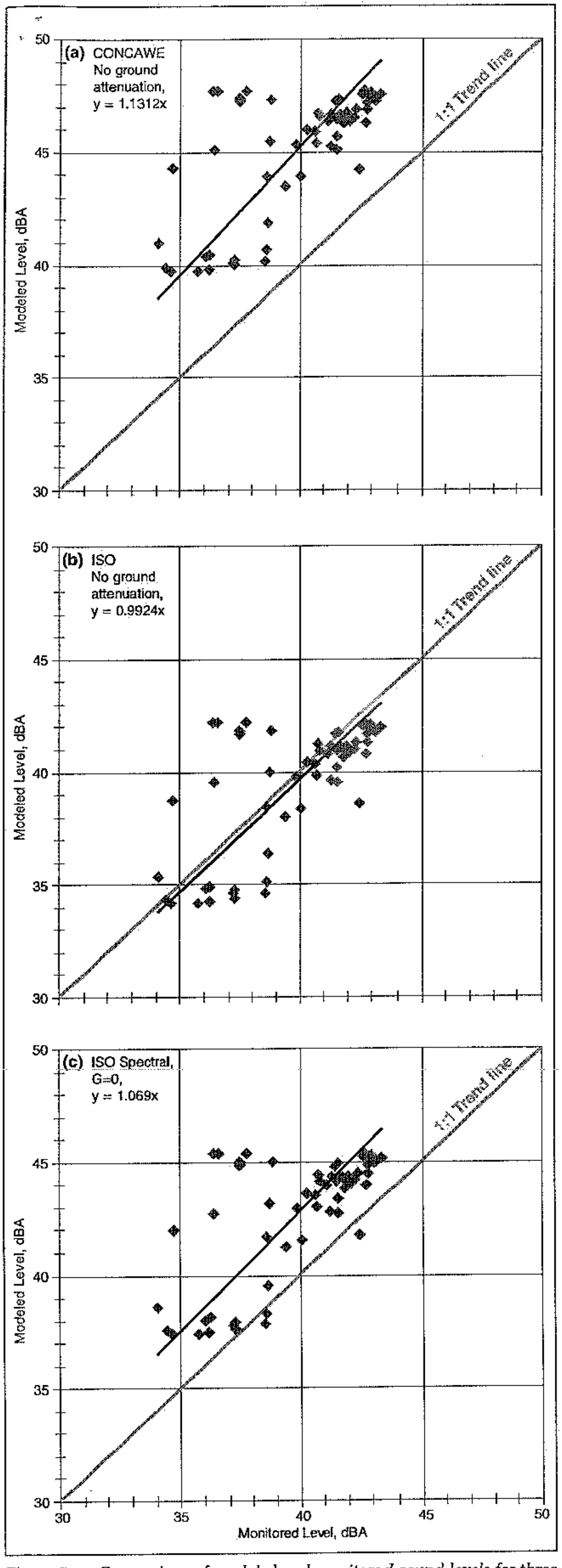

Figure 7a-c. Comparison of modeled and monitored sound levels for three meteorological and ground attenuation combinations. Regression coefficients shown in upper left-hand corner. Regression trend line shown in black; 1:1 trend line, indicating a match between monitored and modeled sound levels, is shown in red. N = 60.

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Accuracy of Model Predictions and the Effects of Atmospheric Stability on Wind Turbine Noise at the Maple Ridge Wind Power Facility, Lowville, NY - 2007

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SUMMARY

New York State is currently on a "fast-track" for developing sources of renewable energy – the goal is renewable energy constituting 25% of all energy sold in New York by 2013. At present there are six commercial wind farms operating in New York State, with four more under construction. There are another 30 projects that are under some stage of environmental review, and there are undoubtedly more that are being considered. There are a number of important issues that confront developers in getting their projects approved; one of them is dealing with wind turbine noise.

Although wind farm noise may be low compared to a big municipal airport, in a quiet rural setting even low level noise can pose a significant problem. Wind power developers use mathematical models to predict the impact of wind turbine noise on nearby residents. However, no one knows if predicted noise impacts are high, low or on target. Developers, planning boards and residents are all assuming that model predictions are accurate and that they do not require any validation. Regrettably, there have been no compliance surveys done on any of the six operational wind farms in New York State.

The main objective of this study was to measure the noise levels at two sites within Atlantic Renewable Energy Corporation's Maple Ridge Wind Power Project located in Lewis County, New York, and compare actual levels with the model predictions that were available in the preconstruction Draft Environmental Impact Statement (DEIS). The second objective was to examine atmospheric stability at Maple Ridge. Atmospheric stability was identified as a significant problem at a wind farm on the Dutch-German border. Stability occurs when ground level winds, where people live and reside, are decoupled from those at wind turbine hub-height. This can occur at the end of the day when the land mass begins to cool. It affects wind turbine noise because wind turbines can be operating and making noise when ground level winds are calm and we expect quiet surroundings.

This study demonstrated that summer, night-time noise levels exceeded levels predicted for two sites within the Maple Ridge Wind Farm. For winds above generator cut-in speed (e.g., 3.0 m/s @ 80-m), the measured noise was 3-7 dBA above predicted levels. The decoupling of ground level winds from higher level winds, i.e., atmospheric stability, was apparent in the noise data at both sites during evening and night-time periods. At wind speeds below 3.0 m/s, when wind turbines were supposedly inoperative, noise levels were 18.9 and 22.6 dBA above the expected background levels for each of the sites and these conditions occurred a majority of the time. The same results were evident in the evening period. Furthermore, digital recordings revealed prominent wind turbine sounds below cut-in speeds.

The fact that nearly all measurements exceeded Atlantic Renewable's predicted impacts suggests there is a problem with the choice of a model and/or how the models are configured. The model protocol used by Atlantic Renewable is very common; most wind power developers in New York use the same protocol. However, different models used in wind farm noise assessments have been shown to produce different results, and the model used by Atlantic Renewable was not designed to model elevated sources of sound, i.e., wind turbines.

Several recommendations are suggested for planning boards, communities and the NYSDEC:

1. The first step should be a validation of the results in this study. A small study should be undertaken quickly to confirm or refute these results. The consultant hired to do the work should be independent of any developer, preferably accountable only to NYSDEC.
2. If the validation study confirms the conclusions in this study, the NYSDEC should make a strong recommendation in their comments to lead agencies to delay issuing any new permits (e.g., a moratorium) for wind farms until a more comprehensive assessment can be undertaken of all the operating wind farms in New York.

3. Because atmospheric stability can have such a profound effect on wind turbine noise, planning boards and regulatory agencies should require developers to submit wind velocity summaries to describe prevalence of atmospheric stability.
4. Wind power developers could do a much better job of predicting noise impacts if planning boards required noise compliance surveys, and if they imposed operation restrictions if actual noise exceeded predictions.
5. NYSDEC should take a more involved and active role in reviewing noise impacts, to date their comments on wind turbine noise are minimal to non-existent. NYSDEC needs to get more involved in reviewing wind farm noise impact assessments.
6. For those non-participating residents within the bounds of existing wind farms, depending on the results of the comprehensive review, it may be appropriate to find some means to mitigate excessive noise, i.e., additional payments and/or shutting down wind turbines during periods of stable atmospheric conditions.

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INTRODUCTION

In New York State at the end of 2007 six commercial wind farms were operational, four were under construction and thirty others were under some stage of environmental review[2]. Two of these projects, totaling 236 wind turbines, are proposed for the Town of Cape Vincent, NY, where I currently reside. The New York State Environmental Quality Review Act (SEQR) requires a careful, comprehensive review of all the potential impacts from any policy or project that could affect the environment, including commercial wind power development. For the two projects in Cape Vincent, developers have submitted Draft Environmental Impact Statements (DEIS) and they are in the process of revising and supplementing these reports. One of the most important issues that developers have to consider is wind turbine noise, particularly as it affects those residents outside of the wind farm project boundaries (AWEA 2008). In Europe, where commercial wind projects have been operating for years, there have been a number of instances where wind turbine noise has become a problem with non-participating residents. As a result, scientists have begun to study and document wind turbine noise impacts on community health

Annoyance with wind turbine noise is the most common complaint, but more serious health problems have begun to emerge as well. In a number of Swedish studies of wind farm residents, researchers found annoyance was related to wind turbine noise, as well as other factors, e.g., visibility, urbanization and sensitivity (Pedersen and Waye 2007). They also determined that wind farm noise was much more annoying than aircraft, road traffic and railway noise at far lower sound levels (Pedersen and Waye 2004). Wind turbine noise is principally broadband, white noise, which in itself is not particularly annoying. The character of wind turbine noise many people find annoying is called amplitude modulation, which relates to the periodic increase in the level of the broadband noise. Amplitude modulated noise can be simulated by tuning an AM radio between two stations, where static is heard, and then increasing the volume every 1-2 seconds. This is not pleasant. For some living within a wind farm, annoyance has lead to sleep

[2] http://www.dec.ny.gov/energy/40966.html

disturbance (Pedersen 2003), which in turn can result in a low-level stress response and other potential health effects associated with stress.

