Comment Letter N1

IBERDROLA RENEWABLES

December 22, 2011

VIA Overnight Mail and Electronic Mail

Department of Planning and Land Use
Project Processing Counter
5201 Ruffin Road, Suite B
San Diego, California 92123

Re: Comments of Iberdrola Renewables, Inc. on Wind Energy Zoning Ordinance and General Plan Amendment (POD10-007, LOG NO. 09-00-003; SCH NO. 2010091030).

Dear Sir or Madam:

N-1

Iberdrola Renewables, Inc. (IRI), submits these comments on the proposed Wind Energy Zoning Ordinance and General Plan Amendment in response to the *Notice of Availability of a Draft Environmental Impact Report and General Plan Amendment* dated November 8, 2011. Tule Wind LLC, the proponent of the Tule Wind Project located in eastern San Diego County, is a wholly owned subsidiary of IRI. IRI is the second-largest wind energy operator in the U.S. with over 4,700 megawatts of installed capacity operating across the U.S. As such, IRI is particularly well suited to provide comments on the DEIR and proposed Wind Energy Zoning Ordinance. IRI previously submitted comments to the County throughout the development of the ordinance. IRI submitted comments to Mr. Carl Stiehl on March 25, 2010 in response to a Notice of Intent dated February 25, 2010, and on November 18, 2009 in response to a Final Scoping Letter dated October 28, 2009.

The following commentary suggests important modifications to the proposed ordinance and additional analysis in the DEIR.

IRI COMMENTS ON AMENDING ORDINANCE

N-2

Several aspects of the proposed ordinance are well-crafted and designed to achieve important local, state and federal goals. Over the past several years, the Department of Planning and Land Use (DPLU) developed a draft ordinance that contains several elements that are necessary to allow appropriate wind energy development in San Diego County. IRI supports the County's goals, stated in Section 1.1 of the Draft EIR, but notes that the goals refer only to federal renewable energy and energy independence targets, but does not include the state goals, which aligned with and even exceed federal goals. The DPLU should

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Response to Comment Letter N

Iberdrola Renewables, Inc.
Jeffrey B. Durocher
December 22, 2011

N-1 This comment is introductory in nature and does not raise a significant environmental issue for which a response is required.

N -2 The County of San Diego acknowledges and appreciates this comment. However the suggested amendment to Section 1.1 of the Project Description to include State renewable targets is already addressed is Section 1.1, Project Objectives #1: "Facilitate the use of renewable wind energy within the County pursuant to existing and future statewide goals."

amend the Project Description to include state renewable targets. Significantly, the legislature this year adopted SBX1-2, which increased California's Renewable Portfolio Standard to 33%, with a target date of December 31, 2020. The Draft EIR's goals will contribute toward achieving this statewide objective. N-2 Cont. N-3

The Proposed Setbacks are Appropriate.

IRI supports the proposed minimum setbacks for wind turbine structures, which are much more realistic and compatible with modern wind turbine technology than those set forth in the existing County Zoning Ordinance Section 6951. The existing setbacks were based on very outdated technology and have the practical effect of precluding wind energy development in a large majority of the County. Adopting new setbacks is the essential change needed to achieve the County's stated goals. N-4 It is important to note that the setbacks proposed in the amending ordinance are *minimum* standards, and that the constraints of a particular parcel of land, turbine spacing requirements, or other limitations will have the effect of larger setbacks in many cases. In fact, the setbacks proposed for the Tule Wind Project that is the subject of a pending Multiple Use Permit (MUP) application, exceed the stated minimum requirements in the proposed ordinance. This is, however, unique to the particular layout and site conditions. N-5

Flexibility is Required.

Although the amending ordinance restricts wind energy development in several ways, it allows appropriate waivers and the flexibility needed to adapt to individual circumstances. For example, Section 6952(c)(4)(ii) and (iii) are important provisions that protect property rights by allowing development on parcels in common ownership or on adjacent parcels owned by consenting owners. Similarly, Sections 6952(c)(4)(i) and 6952(f) are intended to provide balanced development, efficient siting, and property rights necessary to achieve DPLU's stated goals. N-6

The draft ordinance Section 6952(h) includes a requirement to specify the turbine models at the application stage. This requirement is impractical, discordant with industry practice, and unreasonable. Because of the high capital cost of wind turbines, a project proponent cannot secure turbines at the application stage. Similarly, a proponent cannot commit to a particular turbine model or manufacturer. This is particularly important given the long period of time required to permit a project. Technology almost certainly will have changed before a permit is ever issued. For example, the pre-application meeting for the Tule Wind Project was held in 2008, and an application was submitted in 2009. The turbine options under consideration in 2012 did not even exist in 2009. Only after a project is approved can a wind energy developer execute choices among cost-effective turbines that are available for timely delivery at the time of construction. N-7

Standard practice is to consider the largest possible wind turbine dimensions in an application and associated environmental analysis. Numerous jurisdictions around the nation and in California recognize that turbines cannot be specified until project approval is received. Imperial, Kern, Santa Barbara, and Shasta Counties are among those that have all recently provided the needed flexibility in turbine choice by analyzing maximum impacts of a range of turbine sizes. This is also the case for the Tule Wind Project in San Diego County. References to six specific wind projects in California where a range of turbine sizes were N-8

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N-3 The County acknowledges and appreciates this comment. Please refer to response to comment N2 above.

N-4 This comment does not raise a significant environmental issue for which a response is required.

N-5 This comment does not raise a significant environmental issue for which a response is required.

N-6 This comment does not raise a significant environmental issue for which a response is required.

N-7 The County acknowledges and appreciates this comment. Please refer to response to comment H14.

N-8 The County of San Diego acknowledges and appreciates this comment. As also noted in response to comment H14, an applicant may specify multiple turbine models in the application in order for a range of turbine models to be analyzed. The ordinance has been revised to clarify that multiple turbine models may be specified at the application stage of a project.

analyzed are included in Attachment B. N-8 Cont.

IRI concedes that it *is* reasonable for the County to require manufacturer information in civil design drawings submitted with the building permit applications, and that the turbines must not exceed the maximum dimensions analyzed in the California Environmental Quality Act (CEQA) document. N-9

The Proposed Noise Standards are Arbitrary and Capricious and Must be Amended.

Despite the many positive aspects of the proposed ordinance, the amending ordinance has technical flaws that require modification in order to achieve the County's stated goals. Key among these are the draft requirements for low frequency noise. The effect is to create a noise standard that is exceeded by existing sound conditions,[1] which is clearly an untenable approach. N-10

Low frequency sound is not unique to wind turbines. In fact, it is generated by a host of everyday sources, including vehicular traffic, aircraft, rail traffic, and HVAC equipment. Yet the standard would not apply to these common low frequency noise sources, which generate these frequencies much closer to the public on a daily basis. It is unreasonable to regulate low frequency noise from wind turbines located far from residential property, but not sources located immediately adjacent to homes. Because the draft ordinance does not regulate low frequency sound from any other source, it unfairly discriminates against wind. Any such evaluation or metric could be applied uniformly to all regulated noise sources, not just wind turbines. N-11 The attached critique by Dr. Geoff Leventhall attached hereto as Attachment D more thoroughly explores the pitfalls of using such a criteria for wind turbines. N-12

As presented in Figure 1 of Attachment A, the audible and inaudible low frequency noise (infrasound) emitted by a wind turbine is lower than levels of audible low frequency noise and infrasound emitted by ocean waves breaking on a beach. People all over the world live, work, play, and sleep in close proximity to ocean beaches, and generally do not consider ocean sounds to be harmful to health. N-13 In fact, the low frequency and infrasonic noise at beaches also exhibits rhythmic amplitude modulation at levels that are more dramatic than wind turbine noise emissions. Unlike wind turbines, ocean sounds do not completely cease when winds are still. Rather they occur on a continual, 24/7 basis. The example of audible and inaudible low frequency noise naturally occurring at ocean beaches world-wide is further demonstration that there is no connection to low levels of this type of noise and adverse human health effects. N-14

Despite the fact that there is no connection between low frequency noise and human health effects (see DEIR p. 2.8-4), and despite the fact that wind turbines are not an intense source of low frequency noise emissions (see Attachment A, p. 7 and Attachment D, p. 3), the County chooses to regulate these sounds using limits that may already be exceeded by natural sounds in the project area prior to the introduction of wind turbines. N-15 Measurements of operating wind turbines indicate that wind farms sufficiently set back from receptors can N-16

[1] See Attachment A, p. 5.

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N-9 See responses to comments H14 and N8.

N-10 The County does not agree with this comment. See also responses to comment M4, M6, M7, M17, M25, and M26.

N-11 The County acknowledges and appreciates this comment. Wind turbines generate both aerodynamic and mechanical noise containing both high and low frequency components (20- 3,600 Hz.). Noise or unwanted sound from wind turbines are known to create an annoyance. The noise provisions in the proposed ordinance amendment are intended to prevent wind turbines from creating an annoyance and are based on review of scientific studies, as well as methodology used by other jurisdictions. The County is not required to regulate low frequency sound from other sources as part of this project.

N-12 County staff has thoroughly reviewed the critique provided in Attachment D of the comment. However, staff does not agree with this comment (see response to comment N11 above). The County has chosen a rather conservative approach to evaluating and minimizing future wind turbine noise based on review of numerous studies, review of other jurisdictions, and discussions with local acoustical experts.

N-13 The County of San Diego acknowledges and appreciates this comment. The County's focus for

		analysis is on the potential effects of large wind turbines on sensitive receptors in the relatively quiet rural parts of the unincorporated county. The County has determined that such effects can be adverse unless certain limits are applied.
	N-14	Wind turbines are a type of manmade mechanical noise source that generate a noise that differs from natural ocean noise and can be a nuisance. The County does not assert that low levels of wind turbine noise are connected to adverse health effects.
	N-15	The County acknowledges and appreciates this comment. The County concurs that there is not a direct causal relationship between low frequency noise and human health effects. However low frequency noise can create an annoyance. As such, the County has the right to establish regulations to minimize or eliminate noise impacts. The commenter's opposition to the proposed c-weighted regulations will be included in the final EIR and provided to the Board of Supervisors for its review and consideration.
	N-16	The County acknowledges and appreciates this comment. Staff agrees that the use of L_{eq} would be consistent with noise regulations in other counties. However, based on Proposed Criteria In Residential Communities for Low-Frequency Noise Emissions From Industrial Sources (2004) by George F. Hessler Jr., a difference of more than 20 decibels between the

comply with the American National Standards Institute (ANSI) standard for low frequency noise in bedrooms, classrooms, and hospitals, precluding the existence of a "nuisance" or "annoyance." Further, use of the L_{eq} is consistent with noise regulation throughout the U.S. The proposed limits are unreasonable, and IRI considers the proposed limits to be arbitrary and capricious. N-16 Cont.

The County claims without a reasonable basis that a 20 dB increase between low frequency sound (dBC) and background sound (dBA) results in a potential for low frequency noise impact. It is not uncommon for dBC and dBA levels to vary by more than 20 dB without substantial consequences—the difference between dBC and dBA levels within an office building may be 20 dB (for example, 40 dBA and 60 dBC). If such a threshold is to be established, guidelines on magnitudes below which the difference between dBC and dBA levels is immaterial should be considered. N-17

Some states have developed specific-octave-band criteria that address low frequency noise. Illinois and Oregon are two examples. In addition, the ANSI S12.2 criterion could be considered. N-18 IRI proposes an alternate approach to low frequency noise. The proposed regulations place an undue emphasis on limiting the C-weighted (dBC) sound pressure levels. Such restrictions are not supported by the peer reviewed scientific literature. The baseline conditions should be comprised of the cumulative noise level dBA (sound attributable to the project L_{eq} plus ambient L_{eq}). Unlike the proposed ordinance, a standard based on this methodology would not necessarily be exceeded by existing conditions, and thus compliance could be possible. N-19

While several states do have regulations that specifically regulate low frequency noise (either in terms of specific frequency bands or using the overall dBC rating), the levels stated typically indicate that exceedances of 65 dBC *may* indicate the potential for low frequency concern. For example, Division 404, Regulation 1, Section 802 of the Colorado Code of Regulations (CCR) establishes allowable noise limits for oil and gas facilities. The CCR limits are similar to those of other jurisdictions, such as Minnesota and Washington, including a 50 dBA nighttime limit for residential uses. N-20 However, given that oil and gas facilities may generate significant levels of low frequency noise, CCR 802(d) states the following: "In situations where the complaint or Commission onsite inspection indicates that low frequency noise is a component of the problem, the Commission shall obtain a sound level measurement twenty-five (25) feet from the exterior wall of the residence or occupied structure nearest to the noise source, using a noise meter calibrated to the dBC scale. If this reading exceeds 65 dBC, the Commission shall require the operator to obtain a low frequency noise impact analysis by a qualified sound expert, including identification of any reasonable control measures available to mitigate such low frequency noise impact. Such study shall be provided to the Commission for consideration and possible action." That is, dBC is used only as an indicator for potential additional study. N-21

Detailed comments regarding the technical flaws with the amending ordinance and support for IRI's proposal are contained in Attachment A to this letter. N-22

Finally, IRI urges modification to the requirement for ongoing monitoring. The last sentence of Section 6952(f)(3) should be deleted because once the project has been deemed to be compliant with the noise ordinance, it is unreasonable to conduct subsequent noise monitoring on the frequent basis proposed, particularly without any indication that a N-23

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long-term background levels (dBA) and the L_{eq} C-weighted level would result in excessive low frequency impacts.

N-17 Based on Proposed Criteria In Residential Communities for Low-Frequency Noise Emissions From Industrial Sources (2004) by George F. Hessler Jr., a difference of more than 20 decibels between the long-term background levels (dBA) and the Leq C-weighted level would result in excessive low frequency impacts. The County does not agree that guidelines on magnitudes below which the difference between dBC and dBA levels are immaterial is needed. As previously stated, the threshold for determining a low frequency noise impact is 20 decibels. The magnitude or degree a proposed wind project exceeds or falls below the threshold is not required or relevant for purposes of assessing low frequency noise impacts.

N-18 This comment does not raise a significant environmental issue for which a response is required.

N-19 The County acknowledges and appreciates the proposed alternative approach to low frequency noise compliance. It is unclear how the alternative method described in the comment would address the low frequency noise associated with wind turbines.

N-20 This comment does not raise a significant

		environmental issue for which a response is required.
	N-21	The County acknowledges and appreciates the referenced requirement CCR 802(d) which uses the dBC as an indicator for potential additional studies.
	N-22	County staff thoroughly reviewed Attachment A to the comment letter and appreciates this information. However, the County disagrees with this comment (see response to comment N12 above).
	N-23	The proposed ordinance has been modified through the course of numerous public hearings and a public workshop and no longer includes a Post Construction Sound Measurement provision. The current project includes Compliance Review provisions which will require Major Use Permits for large turbine(s) to be conditioned to require a compliance report to the County once every two years. The compliance report shall describe any complaints filed with the County during the previous two year period and all corrective actions taken if the use was found to be out of compliance with the requirements of Section 6952 of the County Zoning Ordinance and/or the applicable noise related Major Use Permit conditions. As a result of this review, the Director will determine that the use is in compliance with the requirements of this section and the applicable noise related Major Use Permit conditions or that the Major Use Permit shall be subject to review by the Planning Commission. If

violation is expected. This is not the standard or practice for any other noise source in the County, and it is not the standard or practice for any other wind project in the Country. Instead, the County should enforce noise standards just as it does for every other use that must comply with noise standards. The County may determine compliance or non-compliance by monitoring, or by responding to comments or complaints regarding compliance. N-23 Cont.

Other Issues with the Ordinance are Capable of Remedy

Some aspects of the proposed ordinance are inconsistent with stated goals, or contain technical errors. Adjustments to the ordinance can remedy some of the well intentioned, but problematic issues in the ordinance. Attachment B to this letter contains detailed comments on the ordinance and proposes remedies thereto. One important example of a legal flaw is presented here. N-24

Both the draft ordinance and the Project Description goals call for approving meteorological (MET) testing facilities without a discretionary permit. IRI supports this objective as a reasonable way to streamline the temporary use of land to measure the wind resources. MET facilities that meet certain parameters could be approved administratively. N-25 The standards contained in Section 11 (Section 6123(a)), however, are almost entirely discretionary standards. For example, terms like "harmony," "suitability," and "harmful" require the application of discretion that is incompatible with a ministerial approval. IRI proposes to correct this flaw while fulfilling stated objectives by allowing METs that are within certain parameters to be approved by ministerial approval. METs that are below the 200-foot FAA lighting requirement and meet setback standards for the underlying district, for example, could be approved ministerially. METs that exceed 200 feet in height or that exceed underlying setbacks could be approved by a discretionary process, such as the discretionary MUP process that exists for MET towers under the existing zoning ordinance. N-26

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the Planning Commission finds that the use no longer complies with the requirements of section 6952 and/or the applicable noise related conditions of the Major Use Permit, the Planning Commission may initiate modification or revocation of the permit in accordance with section 7382.c.

N-24 This comment does not raise a significant environmental issue for which a response is required.

N-25 This comment does not raise a significant environmental issue for which a response is required. However, it should be noted that the draft ordinance and project objectives do not propose approving all MET facilities without a discretionary permit. The draft ordinance and project objectives propose only allowing MET facilities that meet the height designator of the zone to be permitted without a discretionary permit.

N-26 The County does not concur with this comment. Section 6123(a) of the proposed ordinance does not apply to MET facilities that are proposed for ministerial approval. Section 6123 (i) of the proposed ordinance details the requirements for ministerial approval.

IRI COMMENTS ON DEIR

The DPLU Should Expand the Use of the DEIR.

The DEIR requires some revisions and additional analysis, as described herein. Once the EIR is complete and provides a thorough environmental analysis, the intended uses of the EIR should be expanded to use for future wind projects (See DEIR p. 1-13). The EIR's analysis of cumulative impacts is thorough, and provides a basis for tiering by future project-specific EIRs. CEQA Guidelines, Section 15130(d) states that "[a] pertinent discussion of cumulative impacts contained in one or more previously certified EIRs may be incorporated by reference pursuant to the provisions for tiering and program EIRs. No further cumulative impacts analysis is required when a project is consistent with a general, specific, master or comparable programmatic plan where the lead agency determines that the regional or area-wide cumulative impacts of the proposed project have already been adequately addressed, as defined in section 15152(f), in a certified EIR for that plan." The EIR should make clear that its cumulative impact analysis may be used in this way for future projects. N-27

The DPLU Should Revise the DEIR's Evaluation of Significant Impacts.

Table S.1 of the DEIR describes mitigation measures that are recommended for the project. The mitigation measures require future wind projects to use the County's guidelines for determining significance for visual resources, agricultural resources, air quality, biological resources, wildland fire and fire protection, and transportation and traffic. The County's guidelines for determining significance under CEQA are generally quite conservative, and could lead to impacts for future projects being overstated if the guidelines are applied mechanically. Under CEQA, "the fact that a particular environmental effect meets a particular threshold cannot be used as an automatic determinant that the effect is or is not significant." *Protect the Historic Amador Waterways v. Amador Water Agency* (2004) 116 Cal. App. 4th 1099, 1109. The EIR should make clear that the County's guidelines will be applied to future projects consistent with CEQA; i.e., projects that exceed a threshold in the guidelines will not automatically be deemed to have a significant impact. N-28

The DEIR concludes that future wind projects could have significant impacts related to farmland (DEIR p. 2.2-10). While this may be theoretically possible, wind projects have a small footprint (typically occupying approximately 2% of total land area) and are compatible with farming. Commercial wind development can even support and encourage farming by providing lease payments to farmers. N-29

The DEIR finds that future wind projects could have a number of significant impacts on biological resources (DEIR Section 2.4). While this may be theoretically possible, impacts to biological resources are heavily regulated by federal, state and local laws designed to mitigate impacts. Future wind projects that comply with these laws would be unlikely to significantly impact biological resources. Indeed, this was the DEIR's finding for wetlands (DEIR p. 2.4-35). It acknowledged that future projects could impact wetlands, but found that the protections afforded by federal, state and local laws and regulations would mitigate those impacts to below a level of significance. N-30

The DEIR acknowledges on page 2.8-21 that projects receiving a waiver from the C-weighted sound limits will not necessarily result in a significant noise impact. But page 2.8-25 N-31

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N-27 The County does not agree with this comment. First, it should be noted that the DEIR is meant to cover the proposed ordinance amendments. Its purpose is not to cover future discretionary projects. The County considered conducting the type of analysis that would be required to cover future discretionary wind turbine projects; however, a detailed master plan for future wind projects would be required in addition to very detailed studies and permitting requirements. This type of project would extend far beyond the Board of Supervisor's direction and funding allocation.

Second, the cumulative impact analysis for the proposed project considers the recent General Plan Update, as well as projects within other jurisdictions. This is the appropriate scope of analysis for a county-wide project. Future Major Use Permits for large wind turbines may incorporate that analysis by reference. However, it should be noted that there are various other considerations that should be included in a cumulative impact analysis for particular development projects. For example, new Major Use Permit applications were not considered in the County's General Plan Update EIR and are not included in the analysis for this DEIR. Projects, such as new General Plan Amendments, Specific Plans, and use permits, should be considered within the cumulative analysis for particular large wind turbine projects.

	N-28	CEQA Guidelines Section 15064.7 encourages lead agencies to develop and publish thresholds of significance. The County's Guidelines for Determining Significance are just that. While County staff does not apply them "mechanically," they are given credence during environmental review. If a project impact exceeds a guideline for determining significance, then the impact is normally considered to be potentially significant. It should be noted that the County involves the public in updating its guidelines. Therefore, if the commenter believes that additional information should be included in a particular guideline, this information should be provided to staff for consideration in the next update.
	N-29	While a wind turbine tower may have a minimal effect on a given agricultural operation, it could also have substantial adverse impacts. A future large turbine project can be proposed on a property with unique farmland, prime soils, or sensitive livestock. Therefore, it is the County's determination that impacts are potentially significant.
	N-30	The County does not agree with this comment. Utilizing the County's Guidelines for Determining Significance, there is the potential for significant impacts to the County's biological resources that are not regulated by law. Moreover, an impact that is regulated is not necessarily less than significant

		pursuant to CEQA. Federally protected wetlands are unique in that they truly are protected through many levels of regulation and avoidance or mitigation is assured.
	N-31	The County does not concur with this comment. The DEIR analysis states (Section 2.8.4.3 Large turbine(s)) that "...the development of large turbines under the proposed project would potentially contribute to a cumulatively considerable impact.” This analysis does not conclude in absolute terms that in all cases there will be a significant impact.

suggests that any violation of the C-weighted noise limits would have a significant impact: "However, as it is possible for a noise waiver to be granted subject to specific conditions, the development of large wind turbines under the proposed project would potentially contribute to a cumulatively considerable impact (NOI-5)." This reference should be revised to make clear that not all noise waivers would result in a significant noise impact. N-31 Cont.

Similarly, page 2.8-29 suggests that requiring all projects to comply with the C-weighted noise limit would reduce noise impacts to below a level of significance. There is no evidence in the DEIR that C-weighted noise above the recommended threshold would cause significant impacts. The C-weighted noise requirement should be eliminated, or modified as suggested by IRI above. N-32

There is a burden upon the County to demonstrate when C-weighted noise levels reach the level of significance. N-33

This burden is compounded by the fact that much of the low frequency range of sound that C-weighting highlights is most often inaudible to a person with average auditory senses. If the County cannot demonstrate how inaudible sounds can reach a level of significance, then the proposed limits are unreasonable, arbitrary, and capricious. Further, the EIR should make clear that exceeding the C-weighted noise limit does not cause a significant noise impact. N-34

The DEIR Provides Insufficient Analysis of Noise Effects.

The DEIR contains very little information to enable the public to determine whether a C-weighted sound level limit is necessary, appropriate, or desirable. The ordinance provides reference to "other jurisdictions" (DEIR p. 2.8-3) without referencing those jurisdictions or the standards in those jurisdictions. IRI is aware of no jurisdictions that use the L_{90} as a proxy for baseline conditions. N-35

Use of the L_{90} descriptor is inconsistent with environmental noise limits enforced by state and federal agencies throughout the nation that have regulatory programs that limit environmental noise. Some examples include the states of Illinois, Delaware, Maryland, the Federal Transit Administration,[2] all state departments of transportation (with the exception of Minnesota), the U.S. Environmental Protection Agency,[3] the U.S. Department of Housing and Urban Development,[4] U.S. Surface Transportation Board[5] and the Federal Aviation Administration.[6] Those agencies rely on the L_{eq} and L_{dn} descriptors almost exclusively to establish existing noise levels and set limits for future noise levels. N-36

By contrast, the L_{90} descriptor proposed by the amending ordinance artificially eliminates the loudest 90% of sound. This methodology can be simulated by plugging your ears with your fingers. Plugging your ears, or any other method of eliminating 90% of sound does not produce an accurate simulation of what humans experience when N-37

[2] Transit Noise and Vibration Impact Assessment, Federal Transit Administration, May 2006, FTA-VA-90-1003-06.

[3] Public Health and Welfare Criteria for Noise, Environmental Protection Agency, July 27, 1973, 550/9-73-002.

[4] The Noise Guidebook, U.S. Department of Housing and Urban Development, March 1985, HUD-953-CPD.

[5] 49 C.F.R. § 1105.7.

[6] 14 C.F.R. Part 150.

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N-32 The County does not concur with this comment. DEIR Section 2.8 Wind Turbine Noise Characteristics and Noise Effects describes the potential for impacts when C-weighted noise exceeds the proposed threshold.

N-33 This comment does not raise a significant environmental issue for which a response is required. The commenter's opposition to the proposed C-weighted noise provision will be provided in the Final EIR for review and consideration by the County Board of Supervisors.

N-34 The County does not agree with this comment. Please refer to response to comment N32.

N-35 The County acknowledges and appreciates this comment. Although local agencies do not currently have existing regulations that utilize the L_{90} as a baseline requirement, the Town of Montville and the Town of Dixmont currently utilize the L_{90} unit of measurement for background noise levels.

N-36 Please see response to comment N35 for other jurisdictions relying on the L_{90} measurement. In order to analyze noise impacts from a large turbine, it is necessary to establish the quietest ambient condition, as this is the period of time when the introduction of new noise sources such as turbines may be most impactful. The County considers the quietest 10 minute measurement as representative of the existing

		ambient noise levels for residences located in very quiet rural areas.
	N-37	Please see response to N36 for reasons why the L_{90} is a part of the County Draft Wind Turbine Ordinance.

they are outdoors immersed in the ambient acoustic environment. Clearly this is an unreasonable method to estimate existing or future noise levels outdoors. N-37 Cont.

Similarly, for the octave band sound level limits, the DEIR contains no information to suggest that these new regulations are necessary or desirable and will not unduly burden new wind energy projects (DEIR p. 2.8-10). IRI requests that a thorough explanation detailing the technical basis for each proposed limit be provided before these limits are enacted. N-38 This explanation should include results of long-term unattended noise monitoring that show the relationship between existing A- and C-weighted noise levels in portions of the County potentially suitable for wind energy development. N-39 There is no evidence that the County fully understands (i.e. has measured) the relationship between existing A- and C-weighted noise levels in portions of the County potentially suitable for wind energy development. Therefore, IRI feels it is unreasonable to move forward with the noise limits in the draft ordinance because they are not based on rational, factual, or scientific evidence. N-40

Also, the DPLU should revise the DEIR to acknowledge and summarize the large body of scientific evidence that shows low frequency noise from wind turbines does not cause health, safety or environmental impacts. References are provided in Attachment A submitted with this comment letter. The DPLU can find additional information on this topic prepared for the Final EIR prepared for the Tule Wind Project.[7] The DPLU should revise the DEIR to provide complete documentation and analysis of the sources referenced therein. N-41

The DEIR Should Evaluate Additional Alternatives.

The DEIR lists three alternatives, all of which would reduce or eliminate potential wind development. The EIR should analyze a project that further streamlines and encourages the siting of wind projects. Wind energy projects reduce greenhouse gases and other emissions and use less water and resources when compared to other sources of electricity. By quantifying these benefits, an alternative that maximizes the development of wind energy in San Diego County would likely be proven to be the environmentally superior alternative. N-42

The DEIR's alternative section states that eliminating restrictions on large wind turbines or eliminating the need for a MUP would be counter to the Board of Supervisors' direction. But the EIR should still analyze an alternative that is consistent with the Board's direction and that would allow greater wind development. N-43 For example, the EIR should analyze a version of the wind ordinance that does not contain C-weighted noise limits or octave band limits. The analysis should attempt to quantify how much additional clean wind energy such an alternative may yield and the attendant reductions in greenhouse gas emissions. By quantifying these benefits, this analysis is likely to show that removing some of the proposed restrictions on wind projects would be the environmentally superior alternative. N-44

CONCLUSION

[7] See Attachment C, Joint Final Environmental Impact Report/Environmental Impact Statement (EIR/EIS) for the East County Substation/Tule Wind/Energia Sierra Juarez Gen-Tie Projects, Response to Tule Data Request 14 (http://www.cpuc.ca.gov/environment/info/dudek/ecosub/DR/TuleDataRequestResponse14.pdf).

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N-38 The County acknowledges and appreciates this comment. The How to Guide to Siting Wind Turbines (October 28, 2008) by Kamperman and James and the Proposed Criteria In Residential Communities for Low-Frequency Noise Emissions From Industrial Sources (2004) by George F. Hessler Jr., are reliable resources of technical research identifying concerns when low-frequency content is excessive.

N-39 Please see response to comment N38.

N-40 It is not necessary to measure the existing relationship between ambient A-weighted and C-weighted sound to implement the proposed low-frequency sound limit. The proposed low frequency sound limit is only concerned with the low frequency (C-weighted) contribution from a proposed large turbine project above the existing background (A-weighted) sound level. The existing relationship between ambient A-weighted and C-weighted sound are not utilized to determine compliance with the low frequency sound limit. See also response to comment N38.

N-41 The County acknowledges and appreciates this comment. The Draft EIR meets CEQA Standards for Adequacy (CEQA Guidelines Section 15151) in that it provides decision makers with a sufficient degree of analysis. Please note that an EIR need not be exhaustive nor does disagreement among experts make an EIR inadequate.

	N-42	The County does not agree with this comment. The purpose of the EIR is not to compare wind energy projects with other types of energy projects. Rather, the EIR must analyze the County's proposed project and disclose the foreseeable environmental impacts from a plan–to-ground analysis in an objective way. It is not the forum for discussing the merits of the project. Moreover, the County does not agree that an alternative which proposes to further streamline wind energy would be the environmentally superior alternative or a preferred alternative. Wind energy projects can have significant adverse effects on the environment which the County can only estimate and mitigate to a certain degree under the proposed project. An alternative that results in less regulation of wind energy projects will have substantially greater impacts on the environment.
	N-43	The County does not agree with this comment. As noted above in response to comment N42, an alternative that results in less regulation of future wind energy projects will result in a substantial increase in environmental impacts according to the County's analysis. Per CEQA Guidelines Section 15126.6, the discussion of alternatives should focus on alternatives to the project or its location which are capable of avoiding or substantially lessening any significant

		effects of the project.
	N-44	The County does not agree with this comment. As noted above in response to comment N43, the discussion of alternatives should focus on alternatives to the project or its location which are capable of avoiding or substantially lessening any significant effects of the project. The proposed project does not have significant effects related to greenhouse gas emissions. Therefore, an alternative that further reduces greenhouse gas emissions is not an appropriate project alternative for the EIR. Moreover, the elimination of the noise limits would result in increased adverse effects under the commenter's suggested project alternative. It should also be noted that a project alternative that does not include the County's limits on low frequency noise would not produce a meaningful analysis. The result of such an analysis would be that future large wind projects would have reduced setbacks compared to the proposed project, thereby resulting in more severe impacts on sensitive receptors and conflicting with project objective #5: "Minimize the potential for land use conflicts that may arise through the development of wind turbines."

IRI thanks the County of San Diego for its careful consideration of these comments and respectfully requests modifications to the amending ordinance and to the DEIR implicated thereby. N-45

Yours Sincerely,

Jeffrey B. Durocher
Tule Wind LLC

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N-45 This comment concludes the letter and does not raise a significant environmental issue for which a response is required.

ATTACHMENT N1

Attachment A – Technical Memorandum Prepared by HDR

Memo

To:	Jeffrey Durocher, Iberdrola Renewables, Inc.
From:	Gina Ramirez and Tim Casey
cc:	Patrick O'Neill
Date:	December 16, 2011 Job No: 115965

Re: County of San Diego Draft Wind Ordinance – Noise Comments

Per your request, HDR has reviewed the County of San Diego's Draft Environmental Impact Report for the Wind Energy Zoning Ordinance and General Plan Amendment and Draft Wind Ordinance (Appendix A of the DEIR). HDR has identified several areas of concern in the proposed Draft Wind Ordinance.

Of primary concern is that the document upon which the low frequency noise limits are based contains numerous technical inaccuracies. Additionally, the noise limits (low frequency) in the Draft Wind Ordinance are inconsistent with noise standards for other low frequency noise sources within the County of San Diego. For example, generators, HVAC equipment and other noise sources with low frequency noise components are assessed based on A-weighted sound levels.

SUMMARY

The County of San Diego Draft Wind Ordinance:

1. The Draft EIR recognizes that no direct causal relationship has been established between wind turbine low frequency sound and adverse human health effects, yet the Draft Wind Ordinance requires the assessment of low frequency sound. This is an internal inconsistency between the Draft Wind Ordinance and Draft EIR. This inconsistency requires revisions to the Draft EIR and recirculation.
2. Establishes unrealistic noise limits for wind turbines; the net effect will be to require off-set distances in excess of one mile (which will severely limit if not completely prohibit the development of wind energy facilities in County of San Diego);
3. Establishes noise limits for wind turbines which are often exceeded in pre-construction ambient (existing) noise conditions.
4. Imposes low frequency noise regulations which are inconsistent with noise standards for other low frequency noise sources such as vehicular traffic, aircraft, rail traffic, HVAC equipment generators and other industrial noise sources;

5. Uses an inappropriate standard for establishing the existing (pre-wind turbines) noise environment and as a result ignores 90% of common everyday noises misrepresenting ambient (existing) noise levels;
6. Assumes that wind turbines emit harmful levels of low-frequency noise, when there is no scientific or medical basis for this assumption. Infrasonic and low-frequency noise emission from wind turbines are often less than levels emitted by natural sources such as ocean waves crashing on a beach.
7. Requires extensive post-construction noise monitoring that is unnecessary because there is no scientific or medical basis for the assumption that low frequency noise is harmful.

DISCUSSION

Inconsistent Application of Noise Methodology/Limits

The County of San Diego Draft Wind Ordinance proposes low frequency noise limits that are inconsistent with County noise standards for other low frequency noise sources. Existing sound sources such as vehicular traffic, aircraft, rail traffic, HVAC equipment generators and other industrial noise sources are known to emit low frequency noise. The County of San Diego currently assesses all sound sources, regardless of spectral content, based on A-weighted sound level limits. Use of C-weighted sound level limits, or sound level limits using C-weighting scale which places more weight low frequency noise than the A-weighting scale, is inconsistent with the County of San Diego noise assessment standards for low frequency noise generators.

Additionally the Draft EIR, page 2.8-4, recognizes that no direct causal relationship has been established between wind turbine low frequency sound and adverse human health effects, yet the Draft Wind Ordinance requires the assessment of low frequency sound. This is an internal inconsistency between the Draft Wind Ordinance and Draft EIR. This inconsistency requires revisions to the Draft EIR and recirculation.

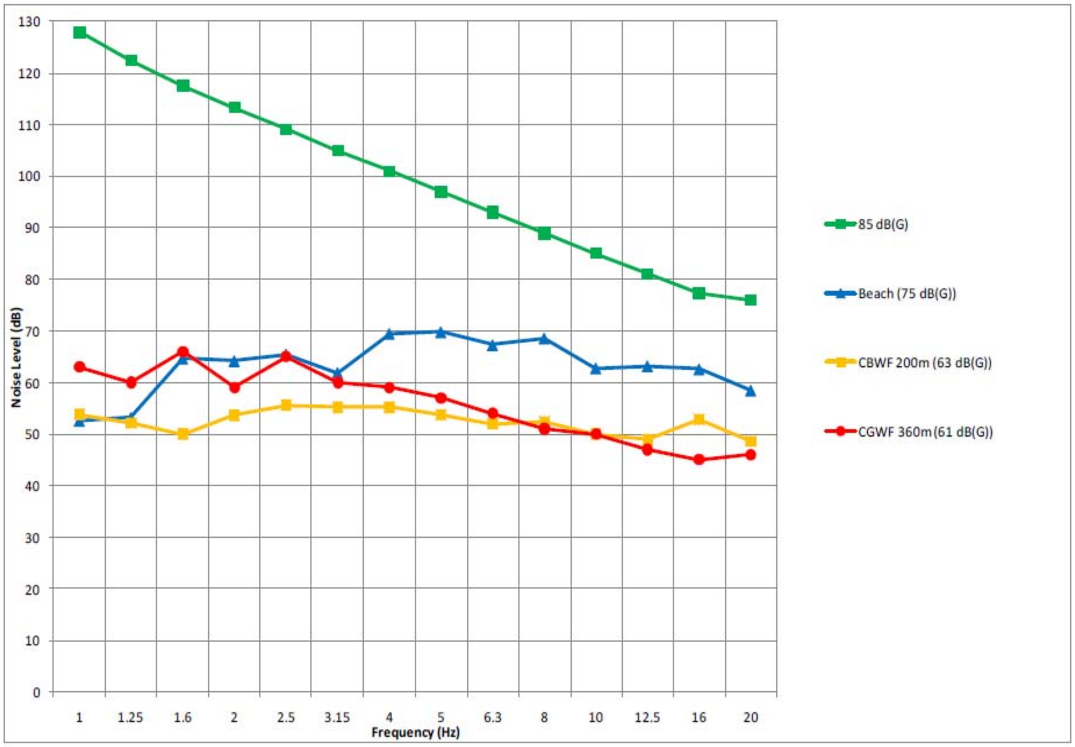
Wind Turbine Low Frequency Noise Emissions

The noise emitted by modern upwind-configured wind turbines contains very low amounts of energy in the infrasonic range, the frequency range below the threshold of hearing, very little low frequency energy, and relatively more energy in the audible range. Modern up-wind configured wind turbines are recognized as emitting less low-frequency noise than older down-wind configured wind turbines.[1] Measurement data reported by Sonus Pty, Ltd[2] compares infrasound measurements at two operating wind farms in Australia, Clements Gap (CGWF – 61 dBG) and Cape Bridgewater (CBWF – 63 dBG), with data measured at a beach in the absence of wind turbine noise. These three data sets are compared with the internationally recognized audibility threshold for infrasonic noise in Figure 1.

The Sonus measurement results indicate that the levels of infrasound in the vicinity of the two Australian wind farms are well below the audibility threshold of 85 dB(G) established by international research.[3] The measurement results are of the same order as that measured from a range of sources including a beach.

[1] Anthony L. Rogers, Ph.D., James F. Manwell, Ph.D., Sally Wright, M.S., PE, " Wind Turbine Acoustic Noise" prepared by the Renewable Energy Research Laboratory, Department of Mechanical and Industrial Engineering, University of Massachusetts at Amherst, January 2006.
[2] Sonus Pty, Ltd. in "INFRASOUND MEASUREMENTS FROM WIND FARMS AND OTHER SOURCES" prepared for Pacific Hydro Pty Ltd, November 2010.
[3] Sonus Pty, Ltd. in "INFRASOUND MEASUREMENTS FROM WIND FARMS AND OTHER SOURCES" prepared for Pacific Hydro Pty Ltd, November 2010.

Figure 1. Infrasound Summary Results from Two Australian Wind Farms



Summary Graph – Infrasound measurement results from two Australian wind farms (Clements Gap at 61 dB(G) and Cape Bridgewater at 63 dB(G)) compared against measurement results at a beach (measured at 75 dB(G)) and the internationally recognised Audibility Threshold (85 dB(G))

Measurements of operating wind turbines published by Epsilon and Associates (Epsilon) also indicate that wind farms at distances beyond 1,000 feet meet the ANSI (American National Standards Institute) standard for low frequency noise in bedrooms, classrooms, and hospitals, and there should be no window rattles or perceptible vibration of lightweight walls or ceilings within homes. In homes there may be slightly audible low frequency noise (depending on other sources of low frequency noise); however, the levels produced by measured wind projects are below criteria and recommendations for low frequency noise within homes.[4] The wind turbine types measured by Epsilon include the GE 1.5sle and Siemens SWT 2.3-93.

Inappropriate Noise Limits

The spectra-imbalance noise limits cited in the County of San Diego's proposed revisions to the zoning ordinance are inconsistent with noise limits accepted by other local and state agencies. Typical noise limits are based on absolute limits or relative limits that regulate the increase in sound level. Based on HDR's noise monitoring measurements of the proposed Tule Wind project

[4] Epsilon Associates, A Study of Low Frequency Noise and Infrasound from Wind Turbines, May 2009.

area, the ambient (existing) noise environment frequently exceeds the proposed low frequency regulations.

As an example, the existing ambient C-weighted sound levels often exceed the LA90 of the quietest 10 minutes. Use of the LA90 as a basis for post-construction C-weighted sound levels result in C-weighted sound level limits below the existing L_{ceq} therefore allowing no increase over existing, which is inconsistent with existing County of San Diego regulations. The use of such noise limits would require large wind turbine setback distances in excess of one (1) mile. In conjunction with stricter noise limits, the County of San Diego's revised noise ordinance requires that the acoustical assessment compare worst case noise emissions with the quietest measureable background levels. Such comparisons create an inaccurate portrayal of normal operating conditions and existing noise levels, and are inconsistent with the norms of accepted practices in the field of environmental acoustics.

A widely accepted absolute noise limit for outdoor environments is 55 dBA L_{dn}, established by the EPA. The day-night noise level (L_{dn}) is a 24-hour average noise level that is calculated using 24 consecutive hourly equivalent noise levels (L_{eq}) and adds a 10 dBA penalty to nighttime L_{eq} values between the hours of 10:00 p.m. and 7:00 a.m. (in recognition of the annoyance associated with nighttime noise). The EPA considers 55 dBA on an L_{dn} basis to be sufficiently low as to minimize or eliminate any potential for sleep interference, indoor/outdoor speech interference, and annoyance. Kamperman and James, the authors of the document upon which the Draft Noise Ordinance is based, suggest that wind turbine noise, by virtue of its nature, requires more stringent noise guidelines than other noise sources – a suggestion in conflict with the opinions of the vast majority of the acoustics, audiology, and health communities.

Inappropriate Basis for Existing Noise Levels

County of San Diego's proposed wind turbine noise requirements and ordinance could misrepresent existing noise levels. The proposed section addressing allowable turbine noise emission above pre-existing noise conditions assess existing noise conditions using a 10-minute L_{90}[5] metric during the quietest hours of the night. The use of the L_{90} to represent existing noise levels excludes 90% of common noise sources in the existing noise environment, such as animals and intermittent traffic. The proposed ordinance then assumes that the lowest 10% of noise levels measured during very short-term durations during the quietest hours of the night are representative of typical ambient outdoor noise levels. As such the representation of pre-existing noise levels proposed by County of San Diego would not accurately quantify the existing ambient noise environment through the exclusion of existing noise sources. More accurate metrics which establish a baseline environmental sound level are the hourly L_{eq}[6] and 24-hour

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[5] An L_{90} is defined as the noise level exceeded 90% of the time, therefore for 90% of the measurement period the noise level exceeds the L_{90}.
[6] $L_{eq(h)}$ represent a constant sound that, over an hour, has the same acoustic energy as the measured time-varying sound level.

L_{dn}[7]. Current acoustical standards, outlined in ANSI S12.9 Part 2 call for use of long term measurements and metrics such as L_{dn} in environmental assessment and planning. Long term measurements which capture noise produced by local traffic, aircraft over flights and common everyday activities are a more accurate representation of current conditions and pre-existing low frequency noise. The draft wind turbine noise requirements and ordinance should be revised to correct this misrepresentation.

ANSI S12.9 Part 3 defines background sound as the all-enncompassing sound associated with a given environment *without contribution from the source or sources of interest*. Pre-construction measurements are performed without the operation of the proposed project, therefore all existing noise sources should be considered part of the existing noise environment. Current County of San Diego noise regulations require the use of the community equivalent sound level, CNEL, as a basis to assess increase over existing. The proposed wind turbine ordinance utilizes metrics which are inconsistent with current regulation and misrepresent existing ambient sound levels.

Relies on Unsupported Claims of Health Effects

The Kamperman and James's document ("The 'How To' Guide to Siting Wind Turbines to Prevent Health Risks from Sound") was commissioned by opponents of wind energy development and much of its contents are unsupported by peer-reviewed, published scientific literature. A recent review of published medical literature using the Pub Med database concluded that there is no documented, peer-reviewed, published evidence that wind turbines generate noise that negatively affects human health. The levels of low frequency noise emitted by modern up-wind turbines have been shown to be below levels that are harmful to human health.

Case studies cited by Kamperman and James to support the hypothesis that wind turbines are a potential for health risk in actuality <u>do not establish a causal</u> relationship between wind turbine generated noise and adverse health effects. Self-reported, pre-selected claims of health effects could potentially serve as a case study to simply draw attention to a stimulus and observed conditions. However, there is no basis for assuming that these self-reported claims establish a cause and effect relationship. Modern epidemiological study methods used every day to assess public health issues require extensive study by numerous, unrelated practitioners, and painstaking levels of scrutiny by additional, numerous, and unrelated practitioners before they suggest cause and effect relationships. The claim that wind turbines cause adverse health effects lacks factual support with peer-reviewed, published, scientific data; therefore these claims should not be used to make environmental policy. In fact, it is now recognized that the self-reported health effects are consistent with common responses to annoyance to noise. It is also recognized

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[7] 24-hour L_{dn} is a noise weighted descriptor created to quantify the manner in which sound is perceived over a 24 hour period. The L_{dn} is equivalent to the $L_{eq(24)}$ with 10 dB added to nighttime sound levels between the hours of 10:00 PM and 7:00 AM to account for people's greater sensitivity to sound during nighttime hours.

that individuals with disapproval of and no control over stimuli are likely to be annoyed by it. In other words, people who self-report health effects associated with exposure to wind turbine noise are also likely to be the people who opposed the wind turbines. This concept is globally accepted by all but a few who discount it in an attempt to bolster their claims of "wind turbine syndrome."

Long-term exposure to very high levels of low frequency noise has been shown to have adverse effects on health. It has been demonstrated that high levels of low frequency noise can excite body vibrations, such as a chest resonance vibration that can occur at a frequency of 50 Hz to 80 Hz[8]. These chest wall and body hair vibrations have also been shown to occur at the infrasonic range[9,10]. However, in those instances, levels were significantly higher than the amounts of low frequency noise emitted by wind turbines. Studied health effects of low frequency sound include vibroacoustic disease which has been linked to prolonged exposure to high intensity low frequency noise, in excess of 110 dB, not low intensity low frequency noise[11,12,13]. Additionally studies have found that there is no evidence of adverse health effects related to low intensity low frequency noise, below 90 dB.[14]

Low frequency sound and infrasound associated with wind turbines are well below 90 dB. Wind turbine generators emit limited levels of low frequency and infrasonic sound. In fact, wind turbines produce modest and acceptable amounts of low frequency noise, as shown by post-construction noise measurement data publicly available and reasonably obtainable on the internet. Recently some concerns have been raised about possible health effects from these inaudible sound levels. One theory comes from Dr. Nina Pierpont who claims that health effects including dizziness, headache, visual blurring and tachycardia, or "Wind Turbine Syndrome", can occur as a result of exposure to wind turbine sound. Dr. Pierpont claims that "Wind Turbine Syndrome", a term she coined, results from a disturbance to the vestibular system by exposure to low levels of infrasound and low frequency sound emitted by wind turbines.

The topics of "Wind Turbine Syndrome", infrasound and low frequency sound below the threshold of hearing have been addressed by Dr. Geoff Leventhall in his testimony in the Glacial Hills wind farm project in Wisconsin. Dr. Leventhall, a former professor who founded an acoustics research program in England that specialized in low frequency and infrasonic research,

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[8] Leventhall, G. (2007). What is infrasound? 93(1-3), (130 -137).

[9] Mohr G.C., Cole J.N., Guild E., and Gierke von, H. E. (1965). Effects of Low Frequency and Infrasonic Noises on Man. 36.817 -827).

[10] Schust, M. (2004). Effects of low frequency noise up to 100 Hz. *Noise and Health.* 6(23), (73 -85).

[11] Castelo Branco N.A.A. and Rodriguez E. (1999). The Vibroacoustic Disease - An Emerging Pathology. *Aviation Space & Environmental Medicine.* 70(3,Pt2), (A1 -A6).

[12] Takahashi, Y., Yonekawa, Y., and Kanada, K. (2001). A new approach to assess low frequency noise in the working environment. *Industrial Health.* 39(3), (281 -286).

[13] Maschke, C. (2004). Introduction to the special issue on low frequency noise. *Noise and Health.* 6(23), (1 -2).

[14] "Wind Turbine Noise Issues." Renewable Energy Research Laboratory; University of Massachusetts. 2006.

is internationally recognized as having expertise in the topics of low frequency and infrasound. Dr. Leventhall stated:

> *Attempts to claim that illnesses result from inaudible wind turbine noise do not stand up to simple analyses of the very low forces and pressures produced by the sound from wind turbines. Additionally, the body is full of sound and vibration at infrasonic and low frequencies, originating in natural body processes. As an example, the beating heart is an obvious source of infrasound within the body. Other sources of background low frequency noise and vibration are blood flows, muscle vibrations, breathing, fluids in the gut and so on. The result is that any effect from wind turbine noise, or any other low level of noise, which might be produced within the body is 'lost' in the existing background noise and vibration.* [15]

Dr. Leventhall goes on to state that "the wide range of symptoms" which Dr. Pierpont associates with "Wind Turbine Syndrome" are "well known to others as the stress effects of audible noise, to which a small number of persons are susceptible."

The work of Dr. Pierpont relied heavily on the research of Dr. Neil Todd from the Faculty of Life Science at University of Manchester, who recently reprimanded Pierpont for her misinterpretation and use of his research. Dr. Pierpont's "Wind Turbine Syndrome" theory has incorrectly sought to insert air-borne noise issues into a paper which is entirely about vibration through direct contact with the skull. Dr. Todd states the following concerning Pierpont's interpretation of his research:

> *Our research is being cited to support the case that 'wind turbine syndrome' is related to a disturbance of vestibular apparatus produced by low-frequency components of the acoustic radiations from wind turbines. Our work does not provide the direct evidence suggested. We described a sensitivity of the vestibular system to low-frequency vibration of the head (through direct physical contact), at about 100Hz, and not air-conducted sound.*[16]

Dr. Leventhall also quoted Dr. Todd, who states that:

> *At present I do not believe that there is any direct evidence to show that any of the above acoustico-physiological mechanisms (associated with wind turbine syndrome) are activated by the radiations from wind turbines. Even if the vestibular system were activated in a controlled acoustic environment, it is not*

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[15] Testimony of Dr. Geoff Leventhall to the Wisconsin Public Utilities Commission, docket 6603-CE-302.

[16] Dr Neil Todd Faculty of Life Science University of Manchester (Todd, N., Rosengren, S. M., and Colebatch, J. G. (2008): Tuning and sensitivity of the human vestibular system to low frequency vibration. *Neuroscience Letters* 444, 36 - 41.) as cited in Levanthal testimony to the Wisconsin Public Utilities Commission, docket 6603-CE-302.

necessarily the case that it would produce pathological effects. Until such evidence is available I have an open mind on "wind turbine syndrome.[17]

Dr. Leventhall goes on to state:

Throughout Pierpont's work there is no clear indication of the excitation levels which she believes might cause a problem. While she must be aware of safe and unsafe doses of medication, she continues to close her mind to the concept of safe doses of sound, although "safe sound" is our everyday experience. Thus, Pierpont's hypothesis [related to "Wind Turbine Syndrome"] fails.[18]

Dr. Leventhall summarizes additional technical portions of Pierpont's theory that infrasound causes health effects by stating:

Pierpont's second hypothesis is equally unfounded. She says that infrasound at 4 – 8Hz enters the lungs and vibrates the diaphragm and its attached liver, so passing confusing messages on to the visceral graviceptors. She gives no evidence to support this, but instead uses references to whole body vibration, applied to the feet or seat, which is a completely different excitation to that from sound. A simple order of magnitude calculation, using basic physics of the level which will be known to a 16-year-old school pupil, shows that the movement of the diaphragm under the forces which might result from wind turbine noise is less than 10 micron. That is less than one hundredth of a millimeter or about one tenth of the average thickness of human hair. During normal breathing, the diaphragm moves several centimeters.[…] Another part of Pierpont's second hypothesis states that infrasound from wind turbines, at a frequency of 1 – 2Hz, vibrates the chest, so adding to the confusing signals which upset the balance system. However, there is already a strong source of infrasound inside the body, beating at 1 –2 Hz, giving far greater magnitudes than might be produced by infrasound from wind turbines at these frequencies: the human heart. The beating heart vibrates the surface of the body at a high enough level to be picked up by a stethoscope, or even the ear. The sound produced by wind turbines does not.[19]

Dr. Leventhall also commented on an issue raised by Mr. Richard James of E-Coustic Solutions:

James uses Dr. Neil Todd as an example to 'demonstrate that there is sufficient evidence to present a causal link between ILFN (infrasound and low frequency noise) and adverse health effects.' What Dr. Todd actually showed was that, for a

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[17] Dr Neil Todd Faculty of Life Science University of Manchester (Todd, N., Rosengren, S. M., and Colebatch, J. G. (2008): Tuning and sensitivity of the human vestibular system to low frequency vibration. *Neuroscience Letters* 444, 36 - 41.) as cited in Levanthal testimony to the Wisconsin Public Utilities Commission, docket 6603-CE-302.