The usual approach wind power developers use in assessing noise impacts is to: 1) conduct a background noise survey, 2) use noise propagation models to predict wind turbine noise impacts on non-participating residents, and 3) align these predictions to some local or state noise standards. In these noise assessments, wind power developers assert a cautious and conservative analysis, and assure us their models are configured so they produce conservative, worst-case scenarios. For example, in a recently completed noise study for the New Grange Wind Farm in Chautauqua County, New York there were thirty-six separate uses of the phrase "worst-case" (HWE 2008). The overall impression for anyone reviewing these reports is that developers use sophisticated, complex mathematical models to make very conservative estimates of noise impacts. The wind power industry, however, has overlooked the real worst-case scenario – the effect of atmospheric stability on wind turbine noise.

The Dutch environmental physicist, G.P. van den Berg, has published extensively on the relationship of atmospheric stability and wind turbine noise (2003, 2004, 2005 and 2006). During the day, the land is heated and the air rises and the near-ground atmosphere is considered unstable; winds that blow at ground level are even more intense at wind turbine hub-heights (e.g., 80m). At evening, the land begins to cool and vertical air movements disappear; wind can be calm near ground, but continue to blow strongly at hub-height. This is considered a stable atmosphere.

Atmospheric stability can have an acute effect on wind turbine noise, too. Wind turbine sounds are more noticeable, since there is little masking of background noise, and more importantly, because atmospheric stability can amplify noise levels significantl. Herein should be the developer's worst-case scenario for their wind turbine noise impact studies: A still evening on the back patio with motionless flowers and trees, but with nearby wind turbines operating near full power and noise – much more noise than would be expected from a similar rural setting elsewhere. From what I have observed locally, atmospheric stability is not a rare phenomenon, on the contrary, it is very common.

In most wind farm noise assessments, however, they never mentioned atmospheric stability. Although stability is ignored by consultants doing noise exposure assessments, atmospheric stability is extremely important to developers who are trying to optimize electric power production: *Choosing to ignore such diurnal effects* (stability) *would surely result in unreliable energy forecasts* (Van Lieshout 2004). The commercial wind industry knows the importance of atmospheric stability for commercial wind power production; however, the industry ignores the issue when assessing noise impacts on rural communities.

I became interested in wind turbine noise when I was faced with proposals for two wind farm projects in Cape Vincent. I was also concerned about the complaints I heard from residents of Maple Ridge as well as those from other parts of the world via the web. In addition, I was suspicious about some of the claims and forecasts made by developers in their modeling of noise impacts. From my experience as a biologist I understand that models are not infallible and that follow-up studies are needed to validate model predictions. Regrettably, in New York there have been no noise compliance surveys done to date on any operating wind farm, nor are there any plans in the future for these kinds of studies (Tomasik 2008).

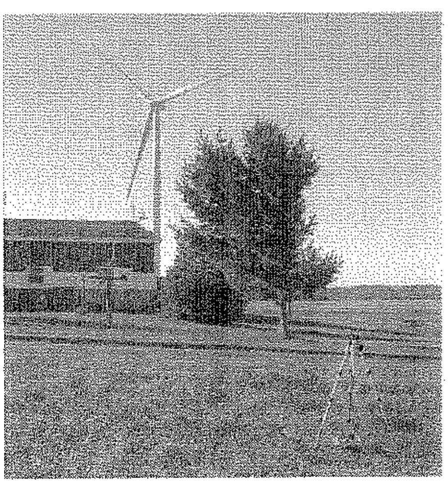
For these reasons, and because of the proximity of Atlantic Renewable Energy Corporation's Maple Ridge Wind Power Project in Lowville, NY, I undertook a study of wind turbine noise in August and September of 2007. The objectives of my study were to 1) compare noise measurements during wind farm operation with model predictions outlined in the Maple Ridge DEIS[3], and 2) determine if the effects of atmospheric stability on wind turbine noise were as pronounced as that observed in Europe. I did not try to describe amplitude modulation and other characteristics of wind turbine noise, not because they are unimportant, but because I was limited in what I could do with my

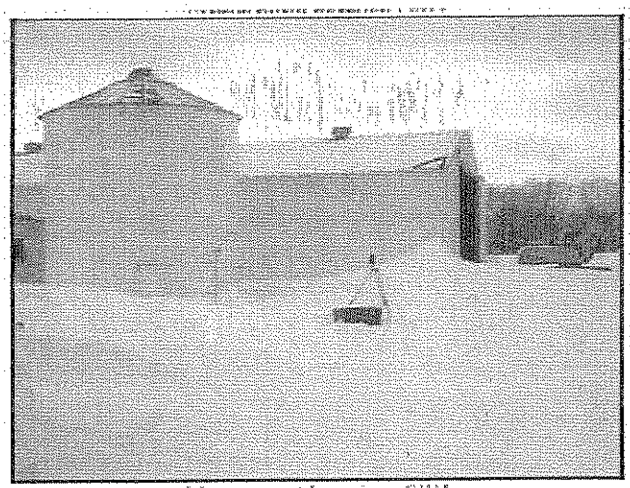
[3] The DEIS for the Maple Ridge Wind Power Project was originally titled Flat Rock Wind Power Project DEIS.

electronic equipment. Hence, the focal point of my study is wind turbine noise as it relates to pre-construction model predictions by Atlantic Renewable for their Maple Ridge Wind Facility.

METHODS

Two landowners within the Maple Ridge Wind Farm allowed me to set up equipment in August-September, 2007. The site referred to as SW1 (Fig.1) is the property of a wind farm cooperator and was one of Atlantic Renewable's noise monitoring sites. SW1 is located on the Swernicki Road and there are six nearby wind turbines between 340 and 638 m (1,116-3,071 ft.). The other site, R14 (Fig. 1), is the residence of a non-participating landowner located near the Rector and Borkowski Roads, which has six wind turbines within 1,000 m; the closest two are both 382 m (1,250 ft.) away. These two sites were useful, because in the Maple Ridge DEIS (AREC 2003) noise predictions were tabulated for both sites and at five generator power settings associated with 80-m, hub-height wind speeds of 3.0, 6.4, 8.0, 9.5 and 12.0 m/s, respectively (Appendix B this report). In the subsequent methodology I tried to duplicate, as best I could, the locations, equipment, noise metrics and analytical approaches used by Atlantic Renewable in their noise report (AREC 2003).





Measurement Location : SW1

Figure 1. ***Two monitoring sites used for 2007 noise compliance study at Maple Ridge Wind Farm. Left is photo of R14 residence (keyed to Maple Ridge Wind Farm DEIS) and photo at the right SW1(2002***

photo from DEIS). The close proximity of the sound measuring equipment to the buildings at the SW1 site was chosen to exactly duplicate the location used by the developer for their background noise survey in December, 2002.

For the noise measurements I used a Quest Model 2900 Type II Integrated and Logging Sound Level Meter. The meter was purchased on April 18, 2007 from Quest Technologies at which time they completed a factory calibration (Appendix C). Noise measurements were recorded for 10-minute segments for L_{eq}, L_{max}, L_{min} an L_{90} metrics. The $L_{eq,\ 10\text{-}min}$ measurement was the principal metric used in study in order to be compatible with Atlantic Renewable's model forecasts. The limitations of the meter and microphone would not allow measurements below about 26 dBA, consequently, levels this low could have been even lower. The meter was fitted with a ½ inch electret microphone and a 75 mm diameter, closed-cell wind screen. Standard foam windscreens help reduce wind-induced microphone noise, but at moderate wind speeds they are not very effective.

Wind-induced microphone noise is a major problem in measuring noise levels associated with wind turbines, because wind not only drives wind turbine generators, but it can also contaminate noise measurements. Atlantic Renewable indicated that 5 m/s wind speeds at the microphone represented the upper limit for uncontaminated noise measurements in their background noise surveys (AREC 2003). Also, in their review of Australian wind farm assessment techniques, Teague and Foster (2006) recommend, "*Time intervals for which the wind speed exceeds 5m/s (11.2 mph) at the receiver microphone need to be excluded from the data-set.*" However, for the noise data collected in this study, I concluded that 5 m/s did not afford adequate protection, and assumed any noise measurements made in winds that exceeded 2 m/s were contaminated (see results section).

Due to a battery-life limitation, the time series for each session was limited to 35 hours of continuous operation. The night-time period was the main focus of these studies, because winds at night diminish and thereby make wind turbine noise more noticeable. In order to maximize night-time data collection, each session began in the evening of day-1 and was terminated the morning of day-3. For each set of batteries, two nights were sampled for each day. At the SW1 monitoring site the data collection periods were: Sept. 19-21: 18:30-06:36, Sept. 21-23: 19:46-06:35, and Sept. 23-25: 18:30-08:42 hrs. At the R14 residence sampling periods were: Aug. 27-29: 21:53-12:42, Aug. 29-31: 16:33-04:15. At each visit to setup equipment or replace batteries, nearby wind turbines were operating. At the beginning and completion of each of the surveys I conducted a field calibration of the sound level meter and none of the calibration tone levels varied by more than +/- 0.3 dBA.

Wind velocity data was collected using an Inspeed Vortex Anemometer[4] with a Madgetech Pulse data logger. The anemometer and logger were located at the same height as the sound level meter (e.g., 1-m above ground level, agl), but approximately 15 meters away. Wind velocity was collected and correlated for the same 10-minute segments as that used for noise data. Atlantic Renewable referenced all their wind speed data to 80-m height, which meant I had to convert the 1-m velocities. To convert wind speed collected at ground level to 80-m, hub-height equivalents, I used the formula described by van den Berg (2006):

$$V_{80\text{-m}} / V_{1\text{-m}} = (h_{80\text{-m}} / h_{1\text{-m}})^m$$

Where velocity of the wind at 80-m is a power function of the ratio of hub and anemometer heights. The shear exponent *m* is an expression of atmospheric stability. Van den Berg (2006) indicated that shear exponents near 0.20 represented moderately unstable atmospheric conditions and 0.41 represented a very stable atmosphere. In my calculation of 80-m velocities I used m= 0.20, identical to that used by Atlantic Renewable in their discussion of microphone noise effects (Section 5.6 AREC 2003). To provide a better understanding of the velocity conversions, with m= 0.2 the resultant ratio of 1-m to 80-m wind velocity was 2.4 – the winds at hub-height were 2.4 times that measured at 1-m. For comparison, velocities during stable conditions (e.g., m= 0.41), would be six times greater at hub-height than at ground level.

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[4] http://www.inspeed.com/anemometers/Vortex_Wind_Sensor.asp

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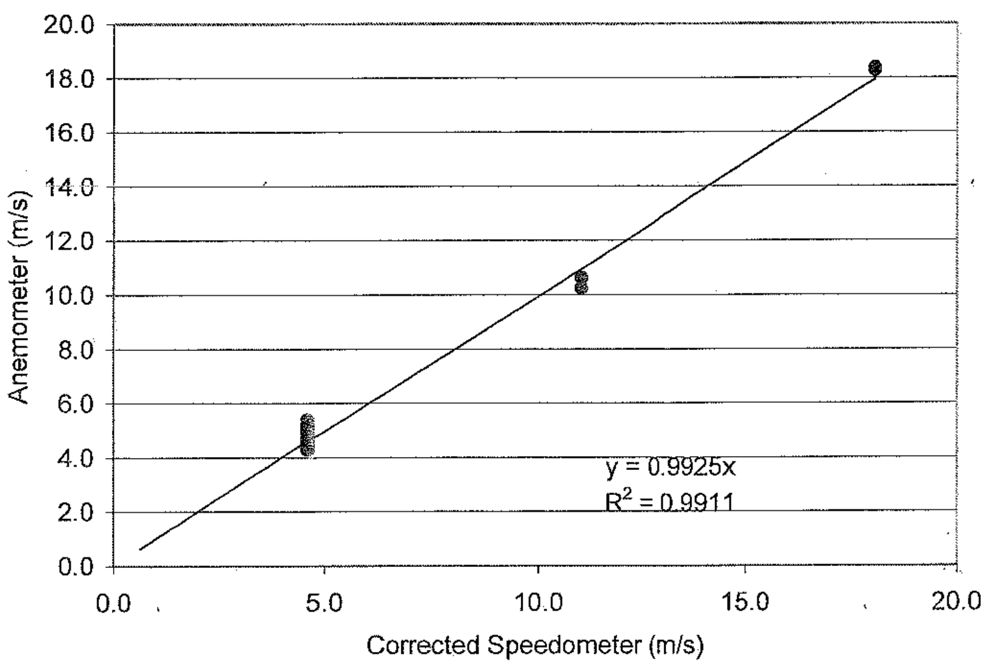
To assess the accuracy of my anemometer, I conducted a simple field calibration on a windless morning with the anemometer attached to a 2-m pole stretched out the window of my van. I first checked the accuracy of the van's speedometer by measuring time and distance, and then compared a number of speeds from 4.6 – 18.1 m/s. There was close agreement between the anemometer and corrected speedometer (e.g., linear regression y= 9925x, r^2= 0.9925, Fig. 2).

Beginning on September 5, 2007 I used an Olympus D30 digital audio recorder in conjunction with the sound level meter. The recordings were conducted using the monaural SP mode with a 22 kHz sampling frequency and an overall frequency response of 100-8,000 Hz. Each recording file had an elapsed time provision that enabled portions of the recording to be coupled with the corresponding noise level data. I was able to listen to the recordings and establish if turbine sounds were prominent. I also used SEA Wave[5] sound spectrographic analysis software to examine the recordings and identify wind turbine, insects and other sound sources.



[5] SEA Wave – Sound Emission Analysis

Figure 2. *Relationship of Vortex anemometer wind speed to corrected motor vehicle speed. The anemometer was attached to a 2-m pole extended from the vehicle. The field calibration was conducted when ground level winds were non-existent.*

At the completion of a survey, I downloaded both the noise and wind speed data and created a flat-file database with Microsoft Excel. I used the various plot and statistical functions of Excel to examine different aspects of the noise and wind speed data. The focus of the analysis was on evening and night-time, because these periods have lower background sounds and, consequently, wind turbine noise is potentially more noticeable.

RESULTS

Microphone Noise – All of the noise level data collected at during August-September, 2007 were plotted against wind speeds at 1-m, microphone height in Figure 3. Gross visual inspection shows a fairly flat response from 0-2 m/s, an inflexion point at approximately 2 m/s, and above this point noise increased with wind speed. For wind speeds above 2 m/s, the increases may be due to wind turbines, increased background noise or other sources, but undoubtedly also include wind-induced microphone noise. Without a more rigorous analysis than a gross inspection of the data and to be very cautious, I assumed noise data collected ≤ 2 m/s were not contaminated by microphone noise. This limit is markedly less than the general guideline of 5 m/s used by others (AREC 2003, SAEPA 2006, Teague and Foster 2006), but it permits a fairly safe assumption that microphone noise will be minimal. Aside from the noise-time plots for the SW1 and R14 sites, only noise data collected at wind speeds ≤ 2 m/s were included in the analyses of noise and wind speed. For subsequent noise/wind speed analyses, wind speeds of the selected data (e.g., ≤ 2 m/s @ 1/m) were converted to wind speeds at 80-m heights using a neutral atmosphere profile in order to conform with Atlantic Renewable's predictions (AREC 2003).