[18] Testimony of Dr. Geoff Leventhall to the Wisconsin Public Utilities Commission, docket 6603-CE-302.

[19] Testimony of Dr. Geoff Leventhall to the Wisconsin Public Utilities Commission, docket 6603-CE-302.

> *vibration input through physical contact to the mastoid area at the back of the head, certain reflexes, indicative of a vestibular response, continue to about 15dB lower than the level at which the hearing mechanism of the inner ear ceases to respond to vibration in the skull. It takes only a little thinking to realize that all of the people who use bone conduction hearing aids are receiving vibration inputs to their vestibular system at levels well above the system's perception threshold. This does not affect them.*[20]

The testimony of Drs. Leventhall and Todd state that there are no scientifically valid peer reviewed studies showing any adverse health effects from infrasonic or low frequency noise emitted from turbines, and that there is no valid mechanism by which the infrasound produced by turbines could affect the human body any differently than other infrasound produced within the body. Therefore, no adverse health effects are anticipated from any infrasound produced by wind turbine generators.

Requires Extensive Post-Construction Measurement

Post-construction measurement for wind turbine projects are typically performed within 12-18 months of commercial operation. Acoustical commissioning measurements ensure that the project is in compliance with local regulations. Increases in noise emission for wind turbine generators are typically associated with mechanical malfunction or need for maintenance. Periodic study every 5 years is unnecessary unless a change in operations is proposed.

Comments on the Draft EIR for the Draft Wind Ordinance

The Draft EIR for the Draft Wind Ordinance:

- Places undue and unsupported emphasis on low frequency noise emissions from wind turbines.
- Is inconsistent with the Draft Wind Ordinance
- Is inconsistent with noise limits utilized throughout the United States
- Utilizes highly subjective criteria make unsound bases for public policy and environmental noise regulations

In the Draft EIR, Section 2.8, the County stresses the notion that C-weighting is more representative of human response to very high levels of low-frequency noise than A-weighting. While there is merit to this notion, its use is inappropriate in regulating wind turbine noise because wind turbines are not an intense source of low-frequency noise emissions. This is demonstrated by inspection of reasonably obtainable and publically available post-construction

[20] Testimony of Dr. Geoff Leventhall to the Wisconsin Public Utilities Commission, docket 6603-CE-302.

noise monitoring data for modern up-wind configured wind turbines. The County's continued assertion that wind turbines emit high levels of low frequency noise is simply unsupported by published monitoring data for wind turbine noise.

Natural gas-fired turbines, basically the same type of engine used on a commercial jet airplane, are one example of ground-based noise sources that do emit high levels of low frequency noise. There is merit in quantifying noise from a gas-fired turbine using C-weighting, because the low frequency noise content is well documented. However, modern up-wind configured wind turbines do not emit the same amount of low frequency noise as gas-fired turbines or jet engines. On this issue, the County is placing undue and unsupported emphasis on low frequency noise emissions from wind turbines. It is unnecessary and inappropriate to regulate wind turbine noise using C-weighted decibels. Furthermore, even airport noise (which unquestionably has more low-frequency content than wind turbine noise) is regulated using A-weighted decibels. The County is simply wrong with this assertion.

The County also claims that "if there is a measured difference of more than 20 dB between wind turbine low frequency sound (dBC) and background sound (dBA), there is potential for low frequency noise impact". This is simply untrue, and as a blanket rule it is a poor descriptor of environmental noise impact. Spectra imbalance studies which compare A-weighted (dBA) and C-weight (dBC) sound levels generally evaluate the equivalent sound level, Leq, for both weighting systems. The Draft Wind Ordinance proposes to compare an A-weighted L90, LA90, with a LCeq which is inconsistent with most sound exposure studies and findings.

The County also states on page 2.8-2, "The most commonly used indices for measuring community noise levels are the Equivalent Energy Level (Leq), and the Community Noise Equivalent Level (CNEL). In fact, very few states and virtually no federal agencies with authority to regulate environmental noise use the CNEL descriptor. The Day-Night noise level (Ldn) and Leq are the more common descriptors used to express community noise, and they are almost exclusively expressed using A-weighting.

The Draft EIR recognizes that no direct causal relationship has been established between wind turbine low frequency sound and adverse human health effects. This should inform the County that the low-frequency content of wind turbine noise is not inherently problematic, and that use of C-weighting is unnecessary and inappropriate. The Draft EIR recognizes scientific research has found no causal relationship between wind turbine low frequency sound and health, yet the Draft Ordinance requires a low frequency noise assessment. This is an internal inconsistency between the Draft Wind Ordinance and Draft EIR. This inconsistency requires revisions to the Draft EIR and recirculation.

The Draft EIR notes that the US EPA has indicated that residential noise exposure of 55 to 65 dBA is acceptable when analyzing land use compatibility. It failed to note that US EPA also considers an Ldn of 55 dBA to be adequately protective of human health and welfare. EPA does not offer dBC guidance. Additionally the airport noise standards discussed in the Draft EIR all utilize A-weighting. Anyone that's been near an airport and a modern wind turbine knows there is more low-frequency noise near airports than near wind turbines. Common sense cannot be ignored, and the Draft EIR should not impose arbitrary and unsupported requirements that contradict simple, everyday experiences (wind turbines are not sources of intense low frequency noise).

Spectral Noise Limits

The Draft EIR discusses spectral noise limits in the Noise Abatement and Control Ordinance. The combination of spectral limits, A- and C-weighted noise limits is an excessive amount of noise regulatory limits, and is inconsistent with how most states in our nation regulate environmental noise. In total, the environmental noise regulatory programs in the County are burdensome, and dramatically simpler environmental noise regulatory programs enacted elsewhere in the United States provide adequate and appropriate protection to human health and welfare. HDR recommends that the County dramatically simplify how environmental noise is regulated.

Also, in the context of environmental noise regulations at the state and federal level, HDR does not agree that exposure of persons to or generation of noise levels in excess of standards established by the County's General Plan, County's Noise Ordinance, County's Noise Compatibility Guidelines, or County's Zoning Ordinance should be considered a significant impact under CEQA. The average person cannot perceive a change in noise levels on the order of one dBA. Yet under this regulatory framework, a one dBA increase could be considered significant during CEQA environmental review. If the incremental increase in noise is not perceivable, it can not be significant.

In the Draft EIR, at the bottom of page 2.8-11, the County states "…therefore, it includes sites that may be impacted with potential increase in noise within the vicinity of a future wind turbine….: Use of the word impact rather than affected or exposed to shows the County's predisposition to assume that exposure to wind turbine noise is inherently harmful to human health and welfare, when the county clearly states that no causal relationship has been established.

HDR disagrees that wind turbine noise can accurately be characterized using this statement: "The noise can be similar to the sound of a helicopter or a small plane taking off, but it only lasts for short bursts of time until the wind gust dies down" which appears on page 2.8-14. Helicopters and small planes have internal combustion engines that produce high levels of noise. Wind turbines are passive machines that only operate when the wind blows. They are analogous to sailboats in this regard, and differ from airplanes and helicopters by virtue of their lack of internal combustion engines. The Draft EIR repeatedly mis-characterizes the nature of wind turbine noise, first through the flawed emphasis on low frequency content in turbine noise emissions and now through this comparison with helicopters and small planes. The Draft EIR is biased, and not objective and factual.

The Draft EIR, page 2.8-16, states "Concerns are occasionally raised about adverse health effects caused by wind turbine low frequency noise, but there is currently no published scientific evidence to conclude wind turbine noise could cause health effects. Therefore, the proposed project may result in significant impacts related to annoyance from low-frequency noise from large wind turbines (NOI-1)." These concepts are repeated later (NOI-2, NOI-3). Herein the County states potential for significant impacts for phenomena which have no published scientific basis. Regulation based on speculation is bad governance. Furthermore, annoyance is highly subjective, unique to each individual and sources for annoyance could include toy poodles and other barking dogs, leaf blowers, lawn mowers, circular saws, etc. Highly subjective criteria make unsound bases for public policy and environmental noise regulations. HDR recommends these concepts be removed from the EIR.

The low density of residential development and magnitude of calculated wind turbine noise level relative to noise levels considered acceptable elsewhere throughout the nation lead HDR to conclude that large wind turbines developed under the proposed project would not result in significant impacts relative to noise exposure. The County's Draft Wind Ordinance is unnecessarily burdensome, based on unproven science (Kamperman and James) and inconsistent with how environmental noise is regulated in urban and rural areas throughout most of the nation.

Conclusion

The Draft EIR and Draft Wind Ordinance are inconsistent in their assessment of low frequency noise which requires revisions to the Draft EIR and recirculation. Additionally the Draft Wind Ordinance inaccurately quantifies existing ambient noise conditions and attempts to limit low frequency noise in a manner which is inconsistent with current County of San Diego regulation for other low frequency noise sources. Use of the proposed standards are unrealistic and will severely limit if not completely prohibit the development of wind energy facilities in County of San Diego.

Referenced Documents

Noise & Health
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EDITORIAL
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Introduction to the special issue on low frequency noise

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Full Text

Historically, early work on low frequency noise and its effects on health and performance were stimulated by the American and Russian space programs, sources of very high levels of low frequency noise and vibration. Animal experiments in the last 50 years have shown that high levels of low frequency noise and vibration can influence the respiratory rate, the heart functions, the stomach and intestine functions and the function of the central nervous system, as well as increase the rate of abnormal mitosis. The increase of low frequency noise and vibrations in the everyday environment is a new challenge for industrialized nations. This special issue draws attention to these problems.

The frequency range below 200 Hz is often called low frequency noise. The boundary is not fixed, but the range from 10 Hz to 200 Hz is of great interest regarding health. Low frequency noise contains both infrasound and some socalled audible noise. Despite the general understanding that infrasound is not audible, it is possible for humans to perceive infrasound if the sound level is high enough, although there is a change in the aural detection process at which the tonality of the auditory sensation is lost. The phenomena of human perception of low frequency noise is reviewed in th first contribution by Moller and Pedersen (Department of Acoustics, Aalborg University, Denmark).

Low frequency noise is part of the everyday acoustic environment. The noise levels of low frequency noise o n the area of the perception threshold where there are considerable individual differences. Noises with a do i the area of low frequency are issued by many technical sources. Vehicles like lorries, busses, trains, a helicopters are major sources. However, low frequency noises are also issued by stationary source the heating, cooling or ventilation of buildings. Low frequency noise can spread a very far distan attenuation in the open air and pass through walls and windows with low attenuation, too.

It is difficult for residents to protect themselves against low frequency emissions. The effects of low frequency noise ar therefore of great interest to public health. Conventional methods of assessing annoyance, typically based on A-weighted equivalent sound level, are inadequate for low frequency noise and lead to incorrect decisions by regulatory authorities. This is the conclusion of the contribution by Leventhall (Noise and Vibration Consultant, Ashtead, United Kingdom). The known effects according to selected physiological parameters, subjective complaints and performance is reviewed by Schust (Federal Institute for Occupational Safety and Health, Germany).

Low frequency noise in the living environment can represent an extreme distress for persons who are sensitive to low frequency sound. Such sensibility can be the result of a natural highsensitivity level or one which can be brought on in the course of the life. The association between low frequency noise and stress as viewed through stress hormone excretion as well as respiratory system impairment in children is discussed by Ising (Berlin Centre of Public Health, Germany) and colleagues. The findings suggest that great attention must be given to nightly sound exposure. The disturbing effect of nightly noise on sleep is recognized generally. There are a large number of studies in which the effect of nightly traffic noise on sleep and wellbeing was examined. However, there is usually little known about what percentage of that noise is low frequency noise. Only the A-weighted sound pressure level is indicated in many publications. The special effect of low frequency noise on sleep is reviewed by Persson Waye (Department of Acoustics, Aalborg University, Denmark).

Low frequency noise frequently appears together with vibrations. Sound in air with a low frequency character can activate vibrations in housing structures. Conversely, low frequency sounds also arise as a result of vibrations in housing structures (secondary sound in air). Room resonance can highly increase the low frequency sound. The disturbing effect of low frequency immission and vibration in residential buildings is presented by Findeis and Peters (Department Noise and Vibration Protection, Brandenburg, Germany).

The isolated assessing of air sound or vibrations is only valid provided that no (noteworthy) interactions occur. There are only few experimental examinations on this topic. One of the few studies was carried out by Sueki et al. (1989) in Japan. In the experiments the vibration perception thresholds and the threshold of adverse effects of vibrations (e.g. languor) was examined with and without low frequency noise. The experiments showed, for example, that audible low frequency sound can reduce the perception threshold for vibrations. The adverse effects of vibrations were stronger with the presence of low frequency noise.

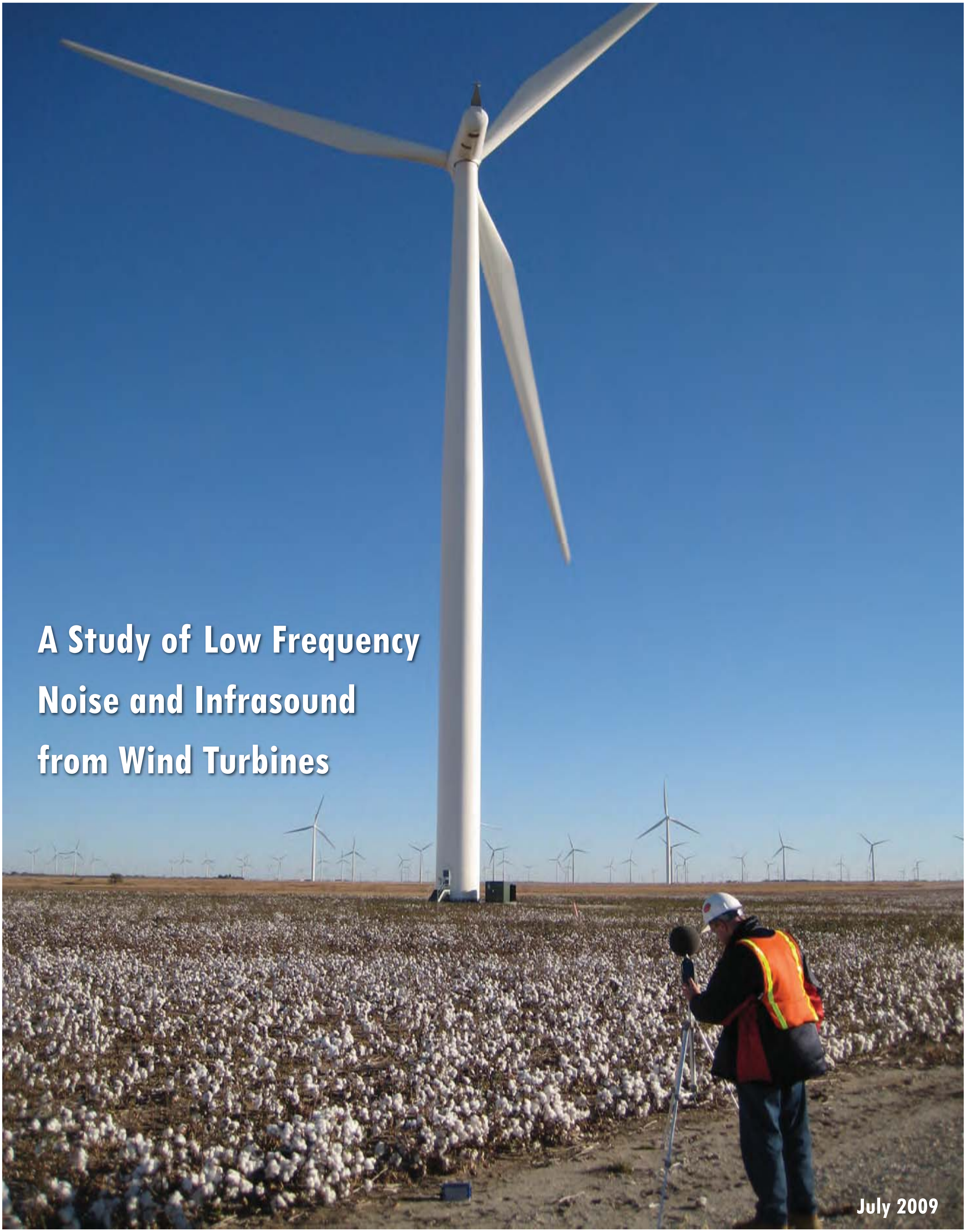
The effect of low frequency noise and vibrations on health is described by Branco (Center for Human Performance, Alverca, Portugal) and his colleagues as vibroacoustic disease (VAD). VAD was first documented in people employed as airplane technicians, commercial and military pilots, mechanical engineers, restaurant workers and disc jockeys. In the meantime, VAD has been seen in populations which were exposed to low frequency noise that is part of everyday environments.

Experiments with both animals and humans have shown that the vibroacoustic stressor causes thickening of cardiovascular structures (cardiac muscle and blood vessels). The pericardial thickening without inflammatory process and in absence of diastolic dysfunction (pathological changes of the diastolic blood pressure function; second value of the blood pressure measurement) is therefore the clinical characteristic of VAD. Depression, increased irritability and aggression, a tendency for isolation and decreased cognitive skills (flexibility of thinking) are additional parts of the clinical picture of VAD.

One of the future challenges of noise effect research is to quantify the effect of environmental low frequency nois combination with vibration, according to annoyance, performance and health indicators. The state of knowledg the extra aural effects of low frequency noise is altogether still unsatisfactory. Some investigations give evi the effect of low frequency noise in the environment is highly underestimated today. It is hoped that this Noise & Health brings more attention to the problem of low frequency noise in the living environment

Thursday, December 22, 2011

Prepared for **NextEra Energy Resources, LLC**, *700 Universe Boulevard, Juno Beach, FL 33408*



A Study of Low Frequency Noise and Infrasound from Wind Turbines

July 2009

Prepared by **Epsilon Associates, Inc.**, *3 Clock Tower Place, Suite 250, Maynard, MA 01754*

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July 2009

Report No. 2433-01

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ES EXECUTIVE SUMMARY

Early down-wind wind turbines in the US created low frequency noise; however current up-wind wind turbines generate considerably less low frequency noise. The results of Epsilon Associates, Inc. (Epsilon) analysis and field testing indicate that there is no audible infrasound either outside or inside homes at the any of the measurement sites – the closest site was approximately 900 feet from a wind farm. Wind farms at distances beyond 1000 feet meet the ANSI standard for low frequency noise in bedrooms, classrooms, and hospitals, meet the ANSI standard for thresholds of annoyance from low frequency noise, and there should be no window rattles or perceptible vibration of light-weight walls or ceilings within homes. In homes there may be slightly audible low frequency noise (depending on other sources of low frequency noise); however, the levels are below criteria and recommendations for low frequency noise within homes. In accordance with the above findings and in conjunction with our extensive literature search of scientific papers and reports, there should be no adverse public health effects from infrasound or low frequency noise at distances greater than 1000 feet from the wind turbine types measured by Epsilon: GE 1.5sle and Siemens SWT 2.3-93.

Siemens SWT 2.3-93 Wind Turbine. Outdoor measurements of Siemens SWT 2.3-93 wind turbines under high output and relatively low ground wind speed (which minimized effects of wind noise) at 1000 feet indicate that infrasound is inaudible to the most sensitive people (more than 20 dB lower than median thresholds of hearing); that outdoor equivalent ANSI/ASA S12.2 perceptible vibration criteria are met; that the low frequency sounds are compatible with ANSI S12.9 Part 4 levels for minimal annoyance and beginning of rattles; that levels meet outdoor equivalent UK Department for Environment, Food and Rural Affairs (DEFRA) disturbance-based guidelines for use by Environmental Health Officers, and that low frequency sounds might be audible in some cases. Based on the comparisons made to these criteria, there are no low frequency noise problems from Siemens SWT 2.3-93 wind turbines at 1000 feet or beyond.

Indoor measurements of two homes with windows open and closed of Siemens SWT 2.3-93 wind turbines at approximately 920 feet (under high output, maximum noise, and high ground winds) and at 1060 feet (under moderate-high output, maximum noise and relatively low ground winds) indicate infrasound is inaudible to the most sensitive people (more than 25 dB lower than median thresholds of hearing). The low frequency noise at 50 Hz and above might be slightly audible depending on background noises within the home or other external noises. The ANSI/ASA S12.2 low frequency criteria for bedrooms, classrooms and hospitals were met, as were the criteria for moderately perceptible vibrations in light-weight walls and ceilings. DEFRA disturbance based guidelines were met for steady low frequency sounds and were within 2 dB for non-steady low frequency sounds. Based on the comparisons made to these criteria, there are no low frequency noise problems indoors from Siemens SWT 2.3-93 wind turbines at 920 feet or beyond.

GE 1.5sle Wind Turbine. Outdoor measurements of GE 1.5sle wind turbines under high output and relatively low ground wind speed (which minimized effects of wind noise) at 1000 feet indicate that infrasound is inaudible to the most sensitive people (more than 20 dB lower than median thresholds of hearing); that outdoor equivalent ANSI/ASA S12.2 perceptible vibration criteria are met; that the low frequency sounds are compatible with ANSI S12.9 Part 4 levels for minimal annoyance and beginning of rattles; that levels meet or are within 1 dB of outdoor equivalent DEFRA disturbance-based guidelines; and that the low frequency sounds might be audible in some cases. Based on the comparisons made to these criteria, there are no low frequency noise problems from GE 1.5sle wind turbines at 1000 feet or beyond.

Indoor measurements with windows open and closed of GE 1.5sle wind turbines at approximately 950 feet (under moderate output, maximum noise, and high ground winds) and at approximately 1025 feet (under moderate output, within 1.5 dBA of maximum noise, and high ground winds) indicate infrasound is inaudible to the most sensitive people (more than 25 dB lower than median thresholds of hearing). The low frequency noise at or above 50 or 63 Hz might be slightly audible depending on background noises within the home or other external noises. The ANSI/ASA S12.2 low frequency criteria for bedrooms, classrooms and hospitals were met, as were the criteria for moderately perceptible vibrations in light-weight walls and ceilings. DEFRA disturbance based guidelines were met for steady low frequency sounds and non-steady low frequency sounds. Based on the comparisons made to these criteria, there are no low frequency noise problems indoors for GE 1.5sle wind turbines at distances beyond 950 feet.

Conclusions. Siemens SWT 2.93-93 and GE 1.5sle wind turbines at maximum noise at a distance more than 1000 feet from the nearest residence do not pose a low frequency noise problem. At this distance the wind farms:

- meet ANSI/ASA S12.2 indoor levels for low frequency sound for bedrooms, classrooms and hospitals;
- meet ANSI/ASA S12.2 indoor levels for moderately perceptible vibrations in light-weight walls and ceilings;
- meet ANSI S12.9 Part 4 thresholds for annoyance and beginning of rattles;
- meet UK DEFRA disturbance based guidelines;
- have no audible infrasound to the most sensitive listeners;
- might have slightly audible low frequency noise at frequencies at 50 Hz and above depending on other sources of low frequency noises in homes, such as refrigerators or external traffic or airplanes; and
- meet ANSI S2.71 recommendations for perceptible ground-borne vibration in residences during night time hours.

1.0 INTRODUCTION

Epsilon Associates, Inc. ("Epsilon") has been retained by NextEra Energy Resources, LLC ("NextEra"), formerly FPL Energy, to investigate whether the operation of their wind turbines may create unacceptable levels of low frequency noise and infrasound. This question has been posed to NextEra, and other wind energy developers and operators of utility-scale wind turbines. NextEra is one of the world's largest generators of wind power with approximately 6,400 net megawatts (MW) as of April 2009.

Epsilon determined all means, methods, and the testing protocol without interference or direction from NextEra. No limitations were placed on Epsilon by NextEra with respect to the testing protocol or upon the analysis methods.

This report is composed of two distinct sections: the first portion defines terms, discusses known effects of low frequency sound, and presents scientific guidelines and standards used to evaluate low frequency sound. The second portion of the report examines specific wind turbines used by NextEra, including data from field measurements at operating wind farms, and compares the measured data to guidelines and standards. In addition, each NextEra wind turbine vendor supplied detailed, reference sound level data in both A-weighted and octave band format in accordance with the international standard IEC 61400-11, "Wind Turbine Generator Systems-Part 11; Acoustic Noise Measurement Techniques." These data were used as an aide to focus the field portion of the measurement program.

2.0 DEFINITIONS

2.1 Low Frequency Noise/Sound

The frequency range 20 – 20,000 Hz is commonly described as the range of *"audible"* noise. The frequency range of low frequency sound is generally from 20 Hertz (Hz) to 200 Hz, and the range below 20 Hz is often described as "*infrasound*". However, audibility extends to frequencies below 20 Hz.

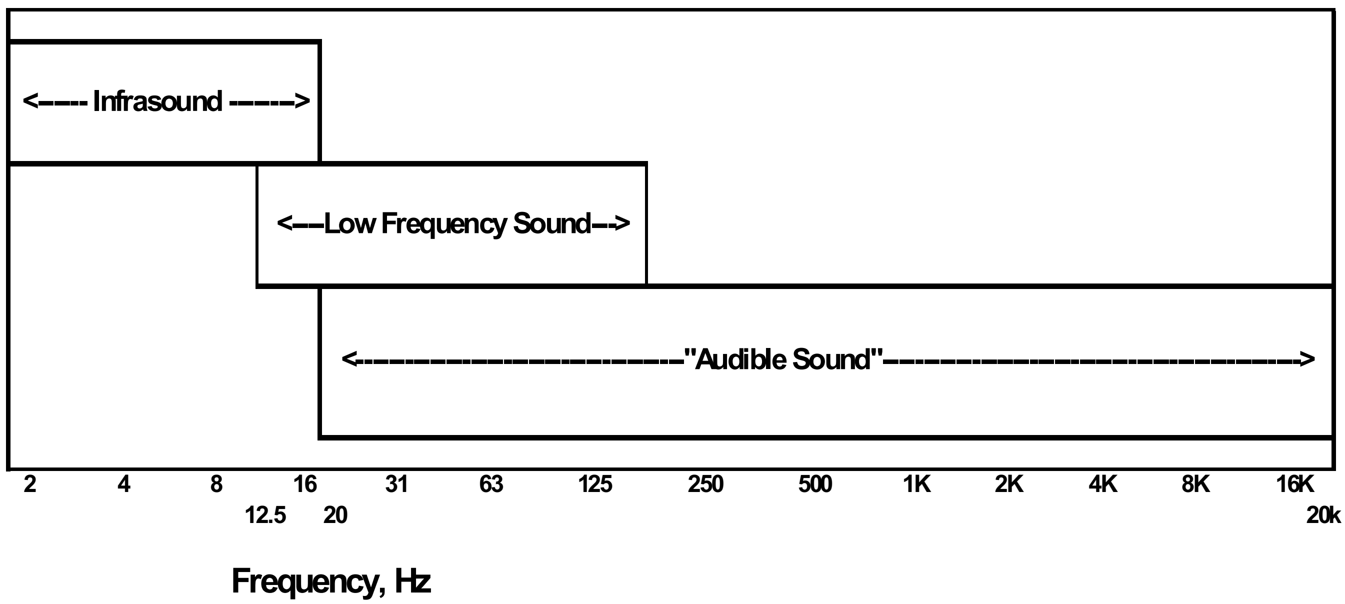
Low frequency sound has several definitions. American National Standards ANSI/ASA S12.2 and ANSI S12.9 Part 4 have provisions for evaluating low frequency noise, and these special treatments apply only to sounds in the octave bands with 16, 31.5, and 63-Hz mid-band frequencies. For these reasons, in this paper on wind turbine noise, we use the term "low frequency noise" to include 12.5 Hz – 200 Hz with emphasis on the 16 Hz, 31Hz and 63 Hz octave bands with a frequency range of 11 Hz to 89 Hz.

2.2 Infrasound

IEC 60050-801:1994 "International Electrotechnical Vocabulary – Chapter 801: Acoustics and electroacoustics" defines "*infrasound*" as "Acoustic oscillations whose frequency is below the low frequency limit of audible sound (about 16 Hz)." This definition is *incorrect* since sound remains audible at frequencies well below 16 Hz provided that the sound level is sufficiently high. In this paper we define infrasound to be below 20 Hz, which is the limit for the standardized threshold of hearing.

Figure 2.2-1 shows these frequency regions and their common labels. Since there is no sharp change in hearing at 20 Hz, the division into "low-frequency sound" and "infrasound" should only be considered "practical and conventional."

Figure 2.2-1 Frequency Range of "Infrasound", "Low Frequency Sound", and "Audible Sound".



3.0 EFFECTS OF LOW FREQUENCY SOUND AND INFRASOUND

3.1 Humans

3.1.1 Threshold of hearing

Moeller and Pedersen (2004) present an excellent summary on human perception of sound at frequencies below 200 Hz. The ear is the primary organ for sensing infrasound. Hearing becomes gradually less sensitive for decreasing frequencies. But, humans with a normal hearing organ can perceive infrasound at least down to a few hertz if the sound level is sufficiently high.

The threshold of hearing is standardized for frequencies down to 20 Hz (ISO 226:2003). Based on extensive research and data, Moeller and Pedersen propose normal hearing thresholds for frequencies below 20 Hz (see Figure 3.1-1). Moeller and Pedersen suggest that the curve for normal hearing is "probably correct within a few decibels, at least in most of the frequency range."

The hearing thresholds show considerable variability from individual to individual with a standard deviation among subjects of about 5 dB independent of frequency between 3 Hz and 1000 Hz with a slight increase at 20 – 50 Hz. This implies that the audibility threshold for 97.5% of the population is greater than the values in Figure 3.1-1 minus 10 dB and for 84% of the population is greater than the values in Figure 3.1-1 minus 5 dB. Moeller and Pedersen suggest using the pure-tone thresholds in Figure 3.1-1 for non-sinusoidal sound; this relationship is what is used in ISO 226 (International Organization for Standardization) for frequencies down to 20 Hz.

Below 20 Hz as frequency decreases, if the noise source is tonal, the tonal sensation ceases. Below 20 Hz tones are perceived as discontinuous. Below 10 Hz it is possible to perceive the single cycles of a tone, and the perception changes into a sensation of pressure at the ears.

3.1.2 Loudness

Below 100 Hz, the dynamic range of the auditory system decreases with decreasing frequency, and the compressed dynamic range has an effect on equal loudness contours: a slight change in sound level can change the perceived loudness from barely audible to loud. This combined with the large variation in individual hearing may mean that a low frequency sound that is inaudible to some may be audible to others, and may be relatively loud to some of those for whom it is audible. Loudness for low frequency sounds grows considerably faster above threshold than for sounds at higher frequencies. (Moeller and Pedersen, 2004)

3.1.3 Non-auditory perceptions

Non-auditory perception of low frequency and infrasound occurs only at levels above the auditory threshold. In the frequency range of 4 – 25 Hz and at "*levels 20 - 25 dB above [auditory] threshold it is possible to feel vibrations* in various parts of the body, e.g., the lumbar, buttock, thigh and calf regions. A feeling of pressure may occur in the upper part of the chest and the throat region" [emphasis added]. (Moeller and Pedersen, 2004).

3.2 Residential Structures

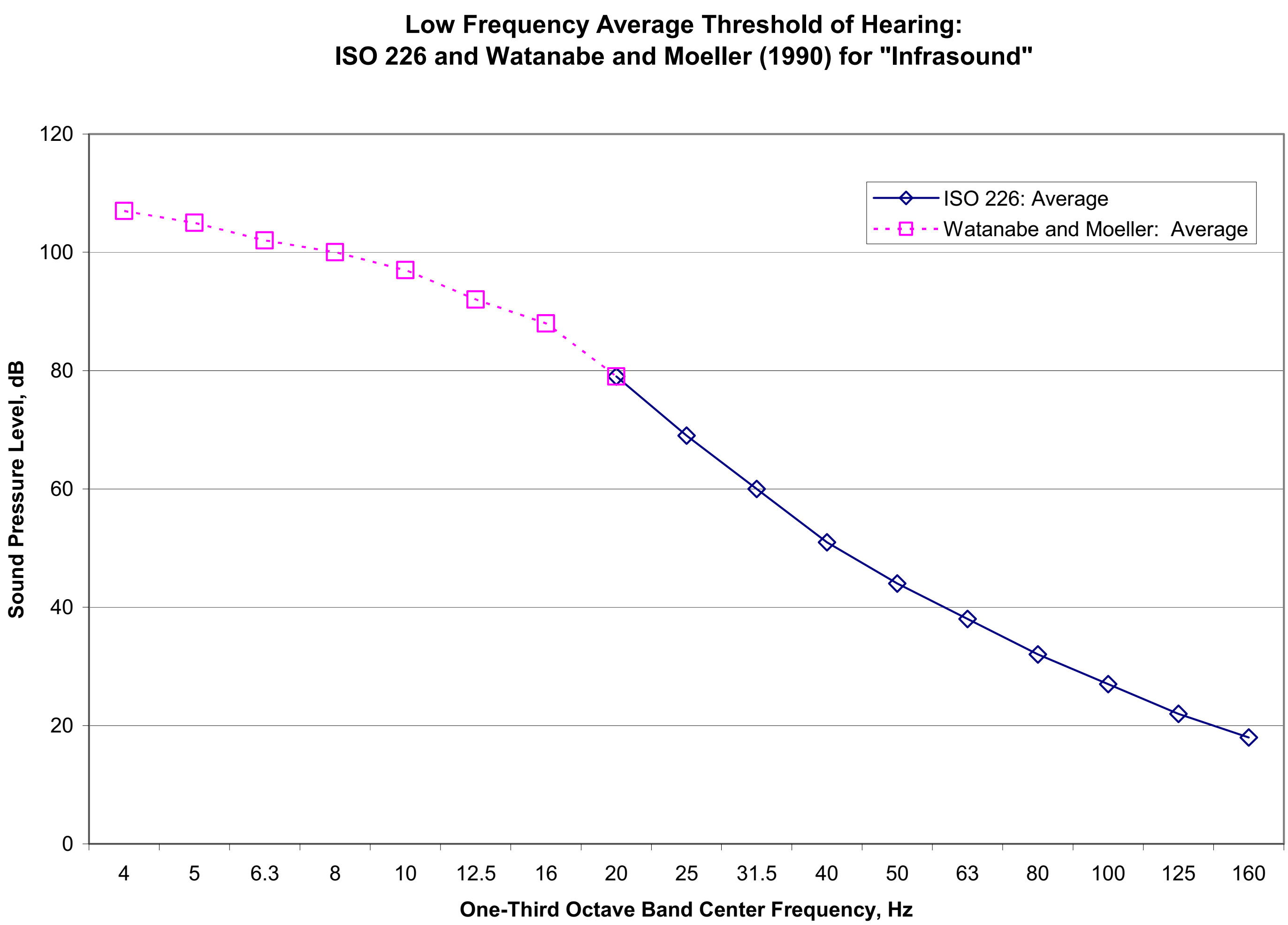
3.2.1 Airborne Vibration

Outdoor low frequency sounds of sufficient amplitude can cause building walls to vibrate and windows to rattle. Homes have low values of transmission loss at low frequencies, and low frequency noise of sufficient amplitude may be audible within homes. Window rattles are not low frequency noise, but may be caused by low frequency noise.

3.2.2 Ground borne Vibration

While not studied nearly as extensively as noise, a few papers were found that examined ground borne vibration from wind turbines (Styles, P. et al, 2005; Hayes McKenzie Partnership, 2006; Gastmeier and Howe (2008)). Measurement of ground borne vibration associated with wind turbine operations were detectable with instruments but were below the threshold of perception, even within the wind farm (Gastmeier and Howe 2008; Snow, D.J., 1997).

Figure 3.1-1 Low Frequency Average Threshold of Hearing



4.0 GUIDELINES AND CRITERIA

4.1 United States Government

There are no specific criteria for low frequency noise in the United States. The US Environmental Protection Agency (EPA) has guidelines for the protection of public health with an adequate margin of safety in terms of annual average A-weighted day-night average sound level (L_{dn}), but there are no corrections or adjustments for low frequency noise. The US Department of Transportation (DOT) has A-weighted sound pressure level criteria for highway projects and airports, but these do not have adjustments for low frequency noise.

4.2 American National Standards (voluntary)

4.2.1 ANSI/ASA S12.9-2007/Part 5

ANSI/ASA S12.9-2007/Part 5 "Quantities and Procedures for description and measurement of environmental sound. Part 5: Sound Level Descriptors for Determination of Compatible Land Use" has an informative annex which provides guidance for designation of land uses compatible with existing or predicted sound levels. The noise metric in ANSI S12.9 Part 5 is the annual average of the adjusted day-night average outdoor sound level (DNL). Ranges of the DNL are outlined, within which a specific region of compatibility may be drawn. These ranges take into consideration the transmission loss in sound level from outside to inside buildings as commonly constructed in that locality and living habits there. There are adjustments to day-night average sound level to account for the presence of low frequency noise, and the adjustments are described in ANSI S12.9 Part 4.

4.2.2 ANSI S12.9-2005/Part 4

ANSI S12.9-2005 Part 4 "Quantities and Procedures for description and measurement of environmental sound. Part 4: Noise assessment and prediction of long-term community response" provides procedures for assessing outdoor environmental sounds and provides for *adjustments* to measured or predicted adjusted annual outdoor day-night A-weighted sound level to account "for the change in annoyance caused by … sounds with strong low-frequency content…"

ANSI S12.9 Part 4 does not specifically define the frequency range for "low-frequency" sounds; however, evaluation methods for low frequency noise in Annex D use a sum of the sound pressure levels in the 16, 31 and 63 Hz octave bands. Procedures apply only when the difference in exterior C-weighted and A-weighted sound levels is greater than 10 dB, ($L_{pC} - L_{pA}$) > 10 dB. Complicated procedures are given for adjustments to L_{Aeq} and L_{dn} values. Adjustments are significant for high levels of low frequency sound.

ANSI S12.9 Part 4 states: "Generally, annoyance is minimal when octave-band sound pressure levels are less than 65 dB at 16, 31.5, and 63-Hz mid-band frequencies. However, low-frequency sound characterized by rapidly fluctuating amplitude ... may cause annoyance when these octave-band sound pressure levels are less than 65 dB."

For sounds with strong low-frequency content, adjusted sound exposure level (LNE) is calculated from low-frequency sound pressure level L_{LF} by:

$$LNE = 2(L_{LF} - 65) + 55 + 10\log(t/1)$$

$$= 2\,L_{LF} - 75 + 10\log(t/1) \qquad \text{(Equation D.1 of ANSI S12.9 Part 4)}$$

where L_{LF} is 10 times the logarithm of the ratio of time-mean square sound pressures in the 16, 31.5, and 63-Hz octave bands divided by the square of the reference sound pressure and

t is the time duration of interest, in seconds, over which the low-frequency sound is present.

The factor of 2 in equation (D.1) accounts for the rapid increase in annoyance with sound pressure level at low frequencies. ANSI S12.9 Part 4 states: "Equation (D.1) also accounts for the additional annoyance from rattles that begins when the low-frequency sound pressure level [L_{LF}] exceeds 75 dB." Later, ANSI S12.9/Part 4 has a contradictory recommendation: "To prevent the likelihood of noise-induced rattles, the low-frequency sound pressure level [L_{LF}] should be less than 70 dB."

ANSI S12.9 /Part 4 identifies two thresholds: annoyance is minimal when the 16, 31.5 and 63 Hz octave band sound pressure levels are each less than 65 dB and there are no rapidly fluctuations of the low frequency sounds. The second threshold is for increased annoyance which begins when rattles occur, which begins at L_{LF} 70 - 75 dB. Since determination of L_{LF} involves integrating concurrently the sound pressures in the three octave bands, an energy sum of the levels in each of these separate bands results in an upper bound to L_{LF}. (The sound pressure level from the summation of these bands will always be less than L_{LF} since the sound pressures are not in phase within these three bands.)

It should be noted that a recent study on low frequency noise from aircraft operations (Hodgdon, Atchley, Bernhard 2007) reported that an expert panel was critical of using this L_{LF} metric because it had not previously been used to characterize aircraft noise and its reliance on the 16 Hz band since aircraft data does not extend down to 16 Hz and can not be used with the FAA Integrated Noise Model.

The adjustment procedure for low frequency noise to the average annual A-weighted sound pressure level in ANSI S12.9 Part 4 uses a different and more complicated metric and procedure (Equation D.1) than those used for evaluating low frequency noise in rooms contained in ANSI/ASA S12.2. (See section 4.2.3). Since we are evaluating low frequency noise and not A-weighted levels, we do not recommend using the procedure for adjusting A-weighted levels. Instead we recommend using the following two guidelines from ANSI S12.4 Part 9: a sound pressure level of 65 dB in each of the 16-, 31.5-, and 63 Hz octave bands as an indicator of minimal annoyance, and 70 - 75 dB for the summation of the sound pressure levels from these three bands as an indicator of possible increased annoyance from rattles. This method is conservative since the sum of the levels in the three bands will always be less than L_{LF}.

4.2.3 ANSI/ASA S12.2-2008

ANSI/ASA S12.2-2008 discusses criteria for evaluating room noise, and has two separate provisions for evaluating low frequency noise: (1) the potential to cause perceptible vibration and rattles, and (2) meeting low frequency portions of room criteria curves.

<u>Vibration and Rattles</u>: Clause 6 and Table 6 of this standard contain limiting values of sound pressure levels for vibrations and rattles from low frequency noise. The frequency range is not defined, but limiting values and discussion relate only to octave-bands with center frequencies of 16, 31 and 63 Hz. This is the same narrow frequency range from low-frequency sounds as in ANSI S12.9/Part 4. Therefore, ANSI S12.9 Part 4 and ANSI/ASA S12.2 are consistent in evaluating and assessing low frequency sounds both for annoyance (interior and exterior measurements) and vibration (interior measurements) by using sound pressure levels only in the 16, 31 and 63 Hz octave-bands.

ANSI/ASA S12.2 presents limiting levels at low frequencies for assessing (a) the probability of *clearly* perceptible acoustically induced vibration and rattles in lightweight wall and ceiling constructions, and (b) the probability of *moderately* perceptible acoustically induced vibration in similar constructions. These 16, 31.5 and 63 Hz octave band sound pressure level values are presented in Table 4.2-1. One set of values is for when "clearly perceptible vibration and rattles" is likely, and a lower set of values is for when "moderately perceptible vibration and rattles" is likely.

Table 4.2-1 Measured interior sound pressure levels for perceptible vibration and rattle in lightweight wall and ceiling structures. [ANSI/ASA S12.2-2008]

Condition	Octave-band center frequency (Hz)		
	16	31.5	63
Clearly perceptible vibration and rattles likely	75 dB	75 dB	80 dB
Moderately perceptible vibration and rattles likely	65 dB	65 dB	70 dB

Since indoor measurements are not always possible, for comparison to outdoor sound levels the indoor criteria from ANSI/ASA S12.2 should be adjusted. Outdoor to indoor low frequency noise reductions have been reported by Sutherland for aircraft and highway noise for open and closed windows (Sutherland 1978) and by Hubbard for aircraft and wind turbine noise for closed windows (Hubbard 1991). Table 4.2-2 presents the average low frequency octave band noise reductions from outdoor to indoors from these two papers for open and closed windows. Sutherland only reported values down to 63 Hz; whereas Hubbard presented values to less than 10 Hz. The closed window conditions of Hubbard were used to estimate noise reductions less than 63 Hz by applying the difference between values for open and closed windows from Sutherland data at 63 Hz. It should be noted that the attenuation for wind turbines in Hubbard is based on only three homes at two different wind farms, whereas the traffic and aircraft data are for many homes. The wind turbine open window values were obtained from the wind turbine closed window values by subtracting the difference in values between windows closed and open obtained by Sutherland.

Table 4.2-2 Average low frequency octave band noise reductions from outdoor to indoors in dB (based on Sutherland (1978) and Hubbard (1991))

Noise Source	Window condition	Octave Band Center Frequency		
		16 Hz	31.5 Hz	63 Hz
Average aircraft and traffic sources	Closed windows	16	15	18
Average aircraft and traffic sources	Open Windows	(11)*	(10)*	12
Average Wind Turbine	Closed Windows	8	11	14
Average Wind Turbine	**Open Windows**	**(3)*⁺**	**(6)* ⁺**	**9⁺**

* No data are available for windows open below 63 Hz octave band. The values for 16 Hz and 31 Hz were obtained by subtracting the difference between the levels for 63 Hz closed and open conditions to the 16 and 31 Hz closed values.

⁺ Used in this report to determine equivalent outdoor criteria from indoor criteria

To be conservative, we use the open window case instead of closed windows. To be further conservative, we use the wind turbine data (adjusted to open windows), which is based on only three homes. However, it should be noted that it is possible for some homes to have some slight amplification at low frequencies with windows open due to possible room resonances. Applying the outdoor to indoor attenuations for wind turbine sources with windows open given in the last row of Table 4.2-2 to the ANSI/ASA S12.2 indoor sound pressure levels in Table 4.2-1 yields the *equivalent* outdoor sound pressure levels that are consistent with the indoor criteria and are presented in Table 4.2-3.

Table 4.2-3 *Equivalent* outdoor sound pressure levels for perceptible vibration and rattle in lightweight wall and ceiling structures based on Tables 4.2-1 and 4.2-2 above for wind turbines.

Condition	Octave-band center frequency (Hz)		
	16	31.5	63
Clearly perceptible vibration and rattles likely	78 dB	81 dB	89 dB
Moderately perceptible vibration and rattles likely	68 dB	71 dB	79 dB

Room Criteria Curves: ANSI/ASA S12.2 has three primary methods for evaluating the suitability of noise within rooms: a survey method - A-weighted sound levels, an engineering method – noise criteria (NC) curves and a method for evaluating low-frequency fluctuating noise using room noise criteria (RNC) curves. "The RNC method should be used to determine noise ratings when the noise from HVAC systems at low frequencies is *loud* and is suspected of containing *sizeable fluctuations or surging*." [emphasis added] The NC curves are appropriate to evaluate low frequency noise from wind turbines in homes since wind turbine noise does not have significant fluctuating low frequency noise sufficient to warrant using RNC curves and since A-weighted sound levels do not adequately determine if there are low frequency problems. [ANSI/ASA S12.2. section 5.3 gives procedures for determining if there are large fluctuations of low frequency noise.]

Annex C.2 of this standard contains recommendations for bedrooms, which are the most stringent rooms in homes: NC and RNC criteria curve between 25 and 30. The recommended NC and RNC criteria for schools and private rooms in hospitals are the same. The values of the sound pressure levels in the 16 – 250 Hz octave bands for NC curves 25 and 30 are shown in Table 4.2-4.

Table 4.2-4 Octave band sound pressure levels for noise criteria curves NC-25 and NC-30. [From Table 1 of ANSI/ASA S12.2]

	Octave-band-center frequency in Hz				
	16	31.5	63	125	250
NC-25	80	65	54	44	37
NC-30	81	68	57	48	41

ANSI/ASA S12.2 also presents a method to determine if the levels below 500 Hz octave band are too high in relation to the levels in the mid-frequencies which could create a condition of "spectrum imbalance". The method for this evaluation is:

- Calculate the speech interference level (SIL) for the measured spectrum. [SIL is the arithmetic average of the sound pressure levels in the 500, 1000, 2000 and 4000 Hz octave bands.] Select the NC curve equal to the SIL value.

- Plot the measured spectra and the NC curve equal to the SIL value on the same graph and determine the differences between the two curves in the octave bands below 500 Hz.

- Estimate the likelihood that the excess low-frequency levels will annoy occupants of the space using Table 4.2-5.

Table 4.2-5 **Measured sound pressure level deviations from an NC (SIL) curve that may lead to serious complaints [From ANSI/ASA S12.2:2008].**

	Measured Spectrum – NC(SIL), dB			
Octave-band frequency, Hz =>	31.5	63	125	250
Possible serious dissatisfaction	*	6 - 9	6 - 9	6 - 9
Likely serious dissatisfaction	*	>9	>9	>9

*Insufficient data available to evaluate

4.3 Other Criteria

4.3.1 World Health Organization (WHO)

No specific low frequency noise criteria are proposed by the WHO. The Guidelines for Community Noise report (WHO, 1999) mentions that if the difference between dBC and dBA is greater than 10 decibels, then a frequency analysis should be performed to determine if there is a low frequency issue. A document prepared for the World Health Organization states that "there is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects. Infrasounds slightly above detection threshold may cause perceptual effects but these are of the same character as for 'normal' sounds. Reactions caused by extremely intense levels of infrasound can resemble those of mild stress reaction and may include bizarre auditory sensations, describable as pulsation and flutter" [Berglund (1995) p. 41]

4.3.2 The UK Department for Environment, Food, and Rural Affairs (DEFRA)

The report prepared by the University of Salford for the UK Department for Environment, Food, and Rural Affairs (DEFRA) on low frequency noise proposed one-third octave band sound pressure level L_{eq} criteria and procedures for assessing low frequency noise [DEFRA (2005)]. The guidelines are based on complaints of disturbance from low frequency sounds and are intended to be used by Environmental Health Officers. Reports by Hayes (2006) and others refer to the proposed criteria as "DEFRA criteria." Tables 4.3-1 and 4.3-2 present the DEFRA criteria for assessment of low frequency noise measured indoors. The criteria are "based on 5 dB below the ISO 226 (2003) average threshold of audibility for steady [low frequency] sounds." However, the DEFRA criteria are at 5 dB lower than ISO 226 only at 20 - 31.5 Hz; at higher frequencies the criteria are equal to the Swedish criteria which are higher levels than ISO 226 less 5 dB. For frequencies lower than 20 Hz, DEFRA uses the thresholds from Watanabe and Moeller (1990) less 5 dB. In developing the DEFRA guidelines, The University of Salford reviewed and considered existing low frequency noise criteria from several European countries.

The DEFRA criteria are based on measurements in an unoccupied room. Hayes Mackenzie (2006) noted that measurements should be made with windows closed; however, we conservatively used windows open conditions for our assessment. If the low frequency sound is "steady" then the criteria may be relaxed by 5 dB. A low frequency noise is considered steady if either of the conditions a) or b) below is met in the third octave band which exceeds the criteria by the greatest margin:

a) L_{10}-L_{90} < 5dB

b) the rate of change of sound pressure level (Fast time weighting) is less than 10 dB per second

Applying indoor to outdoor one-third octave band transfer functions for open windows (from analysis in Sutherland (1978) and Hubbard (1991) yields *equivalent* one-third octave band sound pressure level proposed DEFRA criteria for outdoor sound levels. Table 4.3-1 presents both the indoor DEFRA proposed criteria and equivalent proposed criteria for outdoors for non-steady low-frequency sounds. Table 4.3-2 presents the DEFRA proposed criteria for a steady low frequency sound.

Table 4.3-1 DEFRA proposed criteria for the assessment of low frequency noise disturbance: *indoor* and *equivalent outdoor* L_{eq} one-third sound pressure levels for *non-steady* low frequency sounds. [DEFRA (2005)]

Location	One-Third Octave Band Center Frequency, Hz												
	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Indoor L_{eq}, dB	92	87	83	74	64	56	49	43	42	40	38	36	34
Equivalent Outdoor L_{eq}, dB	94	89	86	78	68.5	61	56	51	51	49	47	45	43

Table 4.3-2 DEFRA criteria for the assessment of low frequency noise disturbance: *indoor* and *equivalent outdoor* L_{eq} one-third sound pressure levels for *steady* low frequency sounds. [DEFRA (2005)]

Location	One-Third Octave Band Center Frequency, Hz												
	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Indoor L_{eq}, dB	97	92	88	79	69	61	54	48	47	45	43	41	39
Equivalent Outdoor* L_{eq}, dB	99	94	91	83	73.5	66	61	56	56	54	52	50	48

* With windows open

4.3.3 C-weighted minus A-weighted (L_{pC}- L_{pA})

Leventhall (2003) and others indicate that the difference in C-weighted and A-weighted sound pressure levels can be a predictor of annoyance. Leventhall states that if (L_{pC} – L_{pA}) is greater than 20 dB there is "a potential for a low frequency noise problem." He further states that (L_{pC} – L_{pA}) cannot be a predictor of annoyance but is a simple indicator that further analysis may be needed. This is due in part to the fact that the low frequency noise may be inaudible even if (L_{pC} – L_{pA}) is greater than 20 dB.

4.3.4 Threshold of hearing

ISO 226:2003 gives one-third octave band threshold of hearing down to 20 Hz. Watanabe and Moeller (1990) have extended these to 10 Hz and lower, and the values are reported in Moeller and Pedersen (2004). Denmark has established low frequency noise criteria based on audibility. The Danish criteria are "based on hearing thresholds for the 10% most sensitive people in an ontologically unselected population aged 50-60 years. These 10% thresholds are typically about 4-5 dB lower than the average threshold for ontologically normal young adults (18-25 years) as given in ISO 226." [DEFRA (2005)]. Other reports indicate that the standard deviation of these thresholds is also about 5 dB. Table 4.3-3 presents one-third octave band threshold of hearing according to ISO 226 and Watanabe and Moeller. The second row in Table 4.3-3 presents the values that are 5 dB less than the threshold.