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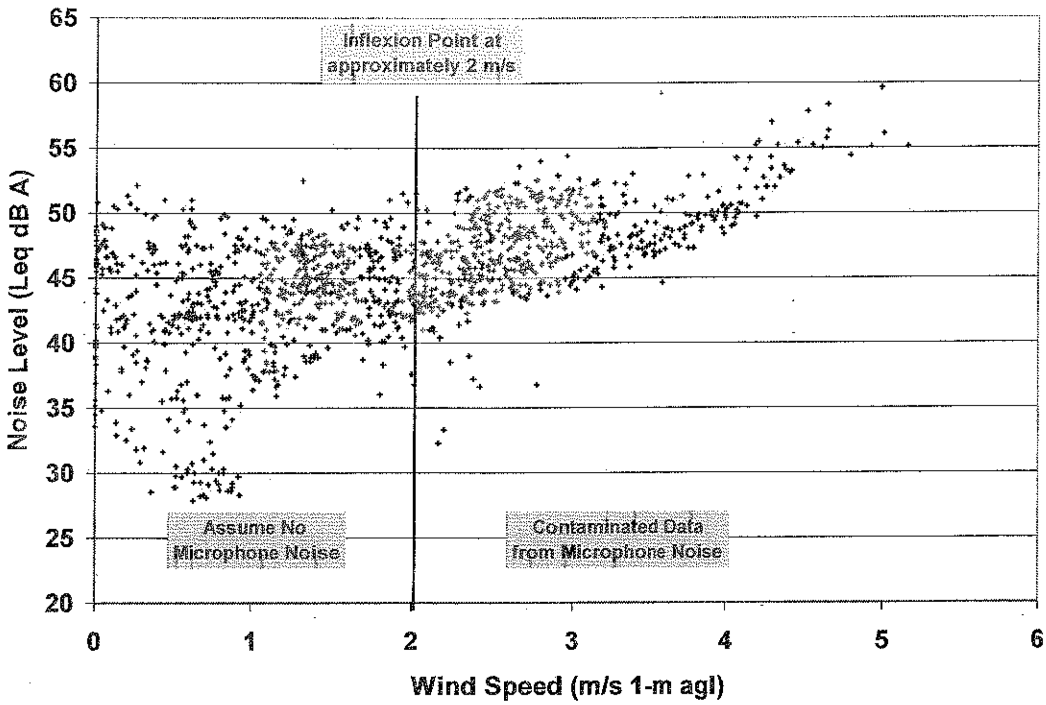

Figure 3. ***Noise levels ($L_{eq,\ 10\text{-}min}$) in relation to wind speeds at microphone level collected at SW1 and R14 monitoring sites at Maple Ridge Wind Farm, August-September, 2007 (n=1,325).***

SW1 Monitoring Site – Between September 19 through 25, 2007, noise levels ($L_{eq,\ 10\text{-}min}$) at SW1 ranged from roughly 30 to 60 dBA, and averaged 43.6 dBA (Figure 4). Wind speed ranged from 0-12 m/s and was generally greater during the day. For a brief period during the early morning of September 20, noise levels dropped below 30 dBA, near background levels, but were never as low for the remainder of the SW1 surveys.

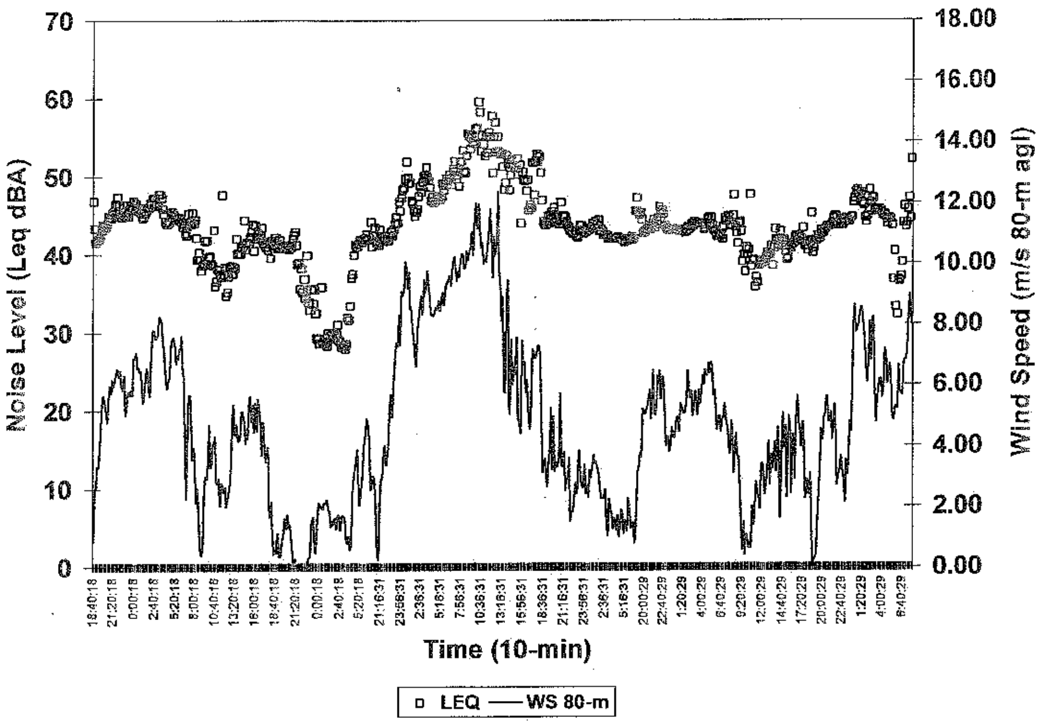

Figure 4. ***Noise ($L_{eq\ 10\text{-}min}$) and wind speed conditions at monitoring site SW1 at Maple Ridge Wind Farm from September 19-25, 2007.***

The noise levels ($L_{eq,\ 10\text{-}min}$) measured at night at SW1 were plotted against selected and converted wind speeds from September 19-25, 2007 (Fig. 5). Included in the plot are Atlantic Renewable's predicted noise impacts for the various 80-m wind speeds associated with cut-in and ¼ power settings (3.0 and 6.4 m/s) for the wind generators. The results are presented in a similar format as that used in their Maple Ridge DEIS (AREC 2003, Appendix C this report). In addition, the average night-time L_{90} background noise was calculated and plotted using the polynomial regressions provided in the Maple Ridge DEIS (AREC 2003).

Above cut-in speed (e.g., $\geq$3.0 m/s), noise estimates ($L_{eq,\ 10\text{-}min}$) were up to 5 dBA above predicted levels and averaged 43.3 dBA; 3.4 dBA above predictions. None fell below the line denoting predicted noise levels.

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Below cut-in speed, when wind turbines were expected to be inoperable, there were three groupings of noise data: 1) 54% were above 40 dBA, 2) 25% were below 30 dBA, and 3) 23% were between 30-40 dBA. The dark squares in Figure 5 represent those segments where the digital recordings were examined for the presence of wind turbine sounds. Review of these recordings showed that those above 40 dBA were dominated by wind turbine noise, and averaged 42.5 dBA or 22.6 dBA above the expected background L_{90} level. There was no wind turbine noise for those segments where noise levels were at or below 30 dBA.

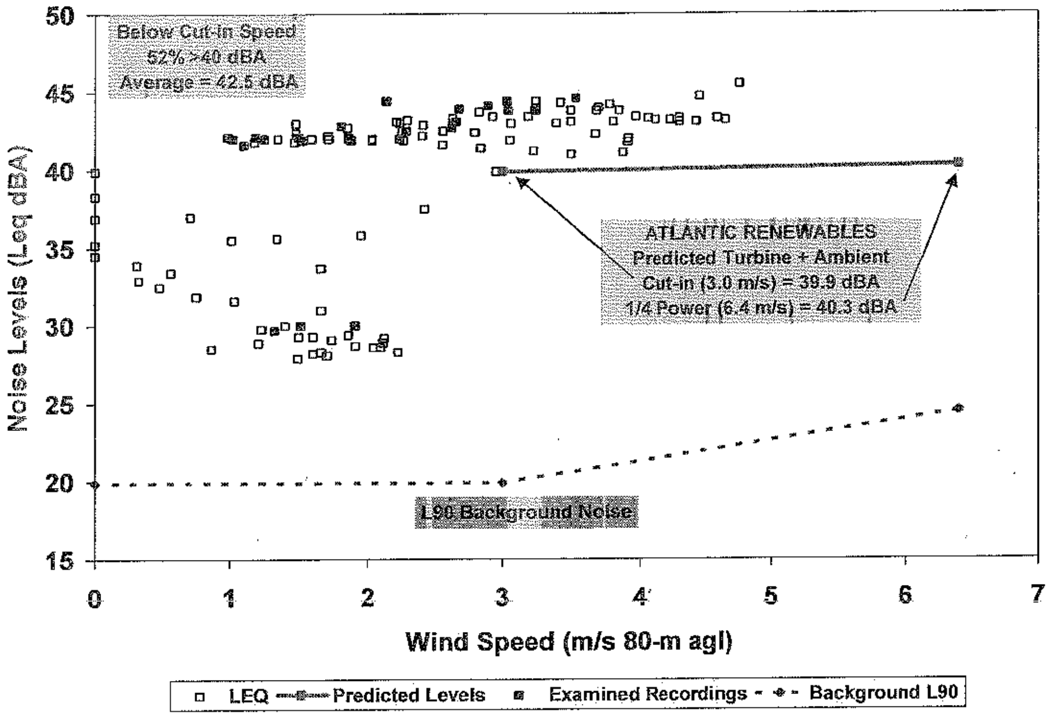

Figure 5. ***Night-time (22:00 – 06:00 hrs.) noise levels ($L_{eq\ 10\text{-}min}$) measured at SW1 monitoring site, Maple Ridge Wind Farm, September 19-25, 2007. Solid line represents the predicted noise from the Maple Ridge DEIS (AREC 2003). The dashed L_{90} background noise was calculated from Atlantic Renewable's regression formulas. Solid squares are those segments where companion digital recordings were examined to establish noise sources.***

R14 Residence – Shortly after this R14 survey was initiated, on the morning of August 27, the $L_{eq,\ 10\text{-}min}$ noise levels dropped to 28.9 dBA, which was presumably near background noise levels (Fig. 6). This level was also preceded by a period of diminished wind velocity, but aside from the drop in noise ($L_{eq,\ 10\text{-min}}$) in the beginning of this survey, noise levels were remarkably consistent, ranging from 40-50 dBA, averaging 46.8 dBA (Fig. 6). This consistency was maintained during both day and night periods and during substantial changes in wind velocity.

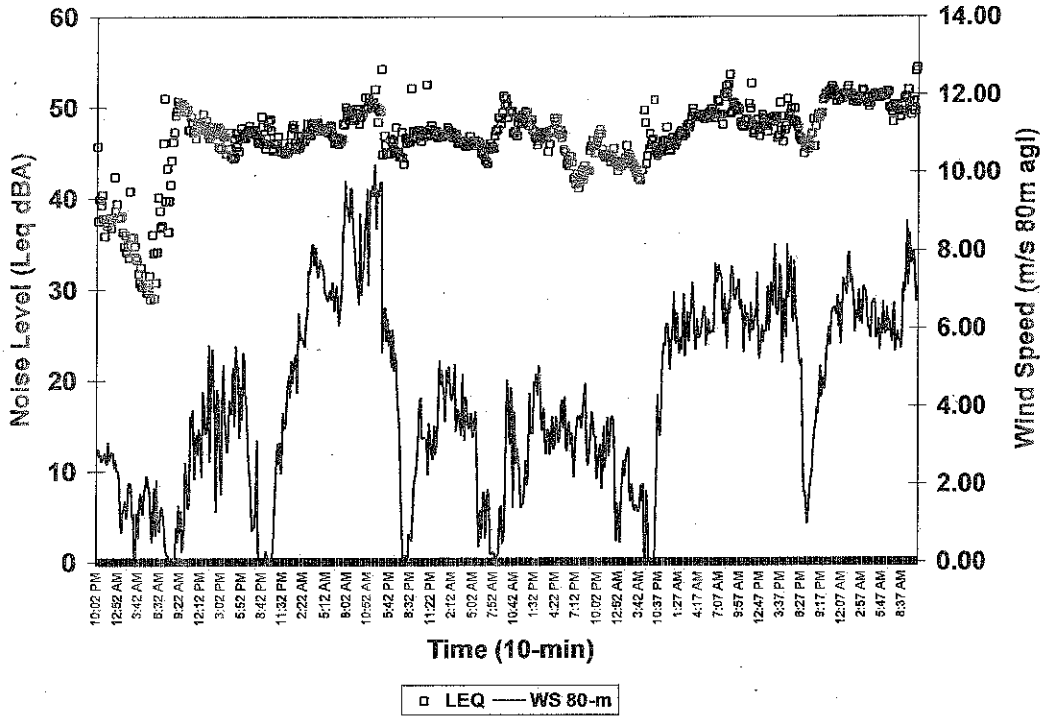

Figure 6. ***Noise ($L_{eq\ 10\text{-}min}$) levels(open squares) and wind speed (solid line) at monitoring site R14 at Maple Ridge Wind Farm from August 27-31, 2007.***

The plot of night-time noise levels on wind speed at R14 was similar to SW1, albeit measured noise exceeded predictions by an even greater amount (Fig 7). Above cut-in speeds noise levels averaged 46.1 dBA, exceeding predicted noise by more than 7 dBA; none of the observed noise values were close to predicted levels. Examination of the few available digital recordings (black squares)[6] showed that the noise above cut-in wind speeds was comprised of both wind turbine and insect noise. Higher noise at R14 compared to SW1 was likely attributable to insects, since insect sounds were not well-defined in the SW1 recordings.

[6] Use of the digital recorder began after most of the R14 survey was completed.

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Below cut-in speed 54% of the noise segments were above 40 dBA (equivalent to the predicted noise at cut-in), 42% were between 30-40 dBA, and 4% were at or below 30 dBA. Fewer noise levels were less than 30 dBA compared to SW1 (25%), and again, this was most likely related to prominent insect noise at R14.

The Maple Ridge DEIS used background levels observed at the R3 monitoring site as a surrogate to measuring background levels at R14 (AREC 2003). Compared to the average R3 L_{90} background noise below cut-in speed (e.g., 25.8 dBA), wind turbine noise at R14 was 18.9 dBA louder than expected.

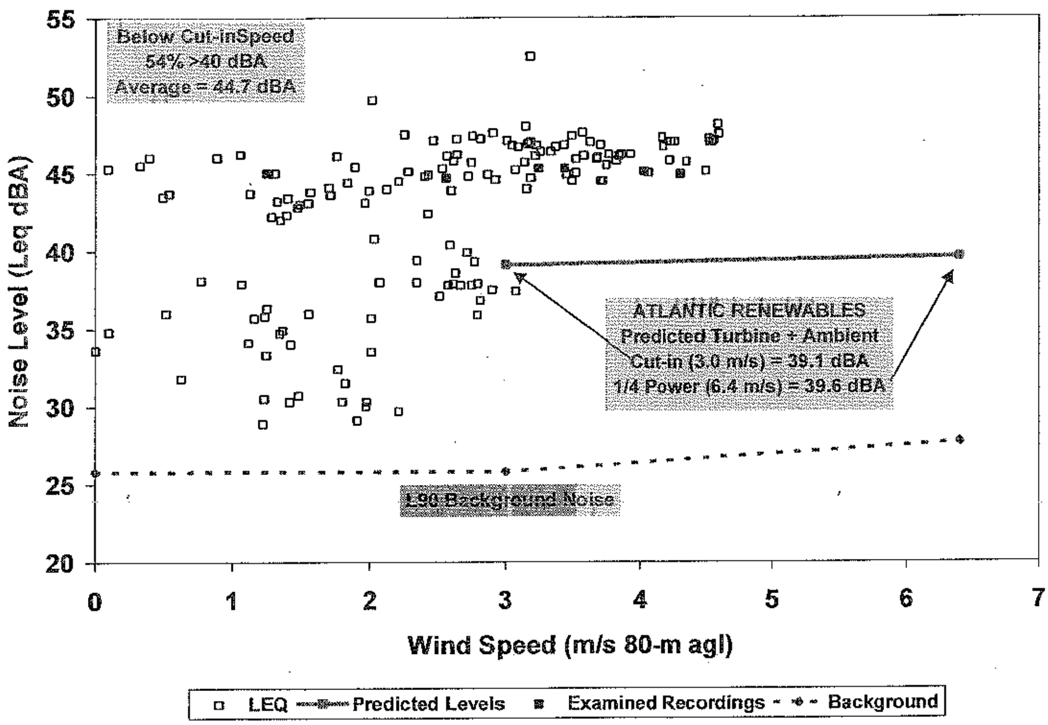

Figure 7. ***Night-time (22:00 – 06:00 hrs.) noise levels ($L_{eq\ 10\text{-}min}$) measured at R14 monitoring site, Maple Ridge Wind Farm, August 27-31, 2007. Solid line represents the predicted noise from the Maple Ridge DEIS (AREC 2003). The dashed L_{90} background noise was calculated from Atlantic Renewable's regression formulas. Solid squares are those segments where companion digital recordings were examined to establish noise sources.***

Evenings and Atmospheric Stability – During the evening at Maple Ridge, when I was setting up the equipment for the noise surveys, I noticed that ground conditions were very calm, yet nearby wind turbines were operating and their noise was very noticeable. I expected this example of stable atmospheric conditions at night, but was surprised it was so obvious late in the day, too. Consequently, I examined a subset of the daytime data from 17:00 to 22:00 hrs looking for evidence of atmospheric stability and elevated noise. The $L_{eq,\ 10\text{-}min}$ noise levels for the evening period of both SW1 and R14 surveys are plotted in Figure 8. Although Atlantic Renewable provided no noise predictions for wind turbines operating in evening, I used their daytime predicted noise levels for SW1 as a surrogate and reference (actually evening background levels and predictions would probably be lower because evenings seem quieter than daytime). Above cut-in speeds (e.g. 3 m/s) the observed noise exceeded daytime predictions for all segments, both at SW1 and R14, similar to what was observed during night-time. Again, elevated noise levels were prevalent below cut-in speeds, as well, i.e., all but three segments were above the 40 dBA level.