Table 4.3-3 Threshold of audibility from ISO 226 and Watanabe and Moeller (1990)

	One-Third Octave band center frequency, Hz																
	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Threshold	107	105	102	100	97	92	88	79	69	60	51	44	38	32	27	22	18
Threshold – 5 dB	102	100	97	95	92	87	83	74	64	55	46	39	33	27	22	17	13

The average threshold of hearing values in Table 4.3-3 are also shown in Figure 3.1-1.

4.3.5 Ground-Borne Vibration

ANSI S2.71-1983 (formerly ANSI S3.29-1983) presents recommendations for magnitudes of ground-borne vibration which humans will perceive and possibly react to within buildings. A basic rating is given for the most stringent conditions, which correspond to the approximate threshold of perception of the most sensitive humans. From the base rating, multiplication factors should be applied according to the location of the receiver; for continuous sources of vibration in residences at nighttime, the multiplication factor is 1.0 – 1.4.

ANSI S2.71-1983 presents one-third octave band acceleration or velocity ratings for z-axis, and x-, y-axis vibrations. For spaces in which the occupants may be sitting, standing, or lying at various times, the standard recommends using a combined axis rating which is obtained from the most stringent rating for each axis. Measurements in each of the 3 axes should be compared to the combined axis rating. Table 4.3-4 presents the base response velocity ratings for the combined axis. The velocity ratings are for root-mean-square (RMS) values.

Table 4.3-4 Base response one-third octave band RMS velocity ratings for the three biodynamic vibration axes and combined axis (From ANSI S2.71-1983 (R2006)

One-Third Octave band center frequency, Hz	Velocity (RMS), m/s		
	z axis	x, y axis	Combined axis
1	1.6×10^{-3}	5.7×10^{-4}	5.7×10^{-4}
1.25	1.1×10^{-3}	4.6×10^{-4}	4.6×10^{-4}
1.6	8.0×10^{-4}	3.6×10^{-4}	3.6×10^{-4}
2	5.6×10^{-4}	2.9×10^{-4}	2.9×10^{-4}
2.5	4.0×10^{-4}	2.9×10^{-4}	2.4×10^{-4}
3.15	2.9×10^{-4}	2.9×10^{-4}	2.1×10^{-4}
4	2.0×10^{-4}	2.9×10^{-4}	1.7×10^{-4}
5	1.6×10^{-4}	2.9×10^{-4}	1.4×10^{-4}
6.3	1.3×10^{-4}	2.9×10^{-4}	1.2×10^{-4}
8	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
10	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
12.5	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
16	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
20	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
25	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
31.5	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
40	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
50	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
63	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}
80	1.0×10^{-4}	2.9×10^{-4}	1.0×10^{-4}

5.0 LITERATURE REVIEW

Epsilon performed an extensive literature search of over 100 scientific papers, technical reports and summary reports on low frequency sound and infrasound - hearing, effects, measurement, and criteria. The following paragraphs briefly summarize the findings from some of these papers and reports.

5.1 H. Moeller and C. S. Pedersen (2004)

Moeller and Pedersen (2004) present a comprehensive summary on hearing and non-auditory perception of sound at low and infrasonic regions, some of which has been cited in sections 3.1.1, 3.1.2, and 3.1.3 of this report.

5.2 Leventhall (2003)

Leventhall presents an excellent study on low frequency noise from all sources and its effects. The report presents criteria in place at that time. Included are figures and data relating cause and effects.

5.3 Leventhall (2006)

Leventhall reviewed data and allegations on alleged problems from low frequency noise and infrasound from wind turbines. Leventhall concluded the following: "It has been shown that there is insignificant infrasound from wind turbines and that there is normally little low frequency noise." "Turbulent air inflow conditions cause enhanced levels of low frequency noise, which may be disturbing, but the overriding noise from wind turbines is the fluctuating audible swish, mistakenly referred to as "infrasound" or "low frequency noise". "Infrasound from wind turbines is below the audible threshold and of no consequence". Other studies have shown that wind turbine generated infrasound levels are below threshold of perception and threshold of feeling and body reaction.

5.4 Delta (2008)

The Danish Energy Authority project on "low frequency noise from large wind turbines" comprises a series of investigations in the effort to give increased knowledge on low frequency noise from wind turbines. One of the conclusions of the study is that wind turbines do not emit audible infrasound, with levels that are "far below the hearing threshold." Audible low frequency sound may occur both indoors and outdoors, "but the levels in general are close to the hearing and/or masking level." "In general the noise in the critical band up to 100 Hz is below both thresholds". The summary report notes that for road traffic noise (in the vicinity of roads) the low frequency noise levels are higher [than wind turbine] both indoors and outdoors.

5.5 Hayes McKenzie (2006)

Hayes McKenzie performed a study for the UK Department of Trade & Industry (DTI) to investigate complaints of low frequency noise that came from three of the five farms with complaints out of 126 wind farms in the UK. The study concluded that:

- ♦ Infrasound associated with modern wind turbines is not a source which will result in noise levels that are audible or which may be injurious to the health of a wind farm neighbor.
- ♦ Low frequency noise was measureable on a few occasions, but below DEFRA criteria. Wind turbine noise may result in indoor noise levels within a home that is just above the threshold of audibility; however, it was lower than that of local road traffic noise.
- ♦ The common cause of the complaints was not associated with low frequency noise but the occasional audible modulation of aerodynamic noise, especially at night. Data collected indoors showed that the higher frequency modulated noise levels were insufficient to awaken the residents at the three sights; however, once awake, this noise could result in difficulties in returning to sleep.

The UK Department of Trade and Industry, which is now the UK Department for Business Enterprise and Regulatory Reform (BERR), summarized the Hayes McKenzie report: "The report concluded that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines." [BERR (2007)]

5.6 Howe (2006)

Howe performed extensive studies on wind turbines and infrasound and concluded that infrasound was not an issue for modern wind turbine installations – "while infrasound can be generated by wind turbines, it is concluded that infrasound is not of concern to the health of residences located nearby." Since then Gastmeier and Howe (2008) investigated an additional situation involving the alleged "perception of infrasound by individual." In this additional case, the measured indoor infrasound was at least 30 dB below the perception threshold given by Watanabe and Moeller (1990) as presented in Table 4.3-3. Gastmeier and Howe (2008) also performed vibration measurements at the residence and nearest wind turbine, and concluded that the vibration levels were well below the perception limits discussed in ISO 2631-2.

5.7 Branco (2004)

Branco and other Portuguese researchers have studied possible physiological affects associated with high amplitude low frequency noise and have labeled these alleged effects as "Vibroacoustic Disease" (VAD). "Vibroacoustic disease (VAD) is a whole-body, systemic pathology, characterized by the abnormal proliferation of extra-cellular matrices, and caused by excessive exposure to low frequency noise." Hayes (2007, 2008) concluded that levels from wind farms are not likely to cause VAD after comparing noise levels from alleged VAD cases to noise levels from wind turbines in homes of complainers. Noise levels in aircraft in which VAD has been hypothesized are considerably higher than wind turbine noise levels. Hayes also concluded that it is "unlikely that symptoms will result through induced internal vibration from incident wind farm noise." [Hayes (2007)] Other studies have found no VAD indicators in environmental sound that have been alleged by VAD proponents. [ERG (2001)]

5.8 French National Academy of Medicine (2006)

French National Academy of Medicine recommended "*as a precaution* construction should be suspended for wind turbines with a capacity exceeding 2.5 MW located within 1500 m of homes." [emphasis added] However, this precaution is not because of definitive health issues but because:

- sound levels one km from some wind turbine installations "occasionally exceed allowable limits" for France (note that the allowable limits are long term averages)

- French prediction tools for assessment did not take into account sound levels created with wind speeds greater than 5 m/s.

- Wind turbine noise has been compared to aircraft noise (even though the sound levels of wind turbine noise are significantly lower), and exposure to high level aircraft noise "involves neurobiological reactions associated with an increased frequency of hypertension and cardiovascular illness. Unfortunately, no such study has been done near wind turbines." [Gueniot (2006)].

In March 2008, the French Agency for Environmental and Occupational Health Safety (AFSSET) published a report on "the health impacts of noise generated by wind turbines", commissioned by the Ministries of Health and Environment in June 2006 following the report of the French National Academy of Medicine in March 2006. [AFSSET (2008)] The AFSSET study recommends that one does not define a fixed distance between wind farms and homes, but rather to model the acoustic impact of the project on a case-by-case basis. One of the conclusions of the AFSSET report is: "The analysis of available data shows: The absence of identified direct health consequences concerning the auditory effects or specific effects usually associated with exposure to low frequencies at high level." ("L'analyse des données disponibles met en évidence: L'absence de conséquences sanitaires directes recensées en ce qui concerne les effets auditifs, ou les effets spécifiques généralement attachés à l'exposition à des basses fréquences à niveau élevé.")

6.0 REPRESENTATIVE WIND TURBINES

At the direction of NextEra, two types of utility-scale wind turbines were studied:

- General Electric (GE) 1.5sle (1.5 MW), and
- Siemens SWT-2.3-93 (2.3 MW).

Typical hub height for these wind turbines is 80 meters above ground level (AGL).

Sound levels for these wind turbine generators (WTGs) vary as a function of wind speed from cut-in wind speed to maximum sound level. Table 6.0-1 below lists the reference sound power levels of each WTG as a function of wind speed at 10 meters AGL as provided by the manufacturer. This is in conformance with the sound level standard for wind turbines [IEC 61400-11].

Table 6.0-1 Sound power levels as a Function of Wind Speed (dBA)

Wind Speed at 10 meters AGL (m/s)	GE 1.5 sle 80 m hub height; 77 m rotor diameter	Siemens SWT-2.3-93 80 m hub height; 92.4 m rotor diameter
3	<96	ND
4	<96	ND
5	99.1	99
6	103.0	103.4
7	≤104	104.9
8	≤104	105.1
9	≤104	105.0
10	≤104	105.0

ND = No Data available

Each wind turbine manufacturer applied the uncertainty factor K of 2 dBA to guarantee the turbine's sound power level. (According to IEC TS 61400-14, K accounts for both measurement variations and production variation.) The results in Section 8.0 use the manufacturer's guaranteed value, that is, 2 dBA above the levels in Table 6.0-1.

One-third octave band sound power level data have also been provided for each turbine reflective of the highest A-weighted level (typically a wind speed of 8 m/s or greater at 10 m AGL). These data are reference (not guaranteed) data, and are summarized below in Table 6.0-2. Cut-in wind speed for the GE 1.5 sle wind turbine is 3.5 m/s while the Siemens wind turbine has a cut-in wind speed of 4 m/s. The last two rows in Table 6.0-2 contain the overall A-weighted sound power levels from Table 6.0-1 and the guaranteed values.

Table 6.0-2 One-Third Octave Sound Power Levels at 8 m/s (un-weighted, dB)

1/3 Octave Band Center Frequency, Hz	GE 1.5 sle 80 m hub height; 77 m rotor diameter	Siemens SWT-2.3-93 80 m hub height; 92.4 m rotor diameter
25	ND	109.0
31.5	ND	105.7
40	ND	105.3
50	106.4	105.3
63	106.1	104.8
80	105.1	104.7
100	103.9	104.8
125	102.8	105.3
160	105.8	103.2
200	101.6	103.7
250	100.6	105.0
315	100.6	102.5
400	99.1	100.2
500	97.0	97.8
630	95.1	95.8
800	94.8	93.5
1000	92.8	92.7
1250	91.7	90.6
1600	90.5	88.2
2000	88.4	87.1
2500	85.8	85.6
3150	83.6	83.9
4000	81.2	82.1
5000	78.1	80.8
6300	76.0	79.9
8000	72.4	79.4
10000	73.3	80.0
Overall - Reference	104 dBA	105 dBA
Guaranteed	106 dBA	107 dBA

ND = No data provided.

7.0 FIELD PROGRAM

Real-world data were collected from operating wind turbines to compare to the low frequency noise guidelines and criteria discussed previously in Section 4.0. These data sets consisted of outdoor measurements at various reference distances, and concurrent indoor/outdoor measurements at residences within the wind farm. Epsilon determined all means, methods, and the testing protocol without interference or direction from NextEra. No limitations were placed on Epsilon by NextEra with respect to the testing protocol or upon the analysis methods.

7.1 GE 1.5sle and Siemens SWT-2.3-93

Field measurements were conducted in order to measure sound levels at operating wind turbines, and compare them to the guidelines and criteria discussed in this report. NextEra provided access to the Horse Hollow Wind Farm in Taylor and Nolan Counties, Texas in November 2008 to collect data on the GE 1.5 sle and Siemens SWT-2.3-93 wind turbines. The portion of the wind farm used for testing is relatively flat with no significant terrain. The land around the wind turbines is rural and primarily used for agriculture and cattle grazing. The siting of the sound level measurement locations was chosen to minimize local noise sources except the wind turbines and the wind itself.

Two noise consultants collected sound level and wind speed data over the course of one week under a variety of operational conditions. Weather conditions were dry the entire week with ground level winds ranging from calm to 28 mph (1-minute average). In order to minimize confounding factors, the data collection tried to focus on periods of maximum sound levels from the wind turbines (moderate to high hub height winds) and light to moderate ground level winds.

Ground level (2 meters AGL) wind speed and direction were measured continuously at one representative location. Wind speeds near hub height were also measured continuously using the permanent meteorological towers maintained by the wind farm.

A series of simultaneous interior and exterior sound level measurements were made at four houses owned by participating landowners within the wind farm. Two sets were made of the GE WTGs, and two sets were made of the Siemens WTGs. Data were collected with both windows open and windows closed. Due to the necessity of coordinating with the homeowners in advance, and reasonable restrictions of time of day to enter their homes, the interior/exterior measurement data sets do not always represent ideal conditions. However, enough data were collected to compare to the criteria and draw conclusions on low frequency noise.

Sound level measurements were also made simultaneously at two reference distances from a string of wind turbines under a variety of wind conditions. Using the manufacturer's sound level data discussed in Section 6.0, calculations of the sound pressure levels as a function of distance in flat terrain were made to aid in deciding where to collect data in the field. Based on this analysis, two distances from the nearest wind turbine were selected - 1000 feet and 1500 feet - and were then used where possible during the field program.

Distances much larger than 1,500 feet were not practical since an adjacent turbine string could be closer and affect the measurements, or would put the measurements beyond the boundaries of the wind farm property owners. Brief background sound level measurements were conducted several times during the program whereby the Horse Hollow Wind Farm operators were able to shutdown the nearby WTGs for a brief (20 minutes) period. This was done in real time using cell phone communication.

All the sound level measurements described above were attended by the noise consultants. One series of unattended overnight measurements was made at two locations for approximately 15 hours to capture a larger data set. One measurement was set up approximately 1,000 feet from a GE 1.5 sle WTG and the other was set up approximately 1,000 feet from a Siemens WTG. The location was chosen based on the current wind direction forecast so that the sound level equipment would be downwind for the majority of the monitoring period. By doing this, the program was able to capture periods of strong hub-height winds and moderate to low ground-level winds.

Ground-borne vibration measurements were made within the Horse Hollow Wind Farm. Measurements were made 400 feet and 1000 feet downwind from both GE 1.5 sle and Siemens 2.3 MW WTGs under full operation. In addition, background vibration measurements were made with the WTGs briefly shutdown.

7.2 Measurement Equipment

Ground level wind speed and direction were measured with a HOBO H21-002 micro weather station (Onset Computer Corporation). The data were sampled every three seconds and logged every one minute. All sound levels were measured using two Norsonic Model Nor140 precision sound analyzers, equipped with a Norsonic-1209 Type 1 Preamplifier, a Norsonic-1225 half-inch microphone and a 7-inch Aco-Pacific untreated foam windscreen Model WS7. The instrumentation meets the "Type 1 - Precision" requirements set forth in American National Standards Institute (ANSI) S1.4 for acoustical measuring devices. The microphone was tripod-mounted at a height of five feet above ground. The measurements included simultaneous collection of broadband (A-weighted) and one-third-octave band data (0.4 hertz to 20,000 hertz bands). Sound level data were primarily logged in 10-minute intervals to be consistent with the wind farm's Supervisory Control And Data Acquisition (SCADA) system which provides power output (kW) in 10-minute increments. A few sound level measurements were logged using 20-miute intervals. The meters were calibrated and certified as accurate to standards set by the National Institute of Standards and Technology. These calibrations were conducted by an independent laboratory within the past 12 months.

The ground-borne vibration measurements were made using an Instantel Minimate Plus vibration and overpressure monitor. A triaxial geophone inserted in the ground measured the particle velocity (PPV). Each measurement was 20 seconds in duration and all data were stored in memory for later retrieval.

8.0 RESULTS AND COMPARISON TO CRITERIA

Results from the field program are organized by wind turbine type. For each wind turbine type, results are presented per location type (outdoor or indoor) with respect to applicable criteria. Results are presented for 1,000 feet from the nearest wind turbine. Data were also collected at 1,500 feet from the nearest wind turbine which showed lower sound levels. Therefore, wind turbines that met the criteria at 1,000 feet also met it at 1,500 feet. Data were collected under both high turbine output and moderate turbine output conditions, and low ground-level wind speeds (defined as sound power levels 2 or 3 dBA less than the maximum sound power levels). The sound level data under the moderate conditions were equivalent to or lower than the high turbine output scenarios, thus confirming the conclusions from the high output cases. A-weighted sound power levels presented in this section (used to describe turbine operation) were estimated from the actual measured power output (kW) of the wind turbines and the sound power levels as a function of wind speed presented in Table 6.0-1 plus an adjustment factor of 2 dBA (correction from reference values to guaranteed values).

Outdoor measurements are compared to criteria for audibility, for UK DEFRA disturbance using equivalent outdoor levels, for rattle and annoyance criteria as contained in ANSI S12.9 Part 4, and for perceptible vibration using equivalent outdoor levels from ANSI/ASA S12.2. Indoor measurements are compared to criteria for audibility, for UK DEFRA disturbance, and for suitability of bedrooms, hospitals and schools and perceptible vibration from ANSI/ASA S12.2.

8.0.1 Audibility

The threshold of audibility criteria discussed in section 4.3.4 is used to evaluate wind turbine sound levels. The audibility of wind turbines both outdoors and indoors was examined.

8.0.2 UK DEFRA Disturbance Criteria

The DEFRA one-third octave band sound pressure level L_{eq} criteria and procedures for assessing disturbance from low frequency noise (see section 4.3.2) were examined. The indoor criteria and equivalent outdoor criteria were compared to measured low frequency noise from wind turbines.

8.0.3 Perceptible Vibration, Rattle and Annoyance – Outdoor Measurements

The ANSI/ASA S12.2 interior perceptible vibration criteria were converted to equivalent outdoor criteria as discussed in section 4.2.3 and compared to the measured low frequency noise from wind turbines. In addition, measured data were compared to ANSI S12.9 Part 4 low frequency sound levels for minimal annoyance and for the threshold for beginning of rattles as described in section 4.2.2.

8.0.4 ANSI/ASA S12.2 Low Frequency Criteria – Indoor Measurements

The ANSI/ASA S12.2 interior perceptible vibration criteria and low frequency portions of the room criteria for evaluating the suitability of noises in bedrooms, hospitals and schools were compared to indoor measurements of low frequency noise from wind turbines. (See section 4.2.3.)

8.1 Siemens SWT-2.3-93

8.1.1 Outdoor Measurements - Siemens SWT-2.3-93

Several periods of high wind turbine output and relatively low ground wind speed (which minimized effects of wind noise) were measured outdoors approximately 1,000 feet from the closest Siemens WTG. This site was actually part of a string of 15 WTGS, four of which were within 2,000 feet of the monitoring location. The sound level data presented herein include contributions from all wind turbines as measured by the recording equipment. The key operational and meteorological parameters during these measurements are listed in Table 8.1-1

Table 8.1-1 Summary of Operational Parameters – Siemens SWT-2.3-93 (Outdoor)

Parameter	Sample #34	Sample #39
Distance to nearest WTG	1,000 feet	1,000 feet
Time of day	22:00-22:10	22:50-23:00
WTG power output	1,847 kW	1,608 kW
Sound power	107 dBA	106.8 dBA
Measured wind speed @ 2 m	3.3 m/s	3.4 m/s
L_{Aeq}	49.4 dBA	49.6 dBA
L_{A90}	48.4 dBA	48.6 dBA
L_{Ceq}	63.5 dBC	63.2 dBC

8.1.1.1 Outdoor Audibility

Figure 8.1-1 plots the one-third octave band sound levels (L_{eq}) for both samples of high output conditions. The results show that infrasound is inaudible to even the most sensitive people 1,000 feet from these wind turbines (more than 20 dB below the median thresholds of hearing). Low frequency sound above 40 Hz may be audible depending on background sound levels.

8.1.1.2 UK DEFRA Disturbance Criteria – Outdoor measurements

Figure 8.1-2 plots the one-third octave band sound levels (L_{eq}) for both samples of high output conditions. The low frequency sound was "steady" according to DEFRA procedures, and the results show that all outdoor equivalent DEFRA disturbance criteria are met.

8.1.1.3 Perceptible Vibration, Rattle and Annoyance – Outdoor Measurements

Figure 8.1-3 plots the 16, 31.5, and 63 Hz octave band sound levels (L_{eq}) for both samples of high output conditions. The results show that all outdoor equivalent ANSI/ASA S12.2 perceptible vibration criteria are met. The low frequency sound levels are below the ANSI S12.9 Part 4 thresholds for the beginning of rattles (16, 31.5, 63 Hz total less than 70 dB), and the 31.5 and 63 Hz sound levels are below the level of 65 dB identified for minimal annoyance in ANSI S12.9 Part 4, and the 16 Hz sound level is within 1.5 dB of this level, which is an insignificant increase since the levels were not rapidly fluctuating.

8.1.2 Indoor Measurements - Siemens SWT-2.3-93

Simultaneous outdoor and indoor measurements were made at two residences at different locations within the wind farm to determine indoor audibility of low frequency noise from Siemens WTGs. In each house measurements were made in a room facing the wind turbines, and were made with either window open or closed. These residences are designated Homes "A" and "D" and were approximately 1,000 feet from the closest Siemens WTG. Both homes were near a string of multiple WTGS, four of which were within 2,000 feet of the house. The sound level data presented herein include contributions from all wind turbines as measured by the recording equipment. The key operational and meteorological parameters during these measurements are listed in Table 8.1-2.

Table 8.1-2 Summary of Operational Parameters – Siemens SWT-2.3-93 (Indoor)

Parameter	Home "A" (closed / open)	Home "D" (closed / open)
Distance to nearest WTG	1,060 feet	920 feet
Time of day	7:39-7:49 / 7:51-8:01	16:16-16:26 / 16:30 -16:40
WTG power output	1,884 kW / 1564 kW	2,301 kW / 2299 kW
Sound power	107 dBA / 106.7 dBA	107 dBA / 107 dBA
Measured wind speed @ 2 m	3.2 m/s / 3.7 m/s	9.6 m/s / 8.8 m/s
L_{Aeq}	33.8 dBA /38.1 dBA	35.0 dBA / 36.7 dBA
L_{A90}	28.1 dBA / 36.8 dBA	29.6 dBA / 31.2 dBA
L_{Ceq}	54.7 dBC / 57.1 dBC	52.8 dBC / 52.5 dBC

8.1.2.1 Indoor Audibility

Figure 8.1-4a plots the indoor one-third octave band sound levels (L_{eq}) for Home "A", and Figure 8.1-4b plots the indoor one-third octave band sound levels for Home "D". The results show that infrasound is inaudible to even the most sensitive people 1,000 feet from these wind turbines with the windows open or closed (more than 20 dB below the median thresholds of hearing). Low frequency sound at or above 50 Hz may be audible depending on background sound levels.

8.1.2.2 UK DEFRA Disturbance Criteria – Indoor Measurements

Figure 8.1-5a plots the indoor one-third octave band sound levels (L_{eq}) for Home "A". The low frequency sound was "steady" according to DEFRA procedures, and the results show that all outdoor equivalent DEFRA disturbance criteria are met. Figure 8.1-5b plots the indoor one-third octave band sound levels (L_{eq}) for Home "D". According to DEFRA procedures, the low frequency sound was not "steady" and therefore the data were compared to both criteria. The results show the DEFRA disturbance criteria were met for steady low frequency sounds, the DEFRA criteria were met for unsteady low frequency sounds except for the 125 Hz band, which was within 1 dB, which is an insignificant difference.

8.1.2.3 ANSI/ASA S12.2 Low Frequency Criteria – Indoor Measurements

Figure 8.1-6a plots the indoor 16 Hz to 125 Hz octave band sound levels (L_{eq}) for Home "A", and Figure 8.1-6b plots the indoor 16 Hz to 125 Hz octave band sound levels (L_{eq}) for Home "D". The results show the ANSI/ASA S12.2 low frequency criteria were easily met for both windows open and closed scenarios. The ANSI/ASA S12.2 low frequency criteria for bedrooms, classrooms and hospitals were met, the spectrum was balanced, and the criteria for moderately perceptible vibrations in light-weight walls and ceilings were also met.

8.2 GE 1.5sle

8.2.1 Outdoor Measurements - GE 1.5sle

Several periods of high wind turbine output and relatively low ground wind speed (which minimized effects of wind noise) were measured outdoors approximately 1,000 feet from the closest GE 1.5 sle WTG. This site was actually part of a string of more than 30 WTGS, four of which were within 2,000 feet of the monitoring location. The sound level data presented herein include contributions from all wind turbines as measured by the recording equipment. The key operational and meteorological parameters for these measurements are listed in Table 8.2-1.

Table 8.2-1 Summary of Operational Parameters – GE 1.5sle (Outdoor)

Parameter	Sample #46	Sample #51
Distance to nearest WTG	1,000 feet	1,000 feet
Time of day	23:10-23:20	00:00-00:10
WTG power output	1,293 kW	1,109 kW
Sound power	106 dBA	106 dBA
Measured wind speed @ 2 m	4.1 m/s	3.3 m/s
L_{Aeq}	50.2 dBA	50.7 dBA
L_{A90}	49.2 dBA	49.7 dBA
L_{Ceq}	62.5 dBC	62.8 dBC

8.2.1.1 Outdoor Audibility

Figure 8.2-1 plots the one-third octave band sound levels (L_{eq}) for both samples of high output conditions. The results show that infrasound is inaudible to even the most sensitive people 1,000 feet from these wind turbines (more than 20 dB below the median thresholds of hearing). Low frequency sound at and above 31.5 - 40 Hz may be audible depending on background sound levels.

8.2.1.2 UK DEFRA Disturbance Criteria – Outdoor measurements

Figure 8.2-2 plots the one-third octave band sound levels (L_{eq}) for both samples of high output conditions. The low frequency sound was "steady" according to DEFRA procedures, and the results show the low frequency sound meet or are within 1 dB of outdoor equivalent DEFRA disturbance criteria.

8.2.1.3 Perceptible Vibration, Rattle and Annoyance – Outdoor Measurements

Figure 8.2-3 plots the 16, 31.5, and 63 Hz octave band sound levels (L_{eq}) for both samples of high output conditions. The results show that all outdoor equivalent ANSI/ASA S12.2 perceptible vibration criteria are met. The low frequency sound levels are below the ANSI S12.9 Part 4 thresholds for the beginning of rattles (16, 31.5, 63 Hz total less than 70 dB), and the 16, 31.5, 63 Hz sound levels are below the level of 65 dB identified for minimal annoyance in ANSI S12.9 Part 4.

8.2.2 Indoor Measurements - GE 1.5sle

Simultaneous outdoor and indoor measurements were made at two residences at different locations within the wind farm to determine indoor audibility of low frequency noise from GE 1.5sle WTGs. In each house, measurements were made in a room facing the wind turbines, and were made with window either open or closed. These residences are designated Homes "B" and "C" and were approximately 1,000 feet from the closest Siemens WTG. Operational conditions were maximum turbine noise and high ground winds at Home "B", and within 1.5 dBA of maximum turbine noise and high ground level winds at Home "C". Home "B" was near a string of multiple WTGs, four of which were within 2,000 feet of the house, while Home "C" was at the end of a string of WTGs, two of which were within 2,000 feet of the house. The sound level data presented herein include contributions from all wind turbines as measured by the recording equipment. The key operational and meteorological parameters during these measurements are listed in Table 8.2-2.

Table 8.2-2 Summary of Operational Parameters – GE 1.5sle (Indoor)

Parameter	Home "B" (closed / open)	Home "C" (closed / open)
Distance to nearest WTG	950 feet	1,025 feet
Time of day	9:29-9:39 / 9:40-9:50	11:49-11:59 / 12:00-12:10
WTG power output	1,017 kW / 896 kW	651 kW / 632 kW
Sound power	106 dBA / 105.8 dBA	104.7 dBA / 104.6 dBA
Measured wind speed @ 2 m	6.2 m/s / 6.8 m/s	6.4 m/s / 5.9 m/s
L_{Aeq}	27.1 dBA / 36.0 dBA	33.6 dBA / 39.8 dBA
L_{A90}	23.5 dBA / 33.7 dBA	27.6 dBA / 34.2 dBA
L_{Ceq}	47.1 dBC / 54.4 dBC	50.6 dBC / 55.1 dBC

8.2.2.1 Indoor Audibility

Figure 8.2-4a plots the indoor one-third octave band sound levels (L_{eq}) for Home "B", and Figure 8.2-4b plots the indoor one-third octave band sound levels for Home "C". The results show that infrasound is inaudible to even the most sensitive people 1,000 feet from these wind turbines with the windows open or closed (more than 20 dB below the median thresholds of hearing). Low frequency sound at and above 63 Hz may be audible depending on background sound levels.

8.2.2.2 UK DEFRA Disturbance Criteria – Indoor Measurements

Figure 8.2-5a plots the indoor one-third octave band sound levels (L_{eq}) for Home "B", and Figure 8.2-5b plots the indoor one-third octave band sound levels (L_{eq}) for Home "C". The results show the DEFRA disturbance criteria were met for steady and non-steady low frequency sounds.

8.2.2.3 ANSI/ASA S12.2 Low Frequency Criteria – Indoor Measurements

Figure 8.2-6a plots the indoor 16 Hz to 125 Hz octave band sound levels (L_{eq}) for Home "B", and Figure 8.2-6b plots the indoor 16 Hz to 125 Hz octave band sound levels (L_{eq}) for Home "C". The results show the ANSI/ASA S12.2 low frequency criteria were met for both windows open and closed scenarios. The ANSI/ASA S12.2 low frequency criteria for bedrooms, classrooms and hospitals were met, the spectrum was balanced, and the criteria for moderately perceptible vibrations in light-weight walls and ceilings were also met.

8.3 Noise Reduction from Outdoor to Indoor

Simultaneous outdoor and indoor measurements were made at four residences within the Horse Hollow Wind Farm to determine noise reductions of the homes for comparison to that used in the determination of equivalent outdoor criteria for indoor criteria, such as ANSI/ASA S12.2 and DEFRA. Indoor measurements were made with windows open and closed. Tables 8.1-2 and 8.2-2 list the conditions of measurement for these houses.

The outdoor sound level data at Home "D" was heavily influenced by high ground winds – the measured levels were higher due to the effect of the wind on the microphone or the measurement of wind effect noise; therefore the data from Home "D" was not used in the comparison of noise reduction, since it would over estimate actual noise reduction.

Figures 8.3-1a and 8.3-1b present the measured one-third octave band noise reduction for the three homes with windows closed and open, respectively. Also presented in these same figures are the one-third octave noise reductions used in Section 4 of this report to obtain equivalent outdoor criteria for the indoor DEFRA criteria ("Table 4.3-1 Noise Reduction - Open Window"). It can be seen that for the window closed condition in Figure 8.3-1a, the measured noise reductions for all houses were greater than that used in our analysis as described in Section 4. For the open window case, the average of the three homes has a greater noise reduction than used in Section 4 and all houses at all frequencies have higher values with one minor exception. Only Home "A" at 25 Hz had a lower noise reduction (3dB), and this difference is not critical since the measured indoor sounds at 25 Hz at each of these home was significantly lower than the indoor DEFRA criteria. Furthermore, the outdoor measurements for both Siemens and GE wind turbines at 1000 feet under high output/high noise levels met the equivalent outdoor DEFRA criteria at 25 Hz.

Table 8.3-1 presents the measured octave band noise reduction for the three homes with windows closed and open, respectively. Also presented in Table 8.3-1 are the octave band noise reductions used in Table 4.2-2 of this report to obtain equivalent outdoor criteria for the indoor ANSI/ASA S12.2 criteria for perceptible vibration. It can be seen that for the window closed condition, the measured noise reductions for all houses were greater than that used in our analysis as described in Section 4. For the open window case, the average of the three homes has a greater noise reduction than used in Section 4 and all houses at all frequencies have higher values with one minor exception. Only Home "A" at 31 Hz (which contains the 25 Hz one-third octave band) had a lower noise reduction (3dB), and this difference is not critical since the measured indoor sounds at 31 Hz at each of these homes was significantly lower than the indoor ANSI/ASA S12.2 criteria. Furthermore, the outdoor measurements for both Siemens and GE wind turbines at 1000 feet under high output/high noise levels met the equivalent outdoor ANSI/ASA S12.2 criteria at 31 Hz.

Table 8.3-1 Summary of Octave Band Noise Reduction – Interior Measurements

Home	Wind Turbine	Windows	16 Hz	31.5 Hz	63 Hz
A	Siemens SWT-2-3-93	Closed	5	6	16
A	Siemens SWT-2-3-93	Open	4	3	12
B	GE 1.5 sle	Closed	20	22	22
B	GE 1.5 sle	Open	13	17	18
C	GE 1.5 sle	Closed	13	14	19
C	GE 1.5 sle	Open	8	13	17
Table 4.2-2 Noise Reduction		Open	3	6	9

8.4 Ground-Borne Vibration

Seven sets of ground-borne vibration measurements were made from Siemens 2.3 and GE 1.5sle wind turbines. The maximum ground-borne vibration RMS particle velocities were 0.071 mm/second (0.0028 inches/second) in the 8 Hz one-third octave band. This was measured 1000 feet downwind from a GE 1.5sle WTG under maximum power output and high wind at the ground. The background ground-borne vibration RMS particle velocity at the same location approximately 20 minutes beforehand was 0.085 mm/sec. Both of these measurements meet ANSI S2.71 recommendations for perceptible vibration in residences during night time hours. Soil conditions were soft earth representative of an active agricultural use. These vibration levels are nearly three orders of magnitude below the level of 0.75 inches/second set to prevent damage to residential structures. No perceptible vibration was felt from operation of the wind turbines. Measurements at the other sites and as close as 400 feet were significantly lower than the above measurements under high wind conditions.

Figure 8.1-1 Siemens SWT-2.3-93 Wind Turbine Outdoor Sound Levels at 1000 feet compared to Audibility Criteria

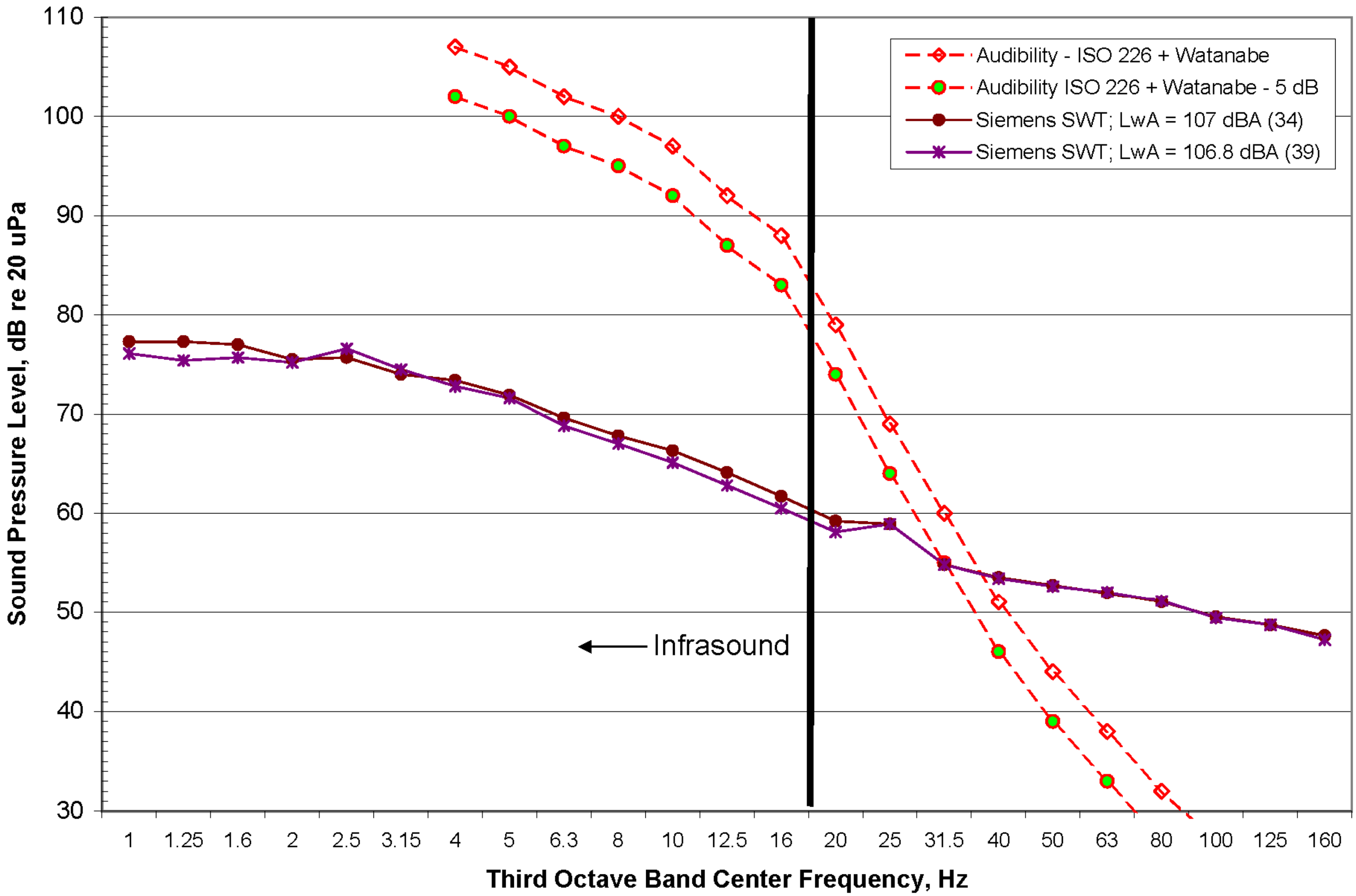


Figure 8.1-2 Siemens SWT-2.3-93 Wind Turbine Outdoor Sound Levels at 1000 feet compared to outdoor equivalent DEFRA Criteria

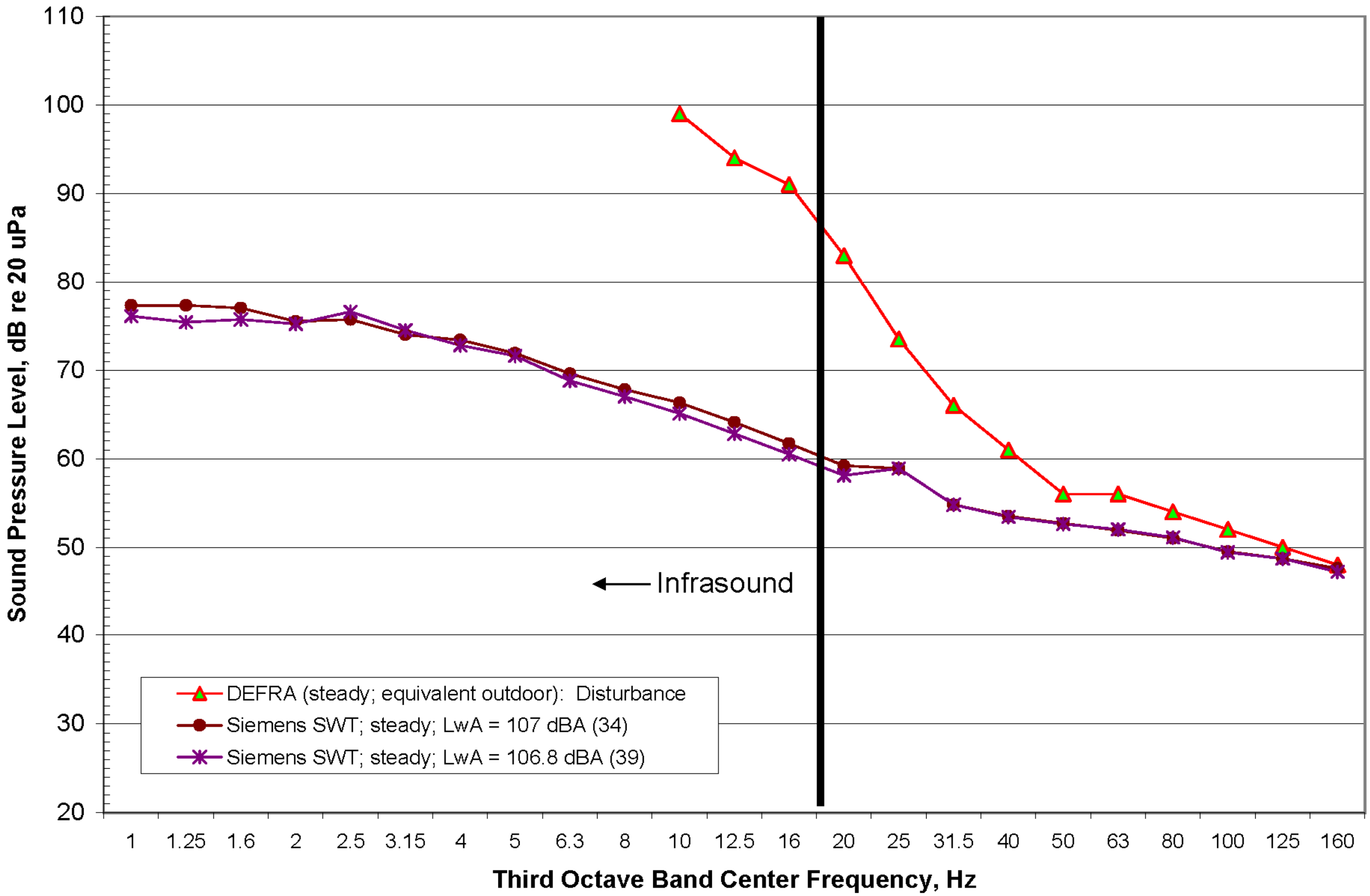


Figure 8.1-3 Siemens SWT-2.3-93 Wind Turbine Outdoor Sound Levels at 1000 feet compared to ANSI Criteria

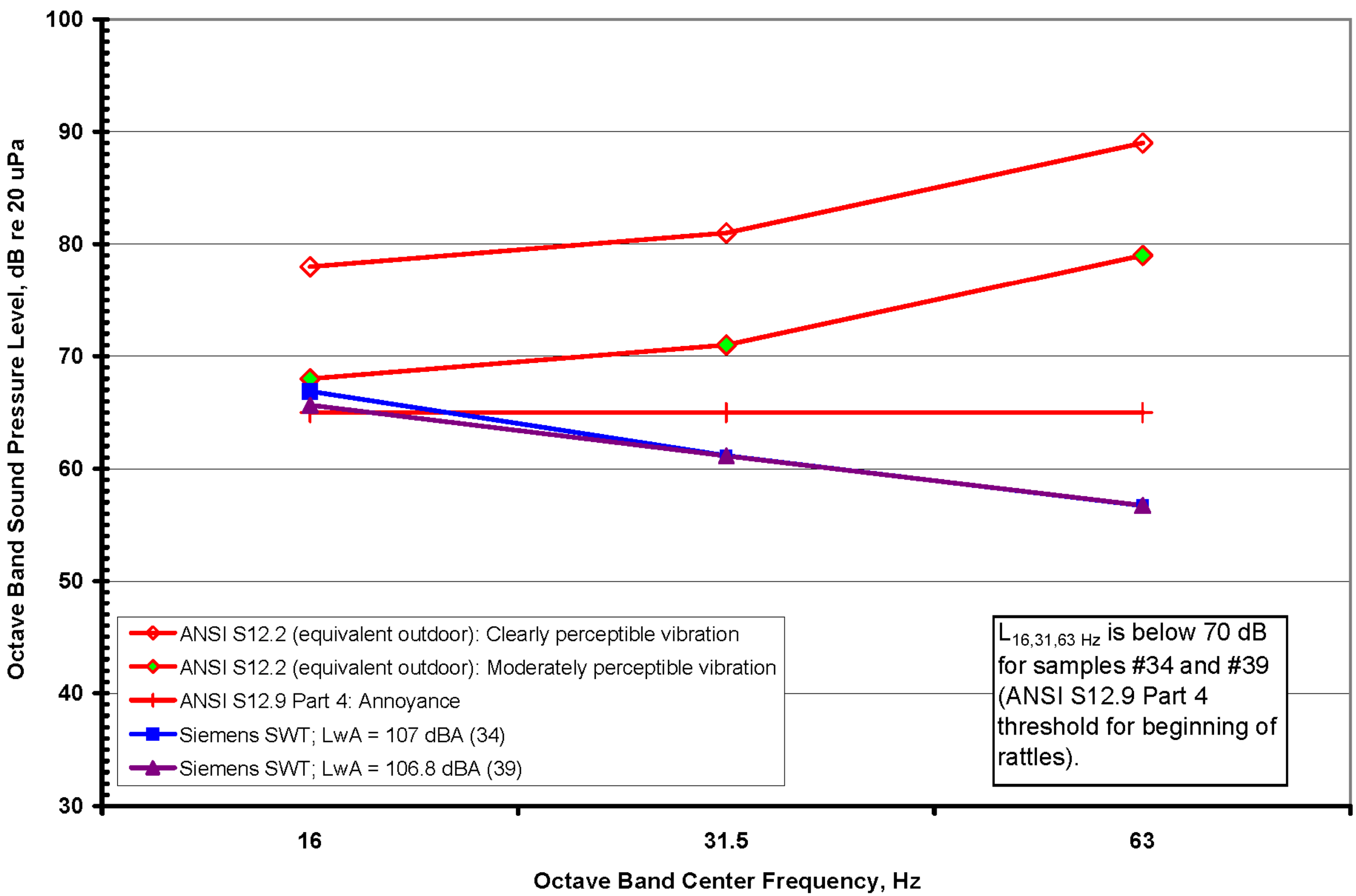


Figure 8.1-4a Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 1060 feet compared to Audibility Criteria (Home "A")

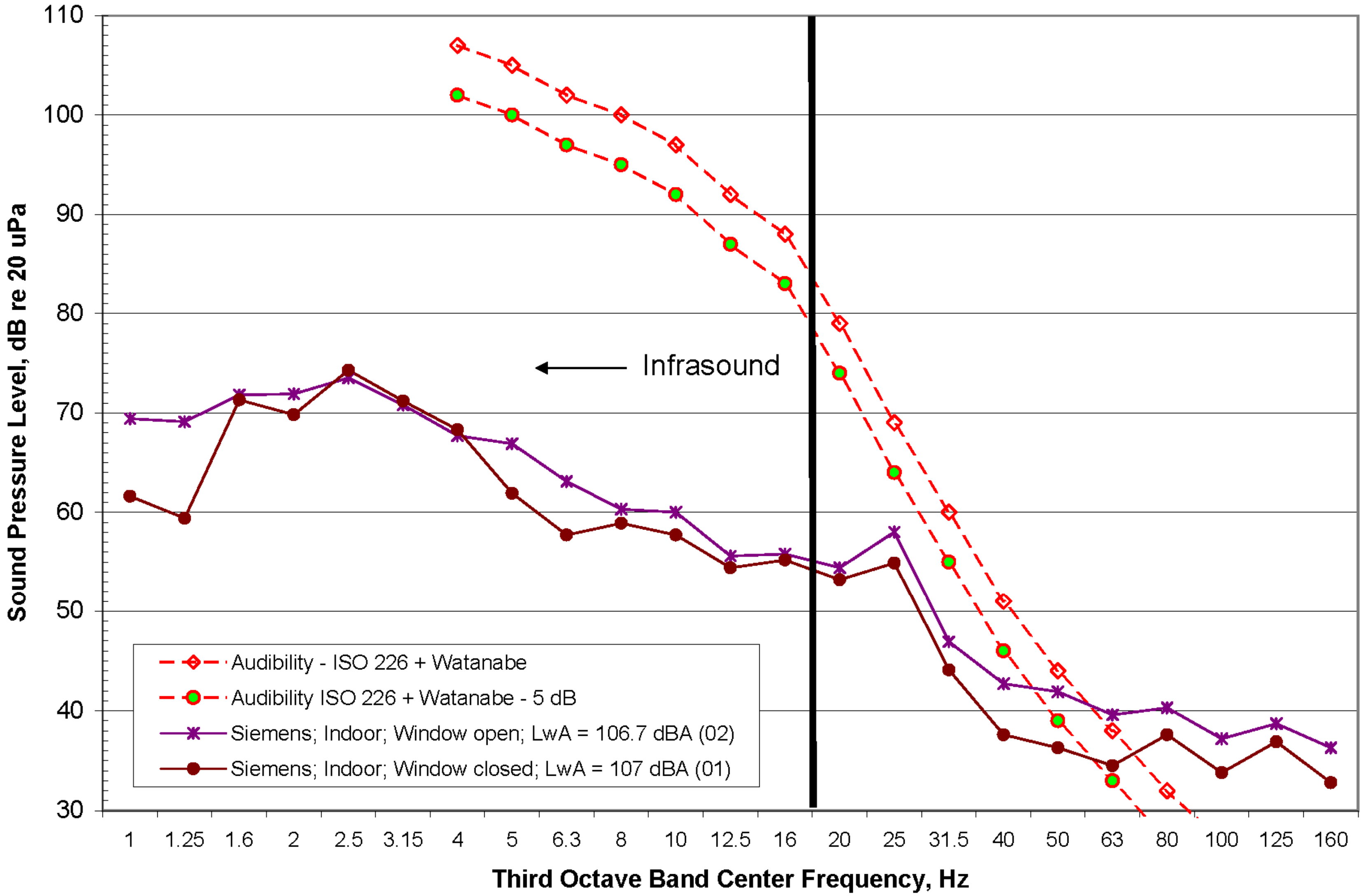


Figure 8.1-4b Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 920 feet compared to Audibility Criteria (Home "D")

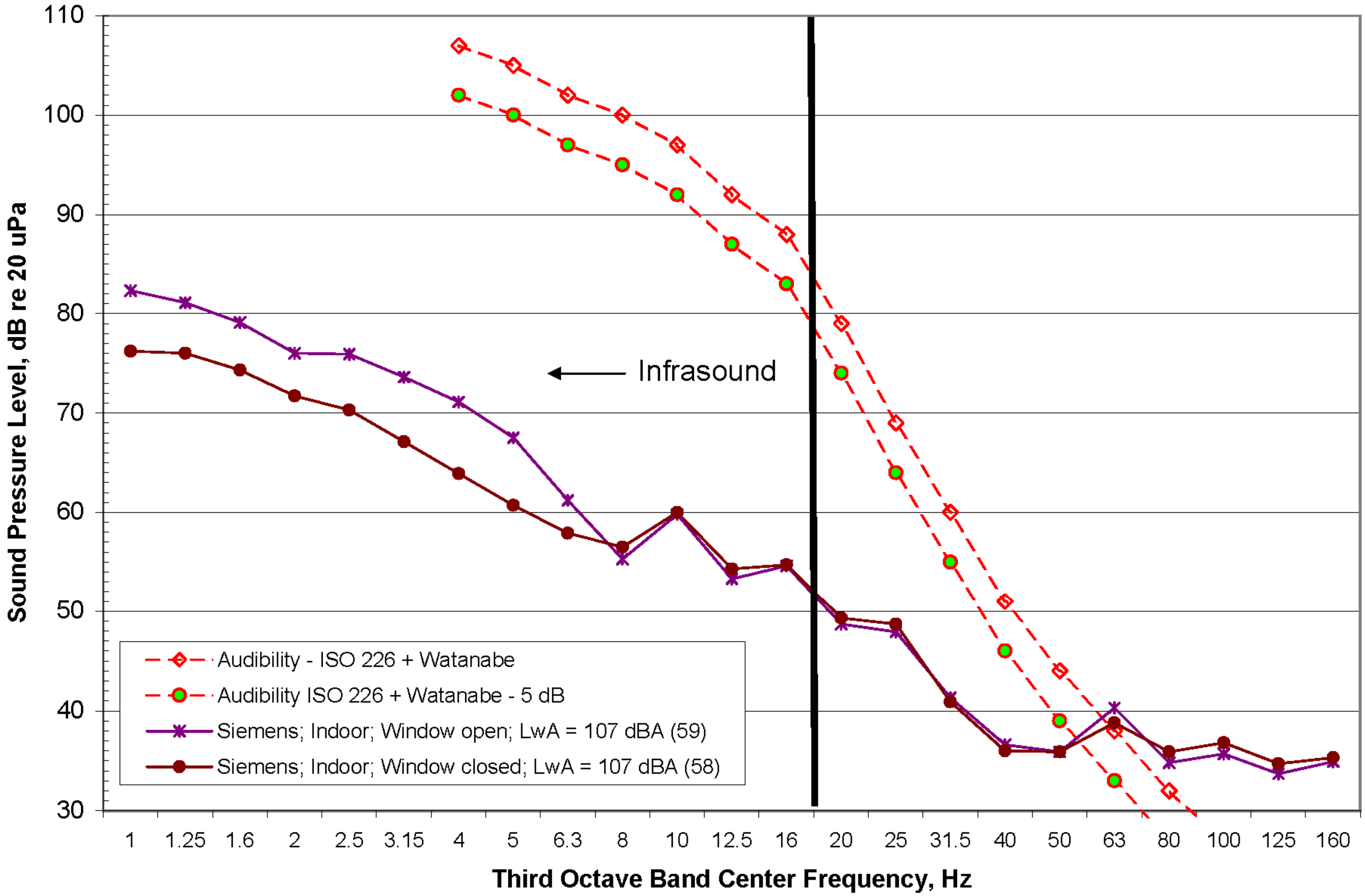


Figure 8.1-5a Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 1060 feet compared to DEFRA Criteria (Home "A")