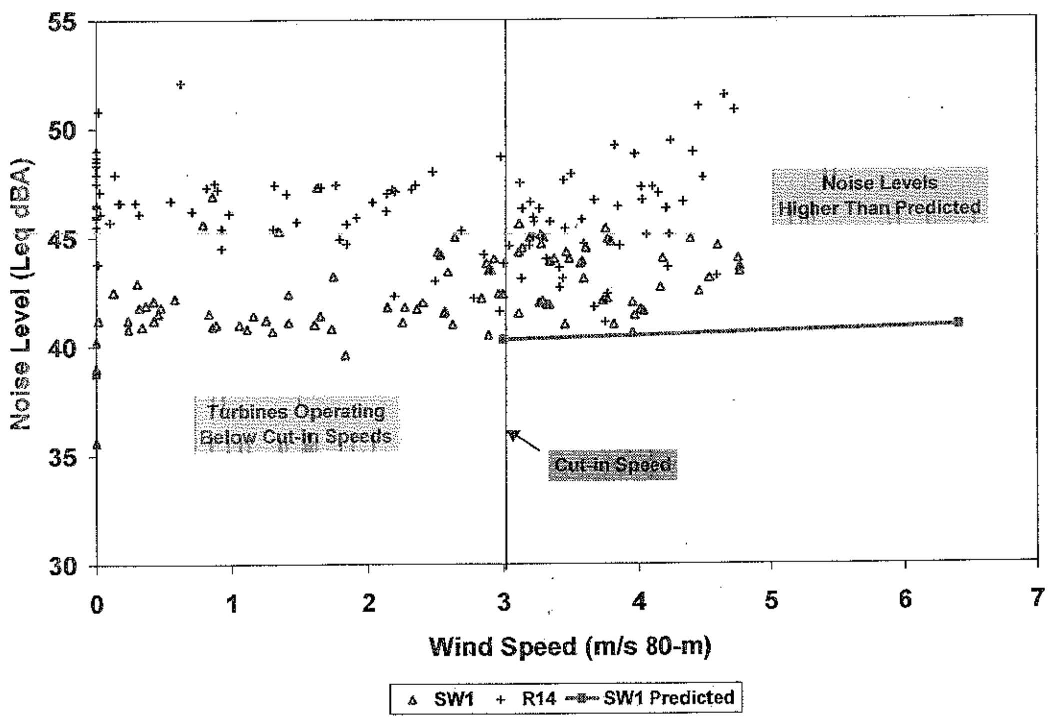

Figure 8. ***Relationship of noise level (Leq, 10-min) to wind speed for EVENING HOURS (17:00 – 22:00 hrs) at the SW1 and R14 sites at the Maple Ridge Wind Farm, August and September, 2007.***

DISCUSSION

Microphone noise contamination of background noise surveys is an issue that has received a lot of attention and criticism. It was a major concern in this study, as well. In an effort to remove any possibility of wind-induced microphone noise contamination, all of the data associated with wind speeds in excess of 2 m/s were purged -- 65% of the 1,325 noise and wind speed data were removed. The 2 m/s cut-off was far more restrictive than the 5 m/s upper limit used by Atlantic Renewable and recommended by others (Teague and Foster 2006). The effect of this more cautious approach, however, was to greatly reduce the potential for wind-induced contamination of the noise data, and thereby ensure better, more reliable noise data.

Atlantic Renewable stated in their DEIS (AREC 2003) that their impact assessment is "... likely a worst-case assessment of the noise impact from the proposed wind farm." This was clearly not the case, however. For winds above generator cut-in speed, average noise exceeded predicted impacts by 3.4 to 7.0 dBA for SW1 and R14, respectively. The decoupling of ground level winds from higher level winds, i.e., atmospheric stability, was apparent in the noise data at both sites during evening and night-time periods. Below cut-in speeds, when wind turbines were supposedly inoperative, noise levels were 18.9 and 22.6 dBA above the expected background levels for R14 and SW1, respectively. Moreover, below cut-in speed the majority of these observations (average 53%) exceeded the predicted noise for cut-in wind speed.

It is apparent that Atlantic Renewable missed or avoided a very important potential impact of wind farm noise. Although they went through the required second level analysis outlined in the NYSDEC noise policy (NYSDEC 2001), they failed to predict a 20+ dBA noise impact in calm conditions that is deemed by the NYSDEC as "very objectionable to intolerable." NYSDEC policy further states, *"When the above analyses indicate significant noise effects may or will occur, the applicant should evaluate options for implementation of mitigation measures that avoid, or diminish significant noise* *effects to acceptable levels."* Atlantic Renewable should have done more to mitigate the impacts of atmospheric stability.

Not only did Atlantic Renewable fail to consider noise impacts related to atmospheric stability, but also, they mislead when they stated, "*However when the wind speed is low, a wind turbine will not operate and as such, no noise impact will occur* [AREC 2003]. This is true at hub-height, since wind turbines need wind to operate, but it is not the case at ground level where people live. The results of this study refute any insinuation or suggestion by developers that noise will not be a problem when the wind is not blowing, and these results are also compatible with other studies documenting the effects of atmospheric stability (van den Berg 2003, 2004, 2005 and 2006). Contrary to the assertions of Atlantic Renewable, wind turbines can operate without wind. The key to this contradiction is to better understand atmospheric conditions.

The reason why wind turbines appeared to be operating below cut-in speeds is because estimates of hub-height (80-m) wind velocity were erroneous. Typically, developers use a neutral atmospheric profile to convert wind speeds from one height to another. I used the same neutral atmosphere wind profile as Atlantic Renewable to calculate 80-m wind speeds, but it was apparent the evening and night-time meteorological conditions at this time at Maple Ridge were typically stable; not neutral. Therefore, Atlantic Renewable's use of a neutral atmospheric profile to estimate microphone level noise from 80-m tower height winds would have substantially underestimated the actual wind velocity. This in turn would indicate that microphone noise contamination was a bigger problem in their original background noise study than they had previously thought, i.e., they overestimated background noise.

Therefore, because atmospheric stability is such a prevalent condition, in modeling noise impacts Atlantic Renewable and other developers need to consider stable atmospheric profiles and not limit their analysis to neutral conditions. Furthermore, with all the years of study of the winds at these proposed wind farm project sites, it is difficult to believe that developers do not fully understand the extent of atmospheric stability, temperature inversions and other meteorological phenomena. Also, these issues are far more important today, because modern wind turbines are considerably taller than earlier versions, and hence, there will be greater disparities between ground and hub-height wind speeds. The noise consultant to Atlantic Renewable at Maple Ridge recently completed a noise survey of a gas-fired electric generation facility in New South Wales Australia and noted: *The wind speed profile with height can also have an influence on the propagation of noise from the source to the receiver. When there is a significant increase in wind speed with height, the sound emitted to the atmosphere by the source undergoes refraction back towards the surface. This can cause a significant increase in the sound propagation to receptor locations downwind of the source* (Hayes McKenzie APW 2007). They went on to indicate the effects of atmospheric stability can increase noise by 5-10 dBA and that the direction of the wind had a substantial influence on the noise perceived at nearby residences. It is apparent developers know about the impact of atmospheric stability, and they undoubtedly know how frequently it occurs, too.

Given the inaccuracies of Atlantic-Renewable's predictions, the obvious question is how could their predictions be so far off the mark[7], especially when Atlantic Renewable's predictions supposedly represent a worst-case scenario? At first glance, we might wonder if the developer substituted a different wind generator from what was described in their DEIS, one that had a higher source level. Atlantic Renewable's noise predictions were based on an A-weighted source level of 103.3 dBA at rated power. Another make or model could increase source levels by about 3 dBA, enough to explain some of the discrepancies in their predictions. I also know there were some apparent problems with the tips of the wind turbine blades, and I saw technicians working on the wind turbine blade tips. Since most of the aerodynamic noise is generated at the blade tips, possibly modifying the blade tips could have altered the noise characteristics of the wind turbines, thereby increasing wind turbine aerodynamic noise. On the other hand, I did not see any maintenance activity associated with wind turbines close to SW1 or R14.