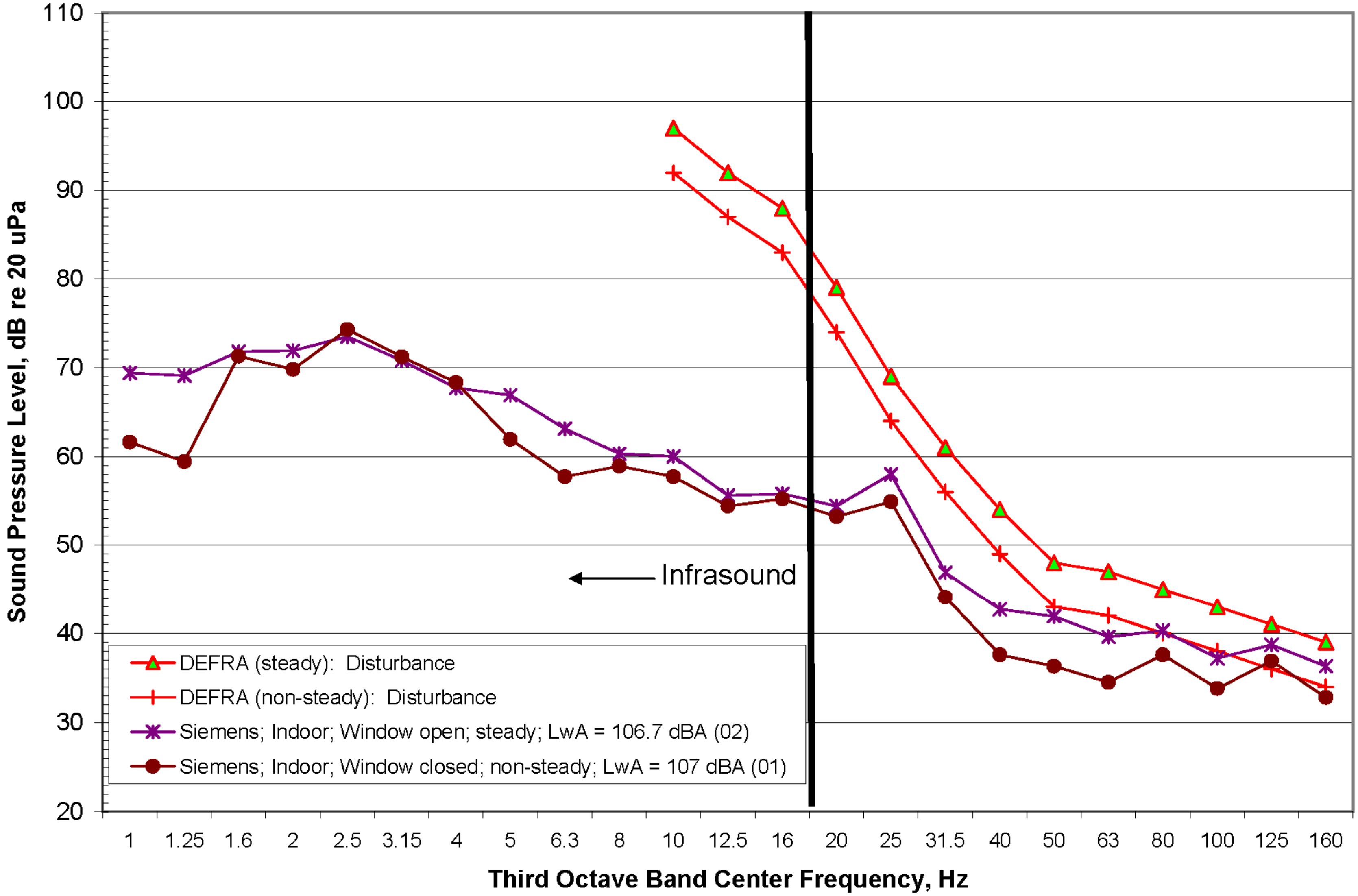


Figure 8.1-5b Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 920 feet compared to DEFRA Criteria (Home "D")

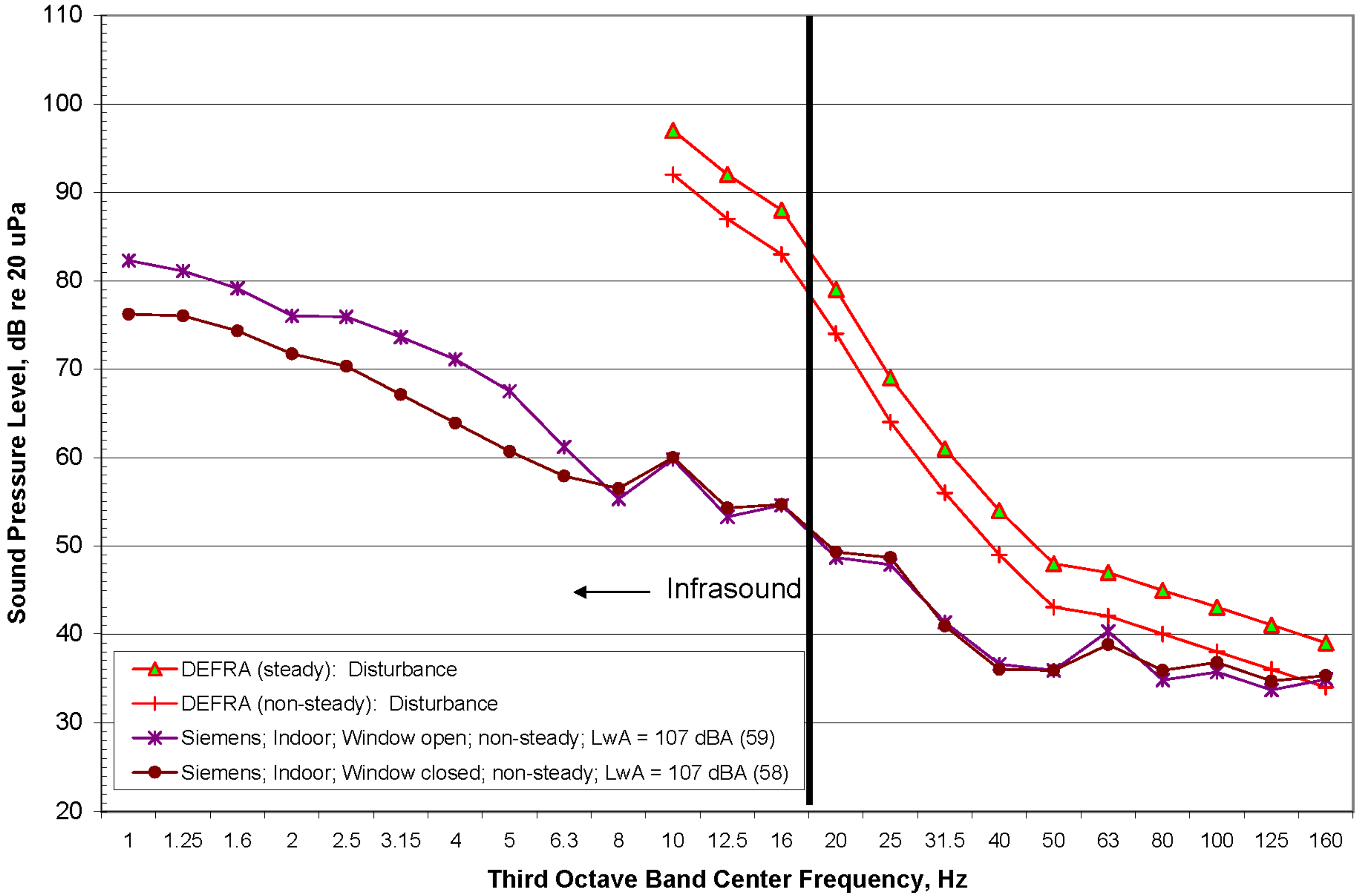


Figure 8.1-6a Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 1060 feet compared to ANSI 12.2 Criteria (Home "A")

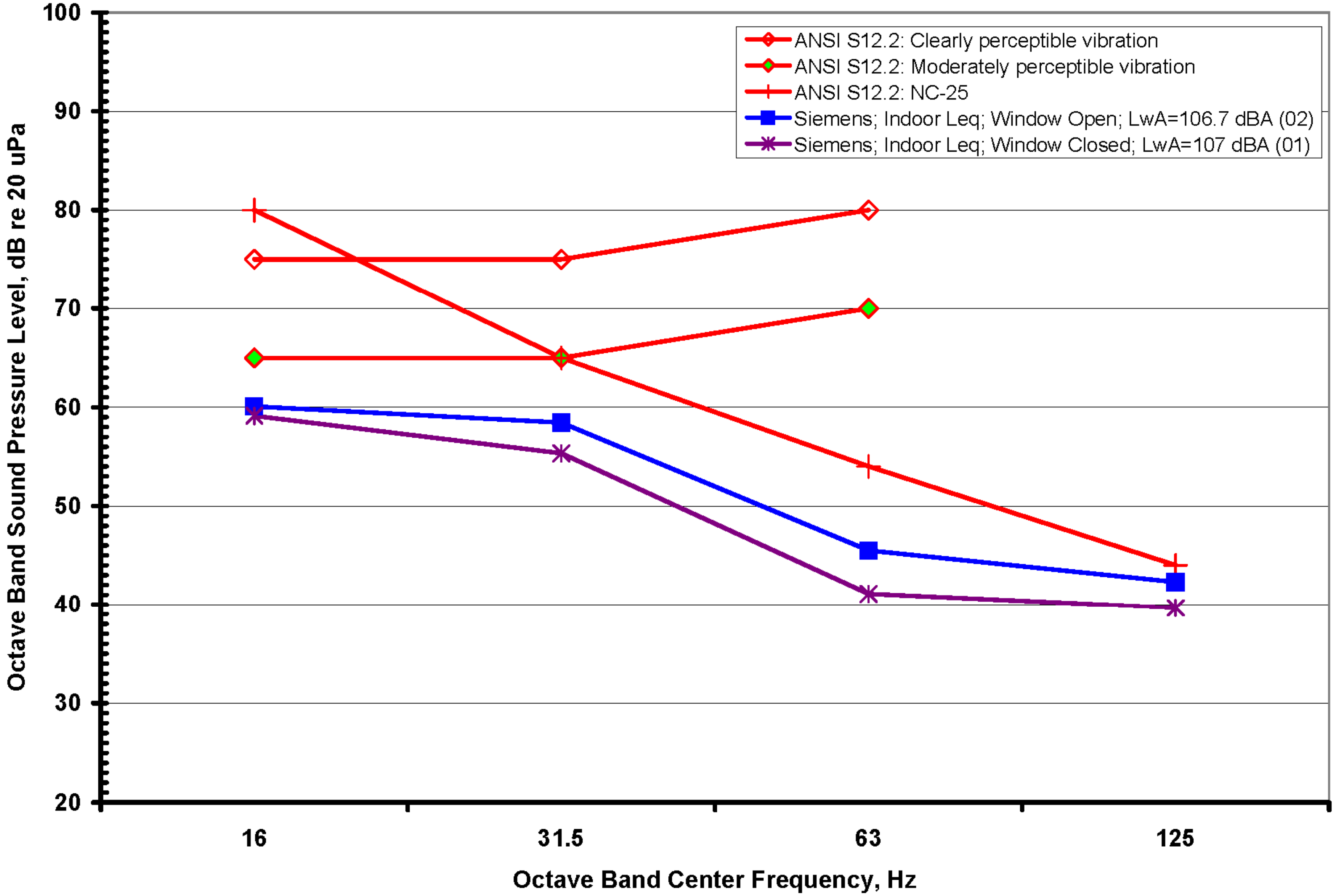


Figure 8.1-6b Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 920 feet compared to ANSI 12.2 Criteria (Home "D")

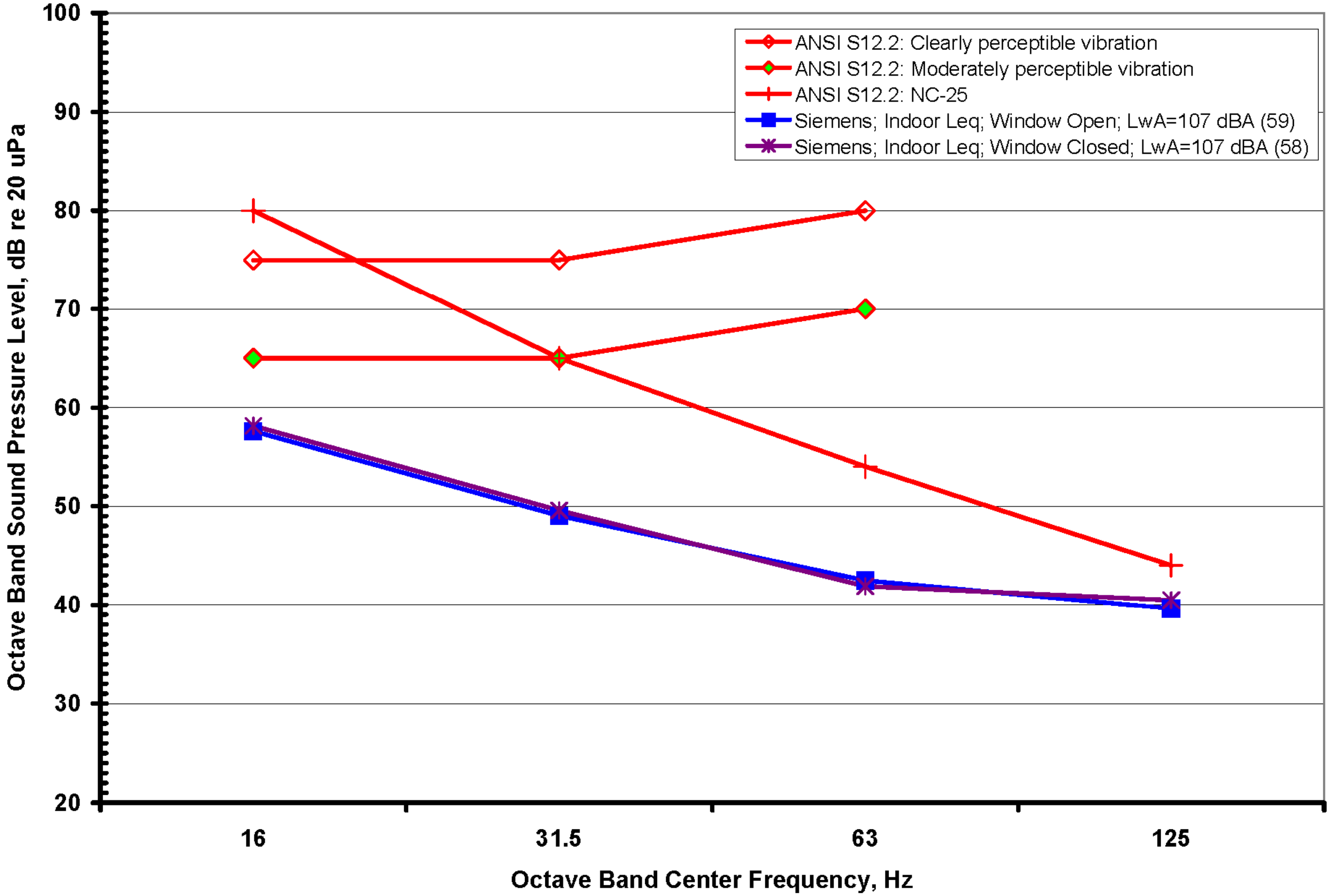


Figure 8.2-1 GE 1.5sle Wind Turbine Outdoor Sound Levels at 1000 feet compared to Audibility Criteria

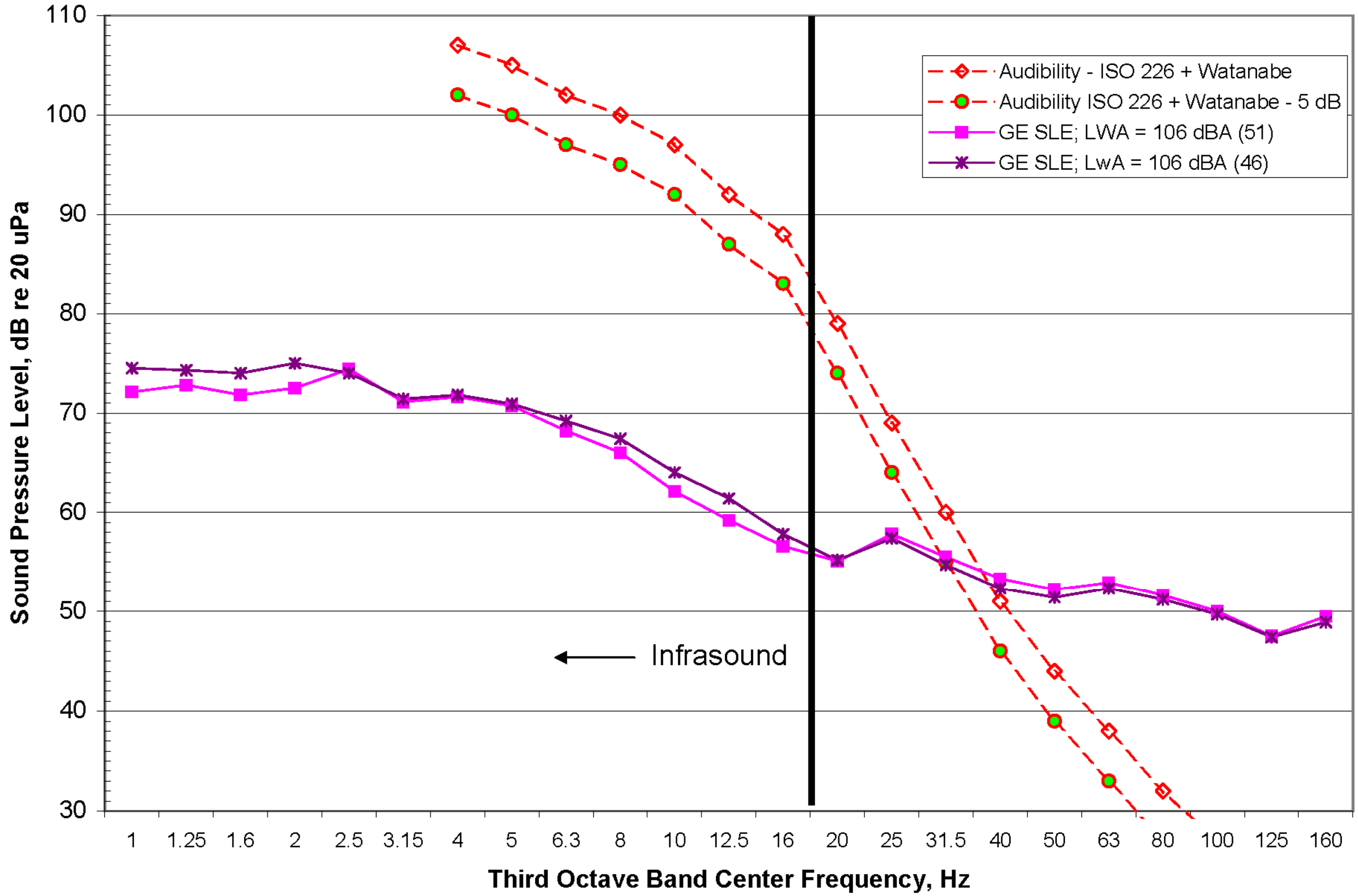


Figure 8.2-2 GE 1.5sle Wind Turbine Outdoor Sound Levels at 1000 feet compared to outdoor equivalent DEFRA Criteria

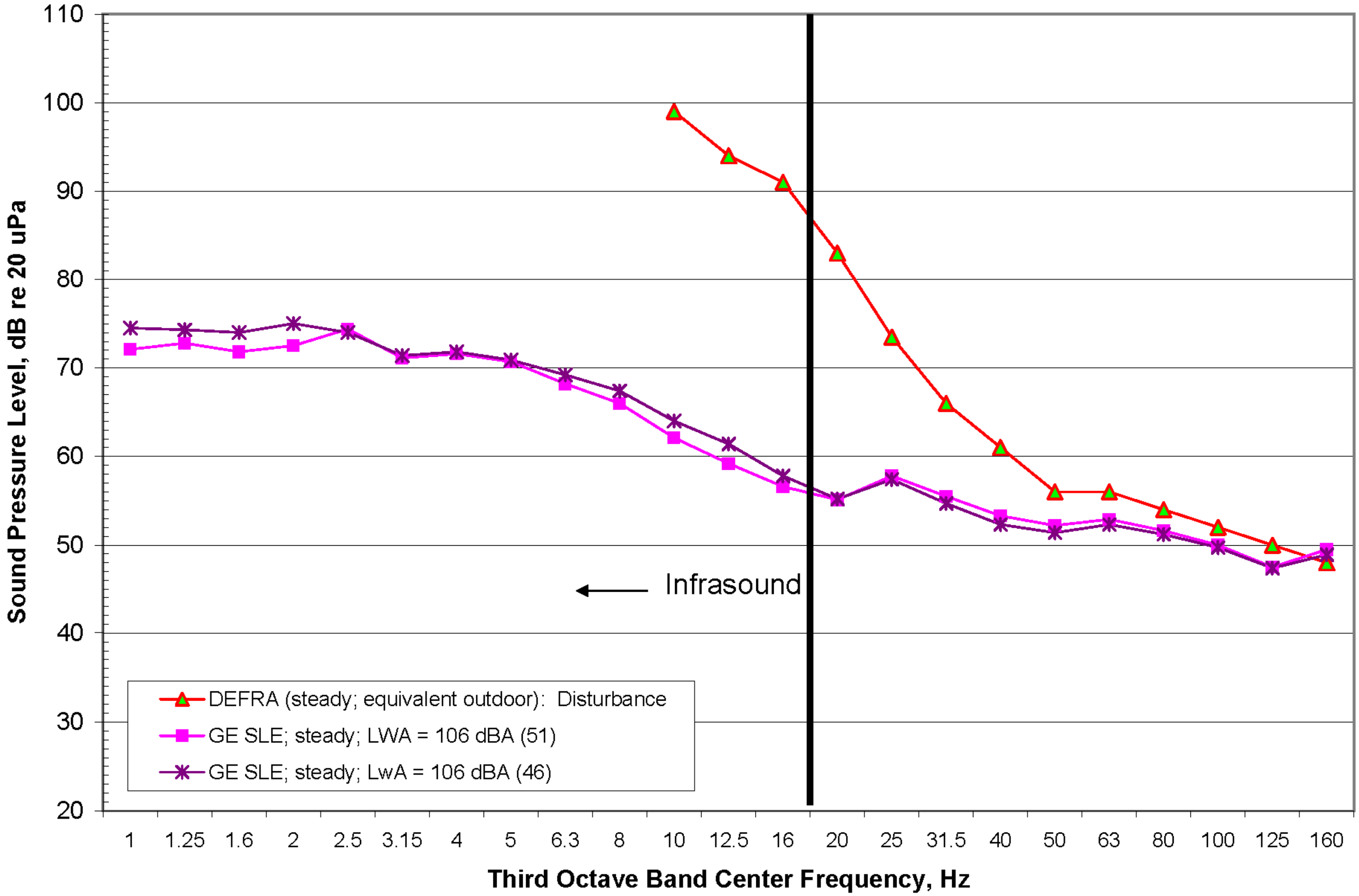


Figure 8.2-3 GE 1.5sle Wind Turbine Outdoor Sound Levels at 1000 feet compared to ANSI Criteria

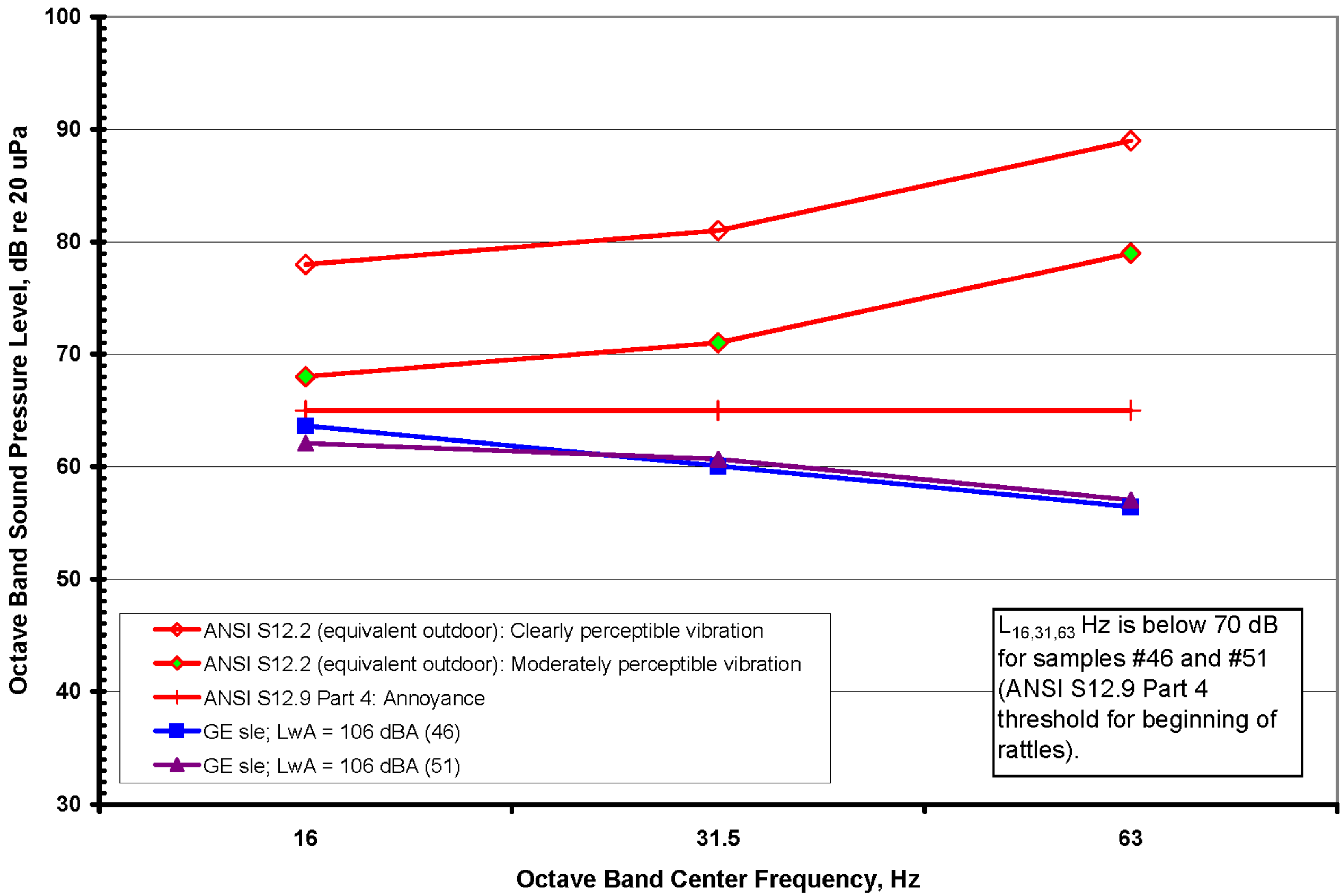


Figure 8.2-4a GE 1.5sle Wind Turbine Indoor Sound Levels at 950 feet compared to Audibility Criteria (Home "B")

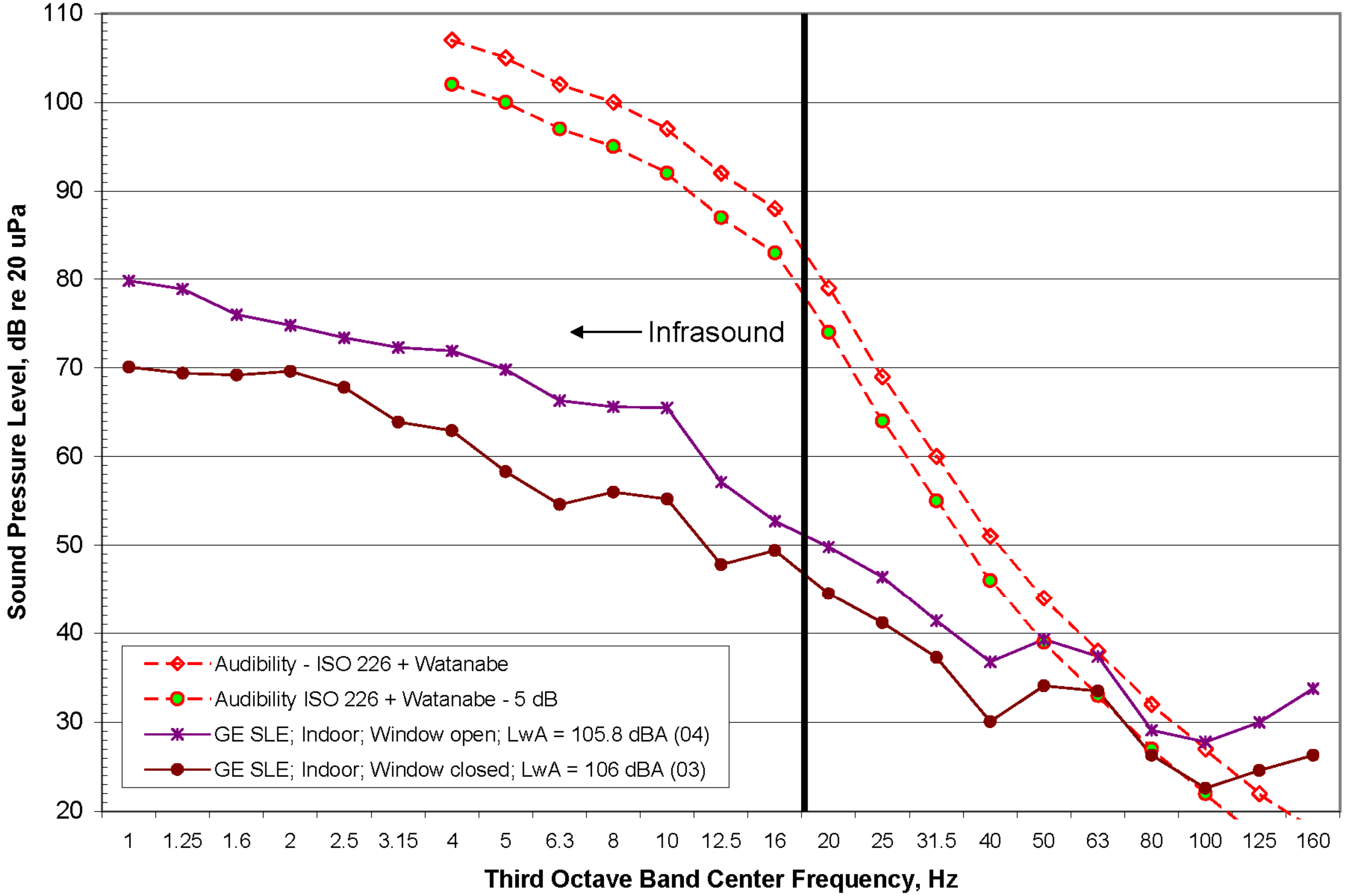


Figure 8.2-4b GE 1.5sle Wind Turbine Indoor Sound Levels at 1025 feet compared to Audibility Criteria (Home "C")

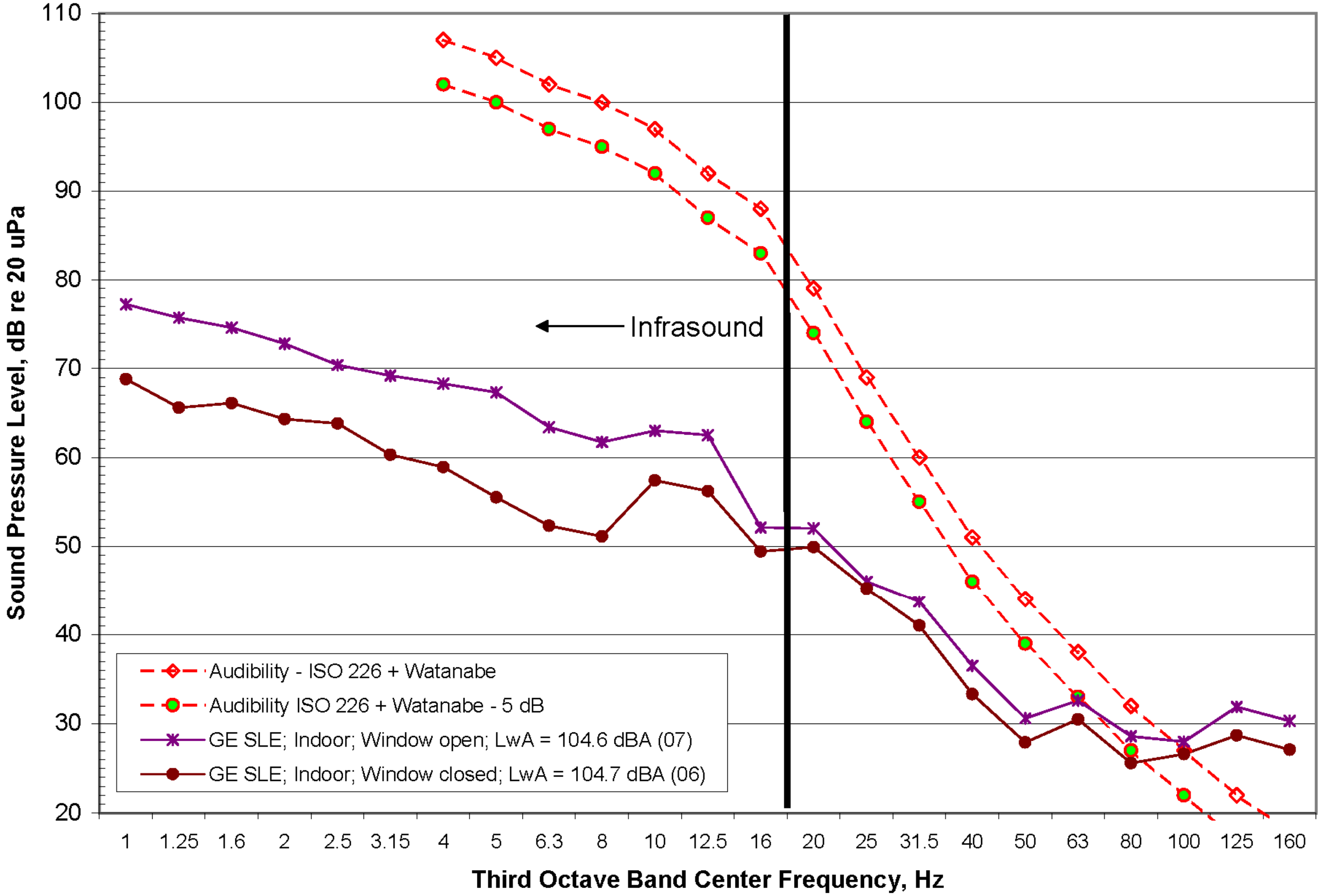


Figure 8.2-5a GE 1.5sle Wind Turbine Indoor Sound Levels at 950 feet compared to DEFRA Criteria (Home "B")

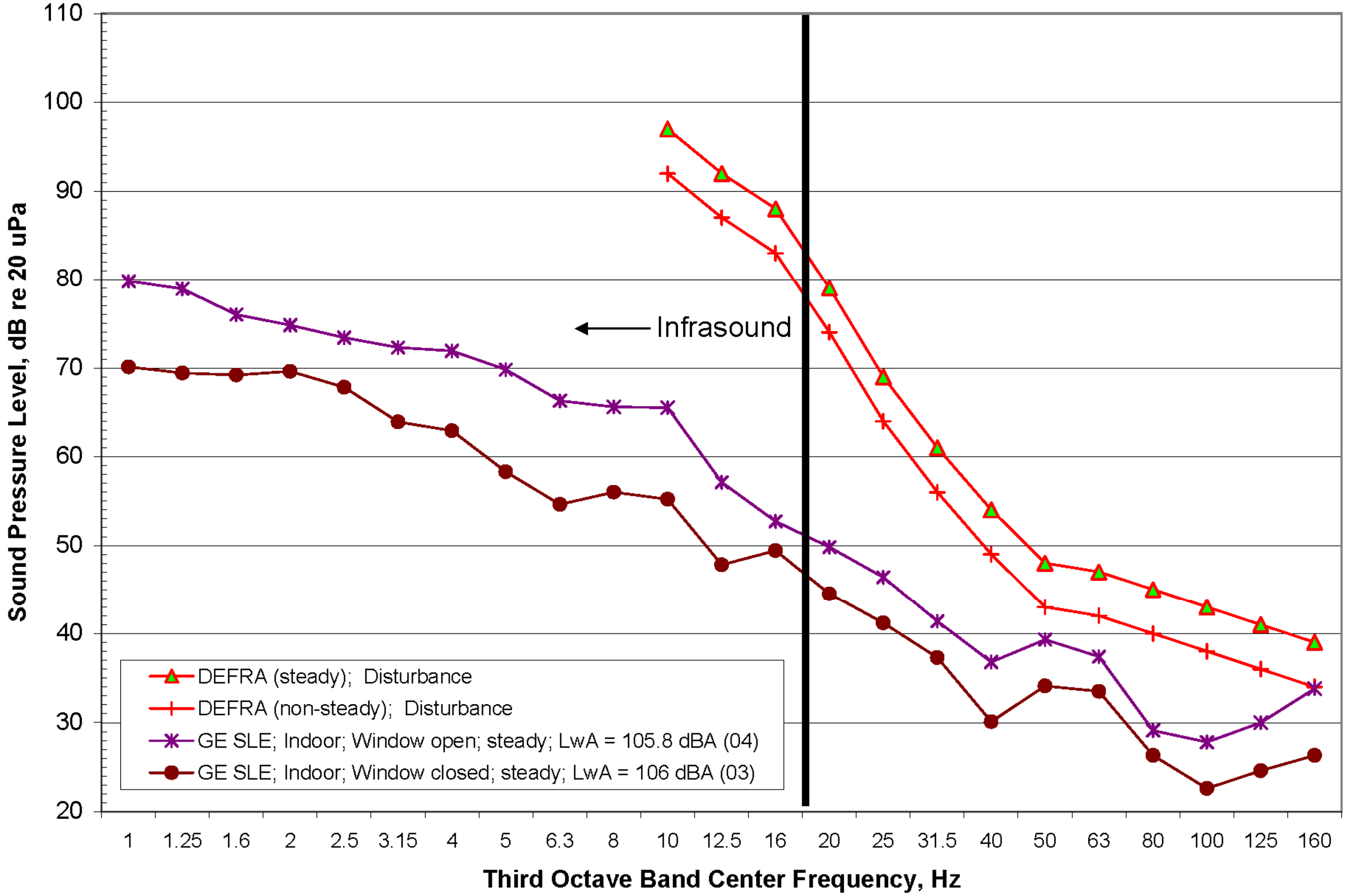


Figure 8.2-5b GE 1.5sle Wind Turbine Indoor Sound Levels at 1025 feet compared to DEFRA Criteria (Home "C")

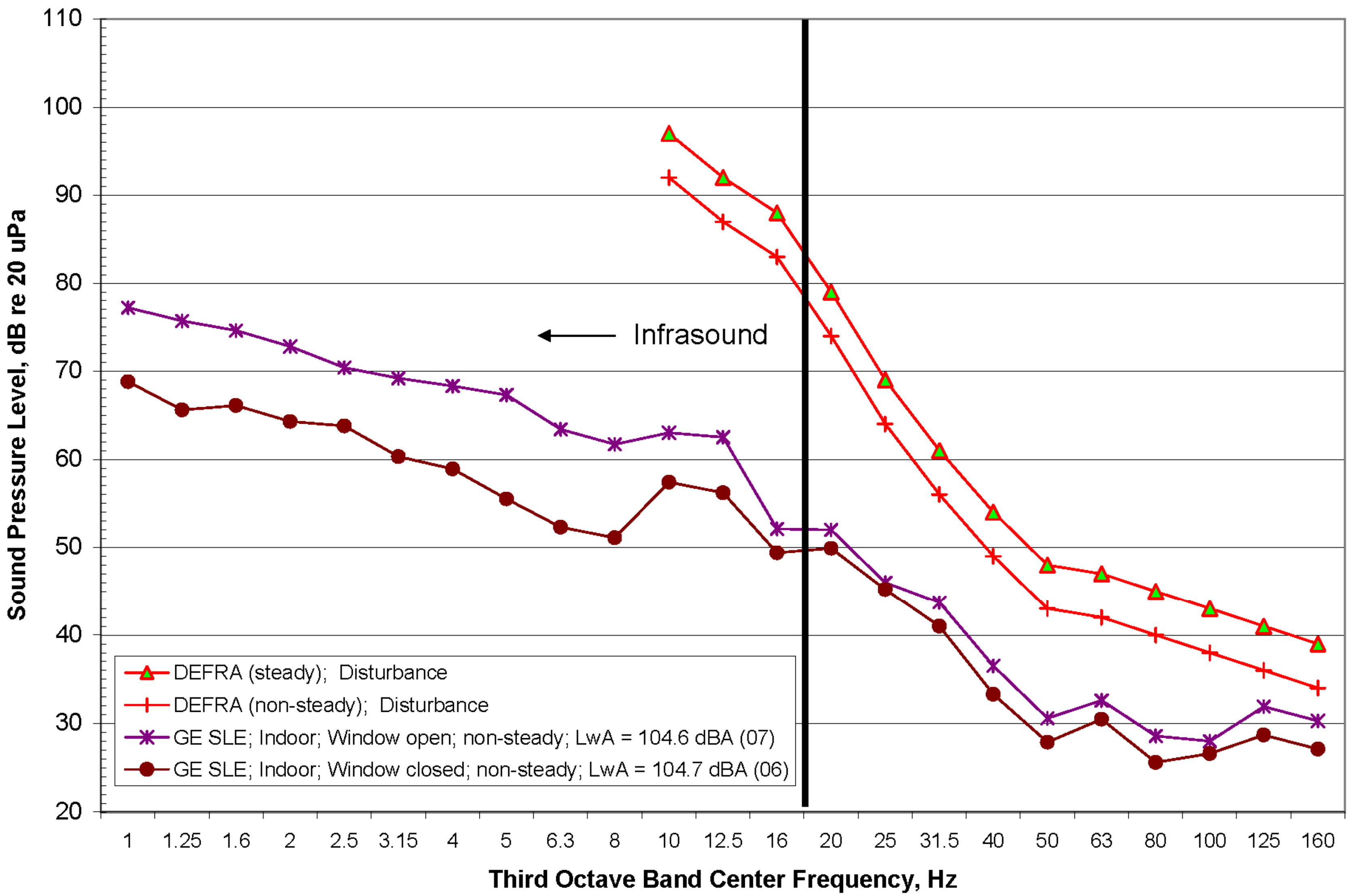


Figure 8.2-6a GE 1.5 sle Wind Turbine Indoor Sound Levels at 950 feet compared to ANSI 12.2 Criteria (Home "B")

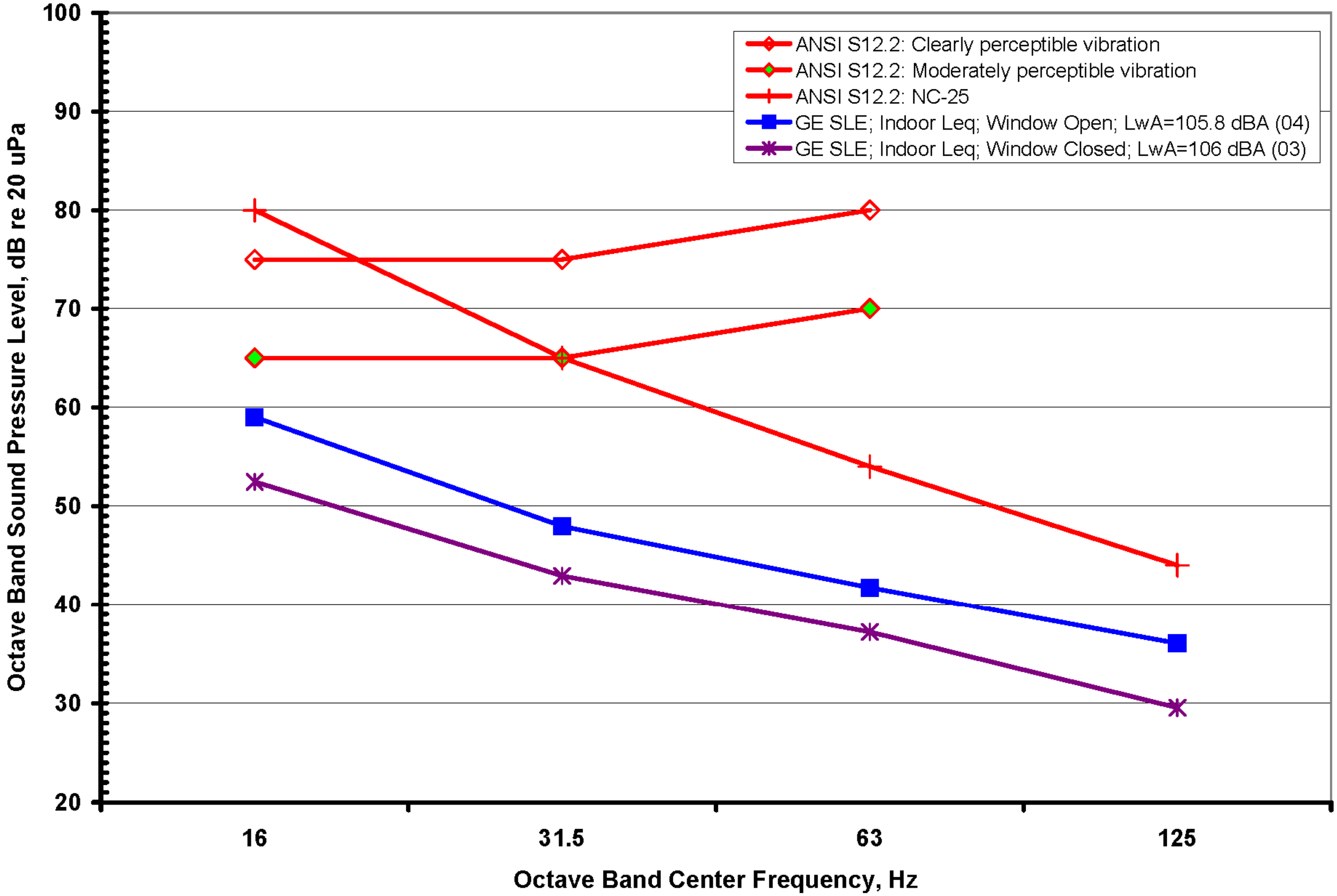


Figure 8.2-6b GE 1.5 sle Wind Turbine Indoor Sound Levels at 1025 feet compared to ANSI 12.2 Criteria (Home "C")

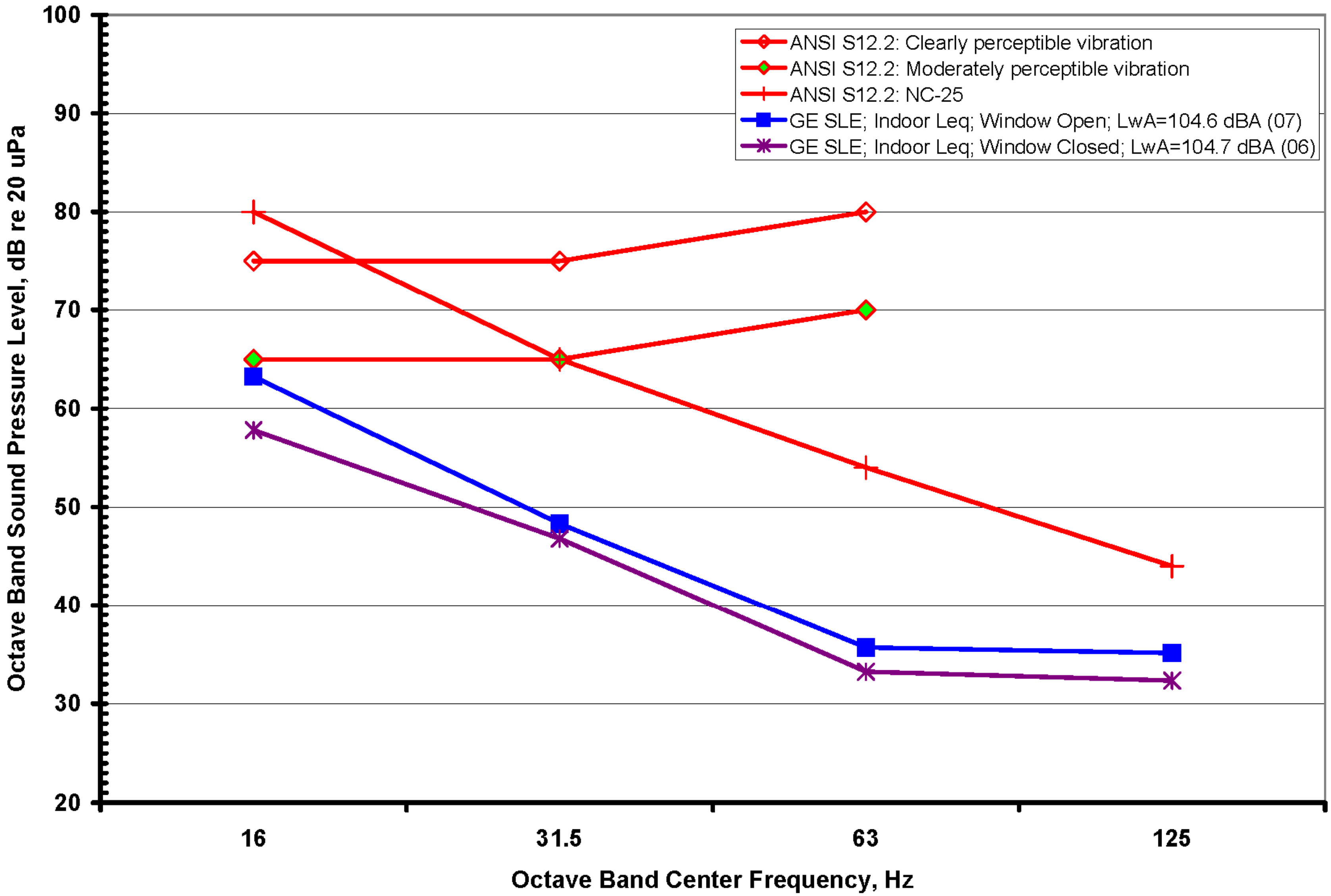


Figure 8.3-1a One-Third Octave Band Interior Noise Reduction – Windows Closed

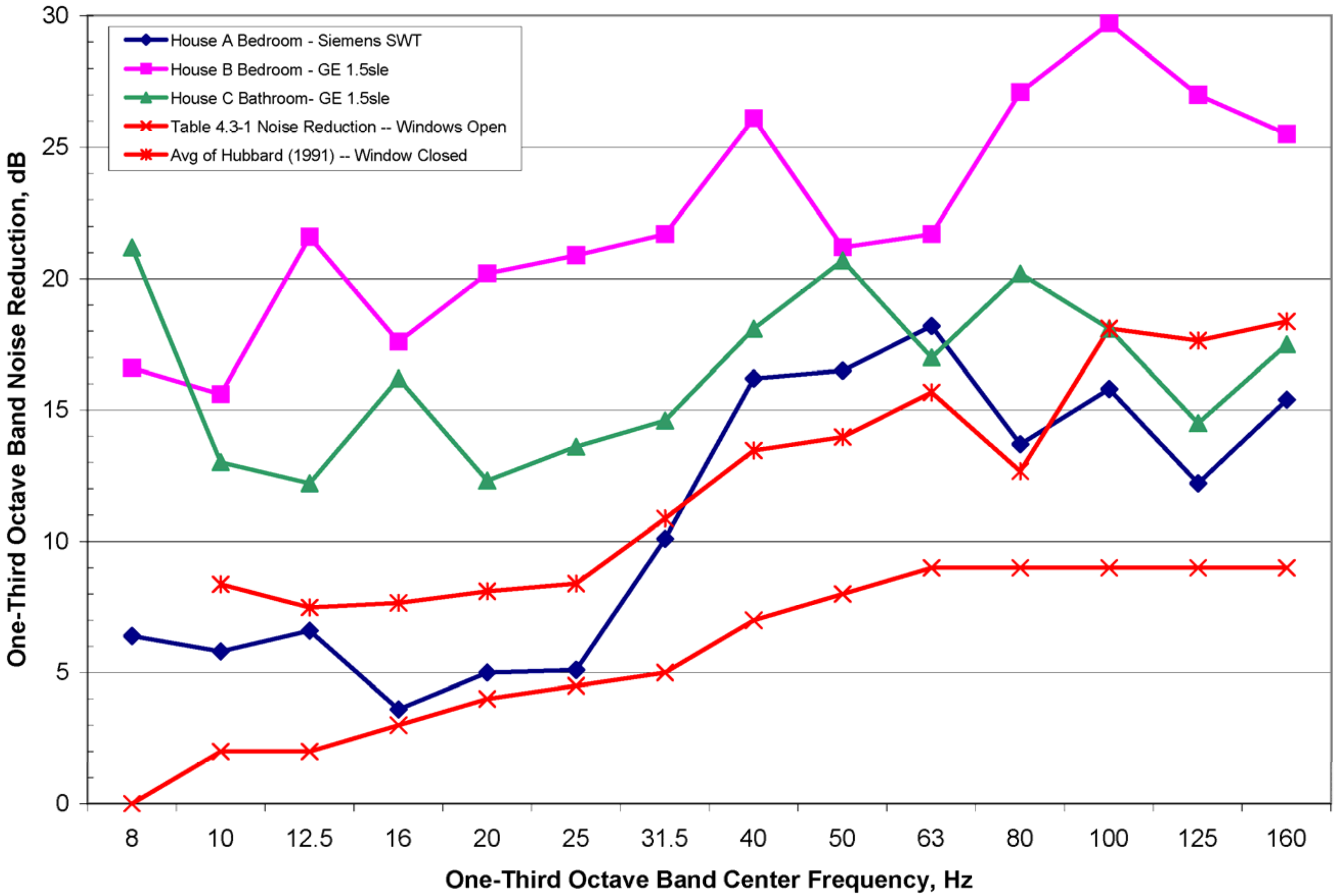
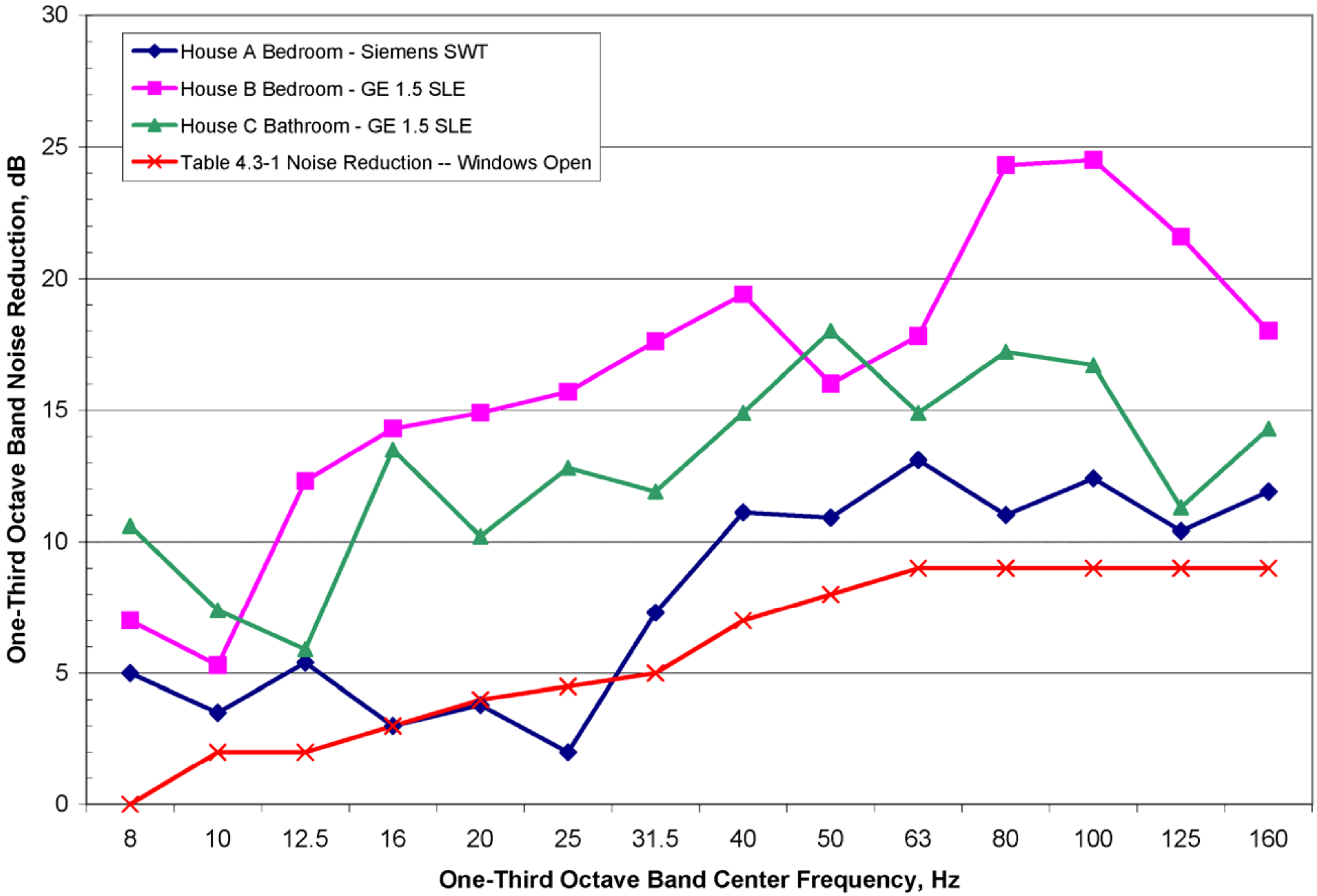


Figure 8.3-1b One-Third Octave Band Interior Noise Reduction – Windows Open



9.0 CONCLUSION

Siemens SWT 2.93-93 and GE 1.5sle wind turbines at maximum noise at a distance more than 1000 feet from the nearest residence do not pose a low frequency noise or infrasound problem. At this distance the wind farms:

- meet ANSI/ASA S12.2 indoor levels for low frequency sound for bedrooms, classrooms and hospitals;
- meet ANSI/ASA S12.2 indoor levels for moderately perceptible vibrations in light-weight walls and ceilings;
- meet ANSI S12.9 Part 4 thresholds for annoyance and beginning of rattles;
- meet UK DEFRA disturbance based guidelines;
- have no audible infrasound to the most sensitive listeners;
- might have slightly audible low frequency noise at frequencies at 50 Hz and above depending on other sources of low frequency noises in homes, such as refrigerators or external traffic or airplanes; and
- meet ANSI S2.71 recommendations for perceptible vibration in residences during night time hours.

In accordance with the above findings, and in conjunction with our extensive literature search of scientific papers and reports, there should be no adverse public health effects from infrasound or low frequency noise at distances greater than 1000 feet from the wind turbine types measured by Epsilon: GE 1.5sle and Siemens SWT 2.3-93.

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Short Communication

A New Approach to Assess Low Frequency Noise in the Working Environment

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Abstract: To assess high-level low frequency noise in the working environment, adverse extra-aural effects caused by the noise should be taken into account. The human body vibration induced by low frequency noise, 'noise-induced vibration', was measured on the body surface and the equal-acceleration level contours of the vibration were tentatively estimated. With these contours, we can predict the magnitude of noise-induced vibration at every measuring position on the body surface. This is helpful in relating the total dosage of low frequency noise with the physical symptoms caused by the noise. But some important points in the contours remain to be investigated and improved. When these points are dealt with, the equal-acceleration level contours will be useful for assessing high-level low frequency noise in the working environment from the standpoint of predicting the adverse extra-aural effects.

Key words: Low frequency noise, Assessment, Human body vibration, Body surface, Acceleration level, Equal-acceleration level contours

Low frequency noise, the frequency of which ranges below 100 Hz, is generated by many machines commonly used in the working environment, such as fans, blowers, compressors, and so on, and the sound pressure level often exceeds 100 dB(SPL)[1]. Low frequency noise hardly impairs the human auditory organs because the human equal-loudness levels are quite high in the frequency range below 100 Hz. Hence, in spite of its prevalent generation and high sound pressure level, low frequency noise has not attracted much attention in the working environment where noise-induced hearing loss is the matter of greatest concern[2].

Apart from adverse effects on the auditory organs, it is known that high-level low frequency noise induces human body vibration, 'noise-induced vibration'. It is speculated that the level of this vibration is not very high, but long-term exposure to it may cause some adverse health effects in a worker. In recent years, Castelo Branco *et al.*[3–7] have reported the extra-aural symptoms found in workers who have been exposed to high-level low frequency noise for more than 10 years and they have called it 'vibroacoustic disease'. Although the causal relationship and the dose-response relationship have not been clarified in detail, the reporters have pointed out that noise-induced vibration is one of the causes of vibroacoustic disease.

To assess high-level low frequency noise in the working environment appropriately, the adverse extra-aural effects should be taken into account, but the A-weighting curve, which is a standardized weighting curve[2] for measuring and assessing noise, and some weighting curves focusing on low frequency noise, such as the LF-weighting curve[8] and the G-weighting curve[9], are not related to the extra-aural effect, because they are designed on the basis of the human psychological and perceptual responses to noise. Thus it is doubtful whether the frequency-weighting characteristics in these existing weighting curves are suitable for assessing the extra-aural effect. It is desirable to establish a new assessing method on the basis of some index which is closely related to the extra-aural effect. Noise-induced vibration may be useful as an index for this. It directly represents the effect of noise on a part of the body where some physical symptom has occurred, and it is expected not to vary in magnitude in long-term exposure to the noise, contrary to any psychological responses

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which may be reduced in magnitude as habituating. These characteristics of noise-induced vibration are helpful in relating the total dosage of the noise in long-term exposure to the physical symptoms caused by the noise.

We measured noise-induced vibration on the body surface and tentatively estimated the equal-acceleration level contours at every measuring position. With these contours we can predict the magnitude of noise-induced vibration on the body surface. Although some important points in the contours remain to be investigated and improved, it is expected that the contours are useful for assessing the adverse physical effects of high-level low frequency noise. In this article, measurement of noise-induced vibration and estimation of the equal-acceleration level contours are reported.

Nine healthy male subjects whose ages ranged from 24 to 57 (mean=37.0, SD=12.5) participated in the study. We selected five measuring positions on the body surface of a standing subject: on the right anterior chest (2 cm above the right nipple), on the left anterior chest (2 cm above the left nipple), on the right anterior abdomen (5 cm under the pit of the stomach, and 5 cm to the right of the midline), on the left anterior abdomen (5 cm under the pit of the stomach, and 5 cm to the left of the midline), and on the forehead (2 cm above the level of the eyebrow, and on the midline).

The measuring method was approved by the ethics committee of the National Institute of Industrial Health, and before the measurements informed consent was obtained from each subject.

The measurements were carried out in a sound-proof test chamber the capacity of which was 3.16 m × 2.85 m × 2.8 m[10]. The temperature in the test chamber was initially set at 25 °C at the subject's position and, if he complained, adjusted to within the 23–27 °C range in order to prevent him from sweating. The humidity in the test chamber was maintained at about 40% with a humidifier. To prevent changing the local vibrating system at the measuring position, we used a small (3.56 mm × 6.86 mm × 3.56 mm) and lightweight (0.5 g) accelerometer (EGA-125-10D, Entran, USA), with which we detected the vibration perpendicular to the body surface[11]. After being low-pass filtered and amplified with a strain amplifier (6M92, NEC San-ei Instruments, Japan), the output signal of the accelerometer was recorded on DAT by a multi-channel data recorder (PC216Ax, Sony Precision Technology, Japan).

Fifteen kinds of low frequency noise stimuli (5 frequencies × 3 sound pressure levels) were reproduced by 12 loudspeakers (TL-1801, Pioneer, Japan) installed in the wall in front of the subject. All the noise stimuli were pure tones the frequencies of which were 20, 25, 31.5, 40 and 50 Hz, and the sound pressure levels of which were 100, 105 and 110 dB (SPL). No noise stimulus in the frequency range higher than 50 Hz was used because the spatial uniformity of the sound pressure levels in the test chamber would deteriorate[10]. Noise stimuli lower than 20 Hz were not used because the noise-induced vibration was not distinguishable from the vibration inherent in the body surface[11].

The subject wore no clothes on the upper half of the body in order to allow the accelerometers to be attached. For the first measurement, inherent body surface vibration was recorded for 1 min with no noise stimulus. Fifteen kinds of noise stimuli were then used in random order for every subject. The duration of each exposure was 1 min, when the noise-induced vibration was recorded. Between any two recording periods, a rest period (1 min) with neither noise stimulus nor recording was assigned.

Analysis with an FFT analyzer (HP3566A, Hewlett Packard, USA) yielded the power spectrum of the vibration measured for every measuring position and every noise stimulus. A spectral component at the frequency of the noise stimulus was transformed to an acceleration level, AL, defined as[12]

$$AL = 20\log_{10} (a_{meas}/a_{ref}).$$

Here a_{meas} is the measured acceleration (m/s^2(r.m.s.)) and a_{ref} is the reference acceleration equal to 10^{-5} m/s^2.

At all the measuring positions, the acceleration level of noise-induced vibration was found to increase with the frequency of the noise stimulus. On the other hand, the acceleration level of the inherent vibration was found to decrease as the frequency increased. It was supposed from this that the noise-induced vibration measured in the lower frequency range was more contaminated by the inherent vibration. Accordingly, the acceleration levels measured at 20 Hz were neglected in estimating the equal-acceleration level contours. The increase step in the measured acceleration levels was found to be about 5 dB, which was in good agreement with the increase step (5 dB(SPL)) in the sound pressure levels of the noise stimuli. This proper characteristic of noise-induced vibration was utilized in the following estimation.

In estimating the equal-acceleration level contours, we assumed that noise-induced vibration was a minute one-dimensional oscillation perpendicular to the body surface. Because the measured acceleration, a_{meas}, is a time-averaged one, it is generally expressed as

$$a_{meas} = \omega^2 A(\omega)/\sqrt{[(\omega_0^2 - \omega^2)^2 + (2\zeta\,\omega_0\omega)^2]}.$$

Here ω, ω_0, ζ, and $A(\omega)$ denote an angular frequency, a natural angular frequency, a damping ratio, and a frequency-dependent amplitude, respectively. The angular frequency is equal to the frequency multiplied by 2π. If the denominator in the above formula is equal to 1, the vibration has no resonance. According to the definition mentioned before, the measured acceleration level (AL) is expressed as

$$AL = 40\log_{10}(\omega) + 20\log_{10}(A(\omega)) - 10\log_{10}[(\omega_0^2 - \omega^2)^2 + (2\zeta\omega_0\omega)^2] + (\text{Constant term}).$$

In this expression, ω_0, $A(\omega)$, and ζ remain unknown.

It has been reported that the acoustic transfer function in the chest is at its maximum in the frequency range higher than 100 Hz[13], which suggests that the noise-induced vibration measured on the chest has no resonance in the 25–50 Hz range. And it is known that the resonance frequencies of the internal organs, such as the stomach, are lower than 10 Hz[14]. Accordingly, for noise-induced vibration measured on the chest and abdomen, we assumed that the effect of resonance was negligible in the 25–50 Hz range. We also assumed that the effect of $A(\omega)$ was negligible in this narrow frequency range. Consequently, with a frequency (f) instead of an angular frequency (ω) we adopted an approximate curve,

$$AL = C_1\log_{10}(f) + SPL + C_2,$$

for the acceleration level (AL) measured on the chest and abdomen. Here C_1 and C_2 were regression coefficients. The C_1s were not necessarily equal to 40 to compensate for neglecting the $A(\omega)$ and the resonance term. To introduce the proper characteristic of noise-induced vibration, we incorporated the sound pressure level (SPL) of the noise stimulus in the above formula.

With respect to the acceleration level measured on the forehead, the rate of increase with frequency was found to suddenly increase in the 40–50 Hz range. This feature was consistent with the resonance-like behavior found in the vibration transmissibility in the human head[15]. Assuming that the noise-induced vibration measured on the forehead had a resonance at 50 Hz and that this resonance dominated the behavior of the vibration in the 25–50 Hz range, we adopted an approximate curve,

$$AL = 40\log_{10}(f) - 10\log_{10}[(50^2 - f^2)^2 + (C_3 f)^2] + SPL + C_4,$$

for the acceleration level, AL, measured on the forehead. Here C_3 and C_4 were regression coefficients. The sound pressure level (SPL) of the noise stimulus was also incorporated in this formula.

To reduce the effect of the inherent vibration, we utilized the proper characteristic of noise-induced vibration. The regression coefficients, C_1s, C_2s C_3 and C_4, were determined with the acceleration levels measured for the 110 dB(SPL) stimulus, and we appropriated the same coefficients for 105 and 100 dB(SPL) stimuli.

In Fig. 1, as an example, the approximate curves obtained on the left chest and on the forehead are shown with the mean measured acceleration levels. In Tables 1 and 2, the C_1s C_2s C_3, C_4 and the coefficients of determination (r^2) obtained in the above approximation are listed. Almost all of the r^2s were larger than 0.8, which showed that these approximations were valid in spite of the rough procedure. It was speculated that the smaller r^2s for the lower sound pressure levels were due to contamination by the vibration inherent in the human body.

Finally, the equal-acceleration level contours estimated at the 5 measuring positions were expressed as

$$SPL = -50\log_{10}(f) + (AL_{chest(R)} + 109),$$
$$SPL = -50\log_{10}(f) + (AL_{chest(L)} + 110),$$
$$SPL = -23\log_{10}(f) + (AL_{abdomen(R)} + 71),$$
$$SPL = -34\log_{10}(f) + (AL_{abdomen(L)} + 87)$$

and

$$SPL = -40\log_{10}(f) + 10\log_{10}[(50^2 - f^2)^2 + (11f)^2] + (AL_{forehead} + 44),$$

respectively. In these formulae, 'R' denotes the right half of the body and 'L' denotes the left. These contours are depicted in Fig. 2. In spite of the right-left differences between the regression coefficients (Table 1), two contours estimated on both sides of the body corresponded well in the 25–50 Hz range.

The gradients with frequency in the estimated equal-acceleration level contours are regarded as frequency-weighting gradients when their signs are reversed. The frequency-weighting gradients are about 15 dB/oct. on the chest, about 10 dB/oct. on the abdomen, and about 20 dB/oct. on the forehead, respectively. These gradients, except for one obtained on the abdomen, are equal to or steeper than the gradient in the existing weighting curves: about 15 dB/oct. (25–50 Hz) in the A-weighting curve, about 13.5 dB/oct. (20–50 Hz) in the LF-weighting curve[8], and about 12 dB/oct. (1–20 Hz) in the G-weighting curve[9]. This simple comparison seems to show that noise in the lower frequency range is more severely assessed with the LF-weighting curve and the G-weighting curve than with the equal-acceleration level contours.

Nevertheless, the equal-acceleration level contours have one important advantage: with the contours we can predict

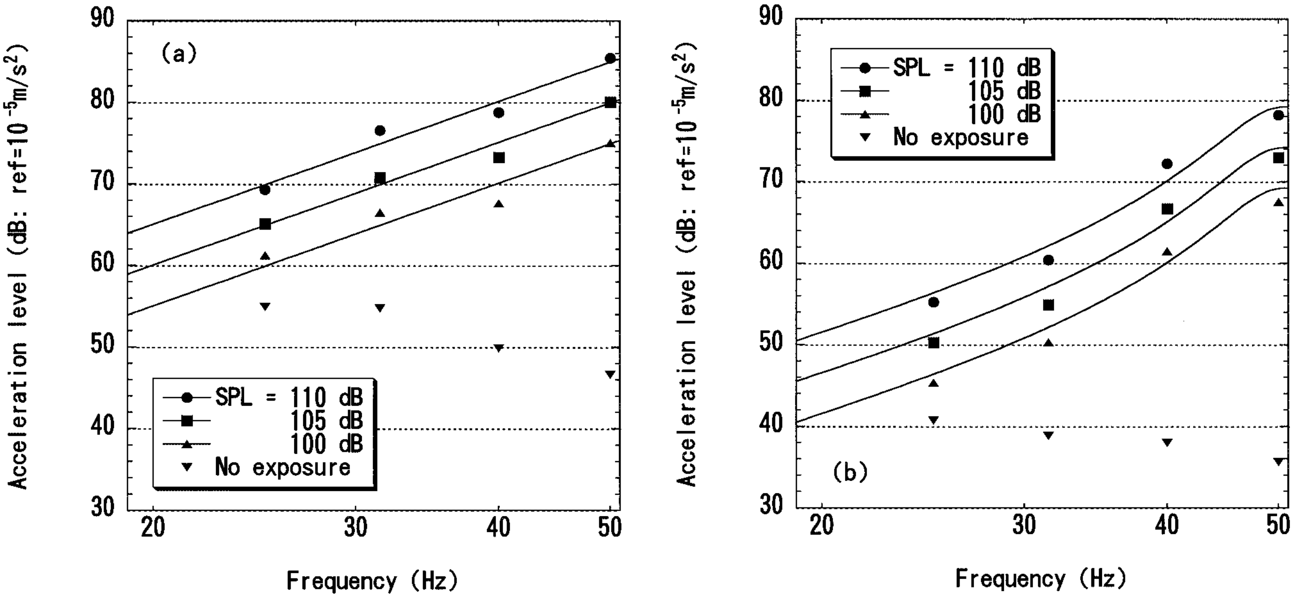


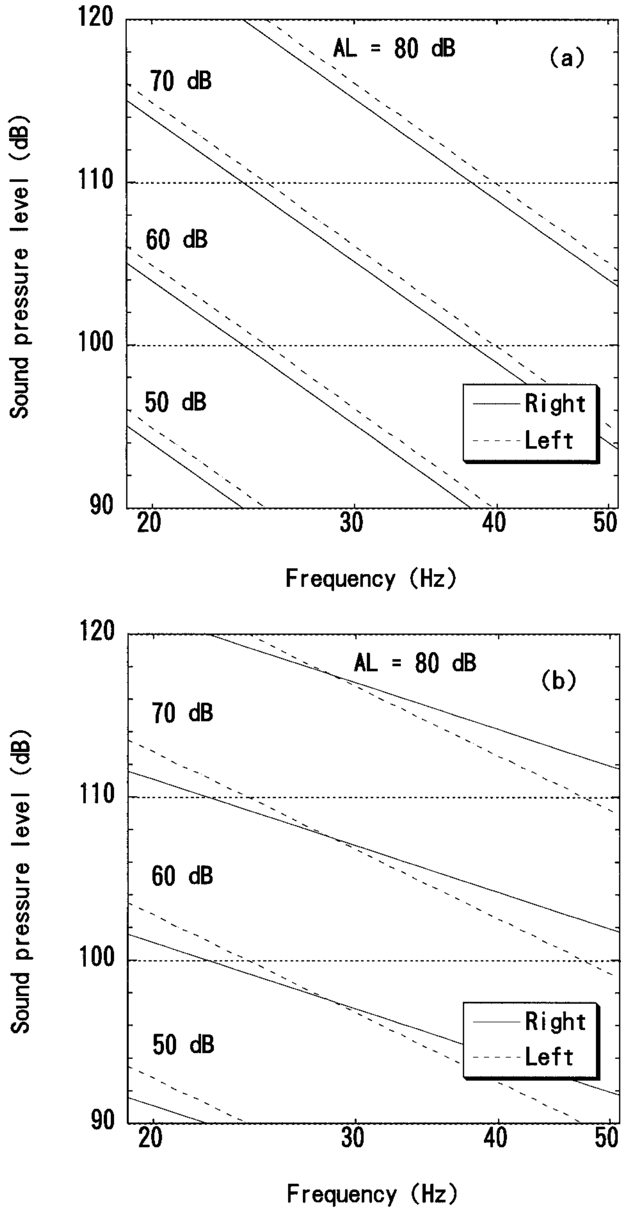
Fig. 1 The mean measured acceleration levels and the approximate curves. (a) On the left chest, and (b) on the forehead.

Table 1. The regression coefficients (C_1 and C_2) and the coefficients of determination (r^2) for the approximate curves obtained on the chest and abdomen.

Measuring positions		Sound pressure levels (dB(SPL))	C_1 (dB)	C_2 (dB)	r^2
Chest	Right	110	50	–109	0.956
		105			0.983
		100			0.952
	Left	110	50	–110	0.980
		105			0.982
		100			0.945
Abdomen	Right	110	23	–71	0.888
		105			0.868
		100			0.849
	Left	110	34	–87	0.853
		105			0.808
		100			0.772

Table 2. The regression coefficients (C_3 and C_4) and the coefficients of determination (r^2) for the approximate curves obtained on the forehead.

Measuring positions	Sound pressure levels (dB(SPL))	C_3 (dB)	C_4 (dB)	r^2
Forehead	110	11	–44	0.985
	105			0.984
	100			0.985



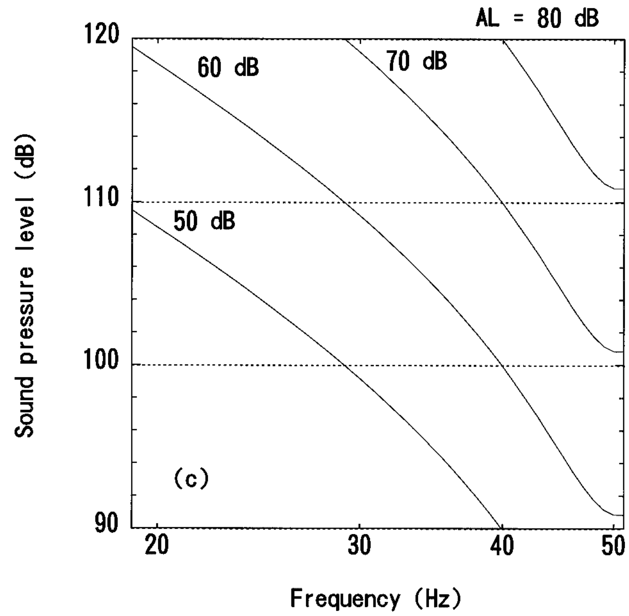


Fig. 2 The estimated equal-acceleration level contours. (a) On the right and left chest, (b) on the right and left abdomen and (c) on the forehead. On the chest and abdomen, solid lines represent the contours obtained for the right half of the body and dotted lines for the left.

the magnitude of noise-induced vibration at every measuring position on the body surface. In general, the physical effects caused by vibration are position-dependent, because robustness and susceptibility to vibration depend on the characteristics specific to each position. With respect to vibroacoustic disease, for example, many symptoms have been found in the chest[5–7], which suggests that the chest has a higher risk of vibroacoustic disease than other parts of the human body. This is consistent with our results showing that the noise-induced vibration measured on the chest is higher than the vibration measured on other parts of the human body. The position-dependent predictability with the equal-acceleration level contours is expected to contribute to assessing high-level low frequency noise from the standpoint of predicting the position-dependent risk of adverse extra-aural effects.

Some important points in the estimated contours remain to be investigated and improved. First of all it is necessary to estimate the contours in the wider range of both frequency and the sound pressure level. With respect to frequency, it is desired for practical use that the contours are applicable in the frequency range up to 100 Hz. With respect to the applicable sound pressure level range, the lower boundary level does not need to be very low, because the extra-aural effect caused by low frequency noise is less important at lower sound pressure levels. But it is desirable for practical use that the contours be available in a range higher than about 80 dB (SPL). Secondly, it is desired to clarify the precise relationship between the vibrations induced on the body surface and in the inner body. This is essentially important for assessing adverse health effects such as vibroacoustic disease. When this relationship is clarified, we can predict the noise-induced vibration in the inner body with the equal-acceleration level contours. Finally, it is desired to establish the precise dose-response relationship between the noise-induced vibration and the degree of the extra-aural symptoms caused by low frequency noise. If this relationship is established, we can directly predict the risk of the adverse extra-aural effects such as vibroacoustic disease with the equal-acceleration level contours.

When these matters are clarified, the equal-acceleration level contours will be useful in assessing high-level low frequency noise in the working environment from the standpoint of predicting the adverse extra-aural effects. Together with the existing evaluating curves, low frequency noise will be measured and assessed from more different points of view.

Acknowledgments

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Wind Turbine Acoustic Noise

A white paper

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Introduction

Wind turbines generate sound via various routes, both mechanical and aerodynamic. As the technology has advanced, wind turbines have gotten much quieter, but sound from wind turbines is still an important siting criterion. Sound emissions from wind turbine have been one of the more studied environmental impact areas in wind energy engineering. Sound levels can be measured, but, similar to other environmental concerns, the public's perception of the acoustic impact of wind turbines is, in part, a subjective determination.

Noise is defined as any unwanted sound. Concerns about noise depend on:

1. the level of intensity, frequency, frequency distribution and patterns of the noise source;
2. background sound levels;
3. the terrain between the emitter and receptor
4. the nature of the receptor; and
5. the attitude of the receptor about the emitter.

In general, the effects of noise on people can be classified into three general categories:

1. Subjective effects including annoyance, nuisance, dissatisfaction
2. Interference with activities such as speech, sleep, and learning
3. Physiological effects such as anxiety, tinnitus, or hearing loss.

In almost all cases, the sound levels associated with wind turbines large & small produce effects only in the first two categories, with *modern* turbines typically producing only the first. The third category includes such situations as work inside industrial plants and around aircraft. Whether a sound is objectionable will depend on the type of sound (tonal, broadband, low frequency, or impulsive) and the circumstances and sensitivity of the person (or receptor) who hears it. Because of the wide variation in the levels of individual tolerance for noise, there is no completely satisfactory way to measure the subjective effects of noise or of the corresponding reactions of annoyance and dissatisfaction.

Operating sound produced from wind turbines is considerably different in level and nature than most large scale power plants, which can be classified as industrial sources. Wind turbines are often sited in rural or remote areas that have a corresponding ambient sound character. Furthermore, while noise may be a concern to the public living near wind turbines, much of the sound emitted from the turbines is masked by ambient or the background sounds of the wind itself.

The sound produced by wind turbines has diminished as the technology has improved. As blade airfoils have become more efficient, more of the wind energy is converted into rotational energy, and less into acoustic energy. Vibration damping and improved mechanical design have also significantly reduced noise from mechanical sources.

The significant factors relevant to the potential environmental impact of wind turbine noise are shown in Figure 1 [Hubbard and Shepherd, 1990]. Note that all acoustic technology is based on the following primary elements: Sound sources, propagation paths, and receivers. In the following sections, after a short summary of the basic principles of sound and its measurement, a review of sound generation from wind turbines, sound propagation, as well as sound prediction methods is given.

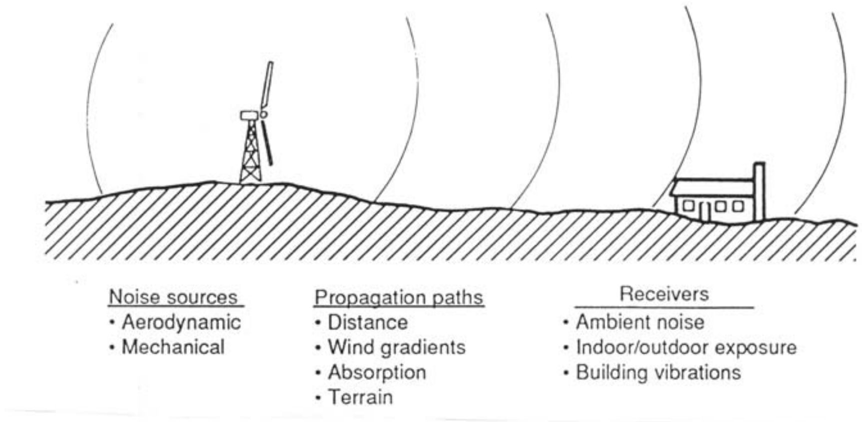

Figure 1: Examples of sources, receivers, and propagation paths

Noise and Sound Fundamentals

Sound and Noise

Sounds are characterized by their magnitude (loudness) and frequency. There can be loud low frequency sounds, soft high frequency sounds and loud sounds that include a range of frequencies. The human ear can detect a very wide range of both sound levels and frequencies, but it is more sensitive to some frequencies than others.

Sound is generated by numerous mechanisms and is always associated with rapid small scale pressure fluctuations, which produce sensations in the human ear. Sound waves are characterized in terms of their amplitude or magnitude (see below), wavelength (λ), frequency (f) and velocity (v), where v is found from:

$$v = f\lambda$$

The velocity of sound is a function of the medium through which it travels, and it generally travels faster in more dense mediums. The velocity of sound is about 340 m/s (1115 ft/s) in air at standard pressures.

Sound frequency denotes the “pitch” of the sound and, in many cases, corresponds to notes on the musical scale (Middle C is 262 Hz). An octave is a frequency range between a sound with one frequency and one with twice that frequency, a concept often used to define ranges of sound frequency values. The frequency range of human hearing is quite wide, generally ranging from about 20 to 20 kHz (about 10 octaves). Finally, sounds experienced in daily life are usually not a single frequency, but are formed from a mixture of numerous frequencies, from numerous sources.

Sound turns into noise when it is unwanted. Whether sound is perceived as a noise depends on subjective factors such as the amplitude and duration of the sound. There are numerous physical quantities that have been defined which enable sounds to be compared and classified, and which also give indications for the human perception of sound. They are discussed in numerous texts on the subject (e.g., for wind turbine sound see Wagner, et al., 1996) and are reviewed in the following sections.

Measurement Scales: Sound Power, Pressure and Intensity

It is important to distinguish between the various measures of the magnitude of sounds: sound power level and sound pressure level. Sound power level is the power per unit area of the sound pressure wave; it is a property of the source of the sound and it gives the total acoustic power emitted by the source. Sound pressure is a property of sound at a given observer location and can be measured there by a single microphone.

Because of the wide range of sound pressures to which the ear responds (a ratio of 10^5 or more for a normal person), sound pressure is an inconvenient quantity to use in graphs and tables. In addition, the human ear does not respond linearly to the amplitude of sound pressure, and, to approximate it, the scale used to characterize the sound power or pressure amplitude of sound is logarithmic [see Beranek and Ver, 1992]. Whenever the magnitude of an acoustical quantity is given in a logarithmic form, it is said to be a level in decibels (dB) above or below a zero reference level.

Sound intensity, I, is defined as the power of the sound per unit area, and so can be measured in watts/m^2, but is more commonly measured in units of decibels, as:

$$I = 10 \log_{10}\left(-I/I_0\right)$$

where the reference intensity, I_0, is often the threshold of hearing at 1000 Hz: $I_0 = 10^{-12}$ W/m^2.

Because audible sound consists of pressure waves, sound power is also quantifiable by its relation to a reference pressure. The sound power level of a source, L_W, in units of decibels (dB), and is given by:

$$L_W = 10 \log_{10}\left(P/P_0\right)$$

with P equal to the sound power level in units of power density and P_0 a reference sound power (often $P_0 = 2 \times 10^{-5}$ N/m^2).

The sound pressure level (SPL) of a sound, L_P, in units of decibels (dB), is given by:

$$L_p = 20 \log_{10}\left(p/p_0\right)$$

with p equal to the effective (or root mean square, RMS) sound pressure and p_0 a reference RMS sound pressure (usually 2×10^{-5} Pa). [See Nave, 2005. This Hyperphysics website, by Georgia State University, is an excellent introduction to sound and hearing.]

The human response to sounds measured in decibels has the following characteristics:

- Except under laboratory conditions, a change in sound level of 1 dB cannot be perceived.
- Doubling the energy of a sound source corresponds to a 3 dB increase

- Outside of the laboratory, a 3 dB change in sound level is considered a barely discernible difference.
- A change in sound level of 5 dB will typically result in a noticeable community response.
- A 6 dB increase is equivalent to moving half the distance towards a sound source
- A 10 dB increase is subjectively heard as an approximate doubling in loudness
- The threshold of pain is an SPL of 140 dB

Figure 2 illustrates the relative magnitude of common sounds on the dB scale. For example, The threshold of pain for the human ear is about 200 Pa, which has an SPL value of 140 dB.

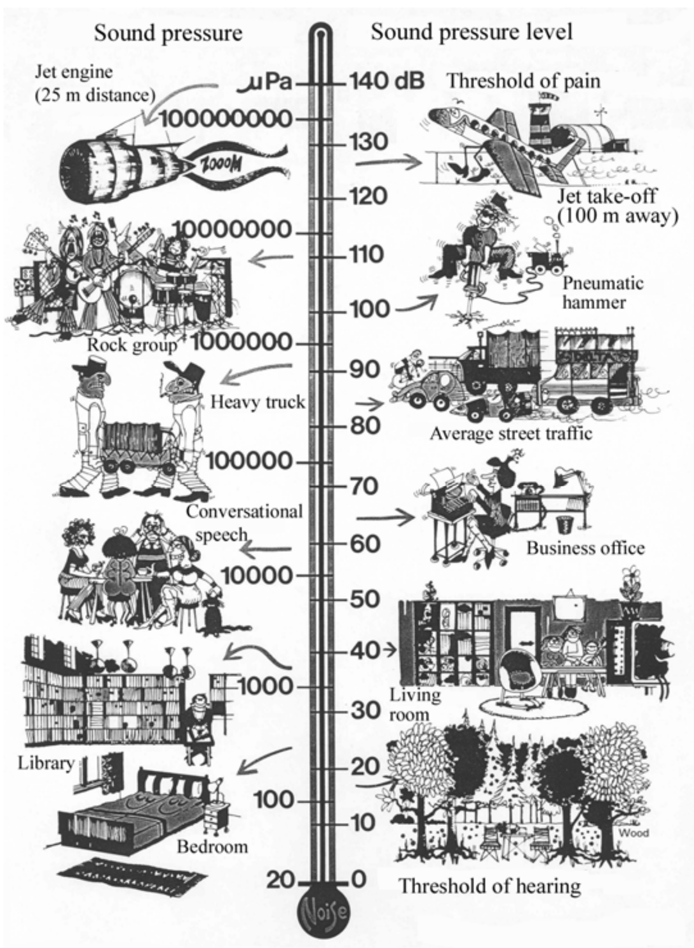

Figure 2: Sound Pressure Level (SPL) Examples (Bruel and Kjaer Instruments)

Measurement of Sound or Noise

Sound pressure levels are measured via the use of sound level meters. These devices make use of a microphone that converts pressure variations into a voltage signal which is then recorded on a meter (calibrated in decibels). As described above, the decibel scale is logarithmic. A sound level measurement that combines all frequencies into a single weighted reading is defined as a broadband sound level. For the determination of the human ear's response to changes in sound, sound level meters are generally equipped with filters that give less weight to the lower frequencies. As shown in Figure 3, there are a number of filters that accomplish this:

- A-Weighting: This is the most common scale for assessing environmental and occupational noise. It approximates the response of the human ear to sounds of medium intensity.
- B-Weighting: this weighting is not commonly used. It approximates the ear for medium-loud sounds, around 70 dB.
- C-Weighting: Approximates response of human ear to loud sounds. It can be used for low-frequency sound.
- G-Weighting: Designed for infrasound

The weighting is indicated in the unit, e.g. measurements made using A-weighting are expressed in units of dB(A). Details of these scales are discussed by Beranek and Ver [1992].

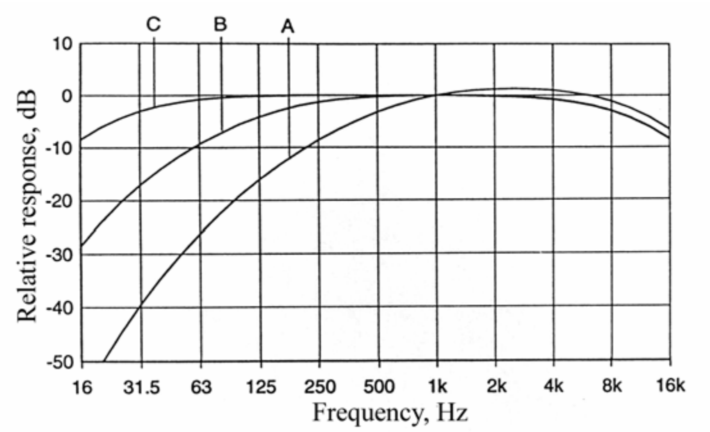

Figure 3: Definition of A, B, and C Frequency Weighing Scales [Beranek and Ver, 1992]

Once the A-weighted sound pressure is measured over a period of time, it is possible to determine a number of statistical descriptions of time-varying sound and to account for the greater community sensitivity to nighttime sound levels. Terms commonly used in describing environmental sound include:

- L_{10}, L_{50}, and L_{90}: The A-weighted sound levels that are exceeded 10%, 50%, and 90% of the time, respectively. During the measurement period L90 is generally taken as the background sound level.
- L_{eq}: *Equivalent Sound Level:* The average A-weighted sound pressure level which gives the same total energy as the varying sound level during the measurement period of time. Also referred to as $L_{A\ eq}$.
- L_{dn}: *Day-Night Level:* The average A-weighted sound level during a 24 hour day, obtained after addition of 10 dB to levels measured in the night between 10 p.m. and 7 a.m.

dB Math

From the comments above it can be seen that decibels do not add numerically as linear measures of other physical things do. Figure 4 shows how to add the decibels of two sound sources that are within 12 dB of each other.

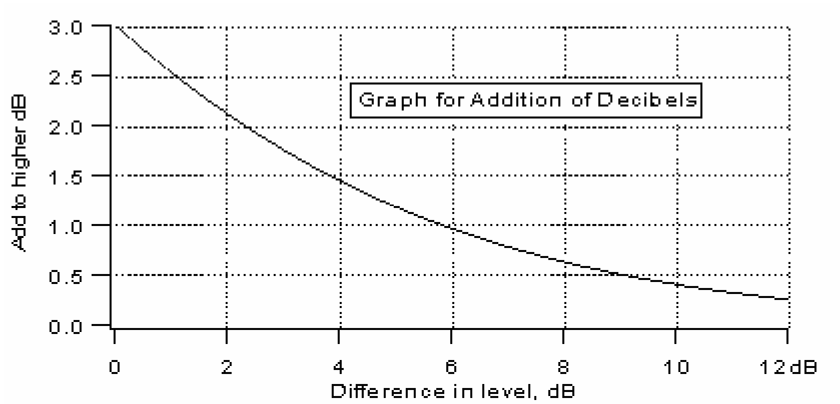

Figure 4: Addition of two sound levels.

For example, when adding two sound sources together, one being 9.5 dB(A) louder than the second, the resultant is approximately 10 dB(A) louder than the second source. It can be seen that when the sound from two sources more than 10 dB(A) apart are combined, the total sound pressure level in decibels is very close to the louder one, with little or no contribution from the softer sound.

Infrasound & Low Frequency Sound

Terminology: Low frequency pressure vibrations are typically categorized as *low frequency sound* when they can be heard near the bottom of human perception (10-200 Hz), and *infrasound* when they are below the common limit of human perception. Sound below 20 Hz is generally considered infrasound, even though there may be some human perception in that range. Because these ranges overlap in these ranges, it is important to understand how the terms are intended in a given context.

Infrasound is always present in the environment and stems from many sources including ambient air turbulence, ventilation units, waves on the seashore, distant explosions, traffic, aircraft, and other machinery[1]. Infrasound propagates farther (i.e. with lower levels of dissipation) than higher frequencies.

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[1] To place infrasound in perspective, when a child is swinging high on a swing, the pressure change on its ears, from top to bottom of the swing, is nearly 120 dB at a frequency of around 1 Hz. [Leventhall, 2004]

Some characteristics of the human perception of infrasound and low frequency sound are:

- Low frequency sound and infrasound (2-100 Hz) are perceived as a mixture of auditory and tactile sensations.
- Lower frequencies must be of a higher magnitude (dB) to be perceived, e.g. the threshold of hearing at 10 Hz is around 100 dB; see Figure 5
- Tonality can not be perceived below around 18 Hz
- Infrasound may not appear to be coming from a specific location, because of its long wavelengths.

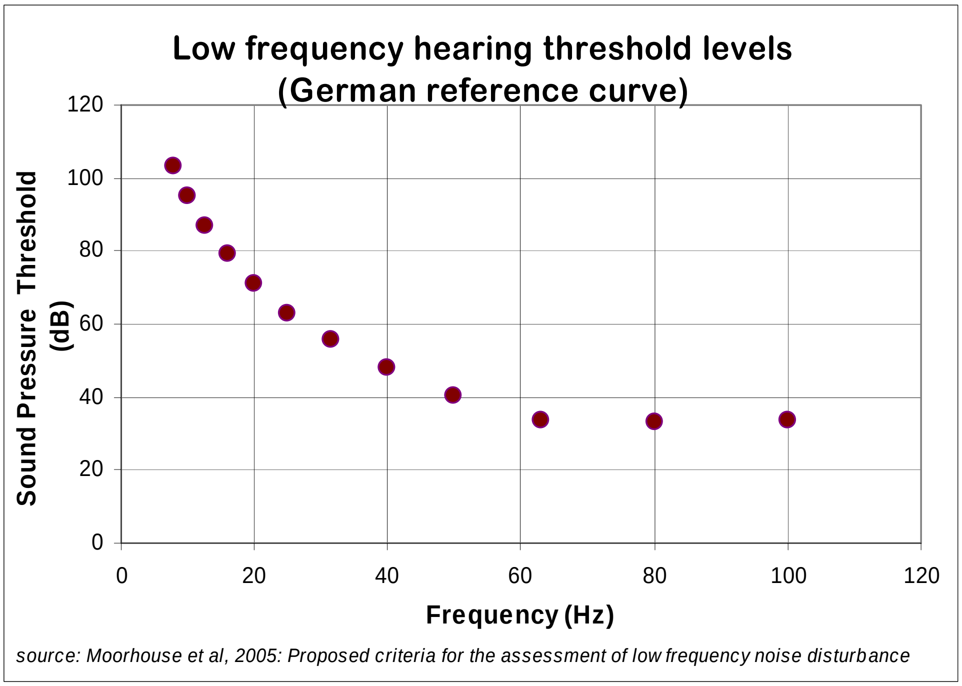

Figure 5: Typical perception threshold of human ear for low frequency sound as a function of pressure

The primary human response to perceived infrasound is annoyance, with resulting secondary effects. Annoyance levels typically depend on other characteristics of the infrasound, including intensity, variations with time, such as impulses, loudest sound, periodicity, etc. Infrasound has three annoyance mechanisms:

- A feeling of static pressure
- Periodic masking effects in medium and higher frequencies
- Rattling of doors, windows, etc. from strong low frequency components

Human effects vary by the intensity of the perceived infrasound, which can be grouped into these approximate ranges:

- 90 dB and below: No evidence of adverse effects
- 115 dB: Fatigue, apathy, abdominal symptoms, hypertension in some humans
- 120 dB: Approximate threshold of pain at 10 Hz
- 120 – 130 dB and above: Exposure for 24 hours causes physiological damage

There is no reliable evidence that infrasound below the perception threshold produces physiological or psychological effects.

Sound from Wind Turbines

Sources of Wind Turbine Sound

There are four types of sound that can be generated by wind turbine operation: tonal, broadband, low frequency, and impulsive:

1. Tonal: Tonal sound is defined as sound at discrete frequencies. It is caused by components such as meshing gears, non-aerodynamic instabilities interacting with a rotor blade surface, or unstable flows over holes or slits or a blunt trailing edge.
2. Broadband: This is sound characterized by a continuous distribution of sound pressure with frequencies greater than 100 Hz. It is often caused by the interaction of wind turbine blades with atmospheric turbulence, and also described as a characteristic "swishing" or "whooshing" sound.
3. Low frequency: Sound with frequencies in the range of 20 to 100 Hz is mostly associated with *downwind* rotors (turbines with the rotor on the downwind side of the tower). It is caused when the turbine blade encounters localized flow deficiencies due to the flow around a tower.
4. Impulsive: This sound is described by short acoustic impulses or thumping sounds that vary in amplitude with time. It is caused by the interaction of wind turbine blades with disturbed air flow around the tower of a downwind machine.

The sources of sounds emitted from operating wind turbines can be divided into two categories: 1) Mechanical sounds, from the interaction of turbine components, and 2) Aerodynamic sounds, produced by the flow of air over the blades. A summary of each of these sound generation mechanisms follows, and a more detailed review is included in the text of Wagner, et al. [1996].

Mechanical Sounds

Mechanical sounds originates from the relative motion of mechanical components and the dynamic response among them. Sources of such sounds include:

1. Gearbox
2. Generator
3. Yaw Drives
4. Cooling Fans
5. Auxiliary Equipment (e.g., hydraulics)

Since the emitted sound is associated with the rotation of mechanical and electrical equipment, it tends to be tonal (of a common frequency), although it may have a broadband component. For example, pure tones can be emitted at the rotational frequencies of shafts and generators, and the meshing frequencies of the gears.

In addition, the hub, rotor, and tower may act as loudspeakers, transmitting the mechanical sound and radiating it. The transmission path of the sound can be air-borne or structure-borne. Air-borne means that the sound is directly propagated from the component surface or interior into the air. Structure-borne sound is transmitted along other structural components before it is radiated into the air. For example, Figure 6 shows the type of transmission path and the sound power levels for the individual components for a 2 MW wind turbine [Wagner, et al., 1996]. Note that the main source of mechanical sounds in this example is the gearbox, which radiates sounds from the nacelle surfaces and the machinery enclosure.

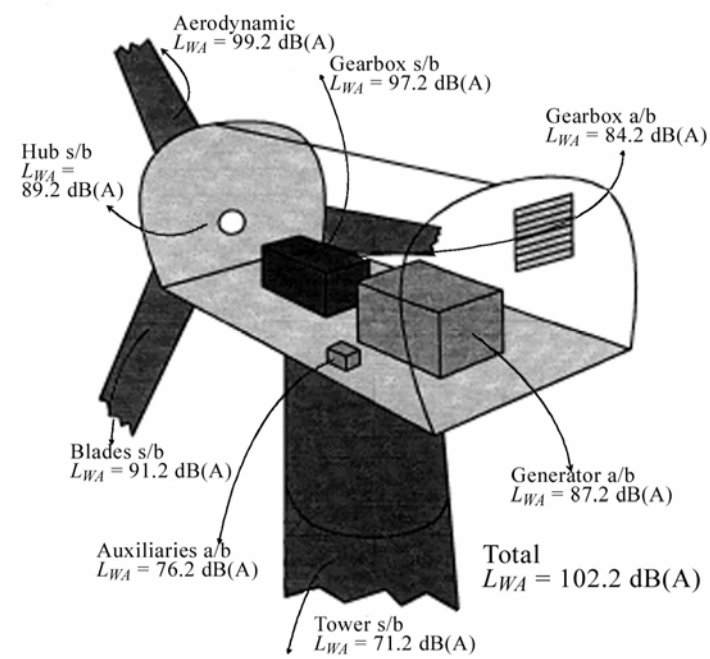

Figure 6: Components and Total Sound Power Level of a Wind Turbine, showing structure-borne (s/b) and airborne (a/b) transmission paths [Wagner, 1996].

Aerodynamic Sounds

Aerodynamic broadband sound is typically the largest component of wind turbine acoustic emissions. It originates from the flow of air around the blades. As shown in Figure 7, a large number of complex flow phenomena occur, each of which might generate some sound. Aerodynamic sound generally increases with rotor speed. The various aerodynamic sound generation mechanisms that have to be considered are shown in Table 1 [Wagner, et al., 1996]. They are divided into three groups:

1. *Low Frequency Sound:* Sound in the low frequency part of the sound spectrum is generated when the rotating blade encounters localized flow deficiencies due to the flow around a tower, wind speed changes, or wakes shed from other blades.
2. *Inflow Turbulence Sound:* Depends on the amount of atmospheric turbulence. The atmospheric turbulence results in local force or local pressure fluctuations around the blade.
3. *Airfoil Self Noise:* This group includes the sound generated by the air flow right along the surface of the airfoil. This type of sound is typically of a broadband

nature, but tonal components may occur due to blunt trailing edges, or flow over slits and holes.

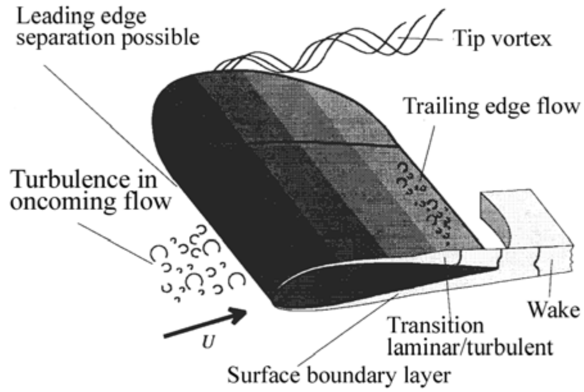

Figure 7: Schematic of Flow around a Rotor Blade [Wagner, 1996].