[7] The dBA difference between predicted and measured levels may seem small, but noise is measured in a logarithmic, not linear scale.

Another possible explanation might be the selection of an inappropriate noise propagation model. Teague and Foster (2006) noted: *The CONCAWE model overpredicted relative to the other models (by about 1 dB relative to Nord2000, by about 4 dB relative to GPM*[8] *and by up to 6 dB relative to ISO9613.*" The ISO9613 model was used by Atlantic Renewable for Maple Ridge assessments, and compared to the others appears to underestimate predicted impacts. Furthermore, the accuracy of the ISO9613 protocol is +/-3 dBA, without considering reflected sounds, and it is not recommended for source levels higher than 30m (ISO 1996).

Using appropriate models properly configured is not only an issue for Atlantic Renewable, but it should be important for all wind power developers in New York State because they all use the same ISO9613 model to predict noise impacts. Teague and Foster (2006) warn, *The application of modeling software to specific situations needs to be carefully considered and, where possible, based on validations with actual measurement data to provide confidence and minimize associated inaccuracies.* As noted earlier, there have been no model validation studies for any of the New York wind farm projects to date, and it is obvious from the results of this study that compliance surveys represent a critical need.

Reviewing agencies, planning board members and the general public need to be aware of misleading claims that modeled noise predictions represent worst-case conditions. A true worst-case scenario should include winter, night-time L_{90} background levels modeled under stable atmospheric conditions, using a conservative, appropriate noise propagation model.

What about Cape Vincent and other communities that are now faced with evaluating environmental assessments by developers who may make many of the same assumptions, claims and predictions as Atlantic Renewable at Maple Ridge, what should they do? The following suggestions may help us all do a better job of assessing noise impacts from proposed wind farms in New York:

[8] General Prediction Model, Nordic.

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- The first step should be a validation of the results in this study. I do not claim to be an acoustic consultant or engineer. Consequently, a small study should be undertaken quickly to confirm or refute these results. The consultant hired to do the work should be independent of any developer, preferably accountable only to NYSDEC.
- If the validation study confirms my results, the NYSDEC should make a strong recommendation in their comments to lead agencies to delay issuing any new permits (e.g., a moratorium) for wind farms until a more comprehensive assessment can be undertaken of all the operating wind farms in New York. Again, the comprehensive study should be done by professionals who are independent from commercial wind power developers, accountable only to the NYSDEC.
- Because atmospheric stability can have a profound effect on wind turbine noise, municipal planning boards should require developers to submit wind velocity data in order to establish the incidence of atmospheric stability at each proposed wind farm site. These summaries should include hourly averages of wind speed at different heights above ground level, along with ratios of velocity, e.g., 1-m:80-m. This should be completed for a recent calendar year.
- I was fortunate that atmospheric stability was such a common event at Maple Ridge. It allowed me to assess wind turbine noise impacts with little or no wind-induced microphone noise from ground-level winds. Because wind-induced noise is such a serious problem with assessing wind farm noise impacts, this approach of focusing on a compliance survey using night-time and evening periods minimizes potential microphone noise contamination. Van den Berg (2006) makes the same point, *...to reduce wind induced sound, it helps to measure over a low roughness surface and at night (stable atmosphere), as both factors help to reduce turbulence, even if the (average) wind velocity on the microphone does not change.*
- From my experience to date, I believe the wind power industry can do a better job predicting wind turbine noise impacts, in spite of the results from this study.

However, running models, predicting noise impacts and comparing them to standards is not sufficient. As any traffic cop knows, posting a speed limit does not guarantee all drivers will comply – you need enforcement, too. Wind power developers will do a much better job predicting impacts if they understand that post-operational noise surveys will be done, and if they exceed their predictions then operational restrictions will be imposed, such as a shut down of wind turbines during stable atmospheric conditions.

- NYSDEC should take a more involved and active role in reviewing noise impacts. Their comments to date focused primarily on bird and bat issues with few comments directed to wind turbine noise. NYSDEC needs to get more involved with noise issues.
- For those non-participating residents within the bounds of existing wind farms, depending on the results of the comprehensive review, it may be appropriate to find some means to mitigate excessive noise, i.e., additional payments and/or shutting down wind turbines during periods of stable atmospheric conditions.

Acknowledgements

I especially want to thank Judith and John Waligori and Rick Beyers for permitting me to use their property for my study. I also appreciate the helpful suggestions provided by Richard Bolton and Charles Ebbing.

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Appendix A Background Experience:

I graduated from Cornell University in 1965 and began work with the New York State Department of Environmental Conservation Department as a fishery biologist. Between 1967 and 1970 I served with the U.S. Marine Corps as an electronics technician. I completed over nine-months of technical schooling that included basic electronics, radio theory and repair, and cryptographic training. In addition, I also completed an intensive U.S. Air Force program in the calibration and repair of electronic test equipment. As a Marine electronics tech I worked in a calibration lab for over a year, and for the remainder of my service time I oversaw a radio repair facility at a Marine Airbase in Hawaii. After my service commitment was completed I returned to my job as a biologist working at the Cape Vincent Fisheries Station. In 1978, I completed a short-course on Hydroacoustic Fish Stock Assessment at the Applied Physics Lab at the University of Washington. During my work with hydroacoustics I became familiar with source levels, noise propagation losses and other acoustic principles. In 1980, I also attended a workshop at the University of British Columbia that focused on simulation modeling of biological systems, which provided some insight into the development and use models to help guide the management of fisheries resources. In the course of my 34 year career I have been an author in more than 25 peer-reviewed journal reports. The last task I completed for the NYSDEC was to lead an investigation of Double-crested Cormorant impacts on fish populations in Lake Ontario. I retired in 1999 as the Lake Ontario Unit Leader at NYSDEC's Cape Vincent Fisheries Station.