Table 1: Wind Turbine Aerodynamic Sound Mechanisms [Wagner et al., 1996]

Type or indication	Mechanism	Main characteristics & importance
Low-frequency sound		
Steady thickness noise; steady loading noise	Rotation of blades or rotation of lifting surfaces	Frequency is related to blade passing frequency, not important at current rotational speeds
Unsteady loading noise	Passage of blades through tower velocity deficit or wakes	Frequency is related to blade passing frequency, small in cases of upwind rotors, though possibly contributing in case of wind farms
Inflow turbulence sound	Interaction of blades with atmospheric turbulence	Contributing to broadband noise; not yet fully quantified
Airfoil self-noise		
Trailing-edge noise	Interaction of boundary layer turbulence with blade trailing edge	Broadband, main source of high frequency noise (770 Hz < f < 2 kHz)
Tip noise	Interaction of tip turbulence with blade tip surface	Broadband; not fully understood
Stall, separation noise	Interaction of turbulence with blade surface	Broadband
Laminar boundary layer noise	Non-linear boundary layer instabilities interacting with the blade surface	Tonal, can be avoided
Blunt trailing edge noise	Vortex shedding at blunt trailing edge	Tonal, can be avoided
Noise from flow over holes, slits and intrusions	Unstable shear flows over holes and slits, vortex shedding from intrusions	Tonal, can be avoided

Infrasound from Wind Turbines

When discussing infrasound from wind turbines, it is particularly important to distinguish between turbines with downwind rotors and turbines with upwind rotors. Some early wind turbines did produce significant levels of infrasound; these were all turbines with downwind rotors. The downwind design is rarely used in modern utility-scale wind power turbines.

Upwind rotors emit broad band sound emissions, which include low frequency sound and some infrasound. Note that the "swish-swish" sound is amplitude modulation at blade passing frequencies of higher frequency blade tip turbulence and does NOT contain low frequencies.

One example of low frequency sound and infrasound from a modern turbine is shown in Figure 8 . The magnitudes of these are below the perception limits of humans, which are shown in Figure 5.

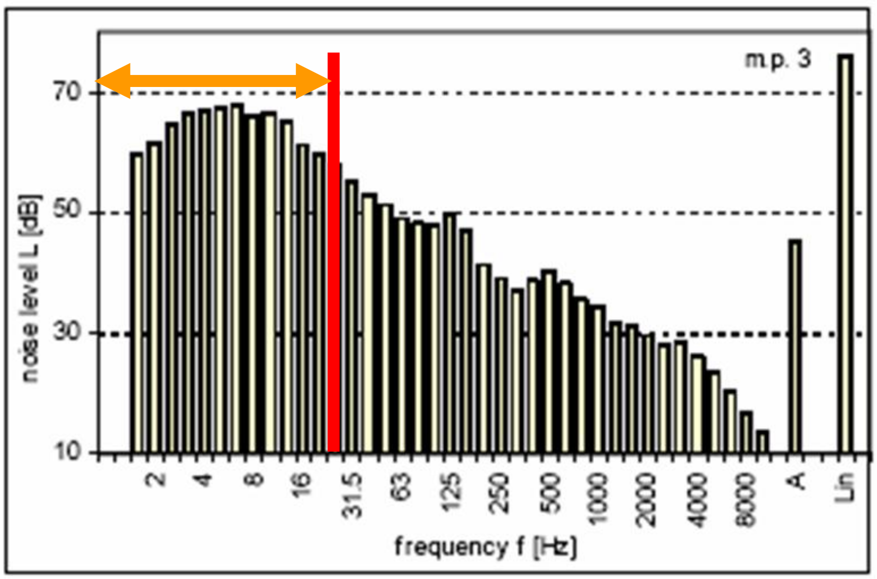

Figure 8: Example of 1/3 octave sound spectra downwind of a Vestas V80. The infrasound levels (range marked by the arrow) are below human perception level

Sound Reduction Methods for Wind Turbines

Turbines can be designed or retrofitted to minimize mechanical sound. This can include special finishing of gear teeth, using low-speed cooling fans and mounting components in the nacelle instead of at ground level, adding baffles and acoustic insulation to the nacelle, using vibration isolators and soft mounts for major components, and designing the turbine to prevent sounds from being transmitted into the overall structure. Efforts to reduce aerodynamic sounds have included [Wagner, et al., 1996] the use of lower tip speed ratios, lower blade angles of attack, upwind rotor designs, variable speed operation and most recently, the use of specially modified blade trailing edges.

Recent improvements in mechanical design of large wind turbines have resulted in significantly reduced mechanical sounds from both broadband and pure tones. Today, the sound emission from modern wind turbines is dominated by broadband aerodynamic sounds [Fégeant, 1999].

Sounds from Small Wind Turbines

Sound is likely to be one of the most important siting constraints for small wind turbines. Small wind turbines (under 30 kW capacity) are more often used for residential power or for other dedicated loads. These systems may be grid-connected or stand-alone systems. Due to the proximity of human activity, these applications could potentially result in noise complaints. Small wind turbines are in many cases louder than large turbines. Small wind turbines may also operate at higher tip speeds or turned partially out of the wind (this is known as furling, and is a common power limiting mechanism for high winds). These operating modes may aggravate sound generation. It is not always easy to obtain reliable sound measurements from the manufacturers of smaller wind turbines, especially at the wind speeds that might be a concern. For all of these reasons it is important to carefully consider sounds from small wind turbines. Below are three examples of studies of sound levels from wind small turbines.

A study of sound produced by a 10 kW Bergey wind turbine at Halibut Point State Park in Rockport, MA, includes measured sound pressure levels under a variety of wind conditions and at a variety of distances from the wind turbine base [Tech Environmental, 1998]. The study showed that under some conditions the wind turbine sound at 600 feet (182 m) from the wind turbine base increased sound levels by 13 dB(A). The study estimated that a buffer zone of 1,600 feet would be required to meet Massachusetts noise regulations (note that this model has been redesigned since that installation, so current models might not require as large a setback.) Finally, the study also mentioned that under high wind conditions in which the wind turbine sound was masked by the wind-induced background sound, as determined by the broadband sound pressure levels, the wind turbine could still be heard due to the presence of helicopter-like thumping sounds during furling. Similar sounds have been described coming from other small wind turbines [Gipe, 2001]. These low-frequency and periodic sounds are not included in the standard A-weighted sound pressure measurements prescribed in the MA DEP regulations.

In another study, sound measurements were made by the National Renewable Energy Laboratory on a 900 Watt wind turbine, the Whisper 40 [Huskey and Meadors, 2001]. This wind turbine has a rotor diameter of 2.1 m (7 ft) and was mounted on a 30 ft tower. The rotor rotates at 300 rpm at low power. The rotation speed increases to 1200 rpm as the rotor rotates out of the wind ("furls") to limit power in high winds. This operation results in a blade-tip speeds between 33 and 132 m/s. Figure 9 illustrates the sound pressure level (with the background sound removed) and the background sound levels at a distance of 10 meters (33 ft) from the wind turbine base. Between 6 and 13 m/s the sound pressure levels due to the operation of the turbine increased more than 13 dB. This is a very large increase in sound level and would be experienced as more than a doubling of the sound level. Moreover, it increased enough that the background sound level, which also increased with wind speed, was not enough to mask the wind turbine sound until the wind speed increased to over 13 m/s (30 mph).

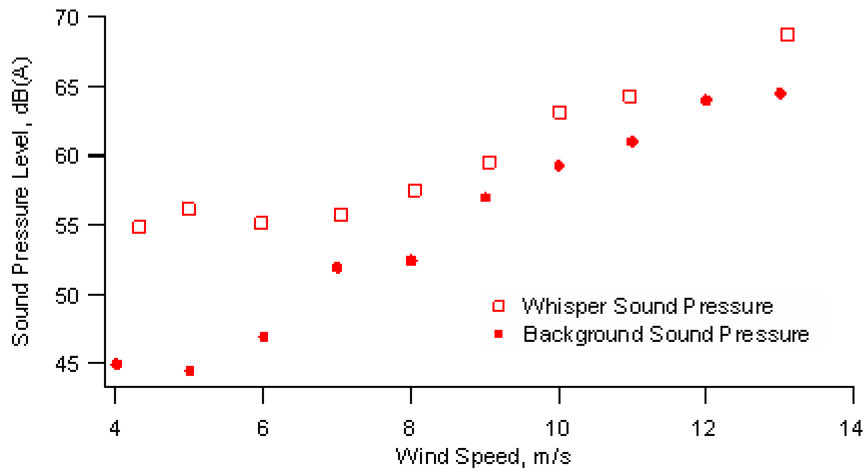

Figure 9: Measured sound power levels of a Southwest Whisper 900 wind turbine

In the third study, the National Renewable Energy Laboratory [Migliore, 2003] performed acoustic texts on eight small wind turbines ranging from 400 watts to 100 kW in rated power, using procedures based on international standards for measurement and data analysis, including wind speeds down to 4 m/s in most cases. A summary of the results are shown in Figure 10, which shows a very wide variety of sound levels. This figure illustrates that measurement in winds over 10 m/s are useful for some of the turbines considered.

Sound measurement standards for small wind turbines: The IEC 61400-11 standard (described below under Noise Standards and Regulations) may not be adequate for estimating sound levels from some small wind turbines. For instance, in contrast to the broad-band aerodynamic sounds from large wind turbines, some small wind turbine designs lead to irregular sounds that may be quite audible at higher wind speeds. Whereas the IEC standard requires the measurements at 6-10 m/s, measurements a lower and higher wind speeds should be included for small wind turbines. In addition, measurement standards do not require the measurement of thumping sounds and other irregular sounds that can be found objectionable. The possibility of irregular sounds and loud sounds in high-wind should be considered when siting small wind turbines in populated areas.

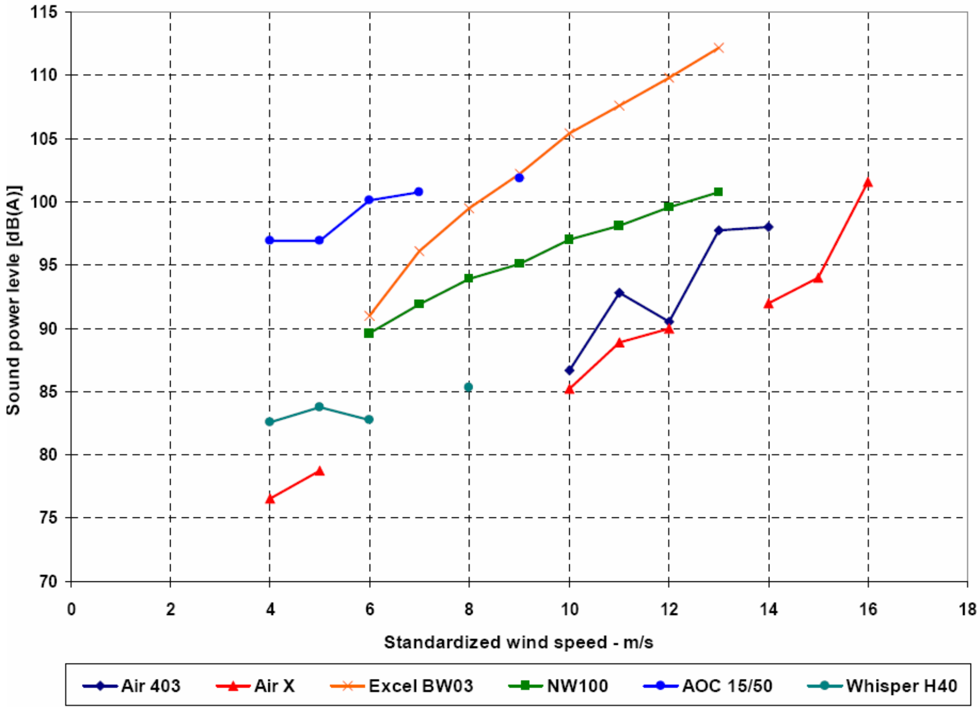

Figure 10: Summary of NREL study of small wind turbine sound: sound pressure level vs. wind speed, with the sound recorded downwind from the turbine [Migliore, 2003]

Factors that Affect Wind Turbine Sound

Wind turbine generated sound that is perceived at any given location is a function of wind speed, as well as turbine design, distance, ambient sound levels and various other factors, which are explored below.

Wind Turbine Design and Sound Emissions

All large, modern wind turbines available commercially today in the US are upwind, horizontal axis, variable pitch, and many have some variability of rotational speed. There are, however, other designs that have been used historically and may appear again in some form.

Several basic design characteristics can influence sound emissions. Wind turbines may have blades which are rigidly attached to the hub and thence to the rotor shaft. Other designs may have blades that can be pitched (rotated around their long axis). Some have rotors that always turn at a constant or near-constant speed while other designs might change the rotor speed as the wind changes. Wind turbine rotors may be upwind or downwind of the tower. Other things being equal, each of these designs might have different sound emissions because of the way in which they operate. In general, upwind rotors as opposed to downwind rotors, lower rotational speeds and pitch control result in lower sound generation.

Aerodynamic sound generation is very sensitive to speed at the very tip of the blade. To limit the generation of aerodynamic sounds, large modern wind turbines may limit the rotor rotation speeds to reduce the tip speeds. Large variable speed wind turbines often rotate at slower speeds in low winds, increasing in higher winds until the limiting rotor speed is reached. This results in much quieter operation in low winds than a comparable constant speed wind turbine.

Small wind turbines (under 30 kW) are also often variable-speed wind turbines. These smaller wind turbine designs may even have higher tip speeds in high winds than large wind turbines. This can result in greater sound generation than would be expected, compared to larger machines. This is also perhaps due to the lower investment in sound reduction technologies in these designs. Some smaller wind turbines regulate power in high winds by turning out of the wind or "fluttering" their blades. These modes of operation can affect the nature of the sound generation from the wind turbine during power regulation.

Sound Propagation

In order to predict the sound pressure level at a distance from source with a known power level, one must determine how the sound waves propagate. In general, as sound propagates without obstruction from a point source, the sound pressure level decreases. The initial energy in the sound is distributed over a larger and larger area as the distance from the source increases. Thus, assuming spherical propagation, the same energy that is distributed over a square meter at a distance of one meter from a source is distributed over 10,000 m^2 at a distance of 100 meters away from the source. With spherical propagation, the sound pressure level is reduced by 6 dB per doubling of distance. This simple model of spherical propagation must be modified in the presence of reflective surfaces and other disruptive effects. For example, if the source is on a perfectly flat and reflecting surface, then hemispherical spreading has to be assumed, which also leads to a 6 dB reduction per doubling of distance, but the sound level would be 3 dB higher at a given distance than with spherical spreading. Details of sound propagation in general are discussed in Beranek and Vers [1992]. The development of an accurate sound propagation model generally must include the following factors:

- Source characteristics (e.g., directivity, height, etc.)
- Distance of the source from the observer
- Air absorption, which depends on frequency
- Ground effects (i.e., reflection and absorption of sound on the ground, dependent on source height, terrain cover, ground properties, frequency, etc.)
- Blocking of sound by obstructions and uneven terrain
- Weather effects (i.e., wind speed, change of wind speed or temperature with height). The prevailing wind direction can cause differences in sound pressure levels between upwind and downwind positions.
- Shape of the land; certain land forms can focus sound

A discussion of complex propagation models that include all these factors is beyond the scope of this paper. More information can be found in Wagner, et al. (1996). For estimation purposes, a simple model based on the more conservative assumption of hemispherical sound propagation over a reflective surface, including air absorption is often used [International Energy Agency, 1994]:

$$L_p = L_w - 10\log_{10}\left(2\pi R^2\right) - \alpha R$$

Here L_p is the sound pressure level (dB) a distance R from a sound source radiating at a power level, L_w, (dB) and α is the frequency-dependent sound absorption coefficient. This equation can be used with either broadband sound power levels and a broadband estimate of the sound absorption coefficient (α = 0.005 dB per meter) or more preferably in octave bands using octave band power and sound absorption data. The total sound produced by multiple wind turbines would be calculated by summing up the sound levels due to each turbine at a specific location using the dB math mentioned above.

An example of the sound that might be propagated from a singe large modern wind turbine is shown in Figure 11. This example assumes hemispherical sound propagation and uses the formula presented above. In this case the wind turbine is assumed to be on a 50 m tower, the source sound power level is 102 dB(A), and the sound pressure levels are at estimated at ground level.

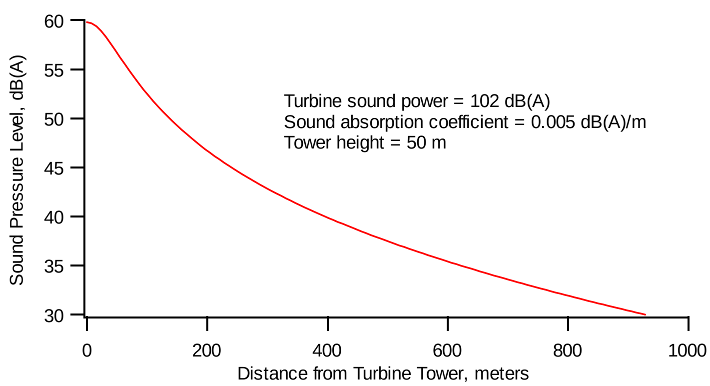

Figure 11: Example of propagation of sound from a large wind turbine

The location of the receptor is also significant. Upwind of a wind turbine there may be locations where no sound is heard. On the other hand sound may be propagated more easily downwind.

Ambient Sounds & Wind Speed

The ability to hear a wind turbine in a given installation also depends on the ambient sound level. When the background sounds and wind turbine sounds are of the same magnitude, the wind turbine sound gets lost in the background.

Ambient baseline sound levels will be a function of such things as local traffic, industrial sounds, farm machinery, barking dogs, lawnmowers, children playing and the interaction of the wind with ground cover, buildings, trees, power lines, etc. It will vary with time of day, wind speed and direction and the level of human activity. As one example, background sound levels measured in the neighborhood of the Hull High School in Hull Massachusetts on March 10, 1992 ranged from 42 to 48 dB(A) during conditions in which the wind speed varied from 5 to 9 mph (2-4 m/s).

Both the wind turbine sound power level and the ambient sound pressure level will be functions of wind speed. Thus whether a wind turbine exceeds the background sound level will depend on how each of these varies with wind speed.

The most likely sources of wind-generated sounds are interactions between wind and vegetation. A number of factors affect the sound generated by wind flowing over vegetation. For example, the total magnitude of wind-generated sound depends more on the size of the windward surface of the vegetation than the foliage density or volume [Fégeant, 1999]. The sound level and frequency content of wind generated sound also depends on the type of vegetation. For example, sounds from deciduous trees tend to be slightly lower and more broadband than that from conifers, which generate more sounds at specific frequencies. The equivalent A-weighted broadband sound pressure generated by wind in foliage has been shown to be approximately proportional to the base 10 logarithm of wind speed [Fégeant, 1999]:

$$L_{A,eq} \propto \log_{10}(U)$$

The wind-generated contribution to background sound tends to increase fairly rapidly with wind speed. For example, during a sound assessment for the Madison (NY) Windpower Project, a project in a quiet rural setting, the background sound was found to be 25 dBA during calm wind conditions and 42 dBA when the wind was 12 mph (5.4 m/s). Background sound generated during sound measurements on a small wind turbine are shown in the Figure 12 [Huskey and Meadors, 2001]. The graph includes a logarithmic fit to that data based on the model mentioned above.

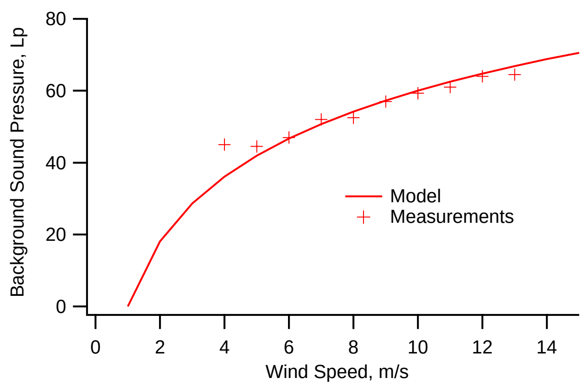

Figure 12: Sample background noise measurements as a function of wind speed

Sound levels from large modern wind turbines during constant speed operation tend to increase more slowly with increasing wind speed than ambient wind generated sound. As a result, wind turbine noise is more commonly a concern at lower wind speeds [Fégeant, 1999] and it is often difficult to measure sound from modern wind turbines above wind speeds of 8 m/s because the background wind-generated sound masks the wind turbine sound above 8 m/s [Danish Wind turbine Manufacturers Association, 2002].

It should be remembered that average sound pressure measurements might not indicate when a sound is detectable by a listener. Just as a dog's barking can be heard through other sounds, sounds with particular frequencies or an identifiable pattern may be heard through background sounds that is otherwise loud enough to mask those sounds. Sound emissions from wind turbines will also vary as the turbulence in the wind through the rotor changes. Turbulence in the ground level winds will also affect a listener's ability to hear other sounds. Because fluctuations in ground level wind speeds will not exactly correlate with those at the height of the turbine, a listener might find moments when the wind turbine could be heard over the ambient sound.

Noise Standards and Regulations

There are standards for measuring sound power levels from utility -scale wind turbines, as well as local or national standards for acceptable noise power levels. Each of these is reviewed here. As of this writing (February 2005), there are no sound measurement standards for small wind turbines, but both the American Wind Energy Association and the International Electrotechnical Commission (IEC) are working on future standards.

Turbine Sound Power Measurement Standards

The internationally accepted standard to ensure consistent and comparable measurements of utility-scale wind turbine sound power levels is the International Electrotechnical Commission IEC 61400-11 Standard: Wind turbine generator systems – Part 11: Acoustic noise measurement techniques [IEC, 2002]. All utility-scale wind turbines available today in the US comply with IEC 61400-11. It defines:

- The quality, type and calibration of instrumentation to be used for sound and wind speed measurements.
- Locations and types of measurements to be made.
- Data reduction and reporting requirements.

The standard requires measurements of broad-band sound, sound levels in one-third octave bands and tonality. These measurements are all used to determine the sound power level of the wind turbine at the nacelle, and the existence of any specific dominant sound frequencies. Measurements are to be made when the wind speeds at a height of 10 m (30 ft) are 6, 7, 8, 9 and 10 m/s (13-22 mph). Manufacturers of IEC-compliant wind turbines can provide sound power level measurements at these wind speeds as measured by certified testing agencies.

Measurements of noise directivity, infrasound (< 20 Hz), low-frequency noise (20-100 Hz) and impulsivity (a measure of the magnitude of thumping sounds) are optional.

Measured sound power levels for a sampling of wind turbines are presented in Figure 13 as a function of rated electrical power. The data illustrate that sound emissions from wind turbines generally increases with turbine size. The graph also shows that wind turbine designers' efforts to address noise issues in the 1990's and later have resulted in significantly quieter wind turbines than the initial designs of the 1980's.

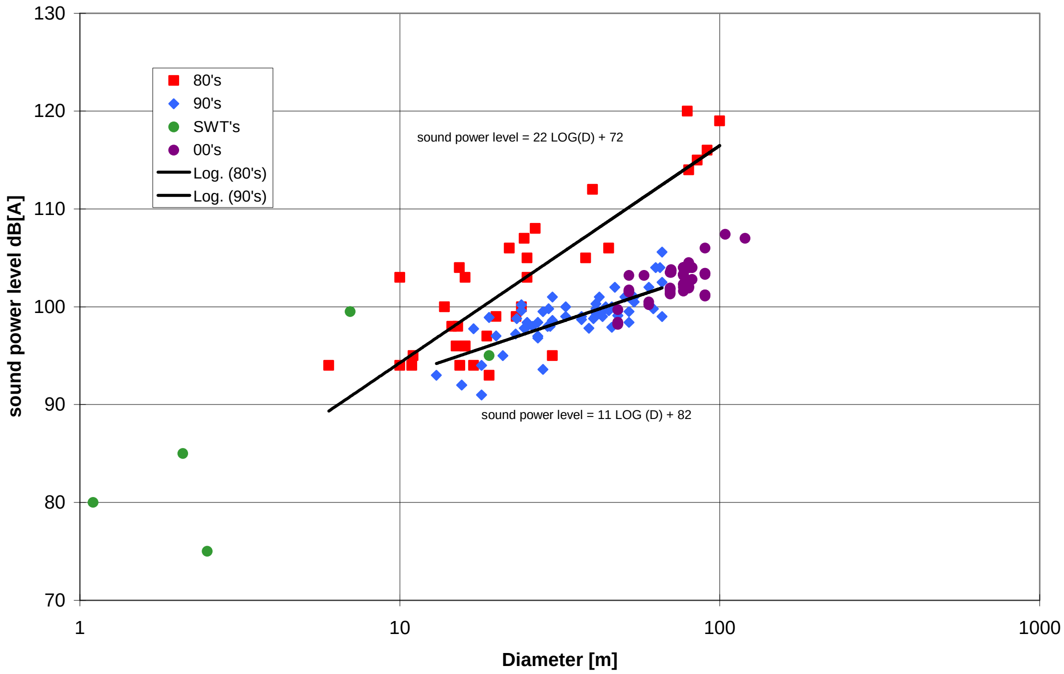

Figure 13: Sample wind turbine measured sound power levels

Community Standards for Determining Acceptable Sound Pressure Levels

At the present time, there are no common international noise standards or regulations for sound pressure levels. In most countries, however, noise regulations define upper bounds for the noise to which people may be exposed. These limits depend on the country and may be different for daytime and nighttime.

For example, in Europe, as shown in Table 2, fixed noise limits have been the standard [Gipe, 1995].

Country	Commercial	Mixed	Residential	Rural
Denmark			40	45
Germany				
(day)	65	60	55	50
(night)	50	45	40	35
Netherlands				
(day)		50	45	40
(night)		40	35	30

Table 2: Noise Limits of Sound Pressure Levels, L_{eq} (in dB(A)) in Various European Countries

In the U.S., although no federal noise regulations exist, the U.S. Environmental Protection Agency (EPA) has established noise guidelines. Most states do not have noise regulations, but many local governments have enacted noise ordinances to manage community noise levels. Examples of such ordinances for wind turbines are given in the latest Permitting of Wind Energy Facilities Handbook [NWCC, 2002].

The Massachusetts Department of Environmental Protection (DEP) regulates noise emissions as a form of air pollution under 310 CMR 7.00, “Air Pollution Control.” These can be found at http://www.mass.gov/dep/air/laws/7a.htm. The application of these regulations to noise is detailed in the DEP’s DAQC Policy Statement 90-001 (February 1, 1990). The regulation includes two requirements. First, any new broadband sound source is limited to raising noise levels no more than 10 dB(A) over the ambient baseline sound level. The ambient baseline is defined as the sound level that is exceeded 90% of the time, the L_{90} level. Second, “pure tones”, defined here as an octave band, may be no greater than 3 dB(A) over the two adjacent octave bands. All these readings are measured at the property line or at any inhabited buildings located within the property.

It should be pointed out that imposing a fixed noise level standard may not prevent noise complaints. This is due to the changing of the relative level of broadband background turbine noise with changes in background noise levels [NWCC, 2002]. That is, if tonal noises are present, higher levels of broadband background noise are needed to effectively mask the tone(s). In this respect, it is common for community noise standards to incorporate a penalty for pure tones, typically 5 dB(A). Therefore, if a wind turbine meets a sound pressure level standard of 45 dB(A), but produces a strong whistling, 5 dB(A) are subtracted from the standard. This forces the wind turbine to meet a standard of 40 dB(A).

A discussion of noise measurement techniques that are specific to wind turbine standards or regulations is beyond the scope of this paper. A review of such techniques is given in Hubbard and Shepherd [1990], Germanisher Lloyd [1994], and Wagner, et al. [1996].

Sample Noise Assessment for a Wind Turbine Project

Much of the interest in wind turbine noise is focused on the noise anticipated from proposed wind turbine installations. When a wind turbine is proposed near a sensitive receptor, a noise assessment study is appropriate; these studies will typically contain the following four major parts of information:

1. An estimation or survey of the existing ambient background noise levels.
2. Prediction (or measurement) of noise levels from the turbine(s) at and near the site.
3. Identification of a model for sound propagation (sound modeling software will includes a propagation model.)
4. Comparing calculated sound pressure levels from the wind turbines with background sound pressure levels at the locations of concern.

An example of the steps in assessing the noise anticipated from the installation of a wind turbine according to the Massachusetts regulations follows.

Ambient Background Levels: Ambient sound levels vary widely and are important for understanding the noise as well as complying with ambient-based regulations. Background sound pressure levels should be measured for the specific wind conditions under which the wind turbine will be operating. In this example it will be assumed that measurements indicate that the L_{90} sound pressure levels are 45 dB(A) at 8 m/s wind speed.

Source Sound Levels: In order to calculate noise levels heard at different distances, the reference sound levels need to be determined. The reference sound level is the acoustic power being radiated at the source, and is not the actual sound pressure level as heard at ground level. Reference sound levels can be obtained from manufacturers and independent testing agencies. Measurements should be based on the standards mentioned above. In this example it will be assumed that the turbine will be on a 50 m tower and has a sound power level of 102 dB(A), as in the previous example of sound propagation from a wind turbine.

Sound Propagation Model: Sound propagation is a function of the source sound characteristics (directivity, height), distance, air absorption, reflection and absorption by the ground and nearby objects and weather effects such as changes of wind speed and temperature with height. One could assume a conservative hemispherical spreading model or spherical propagation in which any absorption and reflection are assumed to cancel each other out. More detailed models could be used that include the effects of wind speed and direction, since sound travels more easily in the downwind direction; however, a conservative model will assume that all directions are downwind at some time. If the hemispherical propagation model is used, then the data in Figure 11 shows the noise levels in the vicinity of the turbine.

Comparison of Calculated Sound Levels with Baseline Sound Levels: Calculated wind turbine sound levels do not include the additional background ambient sound levels. The mathematical relationship governing the addition of dB(A) levels require that if the turbine sound level is no more than 9.5 dB(A) above the ambient noise level, then the total noise levels will be within 10 dB(A) of the ambient sound level. If the ambient sound level is 45 dB(A), then, under Massachusetts regulations, the turbine can generate no more than 54.5 dB(A) at locations of concern. It can be seen from Figure 11 that the sound from the wind turbine would not exceed that limit at all locations more than 75 m (250 ft) from the wind turbine.

Conclusions and Recommendations

Modern, utility-scale wind turbines are relatively quiet; still, when sited within residential areas, noise is a primary siting constraint. The following are recommendations for standards, regulations and siting practices:

- Turbine Standards:
    - Utility-scale turbines: Any incentives to promote wind energy should be provided only to turbines for which the manufacturer can provide noise data based on IEC standards or for turbines which are to be located at sites where there will clearly be no problem.

- Small turbines: national standards for small wind turbine technology in general are needed. For noise in particular, sound levels should be measured at lower and higher wind speeds, in addition to those measured under the IEC standard. Any operation-mode-dependent, time-dependent and frequency-dependent components also need to be described. These standards need to provide sound measures that provide an accurate representation of issues of interest to potential listeners.

- Noise Regulations:
  - Community noise standards are important to ensure livable communities. Wind turbines must be held to comply with these regulations. Wind turbines need not be held to additional levels of regulations.
  - For small wind turbines: Because of the wide variety of sound levels from small wind turbines, blanket setback limits should not be set *a priori*. However, they should be examined carefully based on the technology proposed.

- Wind turbine siting practice:
  - In order to comply with state noise regulations and to fit within community land use, the siting of wind turbines must take sound levels into consideration.
  - If a wind turbine is proposed within a distance equivalent to three times the blade-tip height of residences or other noise-sensitive receptors, a noise study should be performed and publicized.

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BEFORE THE
PUBLIC SERVICE COMMISSION OF WISCONSIN

Application for a Certificate of	)	
Public Convenience and Necessity	)	
to Construct and Place in Service a Wind	)	Docket No. 6630-CE-302
Turbine Electric Generation Facility	)	
Known as Glacier Hills Wind Park	)	
in Columbia County, Wisconsin	)	

DIRECT TESTIMONY OF DR. GEOFF LEVENTHALL
ON BEHALF OF WISCONSIN ELECTRIC POWER COMPANY

Q. Please state you name, occupation, and business address.

A. Dr. Geoff Leventhall. I am an acoustical consultant in sole practice at 150, Craddocks Avenue, Ashtead, Surrey, KT21 1NL, UK.

Q. Please summarize your educational and professional background.

A. I have a BSc in Physics and MSc and PhD in Acoustics. During the 1960s and 1970s I developed an Applied Acoustics Research Group at the University of London, dealing with noise problems and subjective acoustics. I personally supervised 30 students to completion of their PhD degrees, and a much larger number of MSc students were also seen to completion. One of the main interests of the Group was infrasound and low frequency noise, in which I am recognized internationally as an expert. During this time I also practiced part time as a consultant.

In the early 1980s I left London University to be Head of Acoustics at a large engineering consultancy (W S Atkins), becoming Technical Director.

In the late 1980s I was invited to apply for the post of Professor and Head of the, then, Institute of Environmental Engineering in London, where I stayed for about five years, also practicing part time as a consultant. Since that time I have been in practice full time as a consultant.

Much of my work has been in relation to low frequency noise problems. I have carried out work for the UK government department, DEFRA, on low frequency noise and there is an ongoing DEFRA project to help people cope with insoluble low frequency noise problems. I am also working with the US company Wyle Laboratories on a NASA project related to low frequency noise from a new concept heavy lift rotor, which may eventually replace short haul jets. Of course, there is also short-term problem-solving work in low frequency noise.

I first became involved with wind turbine noise in the mid 1980s, before there were any in the UK, looking at assessment methods for response to wind turbine noise. This work continued into the early 1990s, but for much of the remainder of the 1990s I spent more time on one of my other interests from my academic days, active control of noise, and had a consultancy with Digisonix, from Middleton near to Madison. This continued until 1997, about the time when Digisonix's parent company, Nelson Industries, was sold to a company that did not wish to continue with the active control work. I was then able to give more time to my other work, including wind turbine noise. I am regularly consulted in relation to the strange things which people say about infrasound and low frequency noise from wind turbines. In fact, for nearly 40 years I have been trying to educate the public and others in order to undo some of the harm which was caused by media exaggerations in the 1970s and which have more recently developed on the Internet.

I am a former President of the UK Institute of Acoustics and have been awarded two medals by the Institute in recognition of my work.

I am, by invitation, a "Distinguished International Member" of the US Institute of Noise Control Engineering.

I was the founding editor of the Journal of Low Frequency Noise and Vibration, now in its 28th year and edited it for the first 18 years.

I have organized nine of the 13 international series of conferences on Low Frequency Noise and Vibration its Control, which have been held to date, and been advisor to the organisers of a further three. The 14th of these conferences will be held in 2010 in Denmark. Again, I am advisor to the organisers. I was the originator of the International Conference Series on Wind Turbine Noise and organized the three which have been held so far. The fourth is currently being arranged for 2011.

Over the past few years I have been a member of two UK committees concerned with noise and health, both preparing reports on this topic, one of which has been published. I am currently a member of the AWEA committee of independent experts considering the effects of noise on health. This report is not yet completed. My Curriculum Vitae is submitted as Exhibit 17.

Q. On whose behalf are you testifying?

A. Wisconsin Electric.

Q. Please briefly summarize your testimony.

A. Based on my experience of infrasound and low frequency noise, it is my belief that the infrasound from wind turbines is of no consequence. Attempts to claim that illnesses result from inaudible wind turbine noise do not stand up to simple analyses of the very low forces and pressures produced by the sound from wind turbines. Additionally, the body is full of sound and vibration at infrasonic and low frequencies, originating in natural body processes. As an example, the beating heart is an obvious source of infrasound within the body. Other sources of background low frequency noise and vibration are blood flows, muscle vibrations, breathing, fluids in the gut and so on. The result is that any effect from wind turbine noise, or any other low level of noise, which might be produced within the body is "lost" in the existing background noise and vibration. This is considered in more detail in my Appraisal of Wind Turbine Syndrome, which is submitted as Exhibit 18.

More broadly, my testimony establishes that the claims of health effects from the low levels of infrasound and low frequency noise from wind turbines, as described in the Wind Turbine Syndrome and Vibroacoustic Disease hypotheses, fail. However, higher frequency noise from wind turbines, if it is audible, can cause disturbance to some residents, but this effect is no different from that of noise from another source.

My testimony also directly addresses Richard James's submissions to the PSC, which rely heavily on three hypotheses that do not withstand scrutiny: Wind Turbine Syndrome, Vibroacoustic Disease, and, novelly "mechanotensegrity," which, as its principal proponent explained to me, has no known applicability in this context. My testimony also briefly addresses James's criticism of the work done at Glacier Hills by George Hessler, and James's own suggested criteria for permitting wind developments. Finally, I also address James's misplaced reliance on my work.

Q. What are your general reactions to the testimony submitted by Richard James?

A. Part of James's testimony appears to be saying that it is impossible to model wind turbine noise. If James is correct in his approach, where are all the complaints from every wind farm? The problems which he says might occur do not normally do so, and especially not at the important locations nearest to the turbines.

He is incorrect to claim research showing a causal link between wind turbine low frequency sound levels and effects on health. Additionally, the effects of higher frequency wind turbine noise are no different from those of any other similar noise source. There is nothing special or mysterious about wind turbine noise.

<u>DISCUSSION OF VARIOUS CLAIMED HEALTH EFFECTS DUE TO INFRASOUND AND LOW FREQUENCY NOISE</u>

Q. Let's explore your criticisms of James's testimony in more detail. James claims in Exhibit 808 that new medical discoveries establish that low

frequency noise below the threshold of human hearing can have negative impacts on human health. What is your reaction to that claim?

A. I do not agree. The new discoveries to which he is referring appear to be:

Wind turbine Syndrome – put forward by Pierpont

Vibroacoustic disease – put forward by the Portuguese

Tensegrity – put forward by Mulvihill

Q. Please explain your view of Wind Turbine Syndrome.

A. Pierpont's hypothesis about a Wind Turbine Syndrome, as resulting from disturbance to the vestibular systems by the low levels of infrasound from wind turbines, does not stand up to scrutiny.[1] I believe that this part of her work is now discredited and should be acknowledged as such. She has not made any new discoveries but, in the review section of her book (which I have reviewed in prepublication draft as its release date keeps being pushed back), has surveyed what is already known. The wide range of symptoms which she associates with Wind Turbine Syndrome are well known to others as the stress effects of audible noise, to which a small number of persons are susceptible. Also, my medical colleagues tell me that it is unusual to associate such a wide range of symptoms with a single named syndrome, as this makes the syndrome too easy to find.

Q. Please continue.

A. Pierpont has a very poor understanding of acoustics, which continually lets her down. Her work depends on two hypotheses, neither of which she is able to

[1] For a discussion of sound levels produced by wind turbines and perception thresholds, see pages 19-20 of my testimony.

support. Her first hypothesis relied, until recently, heavily on work by Todd et al.[2] However, it was clear to me on reading Todd's paper that she has both misunderstood and misrepresented it. She has incorrectly sought to insert noise issues into a paper which is entirely about vibration through the skull. I asked Todd about this some time ago but, at that time, he did not wish to become involved with the "politics" of wind turbines. However, there was publicity on Pierpont's work on 2nd August 2009 in a UK newspaper. As this article referred to his work, Todd finally came out and repudiated Pierpont, and her use of his research. In a letter to the newspaper (Exhibit 19), he said

> *Our research is being cited to support the case that "wind turbine syndrome" is related to a disturbance of vestibular apparatus produced by low-frequency components of the acoustic radiations from wind turbines. Our work does not provide the direct evidence suggested. We described a sensitivity of the vestibular system to low-frequency vibration of the head, at about 100Hz, and not air-conducted sound.*
>
> *At present I do not believe that there is any direct evidence to show that any of the above acoustico-physiological mechanisms are activated by the radiations from wind turbines. Even if the vestibular system were activated in a controlled acoustic environment, it is not necessarily the case that it would produce pathological effects. Until such evidence is available I have an open mind on "wind turbine syndrome".*

[2] Todd, N., Rosengren, S. M., and Colebatch, J. G. (2008): Tuning and sensitivity of the human vestibular system to low frequency vibration. *Neuroscience Letters* **444**, 36 - 41.

The response from Dr. Todd was published on 9th August and shortly after this all references to him disappeared from Pierpont's web page (www.windturbinesyndrome.com).

Throughout Pierpont's work there is no clear indication of the excitation levels which she believes might cause a problem. While she must be aware of safe and unsafe doses of medication, she continues to close her mind to the concept of safe doses of sound, although "safe sound" is our everyday experience.
Thus, Pierpont's first hypothesis fails.

Q. What is Pierpont's second hypothesis, and does it fare any better in your estimation?

A. Pierpont's second hypothesis is equally unfounded. She says that infrasound at 4 – 8Hz enters the lungs and vibrates the diaphragm and its attached liver, so passing confusing messages on to the visceral graviceptors. She gives no evidence to support this, but instead uses references to whole body vibration, applied to the feet or seat, which is a completely different excitation to that from sound. A simple order of magnitude calculation, using basic physics of the level which will be known to a 16-year-old school pupil, shows that the movement of the diaphragm under the forces which might result from wind turbine noise is less than 10 micron. That is less than one hundredth of a millimetre or about one tenth of the average thickness of human hair. During normal breathing, the diaphragm moves several centimetres. Wind turbine effects will not be passed by the diaphragm on to the visceral gravicaptors, as hypothesized by Pierpont. There is no scientific merit in Pierpont's second hypothesis. In fact, in strictly scientific terms I find little to distinguish this hypothesis from the following equally fanciful Internet posting, which explains why the crew abandoned the Marie Celeste:

> *The mystery was unsolved for decades, until it became clear that infrasound was the explanation of the phenomenon. As it turned out, infrasound of seven hertz emitted by ocean waves under some definite conditions was the reason of it. But infrasound of seven hertz is terrible for people: they may go mad and throw themselves overboard to save their lives.* http://ghosts.monstrous.com/infrasound.htm

Another part of Pierpont's second hypothesis states that infrasound from wind turbines, at a frequency of 1 – 2Hz, vibrates the chest, so adding to the confusing signals which upset the balance system. However, there is already a strong source of infrasound inside the body, beating at 1 –2 Hz, giving far greater magnitudes than might be produced by infrasound from wind turbines at these frequencies: the human heart. The beating heart vibrates the surface of the body at a high enough level to be picked up by a stethoscope, or even the ear. The sound produced by wind turbines does not.

Q. Please comment on James's continued reliance on the writings of Drs. Todd, Rosengren, and Colebatch.

A. I am surprised, and saddened, to find that as late as 5th October, two months after Todd cleared the air by firmly repudiating Pierpont's use of his work, James is still relying on Todd in his "Comments on WEPCO's Glacier Hills Application and Supporting Documents regarding Wind Turbine Noise and Its Impact on the Community" (Exhibit 808). On pages 9 –10 he uses Todd as an example to "demonstrate that there is sufficient evidence to present a causal link between ILFN and adverse health effects." What Todd actually showed was that, for a vibration input through physical contact to the mastoid area at the back of the head, certain reflexes, indicative of a vestibular response, continue to about 15dB lower than the level at which the hearing mechanism of the inner ear ceases to respond to vibration in the skull. It takes only a little thinking to realise that all of the people who use bone conduction hearing aids are receiving vibration inputs to their vestibular system at levels well above the system's perception threshold. This does not affect them, as one might expect from Todd's penultimate sentence in his repudiation of Pierpont, where he is saying, in effect: So what – vestibular excitation is not necessarily a problem.

Q. James relies on Dr. Eileen Mulvihill's writings. What have you found out about the source of these writings and what is your reaction to them?

A. James did not give the details of the paper from which he took the quotation, which he reproduces on page 9 of his Exhibit 808. I searched for the paper and eventually found it on the web page of the New Mexico Citizens Alliance for Responsible Energy and Sustainability (http://www.newmexicocare.org/1pages/vad.html).

This Internet page includes the statement:

> *The presentation below is a summary in response to reports suggesting that identification of "Wind Turbine Syndrome" is unnecessarily alarming and misleading to the general public and that VAD, or Vibroacoustic Disease, is part of some conspiracy*.

This is then followed by reference to papers, amongst others, on

- Military, applications of infrasound as a non-lethal weapon;
- Work carried out in connection with the Apollo space program (i.e. levels equivalent to exposure of astronauts during blast off);
- Echocardiography of aerospace workers (i.e. those working around ground running aero engines); and
- Noise risks in military operations.

All the above relate to very, very high levels of infrasound and bear no connection to the sound produced by wind turbines.

Dr. Mulvihill also reviews papers on aircraft and traffic noises and summarizes papers on VAD, some of which describe experiments on rats, which have been given continuous long term exposure (up to seven months) at levels around 100dB, or more, in the frequency range 80Hz to 500Hz. Another paper describes effects on rats, which have been exposed for 3 months at levels of about 100dB between 50Hz and 100Hz. These exposures would deafen us. It is not surprising that the rats suffered adverse effects. However, the work is not relevant to wind turbine noise, which has levels falling from about 50dB to 35dB over this range. That is from about 50 to 65dB lower than that imposed on the unfortunate rats.

It must be emphasized that, on a noise dose basis, which, as discussed below, the VAD group adheres to**,** the noise dose received from 1 year at 100dB will take 100,000 years to be received at 50dB.

And finally, at the end of this long web page of Dr. Mulvihill's, we find the paragraph quoted wholesale by James. (This webpage is also the source of pages 196 – 206 in James's supporting documents, submitted as Exhibit 809).

Let us be clear. This quotation is not from a refereed publication, but from a self-published Internet page. However, James's extract does give a reference to a paper by Prof. Ingber, which James has included in full at page 308 of his supporting documents.

Q Did you investigate any relevance Prof. Ingber's research might have to the issue of adverse health effects attributable to low frequency sound or infrasound from wind turbines?

A. Yes. Prof. Ingber says on page 320 of Exhibit 809:

> *All organs also use structural hierarchies to mediate the mechanotransduction response. Contraction and dilation of the heart, for example, results in deformation of its component ECMs [extra cellular matrix] which distort cells and their integrin adhesion as well as focal adhesions and the linked cytoskeletal and nuclear components. At every size scale and level of organisation, the level of tone or prestress in these*

discrete structural networks, governs their overall response to stress, both mechanically and biomechanically. This is also true in sound sensation in the ear, responsiveness to air movements in the lung, hemodynamic stresses in blood vessels and the compression in bone and cartilage. Thus, tensegrity helps to guide force retransmission and orchestrate multimolecular responses to stress at all size of scale and in all organ systems

What Prof. Ingber is saying here is that his model of tensegrity, which shows how cells respond to deformations and then return to their original shapes, applies to all movement in the body. He gives the examples of hearing, breathing, stresses caused to blood vessels by the flow of blood, and compressions in stiff structures in the body. To these could be added movement and flow in any part of the body. Cells respond to the stresses in accordance with their function. As this contradicts the assumption that low frequency noise might be harmful, I made contact with Prof. Ingber. His reply contained the following

I was not aware that my work has been cited to support the concept that low frequency noise will adversely influence cell activity, and there is no evidence that I am aware of to support this idea. Moreover, mechanical noise can sometimes have positive effects on cell activity and human physiology. For example, you should read the work of James Collins at Boston University and now at the Wyss Institute that I head (www.wyss.harvard.edu) who has pioneered the use of 'stochastic resonance', which involves applying a sub-threshold mechanical vibratory

> *signal and thereby increasing fidelity of control in elderly patients with gait control problems, diabetics with peripheral neuropathy, etc.*

Thus, Prof. Ingber's research has no bearing on the issues in this case.

Q. Do you agree with James's assertion that Vibro Acoustic Disease can be caused by wind turbine sound?

A. I do not agree. If this assertion was correct, every resident of Madison would be equally at risk, not to mention most of the USA and other first world countries. This is because the infrasonic and low frequency sound levels in urban areas, below about 50Hz, are similar to wind turbine sound levels in this range.

It also seems that Pierpont herself has doubts about VAD. On page 58 of the June 30th prepublication version of her book, she writes in reference to the aeronautical workers who are exposed to very high levels:

> *High intensities of low-frequency noise over prolonged time periods may cause marked neurological damage as described by the Vibroacoustic Disease group in Portugal. This is a provocative body of research, full of interesting case descriptions and pathology studies, but compromised by absence of specified study group criteria, absence of control groups and lack of quantification.*

And this is in reference to the VAD group's main work at very high sound levels - 120dB. There is no merit in the assertions that the low levels of wind turbine sound will cause a problem. From a noise dose point of view, as stated elsewhere, it will take a 100,000 years to receive the same dose from a 50dB noise as that received in one year from a 100dB noise.

Submitted as Exhibit 20 is my full assessment of VAD, which I believe further demonstrates that whatever merit it may have at very high sound levels, it has no applicability at sound levels produced by wind turbines.

JAMES'S VIEWS ON MODELING AND PERMITTING STANDARDS ARE BOTH UNREASONABLE, AND NOT SUPPORTED BY THE SCIENCE

Q. Please explain your view of James's critique of modelling methods used to predict potential sound levels from wind turbines.

A. Other experts have found that the widely-accepted modelling methods used by Mr. Hessler do work satisfactorily. For example, a paper given at the Wind Turbine Noise 2009 Conference, entitled "Wind farm noise predictions and comparison with measurements," showed a good agreement over the three sites investigated and at distances up to one kilometer. This paper is submitted as Exhibit 21. It will be noted that the sites used in that study were either flat or undulating, but an author of the paper tells me that:

> *Over a hilly area the approach should hold fine. You may get a couple of factors to take account of, one is barriers where line of sight to the tip of a turbine is blocked we assume a 2 dB(A) reduction. The other is if the ground falls away significantly between the source and receiver then you can get a +3 dB(A) addition to noise levels .*

In general, accuracy is greatest over shorter distances, so that the nearest residences, at about 300m, will be accurately predicted. These are the most important positions for any analysis.

Q. Do you have reactions to James's paper entitled "The 'How To' Guide to Siting Wind Turbines to Prevent Health Risks from Sound?"

A. I considered this paper in some detail in my earlier comments, which are submitted as Exhibit 22. It seems to me that the paper has two main problems. First, there is undue emphasis on infrasound and low frequency noise. There has been a great deal of irresponsible nonsense written about these, extending over the past 40 years, initially in newspapers and other media, but now on the Internet. Their paper gives me the impression that Kamperman and James may have come to the subject already preconditioned to believe that there was an infrasound problem from wind turbines, and determined to prove it.

Second, their reliance on the difference between the levels of the C-A weighting as a criterion for a low frequency noise problems is not convincing. The development of C – A as an *indicator* of low frequency noise was for tonal noise at low frequencies, not for broadband wind turbine noise. Most low frequency environmental noise problems have been tonal problems in which the A-weighting does not give a proper assessment of the low frequency tone. Consequently, their use of the C-A difference as a criterion is not safe.

Their attempt to carry this through to a criterion fails on a technical level for the following reasons:

The C-A limit is not substantiated.

The comparison of an A-weighted level before installation with a C-weighted level after installation takes no account of existing C-weighted noise prior to installation.

Where, on page 17 of Exhibit 808,James writes his condition as

$$L_{Ceq(immission)} \text{ minus } (L_{A90(background)} + 5) < 20dB$$

And states that

$$L_{Ceq(immission)} = L_{C90\ (background)}) + 5dB$$

These can be combined to give

$$L_{C90\ (background)} \text{ minus } L_{A90(background)} < 20dB$$

Where the L_{C90} is with turbines operating and the L_{A90} is before installation.

In the EIS, Table 5.8.4, measurements are given at existing wind farms for both L_{C90} and L_{A90} levels for turbines on and off. The L_{A90}, turbines off, can be associated with the preconstruction levels. Inspection of the Table shows that the difference between L_{Ceq} (turbines on) and L_{A90} (turbines off) is around 20dB, but the difference between L_{C90} (turbines on) and L_{C90} (turbines off) is only a few decibels. The proposed criterion is not only faulty in its proposed limit, but also unfair in that it suppresses existing low frequency noise. An enlarged part of Table 5.8-3 is included as Exhibit 23, illustrating this point.

Q. James writes that the Glacier Hills Wind Park will "expose the public to unsafe conditions 24 hours a day and 365 days a year." Do you agree?

A. I do not agree. Some opponents of wind turbine developments have, in the past, said that wind turbines are of little benefit because they operate for only about 25% of the time. Nobody, except James, believes that they operate 24/365. The correct figure is probably between 25% and 100%. However some of their operational time is at low speed in low wind conditions, when their noise levels are low. Further, as demonstrated in this testimony, there is simply no support for the assertion that inaudible infrasound or low frequency sound from wind turbines is harmful to human health.

Q. James also states that sound from wind turbines is inherently more annoying than sound from other industrial sources. What do you think?

A. A fluctuating noise is normally more annoying than a steady sound of the same average level. If the higher frequency wind turbine sound is fluctuating in level, there will be this modulation effect. However, this does not occur all the time or at every installation. Studies in the UK have shown that only four out of about 130 wind farms had a problem of fluctuation (amplitude modulation).[3] The response of the British Government to this work was to decide that amplitude modulation was, in reality, not a significant enough problem to merit further work on it. [4]

Other work in Denmark looked at a wide range of sounds evaluated by the Danish method of assessing low frequency noise, which covers the range 10Hz to 160Hz. Wind turbine noise, as heard indoors, was assessed for a 3.6MW turbine at 600m and shown to be lower than all other sources except for a refrigerator.[5]

Q. What is your reaction to James's estimate of the amount of time that wind turbine sound may be amplitude modulated?

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[3] Moorhouse, A., Hayes, M., von Hunerbein, S., Piper, B., and Adams, M. (2007): Research into aerodynamic modulation of wind turbine noise. BERR Report URN 07/1235. *http://www.berr.gov.uk/files/file40570.pdf*.

[4] *www.berr.gov.uk/files/file40571.pdf*

[5] Pedersen, T. H. (2008): Low frequency noise from large wind turbines. *DELTA Report EFP - 06*.

A. On page 6 of his report (Exhibit 808) James says, “The author has confirmed amplitude modulation (blade swish) at every project he has visited.” This is possible, as he probably only visits installations where there have been complaints, but some numbers would be useful. However, on page 7 of his Exhibit 808, he quotes an assessment for New York rural areas. “Stable conditions occurred for 67% of the time and that for 30% of those nights, wind velocities represented worst case conditions where ground level winds were less than 2m/s and hub height winds were greater than wind turbine cut in speeds, 4m/s”. 30% of 67% is 20%.

He also quotes van den Berg’s estimate of 47% of the time over a year for the Rhede Wind Farm on the border between Germany and The Netherlands. However, this is a very extensive flat area, such as is most prone to these effects.

Q. Please describe the levels of infrasound and low frequency noise emitted by wind turbines similar to those proposed for the Glacier Hills Wind Park.

A. I am willing to accept the spectrum given by Kamperman and James in their “How to Site” paper, which can be found at both the beginning and the end of their Exhibit 809, on Fig. 1, page 7 of their paper. This shows the level external to a residence from a 2.5MW turbine at 305m (1000ft). From the graph given, one can extract the low frequency levels in tabulated form as follows:

Freq	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315
Level	63	62	61	59	57	55	53	50	48	46	44	42	42	39	38	37

Q. Please describe the average levels at which infrasound and low frequency sound are audible.

A. The best work on the audibility of infrasound and low frequency noise has been by Watanabe and Moller in Denmark.[6] Auditory threshold levels are

Freq Hz	4	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200
Level dB	107	100	97	92	88	79	69	60	51	44	38	32	27	22	18	14

This shows that the levels in the infrasound region start at 107dB at 4Hz and gradually reduce into the audible region.

When one compares these two tables with each other one arrives at the following in the low frequency region:

Freq Hz	**10**	**12.5**	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**
Threshold	97	92	88	79	69	60	51	44	38	32	27	22	18	14
WT sound	63	62	61	59	57	55	53	50	48	46	44	42	42	39
Difference	34	30	27	20	12	5	-2	-6	-10	-6	-17	-20	-24	-25

[6] Watanabe, T., and Møller, H. (1990a): Hearing thresholds and equal loudness contours in free field at frequencies below 1kHz. *Jnl Low Freq Noise Vibn* **9**, 135-148.

In this comparison table, where the difference is positive, that is up to about 31.5 – 40Hz, the wind turbine sound is not audible to the average person. The low infrasound frequencies are well below the hearing threshold.

This shows that while some low frequency noise produced by wind turbines may be above the hearing threshold, it does not reach harmful levels, because the sound pressure level is low.

<u>JAMES'S RELIANCE ON MY PRIOR ACADEMIC WORK IS MISPLACED.</u>

Q. James relies on a paper you wrote entitled "Low Frequency Noise and Annoyance." What is your reaction to that?

A. I was invited to write a paper on Low Frequency Noise and Annoyance for a special Low Frequency Noise Issue of the Journal of Noise and Health. The paper contains general material on annoyance by noise, and is angled towards low frequency noise. Much of what is in the paper is applicable to any audible noise, including the coping methods referred to by James at the bottom of page 13 of his report, Exhibit 808. They are not specific to low frequency noise. In fact, similar methods are used to help people with high frequency tinnitus. There is nothing mysterious about these methods. They involve learning to desensitize oneself to the noise and its effects. In this, one's attitude toward the noise is very important. [7] [8] The constant propaganda that wind turbines are dangerous to health has caused fear and concern amongst the public. It is well known that if

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[7] Jonsson, E., and Sorensen, S. (1970): Relation between annoyance reactions and attitude to source of annoyance. *Public Health Reports* **85**, 1070 - 1074.

[8] Hatfield, J., Job, R., Carter, N., Peploe, P., Taylor, R., and Morrell, S. (2001): The influence of psychological factors on self-reported physiological effects of noise. *Noise and Health* **3**, 1-13.

there is fear of a noise source, or an antagonism to its creators, then the responses are more negative than they would otherwise have been. This also applies to wind turbines.[9]

I disagree with James's assertion in this section that I have been having an "ongoing debate" with Pierpont. Some five years ago, when she was the leading NIMBY in her locality, I criticised some of her statements about noise. The response of her and her husband was to attempt to discredit me, instead of replying to the points raised. We have never debated. Exhibit 24 shows the response of Pierpont to my submission in this proceeding on Wind Turbine Syndrome. Finally, as it has been shown that the claims of health effects through direct physiological action by low levels of infrasound and low frequency noise are untenable, James's final sentence on page 13 is not relevant.

Q. James also relies on a paper you wrote entitled "Effects on Performance and Work Quality Due to Low Frequency Ventilation Noise." What is your reaction to that?

A. The spectrum which was used for the low frequency element of the noise in that study was vastly different from that of wind turbine noise in several respects. It mirrored more closely the spectrum which is produced by tonal low frequency noises in the environment. The low frequency component of the noise was an amplitude modulated tone of around 35Hz, fluctuating in level about twice per second to produce a rapid throbbing sound. The maximum tone level was about

[9] Pedersen, E., van den Berg, F., Bakker, R., and Bouma, J. (2009): Response to noise from modern wind farms in The Netherlands. *J Acoust. Soc. Am* **126**, 634-643.

40dB above the surrounding noise levels and clearly audible. The spectrum is submitted as Exhibit 25. Of course, this additional noise was noted by the participants as a disturbing factor. Nevertheless, differences between performance in this low frequency noise and in medium frequency noise were small. Social orientation changed by about 7% and pleasantness by about 10%. The change in annoyance was not statistically significant.

This work cannot be compared with the effects claimed to be attributable to wind turbines. James is incorrect when, on page 18 of his Exhibit 808, he compares the experimental levels of this work with those of wind turbines in homes. In our work the level was about 75dB in the 31.5 Hz 1/3 octave band. The levels outside residences given by Kamperman and James at 31.5Hz are 55dB, and will be even lower inside.

Q. In addition to relying on your work, James submitted several hundred pages of supporting materials in Exhibit 809. Could you comment on those materials?

A. I found this to be a rather confusing collection of material, with only part of it relevant to his testimony. I have addressed some of it in my testimony, but, like James, I have not referred directly to most of it.

APPLICATION OF THE PRECAUTIONARY PRINCIPLE IS UNWARRANTED IN THIS CONTEXT

Q. James advocates application of the precautionary principle with regard to wind turbine noise. Do you agree?

A. This is related to the different approaches of Clinicians and Legislators. Clinicians deal with individuals – their patients -- and are concerned for the well-being of each one as a unique person. A legislator, or planner, considers people as a group and develops criteria for protection of the majority. For noise sources, this has normally been achieved by a social survey, which relates number annoyed to a physical characteristic of the noise, such as dBA or L_{dn}. A decision is then made on where to set the limiting level for a protection criterion. Criteria do not, and never have been, designed to protect the most sensitive, although the special problems of the sensitive may influence the criteria.

A difficult decision has to be made, balancing national needs against individual needs. The approaches of both Clinicians and Legislators are valid within their own spheres. However, problems may arise when one impinges on the field of the other.

Q. Does this conclude your testimony?

A. Yes.

BEFORE THE
PUBLIC SERVICE COMMISSION OF WISCONSIN

Application for a Certificate of Public Convenience and Necessity to Construct and Place in Service a Wind Turbine Electric Generation Facility Known as Glacier Hills Wind Park in Columbia County, Wisconsin	)	Docket No. 6630-CE-302

SUR-SURREBUTTAL TESTIMONY OF DR. GEOFF LEVENTHALL
ON BEHALF OF WISCONSIN ELECTRIC POWER COMPANY

Q. Please state your name.

A. Dr. Geoff Leventhall.

Q. Did you previously provide rebuttal testimony in this case?

A. I did.

Q. What is the purpose of your sur-surrebuttal testimony?

A. To respond to certain statements made in the surrebuttal testimony of CWESt witness Richard James.

Q. On page SR9.16, Mr. James accuses you of "lumping together" low frequency sound and infrasound. How do you respond?

A. He is wrong. Mr. James correctly states my belief about infrasound from wind turbines, which is that it is of no consequence. This is supported by the research of Jakobsen of Denmark and van den Berg, of the Netherlands. There is, of course, a continuum from infrasound to low frequency noise, but when the infrasound is negligible, as with wind turbines, we need to consider only audible low frequency noise. In fact, whenever Mr. James uses the abbreviation ILFN, which he does frequently, for infrasound and low frequency noise, it is he who is lumping them together.

Mr. James mentions my earlier work on mitigation of low frequency noise, but does not acknowledge that there are different sorts of low frequency noise. Most of the environmental studies were done on disturbance from tonal noise - machines, fans etc. A continuous low frequency noise, falling in level into higher frequencies, is less annoying than one with high separate components. This is because it does not display a distinctive character. As mentioned in earlier testimony, it has been shown that noise falling at about 5 dB per octave, similar to wind turbine noise, is bland and unobtrusive.

Q. Mr. James claims that it is not possible for effects from wind turbine noise to become "lost" amongst the other internal noises of the human body because humans have adapted to ignore normal bodily noises. What is your reaction to that statement?

A. Human beings have not adapted to disregard normal body sounds. We are not normally aware of even the strongest of these sources – the heart, but may be concerned when the heartbeat intrudes into our consciousness. Further, the fact that we are not normally aware of internal sounds does not mean that they are not present. Similarly, those who suffer from tinnitus have not adapted to it, but may be more or less attuned to it depending on a number of factors.

What Mr. James is saying is contrary to all that we know about masking of a low sensation by a higher sensation, such that the low sensation is not detected. How many times have we not been able to hear what is said because of traffic noise, or some other noise? Nevertheless, Mr. James appears to believe, like Dr. Pierpont, that low level external infrasound from wind turbines at 1 – 2 Hz will have an effect internally above the high internal sound and vibration of the heartbeat.

Q. Please continue.

A. The external sounds at 40-70 dB to which Mr. James refers on page SR9.16 must first enter the body, a process which causes them to be attenuated to even lower internal levels, before being compared with the existing internal sounds. Further, 40-70 dB are very low levels. In my rebuttal testimony I have shown that a level of 54 dB exerts a force on the body equivalent to that of a layer of water one micron thick (10^{-6} m), whilst the skin is typically around 1mm thick, which is 1000 times that of the layer of water. There is no effect without a mechanism. Mr. James offers no mechanism by which this miniscule force penetrates the skin and then goes on to the other organs, which are separate from the skin – not part of it.

But on the other hand, sound sources within the body cause sufficient vibration in the body for the skin to radiate sounds externally. As an example, when we hear another person's "tummy rumble," it is because the internal fluctuations have vibrated the outer surface and transmitted sound.

Q. Mr. James charges that you have "dismissed" the studies cited by Dr. Mulvihill. Is he correct?

A. No. I showed that those studies looked at very high levels of sound, well above levels produced by wind turbines. They may well be perfectly good studies for what they represent, but they are at levels of over 100 dB, that is 50 – 60 dB greater than the levels from wind turbine noise.

Q. Is it any more correct for Mr. James to say that you "dismiss" the work of the vibroacoustic disease team?

A. No. In my critique, there is a footnote at the end making clear that what I say about their attempt to swing VAD onto wind turbines is not intended as a criticism of their work at high levels on aircraft technicians. I leave that to others.

I note that on page SR9.19 at lines 9-12, Mr. James concedes that the VAD team's work involves higher sound levels, but claims that other research bridges the gap between VAD levels and wind turbine levels. His failure to identify this "other research" is telling. The VAD team's opinions on wind turbine noise have not been published in refereed journals. Two and a half years ago, they announced that they had made a connection, but have not progressed further. One can only speculate on why they have done nothing more on such a hot topic.

Q. Mr. James implies that you have somehow misrepresented your e-mail correspondence with Dr. Ingber regarding the applicability of his theories of mechanotransduction to wind turbine noise. How do you respond?

A. I was careful to ask Dr. Ingber's permission to quote him and used only his own unedited words.

Further, I would suggest that it is actually Mr. James who misrepresents the correspondence with Dr. Ingber. As reflected in the e-mail excerpt on page SR9.18 of Mr. James's surrebuttal testimony, Dr. Ingber indicated that he did not know whether low frequency vibration might have a positive, negative or null effect on the human body. Of course, he is speaking like a cautious academic might be expected to. Obviously, though, Dr. Ingber is not saying, as Mr. James originally indicated in Exhibit 807, that mechanotransduction provides the "missing link" between wind turbine noise and physiological effects on the human body.

Q. Does Mr. James make any significant concessions in his surrebuttal testimony?

A. I am delighted to see that Mr. James is now being more cautious about his claims of numbers of people who might be affected by wind turbine sound. In the space of six lines he uses phrases like "a small subset," "not all people," "do not affect large percentages," and "a small proportion."

However, Mr. James's focus on this "small subset" of especially sensitive people may be misplaced. It is my experience, and that of other researchers, in investigating the auditory threshold of complainants of low frequency noise, that they do not have sensitive hearing thresholds. They scatter around the normal average. They complain, and are stressed, simply because they can hear the noise, whilst others who can also hear it do not complain.

Q. Does this conclude your sur-surrebuttal testimony?

A. Yes.

APPENDIX B

OBSERVATIONS AND ANALYSIS OF AQUIFER CHARACERISTICS

ROUGH ACRES RANCH

MCCAIN VALLEY, EAST SAN DIEGO COUNTY, CALIFORNIA

Geo-Logic ASSOCIATES
Geologists, Hydrogeologists and Engineers

Date: December 1, 2010
Project No.: 2010-0005

To: John Hower, CEG
Sarah Battelle, CHG

From: Mark Vincent, CHG

Regarding: **Observations and Analyses of Aquifer Characteristics Rough Acres Ranch, San Diego County, California**

INTRODUCTION

This memo presents a summary of observations and analyses made following a stepped and a constant rate aquifer pumping and recovery test in wells located at Rough Acres Ranch located approximately in McCain Valley in eastern San Diego County, California. The tests were performed to determine whether sufficient volumes of water are available for the Tule Wind Farm construction projects. Analyses performed included calculation of transmissivity, hydraulic conductivity, and storativity for a pumping well and observation wells.

WELL AND AQUIFER CONDITIONS

A well labeled as Well #6a was used as the pumping well for this test. Another well labeled as Well #6 (also referred to as South Well) is located 36 feet away from the pumping well and was monitored and analyzed as an observation well. More distant observation wells were monitored including Well #9 (Horse Corral Well), Walker Residence Well, Well #4 (RV Well), Well #2, and Well #8 (Far Field Well) (Figure 1).

Records for drilling and construction of the wells used for these pumping tests are incomplete or nonexistent. A well identified on Department of Water Resources (DWR) records as being owned by Harmony Grove Partners (identified as Form No. 1089956) is believed to be the log for Well #6a. Logs for Well #4 (RV Well) and Well #8 (Far Field Well) were also obtained. No records are available for Well #6 (South Well), The Walker Residence Well, Well #9 (Horse Corral Well), or Well #2.

Although DWR records indicate the borehole for Well #6a was drilled to a total depth of 420 feet, the bottom of the well is recorded to be at a depth of 385 feet below ground surface. Records are incomplete but it was assumed that the well screen extends from a depth of 75 to 385 feet below ground surface. A cement sanitary seal is reported to extend from ground surface to a depth of 56 feet. Wells #6 and #6a used in this pumping test have existing electric submersible pumps installed in them. Based on the production rates achieved during the tests performed, the wells are likely to be outfitted with four-inch diameter electric submersible pumps. Based on the depth and pressure head on the transducers installed in the wells for the test, it was assumed that both of the boreholes are 385 feet deep and are 6.5-inches in diameter. It was further assumed that the wells were constructed with 4-inch diameter well casing and that they are perforated or screened from a depth of 75 feet below ground surface. Details of well construction could not be verified in the field because of the presence of pumps, discharge pipes, electrical wires, and surface sanitary seals. Available well logs are included at the back of this document.

The area immediately around Well #6 and #6a is underlain by alluvium comprised of poorly sorted sand, gravel, and silt derived from the crystalline basement rock exposed on the adjacent canyon sidewalls. The crystalline basement rocks are classified as tonalite and yield groundwater from fractures. The well log reportedly recorded for Well #6a indicates that there is about 70 to 85 feet of alluvium overlying the tonalite. Groundwater was measured at a depth of 27.81 feet below the top of sanitary seal on Well #6a.

TEST METHODS

Observations of groundwater elevation were recorded in a pumping well and six observation wells in McCain Valley. Data was collected using pressure transducers connected to data loggers. Barometric pressure changes were recorded during the test and corrections were made to the pressure head data collected during the tests.

A stepped aquifer pumping test was performed using Well #6a to determine the optimum pumping rate for a longer duration test. The pressure transducers were deployed and began recording data on August 20, 2010 to perform the stepped pumping test. The stepped pumping test was performed at pumping rates of 28 gallons per minute (gpm), 38 gpm, 55 gpm and 60 gpm. A semi-logarithmic plot of elapsed time versus drawdown for the stepped pumping test is shown on Figure 2.

The constant rate pumping and recovery test was performed from August 24 through 27, 2010. The pump was powered-down on August 27, 2010 and allowed to recover for 10 hours when the pressure transducers were removed from the wells. A recovery test was performed by turning off the pumps and recording the increasing head levels over time.

DATA ANALYSIS

Changes in groundwater level data recorded during this test were corrected for barometric pressure changes and used to generate a file containing tabulated time and changes in pressure head. The data was used to generate time-drawdown graphs for the pumping and observation wells and imported into computer software used to calculate the transmissivity and storativity of the fractured tonalite.

The stepped pump test analysis consists of plotting the drawdown versus time for each pumping rate on a time versus drawdown plot with time plotted on a logarithmic scale. Forward projections of each segment representing a different pumping rate can be used to predict the likely drawdown for the pumping well during for the selected duration of the test. A pumping rate of 50 gpm was selected as the target pumping rate because it would allow for ample drawdown without the well running dry during the test.

The method of Schafer (1978) was employed to determine how much of the data set for Well #6a was impacted by casing storage effects. The method is a simplification of the method first developed by Papadopulos and Cooper (1967) but does not require prior knowledge of the transmissivity or well efficiency. The point at which casing storage effects are overcome was calculated to occur approximately 23 to 25 minutes into the test based on the assumptions about well construction practices, pumping rates, and drawdown. Very early pumping data was ignored in the analyses described below due to casing storage effects.

Time versus drawdown plots were prepared for the pumping and observation wells for the pumping and recovery portions of the test. The plots are shown with the time axis plotted on a logarithmic scale and drawdown on a linear scale.

Figure 3 shows the time-drawdown plot for Well #6a during pumping. The first 23 to 25 minutes of the test show the casing storage effects. Well #6a drawdown plots as a straight line on the time-drawdown chart representing constant aquifer properties during that portion of the drawdown cone development. A sudden change in the drawdown curve starts at approximately 11 or 12 minutes; which may reflect leakage from the alluvium above the fractured bedrock.

A residual drawdown plot for Well #6a is shown on Figure 4. The plot shows the change in drawdown versus the ratio of the time since the pump test started divided by the time since the recovery portion of the test started (t/t`). The residual drawdown at a t/t` ratio of 1 is shown to be about 0.33 feet (a less than significant change in storage noted in the pumping well over the course of the pumping and recovery portions of the aquifer stress test).

A time-drawdown plot of Well #6 (the observation well also referred to as South Well) located 36 feet away from the pumping well shows a decrease in drawdown from approximately 30 minutes to approximately 400 minutes which may result from leakage from the alluvium above the fractured bedrock (Figure 5). The Well #6 plot shows even less drawdown versus time after 400 minutes possibly reflecting the fractured bedrock aquifer.

The Well #6 recovery portion of the test is plotted as the residual drawdown versus t/t` shows a flat line on the semi-logarithmic plot (Figure 6) indicative of uniform aquifer conditions from a t/t` ratio of about 8 to 110 into the recovery test period. The residual drawdown value measured for a t/t' ratio of 1 is about -0.22 feet. It is not regarded to be significant compared to the County standard maximum change of 0.5 feet.

The Well #9 (Horse Corral Well) was monitored and the time-drawdown plot reflects that the well pump cycled on and off five times during the test (Figure 7). No analyses were performed for this well because the changes in drawdown versus time due to the pump activating are far greater than any drawdown likely to be induced by the pumping test at Well #6a.

Well #2 (Pond Well) and Well #9 (Far Field Well) were monitored for changes in head during the pumping test. Figure 8 and 9 show the time-drawdown plots for Wells #2 and #9. Both plots show similar small, cyclic, barometric changes in head but are not likely to have resulted from the pumping test. No analyses were performed using the data from these wells.

Water level drawdown data were evaluated using the computer software program AquiferTest version 3.5 (Waterloo Hydrogeologic, 2002). The program performs curve matching of the time drawdown data to calculate transmissivity, hydraulic conductivity, and storativity using different methods. The methods employed included Cooper-Jacob (1946), Moench (1993), Neuman (1975), and Theis (1935).

DISCUSSION

As shown on Table 1, the calculated hydraulic conductivity values for all of the analytical methods employed ranged from a low of 7.50E-04 feet/day for data collected from Well #6 (South Well) using the Theis method for the data collected from the end of the recovery test to a high of 7.50E+00 feet/day using the Cooper Jacob method with late time data for Well #6 (South Well). An average conductivity of 1.85 feet/day was calculated from all methods from both Well #6 and #6a. The Storativity values range from a low of 4.48E-06 for Well #6 late time data calculated using the Moench Fracture Flow method and a high of 7.87E-01 for a match to the late time data recorded in Well #6 using the Moench method with the vertical hydraulic conductivity set at one-tenth the horizontal hydraulic conductivity.

All of the analytical results show a higher transmissivity and hydraulic conductivity value for matches to the observation Well #6. The pumping well and observation well used for these analyses are located in a portion of McCain Valley which is entirely covered in up to 75 to 80 feet of alluvium (Figure 10). Based on the measured depth to groundwater in Well #6 and #6a, approximately 47 to 52 of saturated alluvium overlies the fractured bedrock at the test site (Figure 11). The saturated alluvium is likely to act like a reservoir recharging the fractures in the bedrock. The aerial extent of the fractured bedrock aquifer and the amount of storage in the fractures is likely controlled in part by the presence of the alluvial aquifer. Because the fractures in the bedrock appear to be of aerially limited extent, the actual volume of groundwater available may be limited with larger volumes of groundwater available within the canyon areas where fracturing may be most prevalent and alluvium is saturated.

CLOSURE

This summary of observations and analyses has been prepared in general accordance with accepted professional geotechnical and hydrogeologic principles and practices. This report makes no other warranties, either expressed or implied as to the professional advice or information included in it. Our firm should be notified of any pertinent change in the project, or if conditions are found to differ from those described herein, because this may require a reevaluation of the conclusions. This report has not been prepared for use by parties or projects other than those named or described herein. It may not contain sufficient information for other parties or purposes.

Geo-**L**ogic **A**ssociates

Mark W. Vincent, PG 5767, CEG 1873, CHg 865
Senior Geologist

Attachments: Table 1 - Aquifer Stress Test Results
Figure 1 - Well Location Plan
Figure 2 - Step Test Time Drawdown Plot
Figure 3 - North Well Time Drawdown Plot Pumping
Figure 4 - North Well Time Drawdown Plot Recovery
Figure 5 - South Well Time Drawdown Plot Pumping
Figure 6 - South Well Time Drawdown Plot Recovery
Figure 7 - Thing Valley Well Time Drawdown Pumping
Figure 8 - Thing Valley Well Time Drawdown Recovery
Figure 9 - Geologic Map
Appendix A - Analytical Results from Aquifer Test Program
Appendix B - Department of Water Resources Well Completion Reports

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Waterloo Hydrogeologic (co-developed with Thomas Roerich), 2002, AquiferTest version 3.5, Advanced Pumping Test and Slug Test Analytical Software.

Table 1

Aquifer Stress Test Results

Rough Acres Ranch - McCain Valley

Well Designation	Condition	Distance From Pumping Well (feet)	Groundwater Depth from Ground Surface (feet)	Assumed Aquifer Thickness (feet)	Average Pumping Rate (gpm)	Analytical Method	Transmissivity (feet^2/day)	Conductivity (feet/day)	Storativity	Comments
Well #6a	Pumping	1	28	500	50	Cooper-Jacob	6.30E+02	1.26E+00	NA	Match to late data.
Well #6a	Pumping	1	28	500	50	Moench Fracture Flow	1.12E+02	2.25E-01	2.70E-04	Match to late data.
Well #6a	Pumping	1	28	500	50	Moench	1.21E+02	2.43E-01	1.72E-01	Match to late data.
Well #6a	Pumping	1	28	500	50	Neuman	5.69E+01	1.14E-01	1.62E-02	Spec Yld. = 1.62E+02
Well #6a	Pumping	1	28	500	50	Theis	2.69E+01	5.39E-02	1.64E-01	Match to early data.
Well #6a	Pumping	1	28	500	50	Theis	1.51E+02	3.03E-01	3.19E-05	Match to late data.
Well #6a	Pumping	1	28	500	50	Walton	1.11E+02	2.21E-01	7.08E-04	Match to late data.
Well #6a	Recovery	1	28	500	0	Theis Recovery	2.17E-02	4.35E-05	NA	Match to early data.
Well #6a	Recovery	1	28	500	0	Theis Recovery	7.27E+00	1.45E-02	NA	Match to late data.
South Well #6	Pumping	36	27.81	500	50	Cooper-Jacob	2.14E+03	4.28E+00	NA	Match to middle data.
South Well #6	Pumping	36	27.81	500	50	Cooper-Jacob	3.75E+03	7.50E+00	NA	Match to late data.
South Well #7	Pumping	36	27.81	500	50	Moench Fracture Flow	2.95E+03	5.91E+00	4.48E-06	Match to late data.
South Well #6	Pumping	36	27.81	500	50	Moench	1.30E+03	2.60E+00	7.87E-01	Kv=1/10 Kh
South Well #6	Pumping	36	27.81	500	50	Neuman	9.67E+02	1.93E+00	NA	Match to all data.
South Well #6	Pumping	36	27.81	500	50	Theis	3.18E+03	6.36E+00	3.29E-06	Match to late data.
South Well #6	Pumping	36	27.81	500	50	Walton	1.13E+03	2.26E+00	1.47E-03	Match to early data.
South Well #6	Recovery	36	27.81	500	0	Theis Recovery	3.75E-01	7.50E-04	NA	Match to early data.
South Well #6	Recovery	36	27.81	500	0	Theis Recovery	2.23E+00	4.47E-03	NA	Match to late data.
						Average Values	**9.24E+02**	**1.85E+00**	**1.14E-01**	

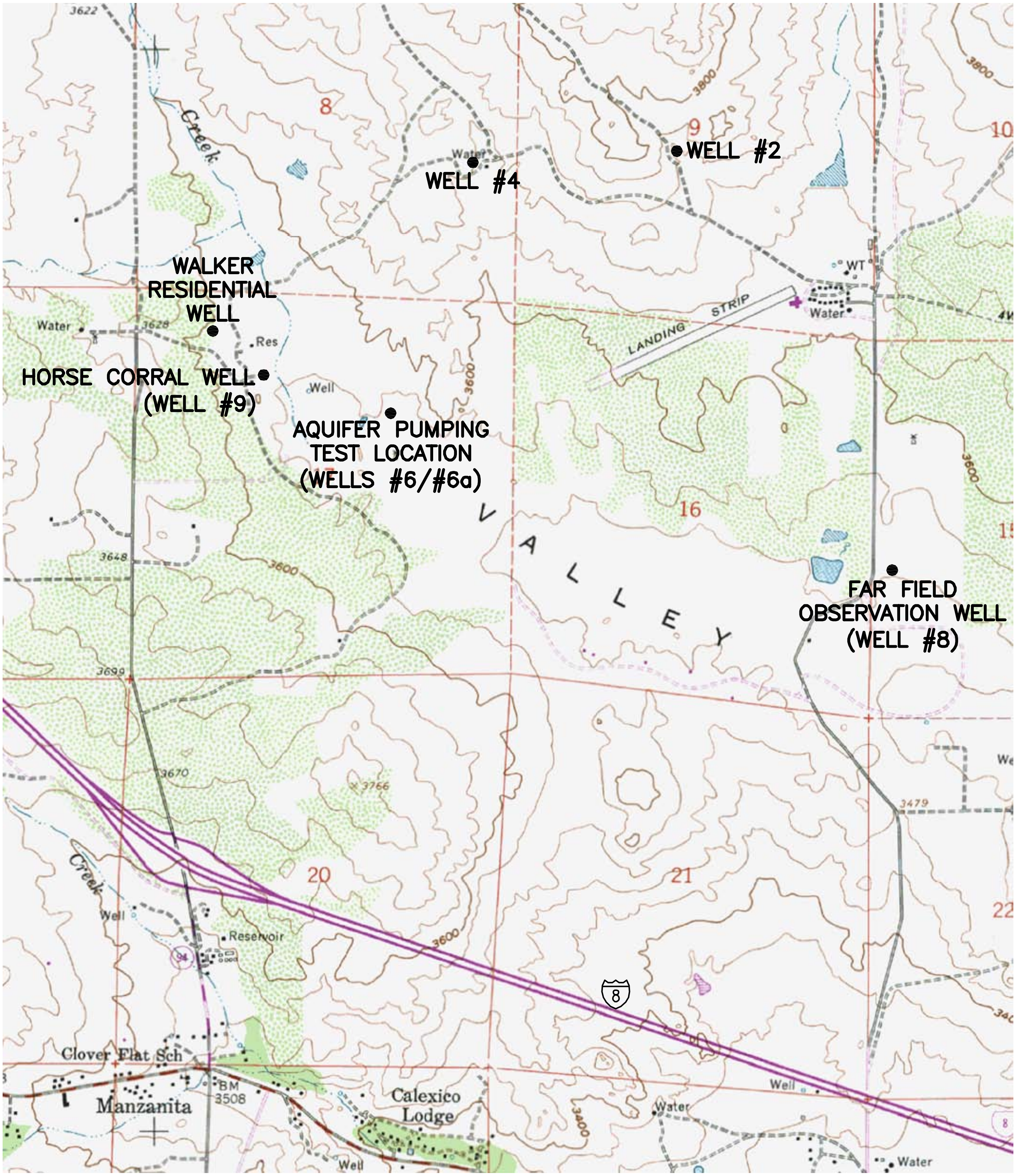


FIGURE 2B

WELL LOCATION MAP
ROUGH ACRES RANCH AQUIFER TEST SITE

TULE WIND PROJECT
SAN DIEGO COUNTY, CA

Geo-Logic ASSOCIATES

DRAWN BY: VL | DATE: NOVEMBER 2010 | JOB NO. 2010-005

GRAPHIC SCALE
1000 0 500 1000 2000
(in feet)
1 inch = 2000 ft.

N

REFERENCE: 7.5 MINUTE SERIES (TOPOGRAPHIC) LIVE OAK SPRINGS (1975) CALIFORNIA QUADRANGLE

Figure 2
Step Drawdown Test
Well #6a - Pumping Well
Rough Acres Ranch, McCain Valley

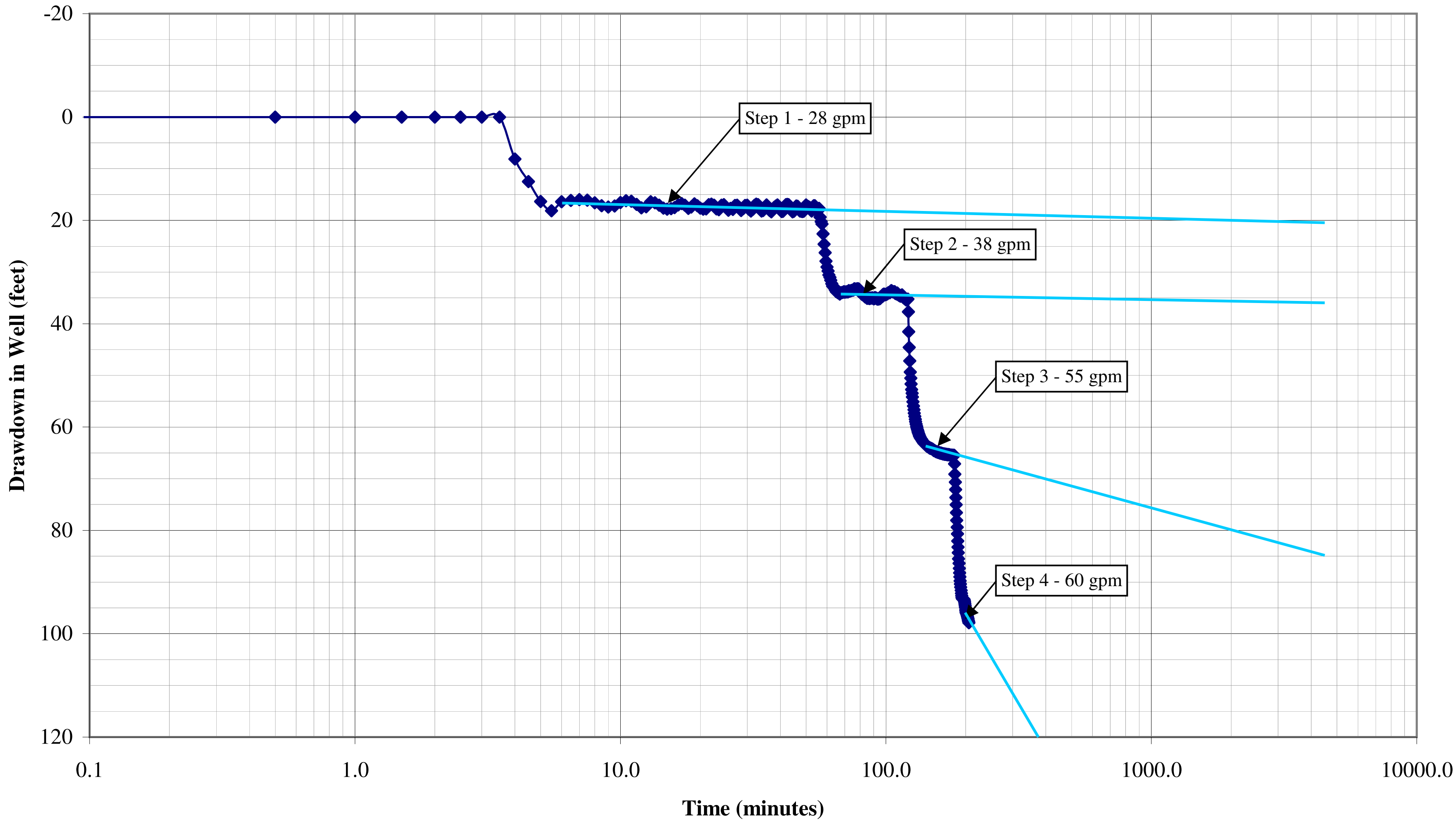


Figure 3
Drawdown in Pumping Well during 72-hour Pumping Test at 50 gpm
North Well at Rough Acres Ranch