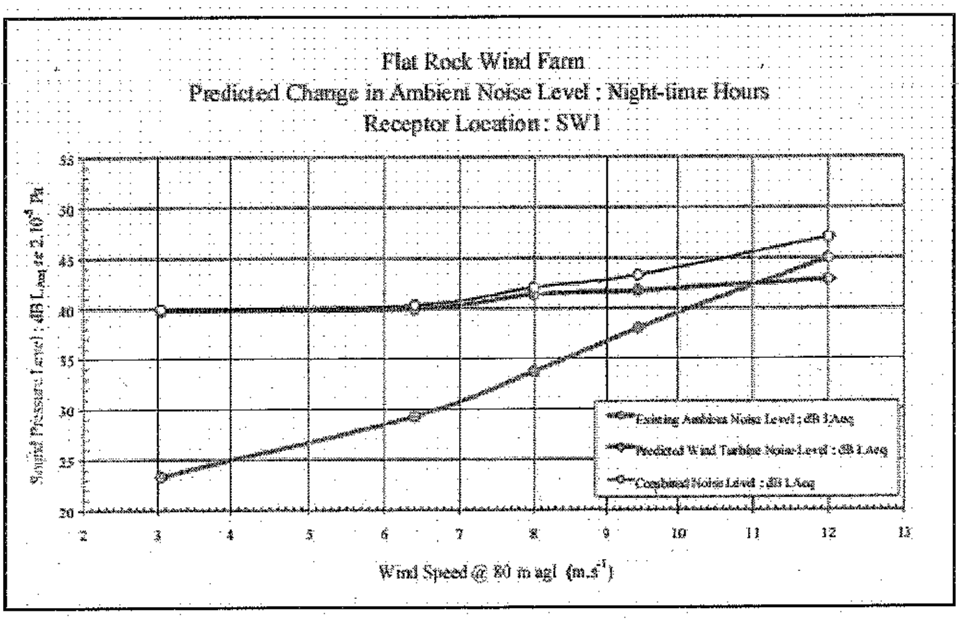
Appendix B Maple Ridge DEIS Data

Flat Rock Wind Farm. Noise Impact Assessment

Appendix 7: Predicted Change in Ambient Noise Levels

Night-time Predicted Change in Ambient Noise Levels			Predicted Wind Turbine LAeq					Nearest Background Noise Level	Existing Ambient Noise Level					Predicted New Ambient Noise Level					Predicted Change in Ambient Noise Level				
Dwelling Name	Dwelling Type	Participant	Cut-in	1/4 Power	1/2 Power	3/4 Power	Rated Power		Cut-in	1/4 Power	1/2 Power	3/4 Power	Rated Power	Cut-in	1/4 Power	1/2 Power	3/4 Power	Rated Power	Cut-in	1/4 Power	1/2 Power	3/4 Power	Rated Power
R12	Residence	Y	38.4	38.6	40.0	40.4	41.5	R3	28.2	31.1	34.7	38.8	46.7	38.8	39.3	41.1	42.7	47.9	[illegible]	8.2	[illegible]	3.9	1.1
R13	Residence	N	38.5	38.9	40.3	40.7	41.8	R3	28.2	31.1	34.7	38.8	46.7	39.1	39.5	41.3	42.8	47.9	10.9	[illegible]	[illegible]	4.0	1.2
R14	Residence	N	38.7	38.9	40.3	40.7	41.8	R3	28.2	31.1	34.7	38.8	46.7	39.1	39.6	41.4	42.9	48.0	[illegible]	[illegible]	[illegible]	4.1	1.2
R15	Residence	N	37.3	37.7	39.1	39.5	40.6	R3	28.2	31.1	34.7	38.8	46.7	37.8	38.5	40.4	42.2	47.7	[illegible]	[illegible]	[illegible]	3.3	0.9
R16	Garage	N	36.2	36.4	37.8	38.2	39.3	R3	28.2	31.1	34.7	38.8	46.7	36.8	37.5	39.5	41.5	47.5	[illegible]	[illegible]	4.8	2.7	0.7
R17	Residence	Y	35.1	35.3	36.7	37.1	38.2	R3	28.2	31.1	34.7	38.8	46.7	35.9	36.7	38.8	41.1	47.3	[illegible]	[illegible]	4.1	2.2	0.6
R18	Residence	Y	34.3	34.6	36.0	36.4	37.5	R3	28.2	31.1	34.7	38.8	46.7	35.3	36.3	38.4	40.8	47.2	[illegible]	[illegible]	3.7	2.0	0.5
R19	Seasonal	Y	34.3	34.7	36.1	36.5	37.6	R3	28.2	31.1	34.7	38.8	46.7	35.4	36.3	38.5	40.8	47.2	[illegible]	[illegible]	3.8	2.0	0.5
R20	Seasonal	N	33.2	33.6	35.0	35.4	36.5	R3	28.2	31.0	34.7	38.8	46.7	34.4	35.5	37.8	40.4	47.1	[illegible]	4.4	3.1	1.6	0.4
R21	Seasonal	Y	32.9	33.2	34.6	35.0	36.1	R3	28.2	31.1	34.7	38.8	46.7	34.1	35.3	37.7	40.3	47.1	[illegible]	4.2	3.0	1.5	0.4
R22	Seasonal	Y	36.4	36.6	38.0	38.4	39.5	R3	28.2	31.1	34.7	38.8	46.7	37.0	37.7	39.6	41.6	47.3	[illegible]	[illegible]	4.9	2.8	0.6
SW1	Rental	Y	39.8	40.0	41.4	41.8	42.9	SW1	23.4	29.3	33.7	38.0	45.0	39.9	40.3	42.0	43.3	47.1	[illegible]	[illegible]	[illegible]	[illegible]	2.1
SW2	Rental	Y	39.5	39.7	41.1	41.5	42.6	SW1	23.4	29.3	33.7	38.0	45.0	39.6	40.1	41.8	43.1	47.0	[illegible]	[illegible]	[illegible]	[illegible]	2.0
FR1	Residence	Y	37.7	37.9	39.3	39.7	40.8	FR2	21.4	30.1	36.1	41.3	48.6	37.8	38.4	41.0	43.6	49.3	[illegible]	[illegible]	4.9	2.3	0.7
FR2	Residence	N	39.9	40.0	41.4	41.8	42.9	FR2	21.4	30.1	36.1	41.3	48.6	40.0	40.5	42.5	44.6	49.6	[illegible]	[illegible]	[illegible]	3.3	1.0
FR3	Rental	Y	40.6	40.8	42.2	42.6	43.7	FR2	21.4	30.1	36.1	41.3	48.6	40.7	41.1	43.1	45.0	49.8	[illegible]	[illegible]	[illegible]	3.7	1.2
FR4	Rental	Y	39.7	39.9	41.3	41.7	42.8	FR2	21.4	30.1	36.1	41.3	48.6	39.8	40.3	42.3	44.5	49.6	[illegible]	[illegible]	[illegible]	3.2	1.0
FR5	Rental	Y	42.5	42.7	44.1	44.5	45.6	FR2	21.4	30.1	36.1	41.3	48.6	42.6	43.0	44.5	46.2	50.4	[illegible]	[illegible]	[illegible]	4.9	1.8
FR6	Seasonal	N	37.6	37.8	39.2	39.6	40.7	FR2	21.4	30.1	36.1	41.3	48.6	37.7	38.5	40.9	43.5	49.3	[illegible]	[illegible]	4.9	2.3	0.7
FR7	Bar/ Restaurant	N	35.7	35.9	37.3	37.7	38.8	FR2	21.4	30.1	36.1	41.3	48.6	35.8	36.9	39.7	42.9	49.0	[illegible]	[illegible]	3.7	1.6	0.4
RO1	Seasonal	N	37.5	37.9	39.3	39.7	40.8	R3	28.2	31.1	34.7	38.8	46.7	38.2	38.7	40.8	42.3	47.7	[illegible]	[illegible]	[illegible]	3.5	1.0
RO2	Seasonal	N	36.6	36.8	38.2	38.6	39.7	R3	28.2	31.1	34.7	38.8	46.7	37.2	37.8	39.8	41.7	47.5	[illegible]	[illegible]	[illegible]	2.9	0.8
RO3	Seasonal	N	34.0	34.3	35.7	36.1	37.2	R3	28.2	31.1	34.7	38.8	46.7	35.0	36.0	38.2	40.7	47.2	[illegible]	4.8	3.5	1.8	0.5
RO4	Seasonal	Y	37.4	37.6	39.0	39.4	40.5	R3	28.2	31.1	34.7	38.8	46.7	37.8	38.4	40.3	42.1	47.7	[illegible]	[illegible]	[illegible]	3.3	0.9
G1	Residence	Y	32.5	32.5	34.3	34.3	35.6	SW1	23.4	29.3	33.7	38.0	45.0	32.9	34.1	36.9	39.6	45.5	[illegible]	[illegible]	3.2	1.6	0.5
G2	Residence	Y	37.4	37.6	39.0	39.4	40.5	SW1	23.4	29.3	33.7	38.0	45.0	37.4	38.2	40.1	41.8	46.3	[illegible]	[illegible]	[illegible]	3.7	1.3

Flat Rock Wind Power LLC — Page 14 of 16 / Appendix 7 — Hayes McKenzie Partnership: Appendix 7 Flat Rock Wind Farm Change in Ambient Noise Levels.doc



Example of Maple Ridge DEIS predicted impacts for SW1 Receptor.

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Appendix C

Certificate of Calibration

Certificate No: CD8020047

Submitted By: CLIF SCHNEIDER
1560 VINCENT STREET
CAPE VINCENT, NY 13618

Serial Number:	CD8020047	Date Received:	4/17/2007
Customer ID:		Date Issued:	4/17/2007
Model:	2900 SLM	Valid Until:	4/17/2008

Test Conditions:

- Temperature: 18°C to 29°C
- Humidity: 20% to 80%
- Barometric Pressure: 890 mbar to 1050 mbar

Model Conditions:

- As Found: IN TOLERANCE
- As Left: IN TOLERANCE

SubAssemblies:

Description:	Serial Number:
MICROPHONE QE 7052 1/2 IN. ELECTRET	12026

Calibrated per Procedure: 56V996

Reference Standard(s):

I.D. Number	Device	Last Calibration Date	Calibration Due
ET0000523	B&K / QUEST ENSEMBLE	6/15/2006	6/15/2007

Measurement Uncertainty:

+/- [illegible] ACOUSTIC ([illegible]) +/- [illegible] VAC +/- [illegible] VDC
Estimated at 95% Confidence Level (k=2)

Calibrated By: Paul M. Wegmann 4/17/2007
PAUL WEGMANN Service Technician

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