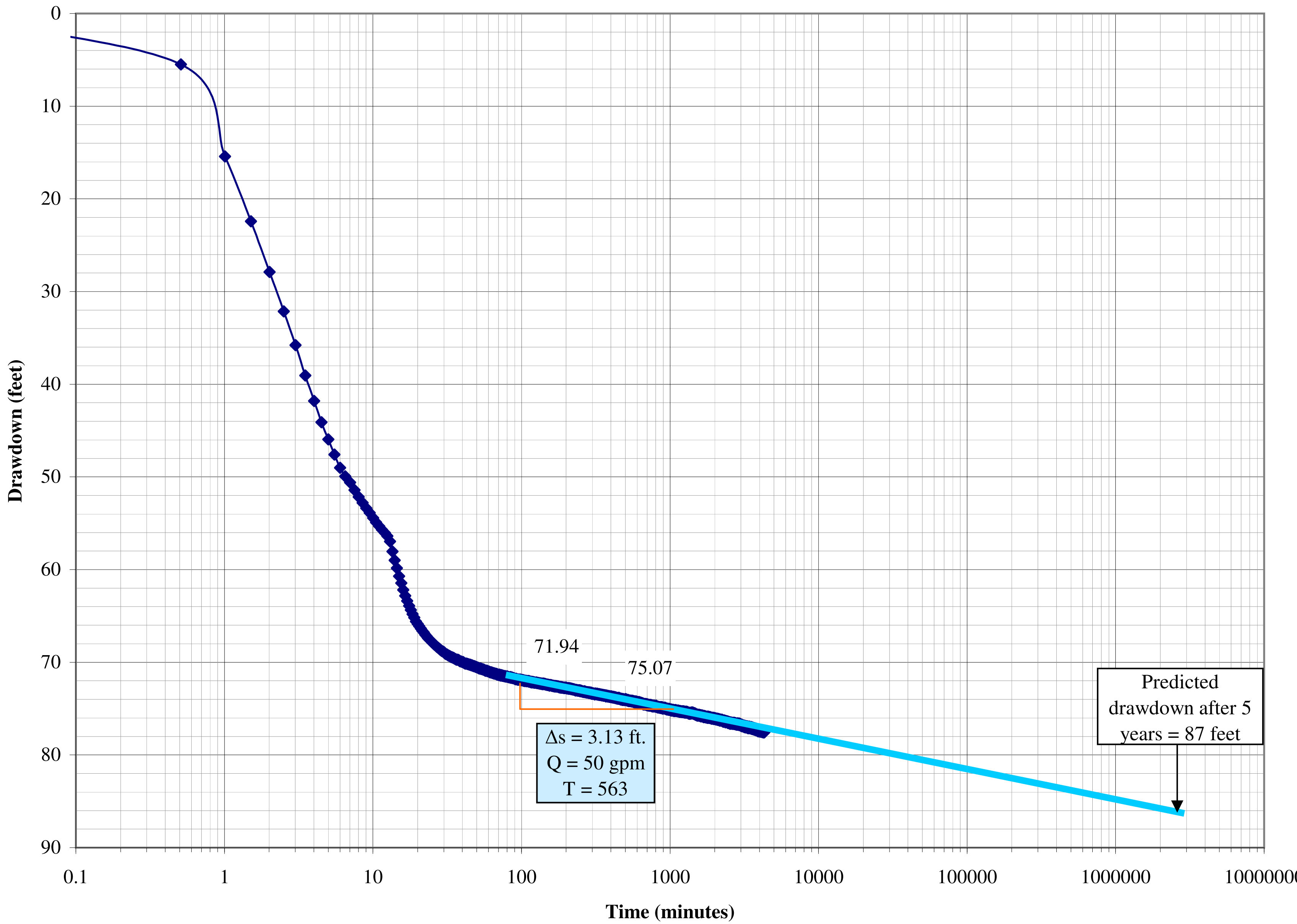


Figure 4
Residual Drawdown Plot
Pumping Well #6a

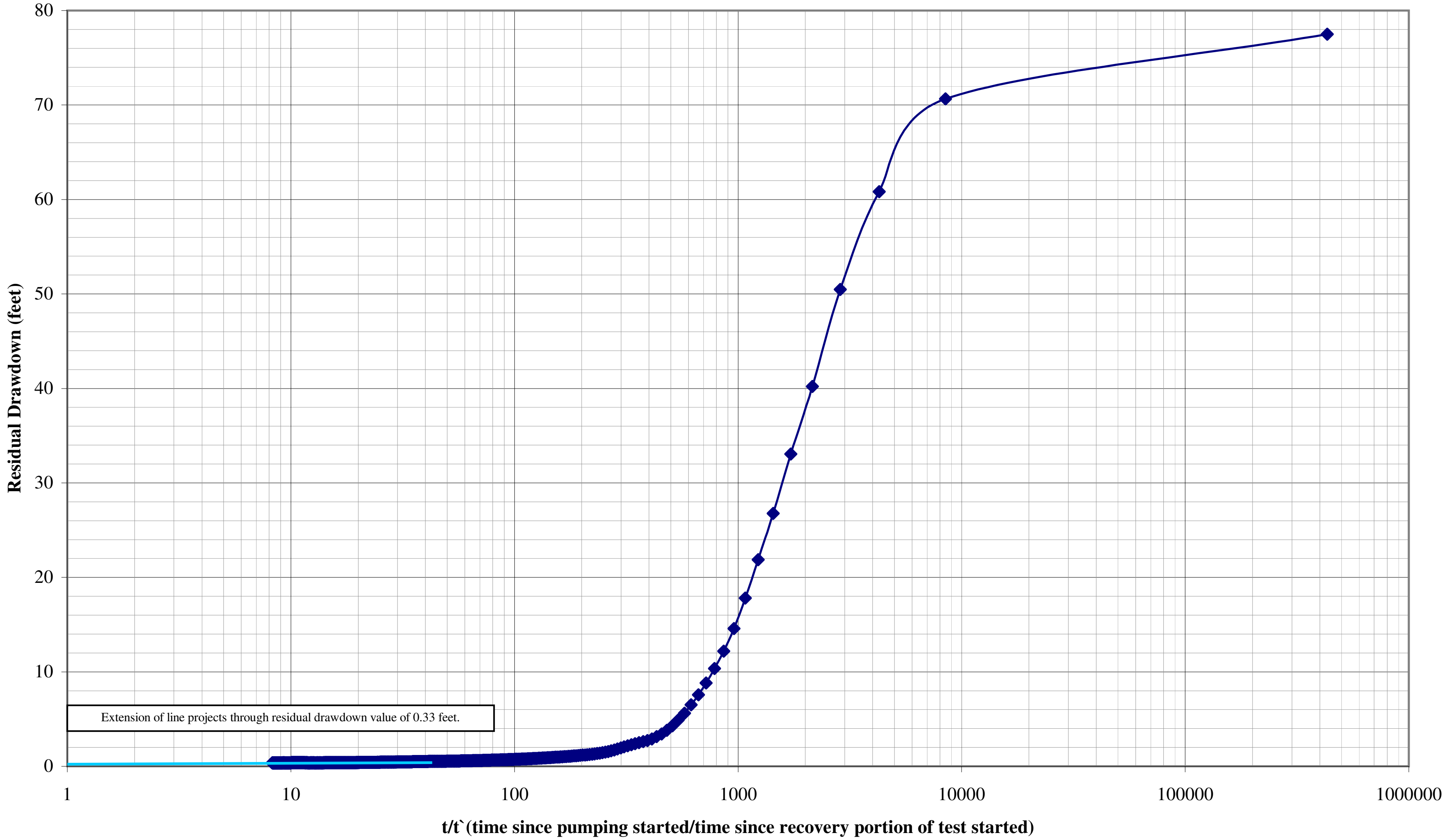


Figure 5
Well #6 - Observation Well
Time-Drawdown Plot
Rough Acres Ranch

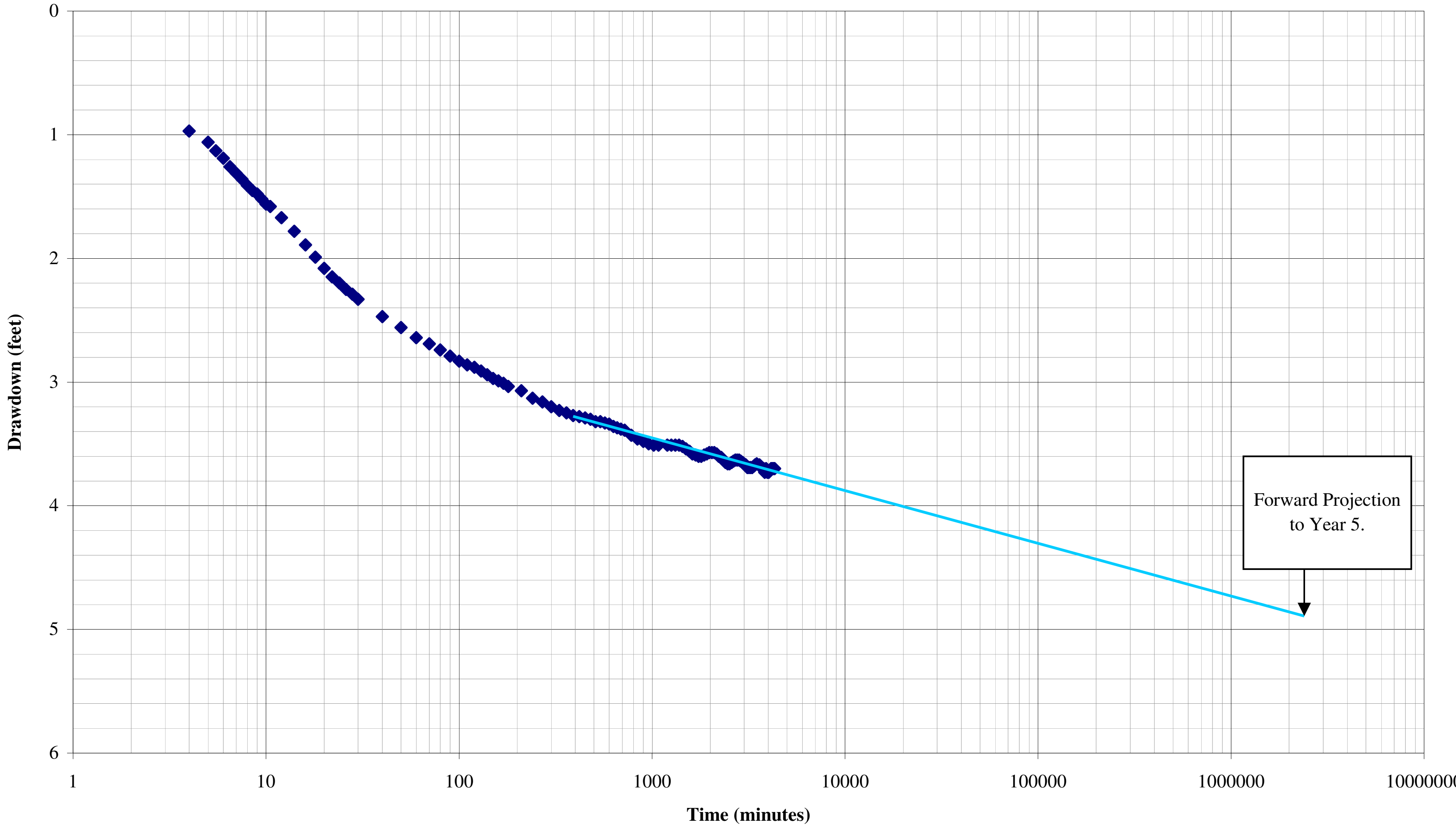


Figure 6
South Well - Observation Well
Residual Drawdown Plot
Rough Acres Ranch

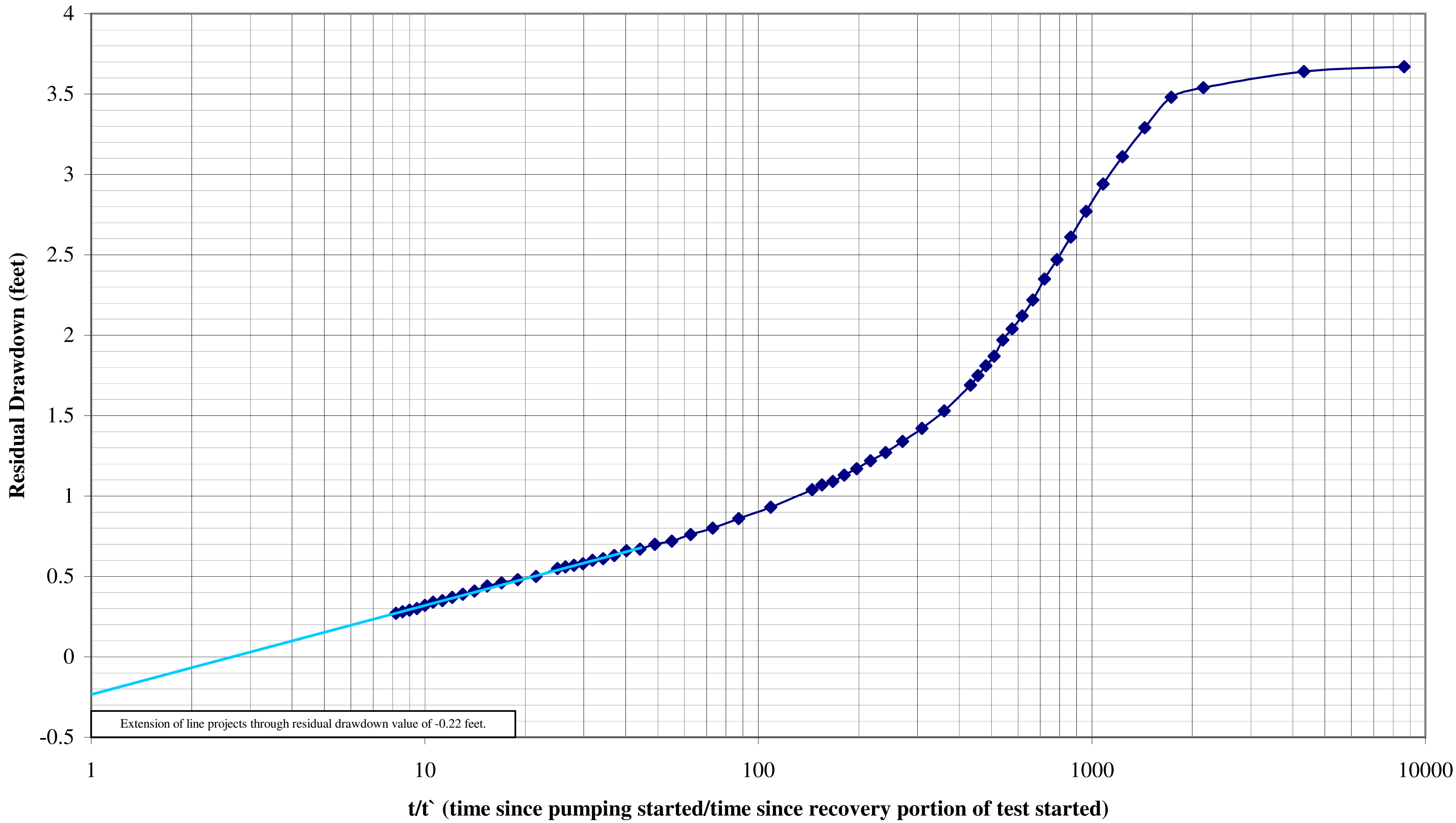


Figure 7
Horse Corral Well
(Observation Well)
Time-Drawdown Plot

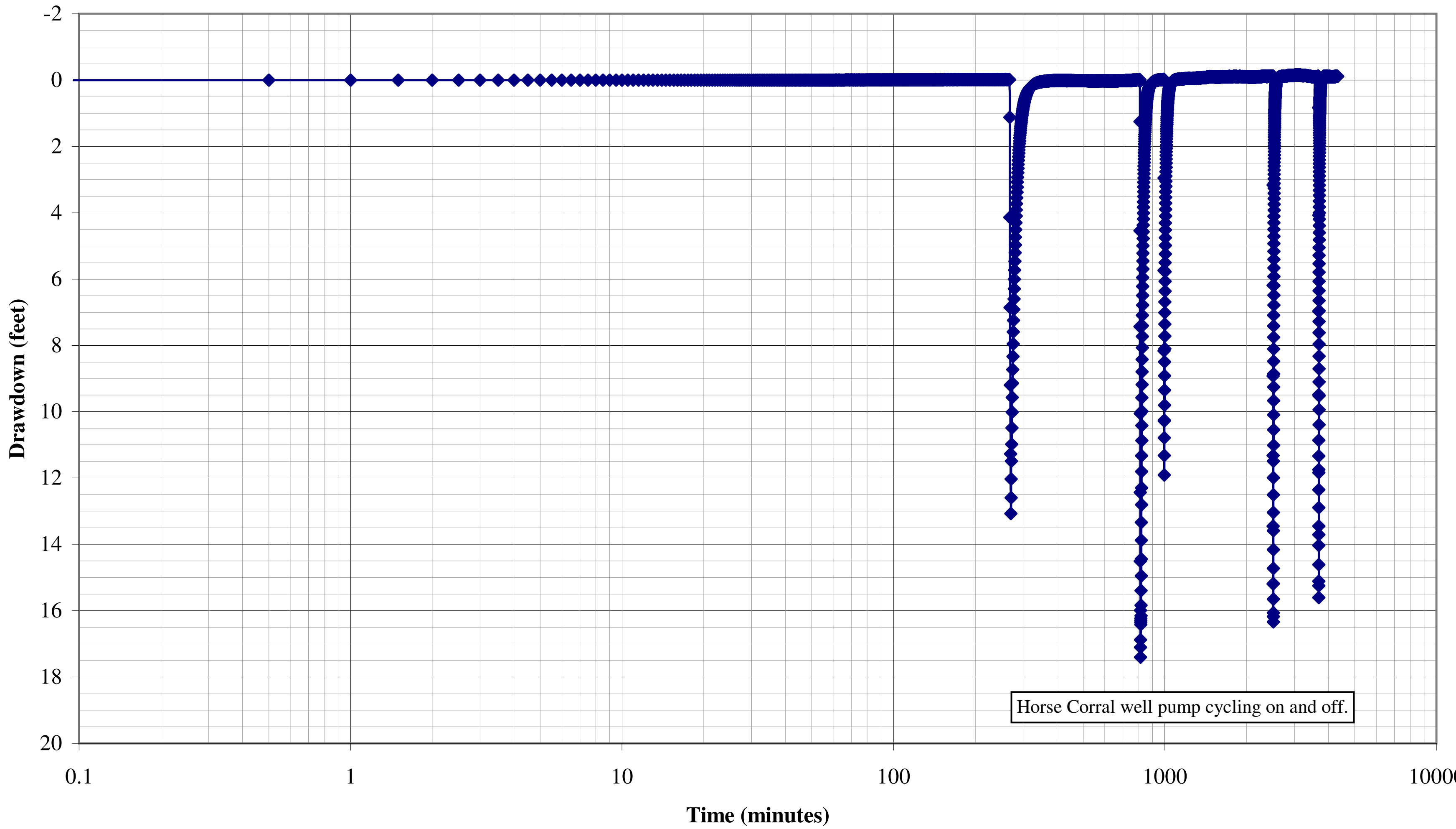


Figure 8
Well #2 - Observation Well
Distance-Drawdown Plot
Rough Acres Ranch

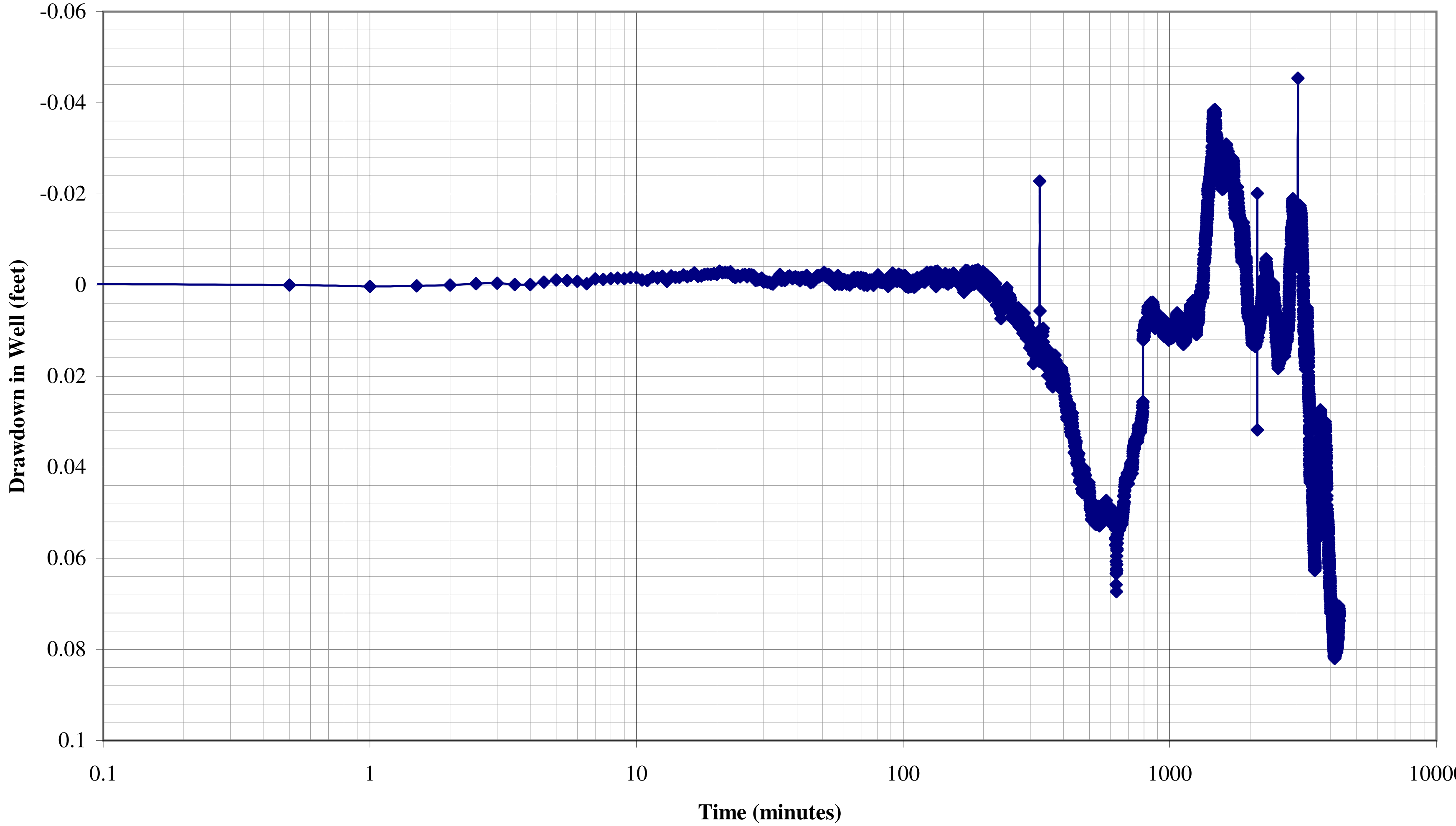
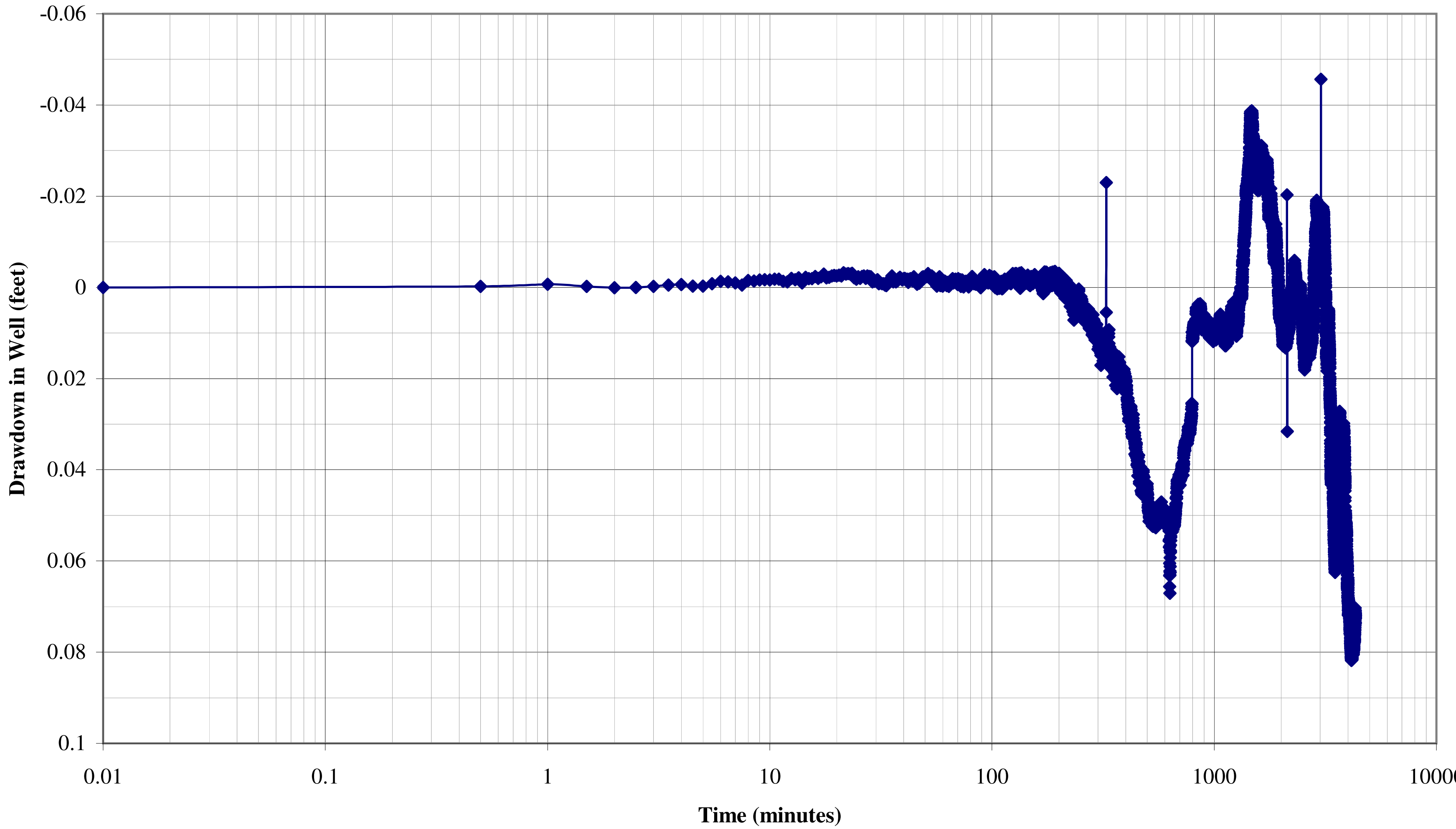
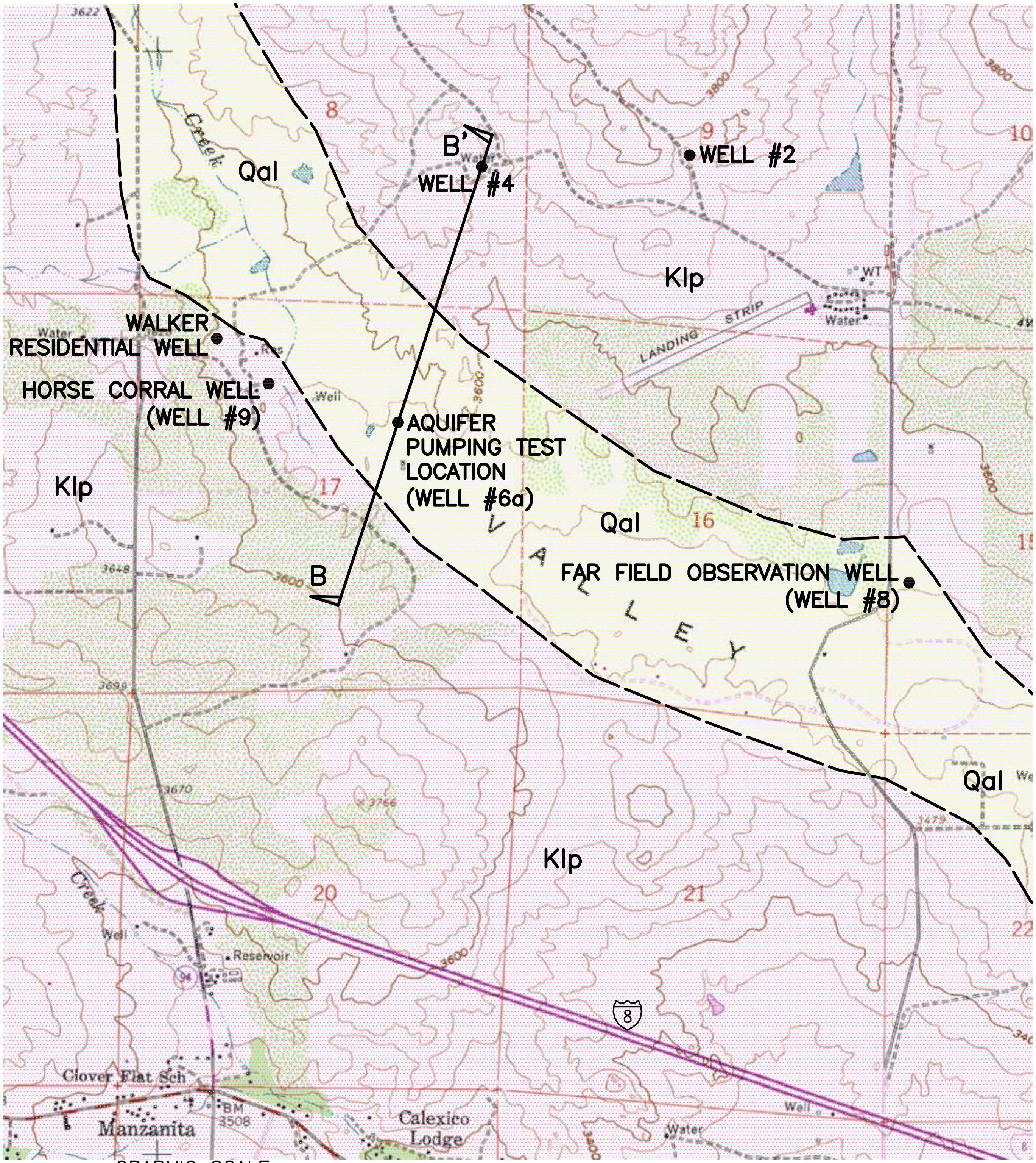


Figure 9
Well #8 Far Field - Observation Well
Time-Drawdown Plot
Rough Acres Ranch





GRAPHIC SCALE

1000 0 500 1000 2000

(in feet)

1 inch = 2000 ft.

N

REFERENCE: PRELIMINARY GEOLOGIC MAP OF EL CAJON 30' x 60' QUADRANGLE, SOUTHERN CALIFORNIA, V. R. TODD, 2004

EXPLANATION:

Qal ALLUVIUM

Klp TONALITE OF LA POSTA (EARLY AND LATE CRETACEOUS)

— — — APPROXIMATE GEOLOGIC CONTACT

B B' CROSS-SECTION LOCATION

FIGURE 7

GEOLOGIC MAP
ROUGH ACRES RANCH AQUIFER TEST SITE

TULE WIND PROJECT
SAN DIEGO COUNTY, CA

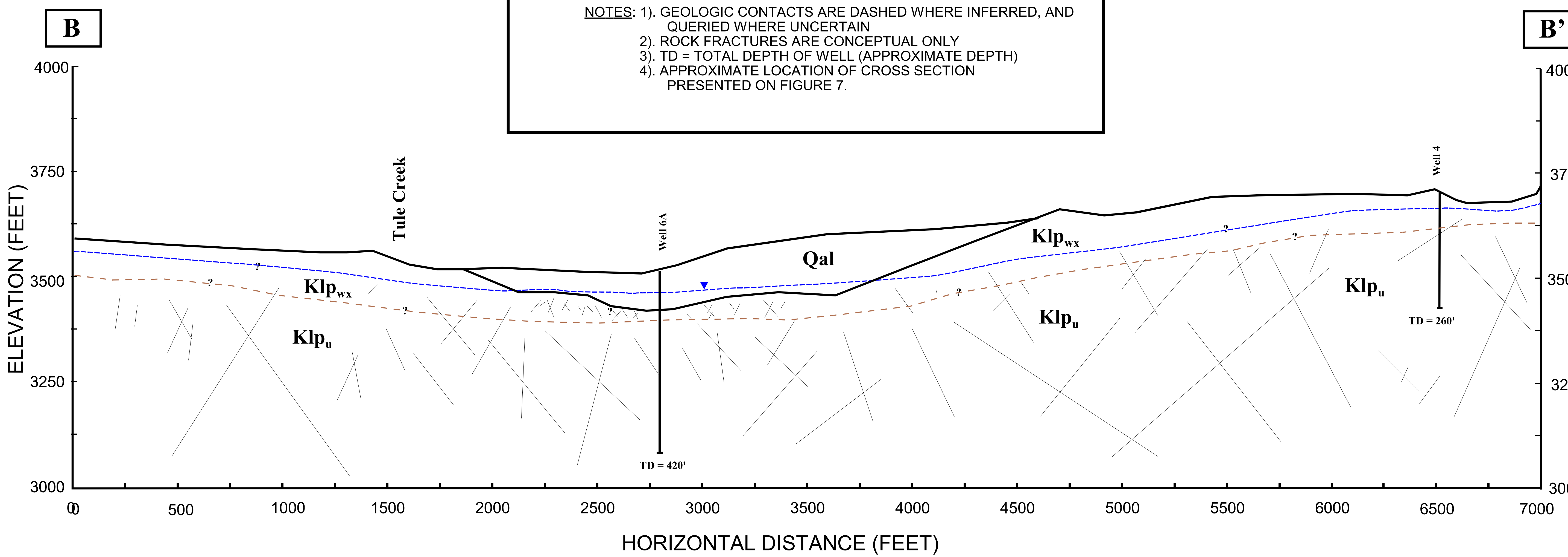
Geo-Logic ASSOCIATES

DRAWN BY: VL	DATE: NOVEMBER 2010	JOB NO. 2010-005

LEGEND

Qal	RECENT ALLUVIUM
Klp_{wx}	LA POSTA TONALITE, WEATHERED
Klb_{u}	LA POSTA TONALITE, UNWEATHERED
(blue dashed line)	APPROXIMATE GROUNDWATER TABLE
(crossing lines)	ROCK FRACTURES (SCHEMATIC ONLY)

<u>NOTES</u>: 1). GEOLOGIC CONTACTS ARE DASHED WHERE INFERRED, AND QUERIED WHERE UNCERTAIN
2). ROCK FRACTURES ARE CONCEPTUAL ONLY
3). TD = TOTAL DEPTH OF WELL (APPROXIMATE DEPTH)
4). APPROXIMATE LOCATION OF CROSS SECTION PRESENTED ON FIGURE 7.



NORTH 18° EAST

HORIZONTAL SCALE: 1 INCH = 500 FEET
VERTICAL SCALE: 1 INCH = 250 FEET
2x VERTICAL EXAGGERATION
(11 X 17 INCH FORMAT ONLY)

References: USGS, 1975, 7.5' Live Oak Springs, CA Quadrangle.

FIGURE 8

CONCEPTUAL HYDROGEOLOGIC CROSS SECTION

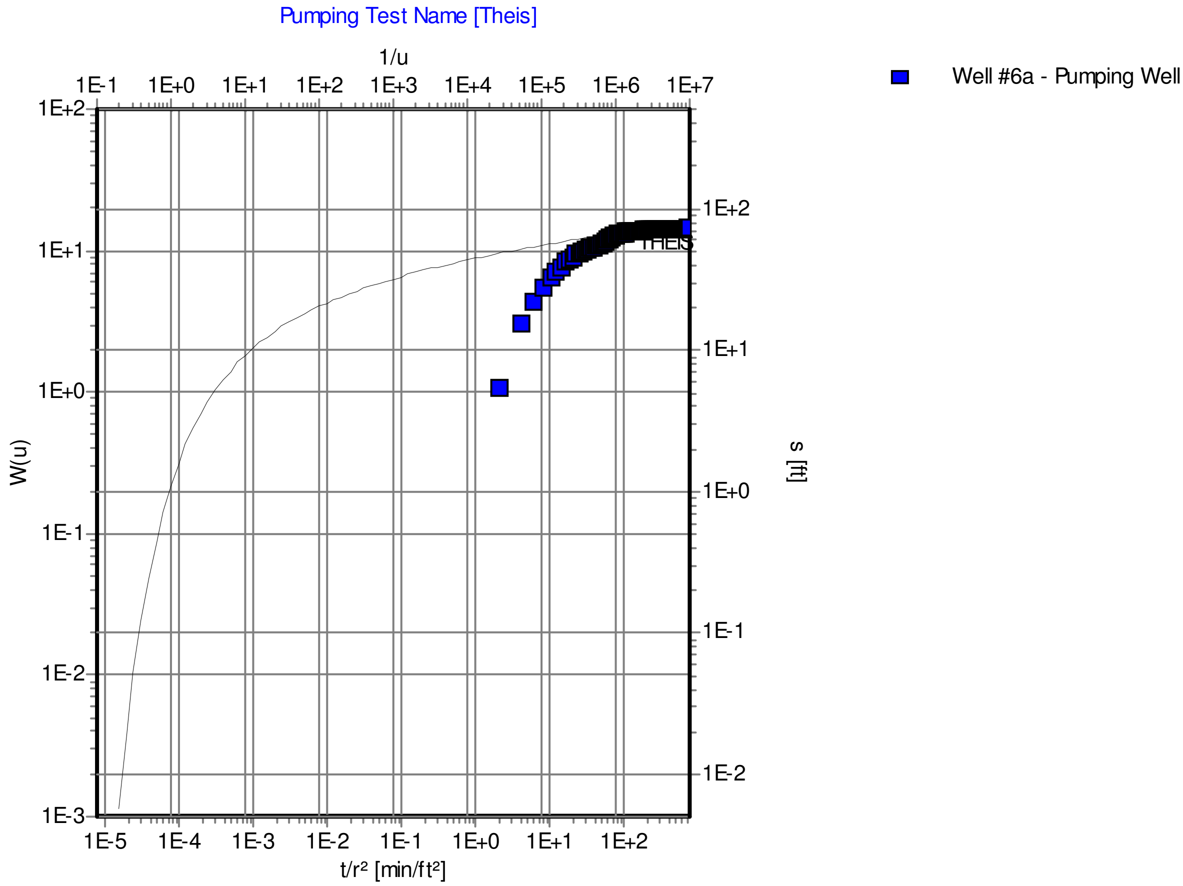
ROUGH ACRES STUDY AREA
SAN DIEGO COUNTY, CALIFORNIA

Geo-Logic ASSOCIATES

Draft	Date	Project No.
JGF	OCT 2010	2010-0005

Appendix A
Analytical Results from Aquifer Test Program

Waterloo Hydrogeologic, Inc. 460 Philip Street - Suite 101 Waterloo, Ontario, Canada Phone: +1 519 746 1798	**Pumping Test Analysis Report** Project: Rough Acres Number: Client:

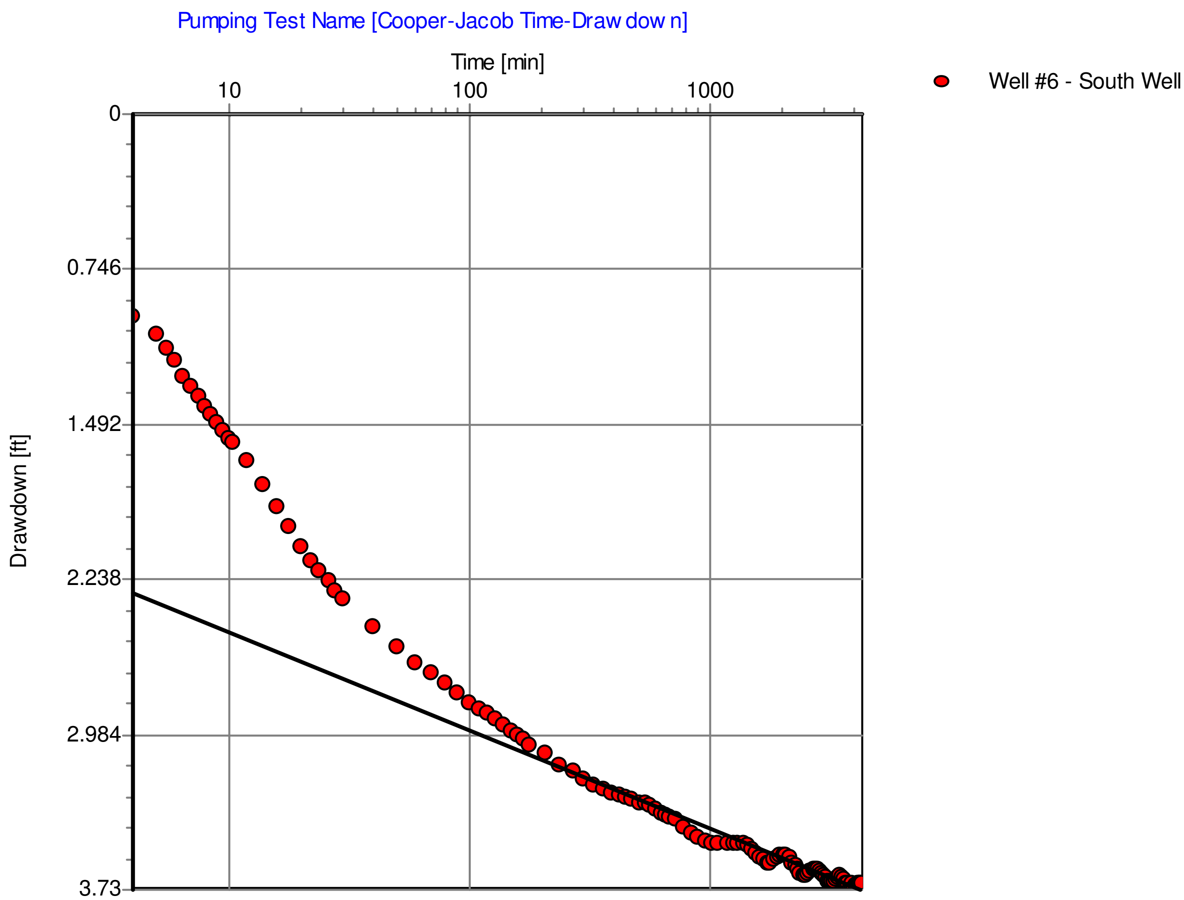


Pumping Test:	**Pumping Test Name**			
Analysis Method:	**Theis**			
Analysis Results:	Transmissivity:	1.51E+2 [ft²/d]	Conductivity:	3.03E-1 [ft/d]
	Storativity:	3.19E-5		
Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Confined Aquifer	
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		
Comments:	Match to late time data. Pumping Well.			

Evaluated by: MWV

Evaluation Date: 11/18/2010

Waterloo Hydrogeologic, Inc.	Pumping Test Analysis Report
460 Philip Street - Suite 101	Project: Rough Acres
Waterloo, Ontario, Canada	Number:
Phone: +1 519 746 1798	Client:



Pumping Test: **Pumping Test Name**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	3.75E+3 [ft²/d]	Conductivity:	7.50E+0 [ft/d]
	Storativity:	2.28E-7		

Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Confined Aquifer	
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		

Comments: Match to latest time data. Observation Well.

Evaluated by: MWV

Evaluation Date: 11/18/2010

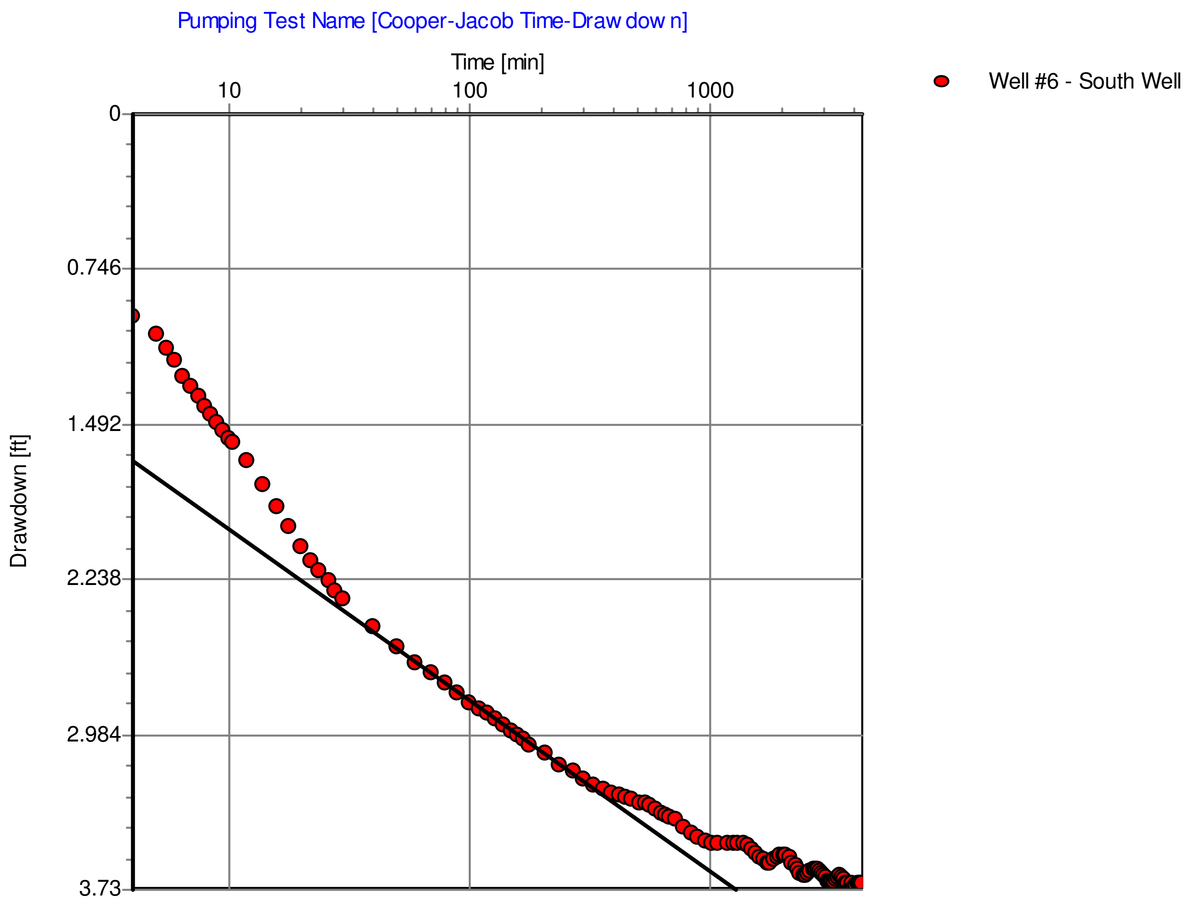
Waterloo Hydrogeologic, Inc.
460 Philip Street - Suite 101
Waterloo, Ontario, Canada
Phone: +1 519 746 1798

Pumping Test Analysis Report

Project: Rough Acres

Number:

Client:



Pumping Test: **Pumping Test Name**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:

Transmissivity:	2.14E+3 [ft²/d]	Conductivity:	4.28E+0 [ft/d]
Storativity:	1.01E-4		

Test parameters:

Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
Casing radius:	0.167 [ft]	Confined Aquifer	
Screen length:	310 [ft]		
Boring radius:	0.271 [ft]		
Discharge Rate:	50 [U.S. gal/min]		

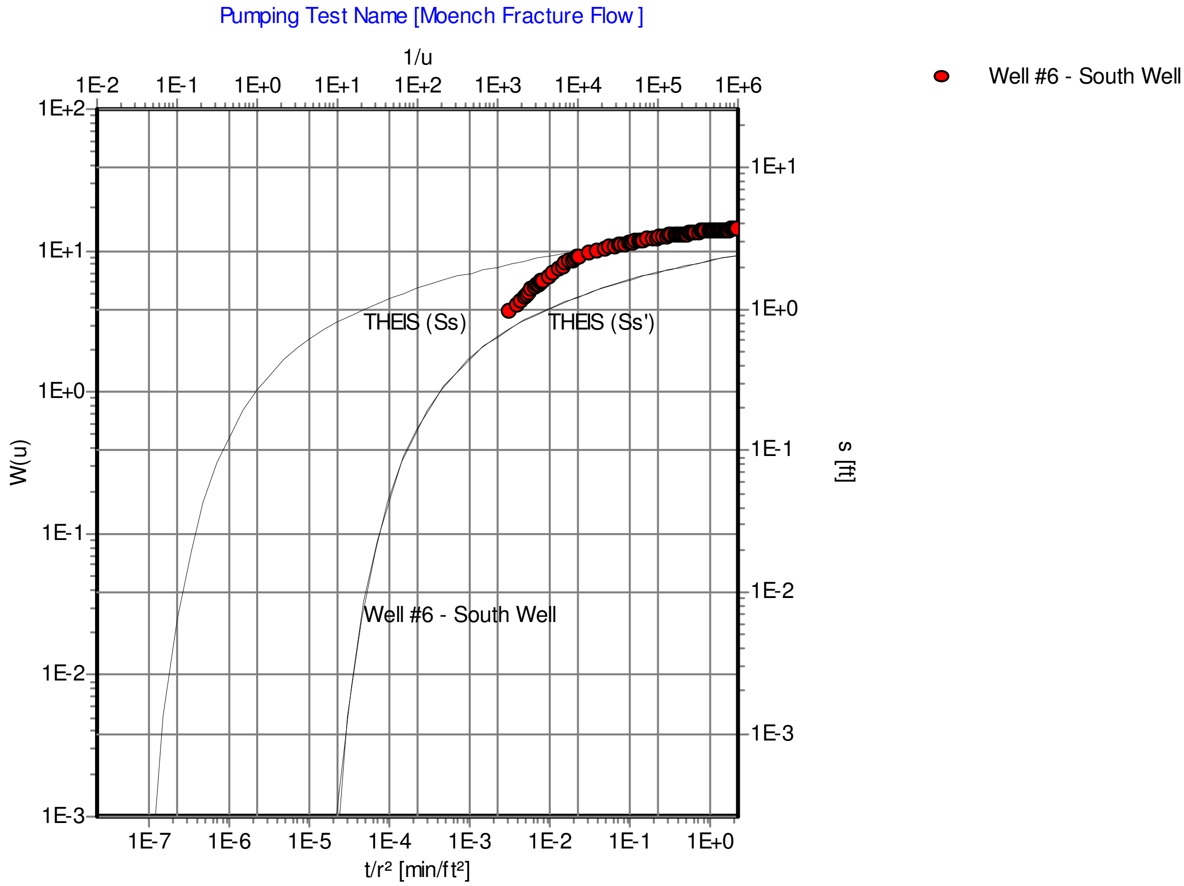
Comments: Match to middle time data. Observation Well.

Evaluated by: MWV

Evaluation Date: 11/18/2010

Waterloo Hydrogeologic, Inc.
460 Philip Street - Suite 101
Waterloo, Ontario, Canada
Phone: +1 519 746 1798

Pumping Test Analysis Report
Project: Rough Acres
Number:
Client:

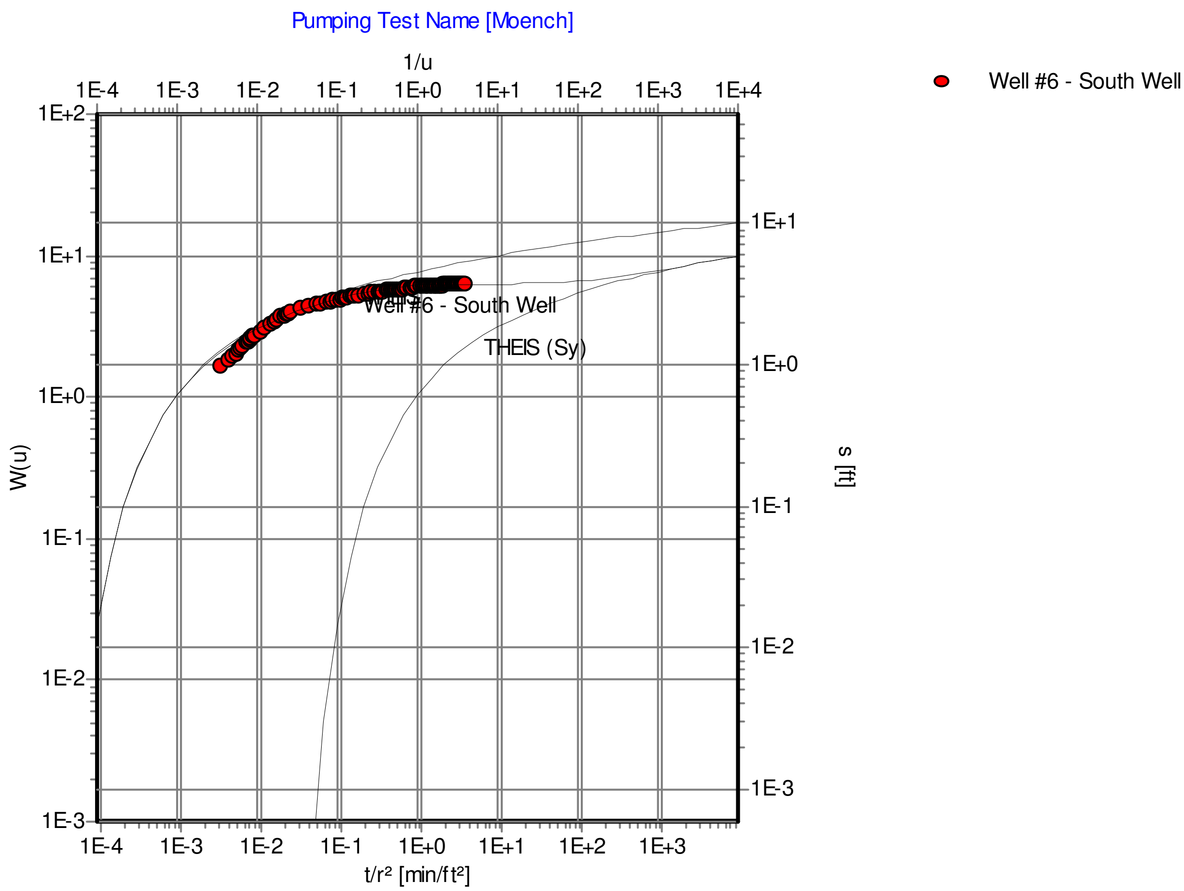


Pumping Test:	**Pumping Test Name**			
Analysis Method:	**Moench Fracture Flow**			
Analysis Results:	Transmissivity:	2.95E+3 [ft²/d]	Conductivity:	5.91E+0 [ft/d]
	Storativity:	4.48E-6		
Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	b:	357 [ft]
	Screen length:	310 [ft]	Kv/Kh:	0.1
	Boring radius:	0.271 [ft]	C:	0.231
	Discharge Rate:	50 [U.S. gal/min]	K(block)/K(Skin):	0.1
	Ss(blk)/Ss(fract):	200	K(block)/K(fracture):	0.1

Comments: Match to late time data.

Evaluated by: MWV
Evaluation Date: 11/18/2010

Waterloo Hydrogeologic, Inc. 460 Philip Street - Suite 101 Waterloo, Ontario, Canada Phone: +1 519 746 1798	**Pumping Test Analysis Report** Project: Rough Acres Number: Client:



<u>Pumping Test:</u> **Pumping Test Name**

<u>Analysis Method:</u> **Moench**

<u>Analysis Results:</u>	Transmissivity:	1.30E+3 [ft²/d]	Conductivity:	2.60E+0 [ft/d]
	Storativity:	7.87E-1	Conductivity (vertical):	2.60E-1 [ft/d]

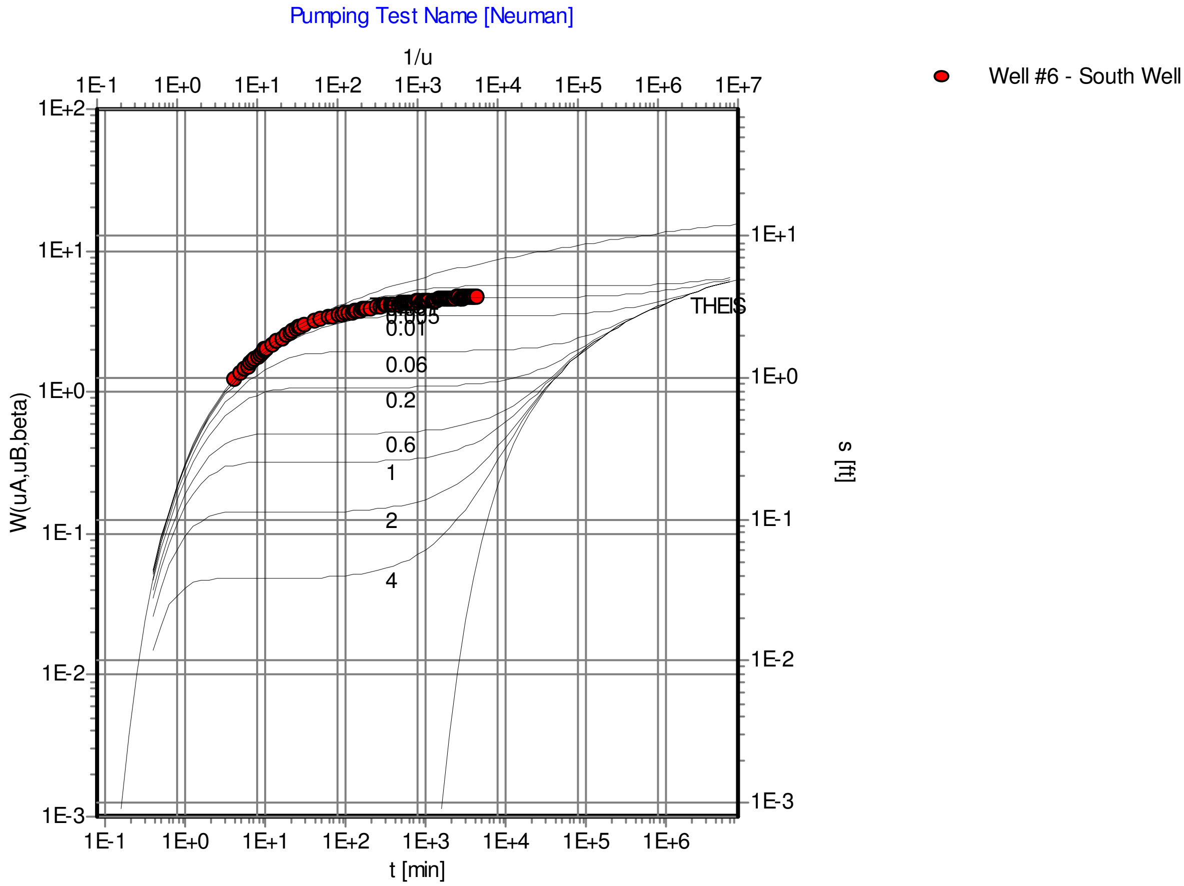
<u>Test parameters:</u>	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Unconfined Aquifer	
	Screen length:	310 [ft]	S/Sy:	0.001
	Boring radius:	0.271 [ft]	Kv/Kh:	0.1
	Discharge Rate:	50 [U.S. gal/min]	Gamma:	1E9
	b:	357 [ft]		

<u>Comments:</u> Match to late time data.

Evaluated by: MWV

Evaluation Date: 11/18/2010

Waterloo Hydrogeologic, Inc.	**Pumping Test Analysis Report**
460 Philip Street - Suite 101	Project: Rough Acres
Waterloo, Ontario, Canada	Number:
Phone: +1 519 746 1798	Client:



Pumping Test: **Pumping Test Name**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	9.67E+2 [ft²/d]	Conductivity:	1.93E+0 [ft/d]

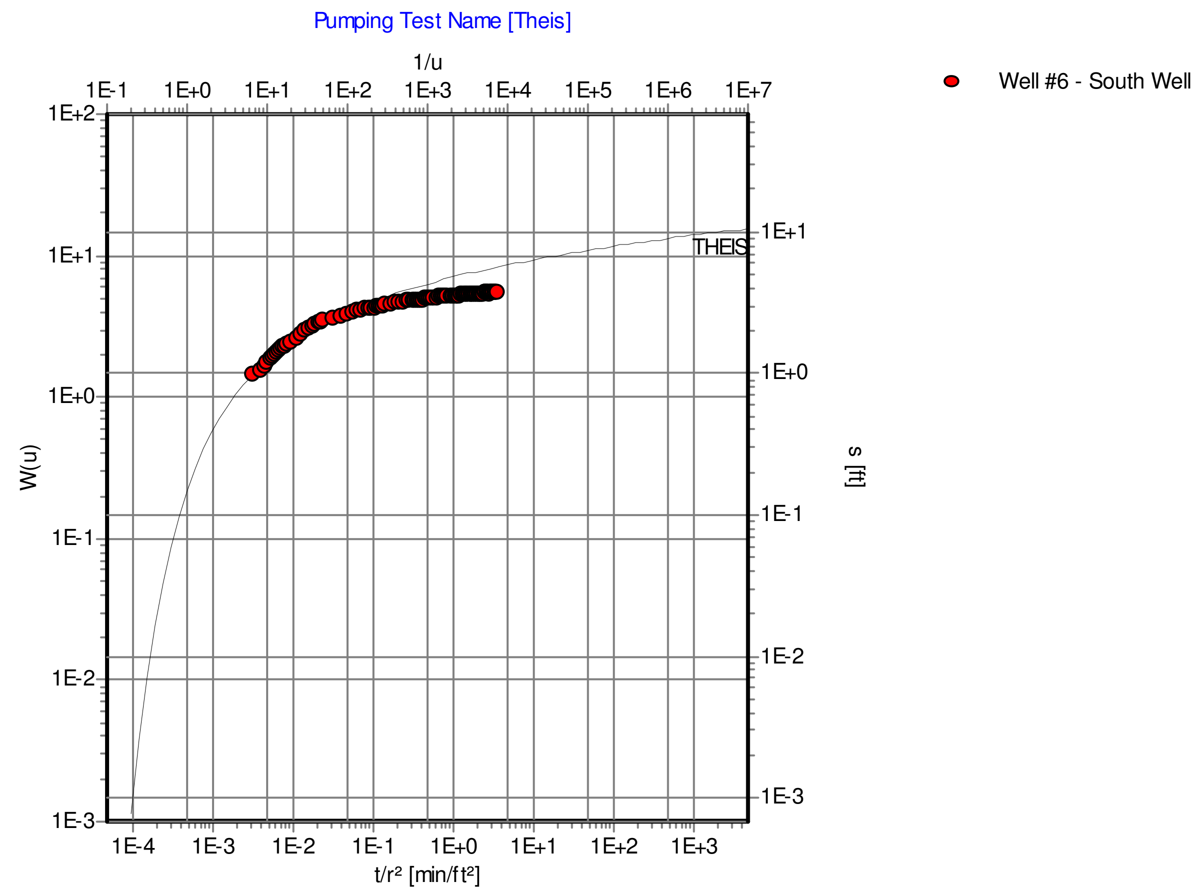
Test parameters:				
	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Beta:	0.005
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		
	LOG(Sy/S):	4		

Comments: Match to entire data set.

Evaluated by: MWV

Evaluation Date: 11/18/2010

Waterloo Hydrogeologic, Inc.	Pumping Test Analysis Report
460 Philip Street - Suite 101	Project: Rough Acres
Waterloo, Ontario, Canada	Number:
Phone: +1 519 746 1798	Client:

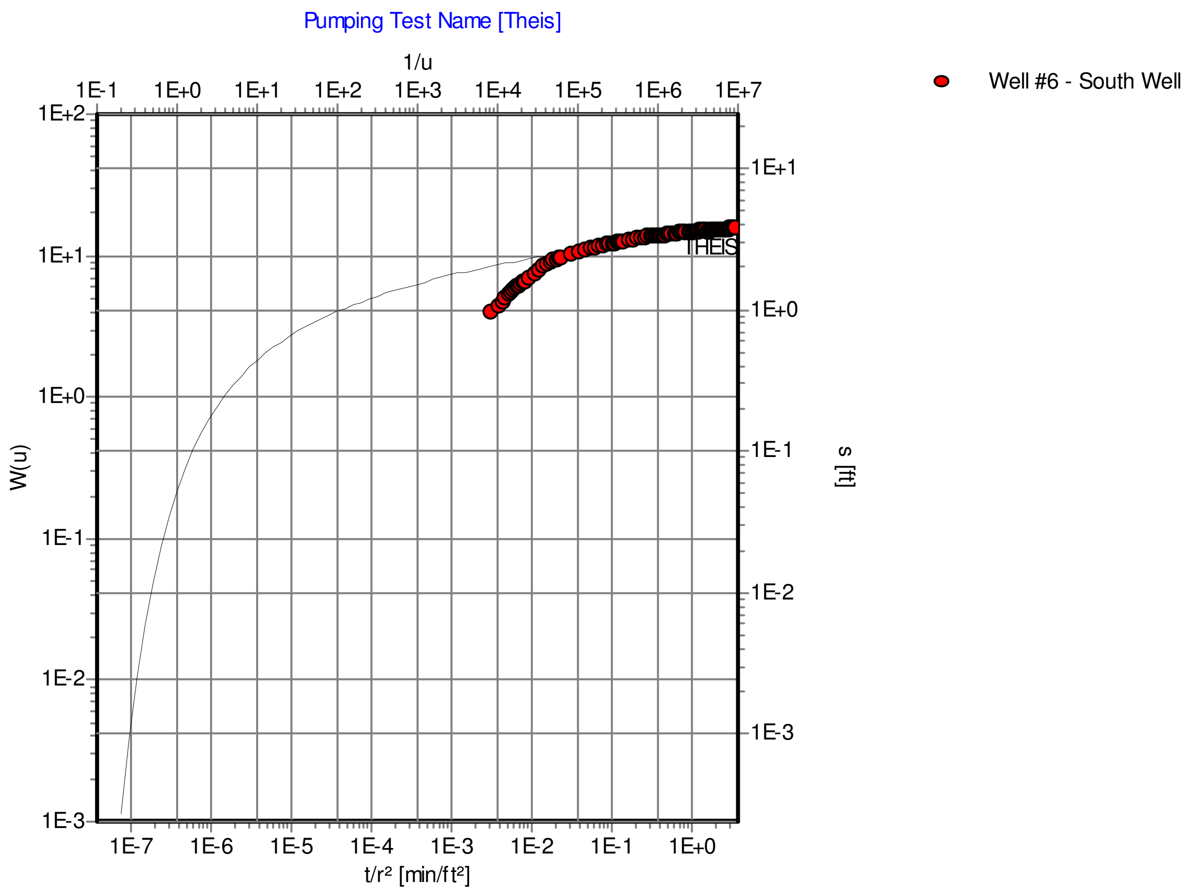


Pumping Test:	**Pumping Test Name**			
Analysis Method:	**Theis**			
Analysis Results:	Transmissivity:	1.13E+3 [ft²/d]	Conductivity:	2.26E+0 [ft/d]
	Storativity:	1.47E-3		
Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Confined Aquifer	
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		
Comments:	Match to early time data. Observation Well.			

Evaluated by: MWV

Evaluation Date: 11/18/2010

Waterloo Hydrogeologic, Inc. 460 Philip Street - Suite 101 Waterloo, Ontario, Canada Phone: +1 519 746 1798	**Pumping Test Analysis Report** Project: Rough Acres Number: Client:



Pumping Test: **Pumping Test Name**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	3.18E+3 [ft²/d]	Conductivity:	6.36E+0 [ft/d]
	Storativity:	3.29E-6		

Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Confined Aquifer	
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		

Comments: Match to late time data.

Evaluated by: MWV

Evaluation Date: 11/18/2010

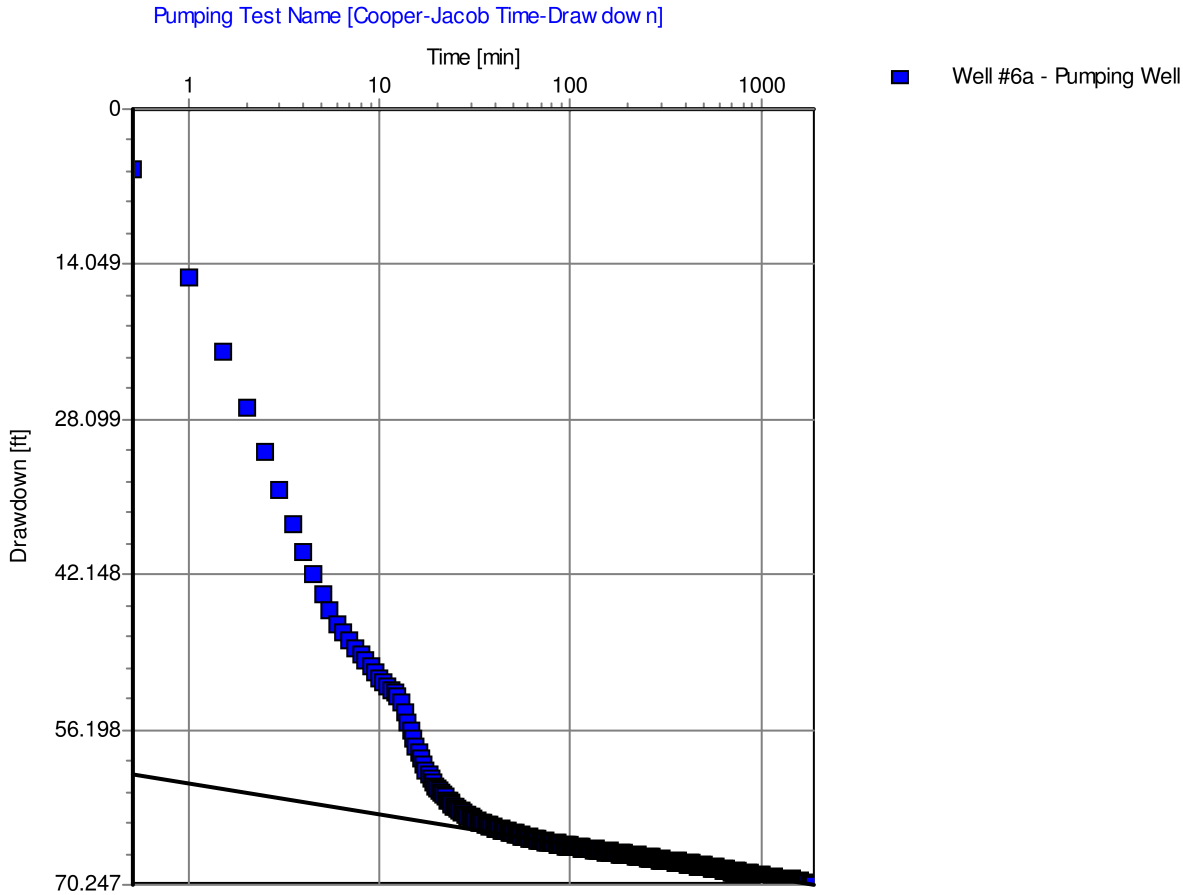
Waterloo Hydrogeologic, Inc.
460 Philip Street - Suite 101
Waterloo, Ontario, Canada
Phone: +1 519 746 1798

Pumping Test Analysis Report

Project: Rough Acres

Number:

Client:



Pumping Test:	**Pumping Test Name**			
Analysis Method:	**Cooper-Jacob Time-Drawdown**			
Analysis Results:	Transmissivity:	6.30E+2 [ft²/d]	Conductivity:	1.26E+0 [ft/d]
Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Unconfined Aquifer	
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		
Comments:	Match to late time data.			

Evaluated by: MWV

Evaluation Date: 11/17/2010

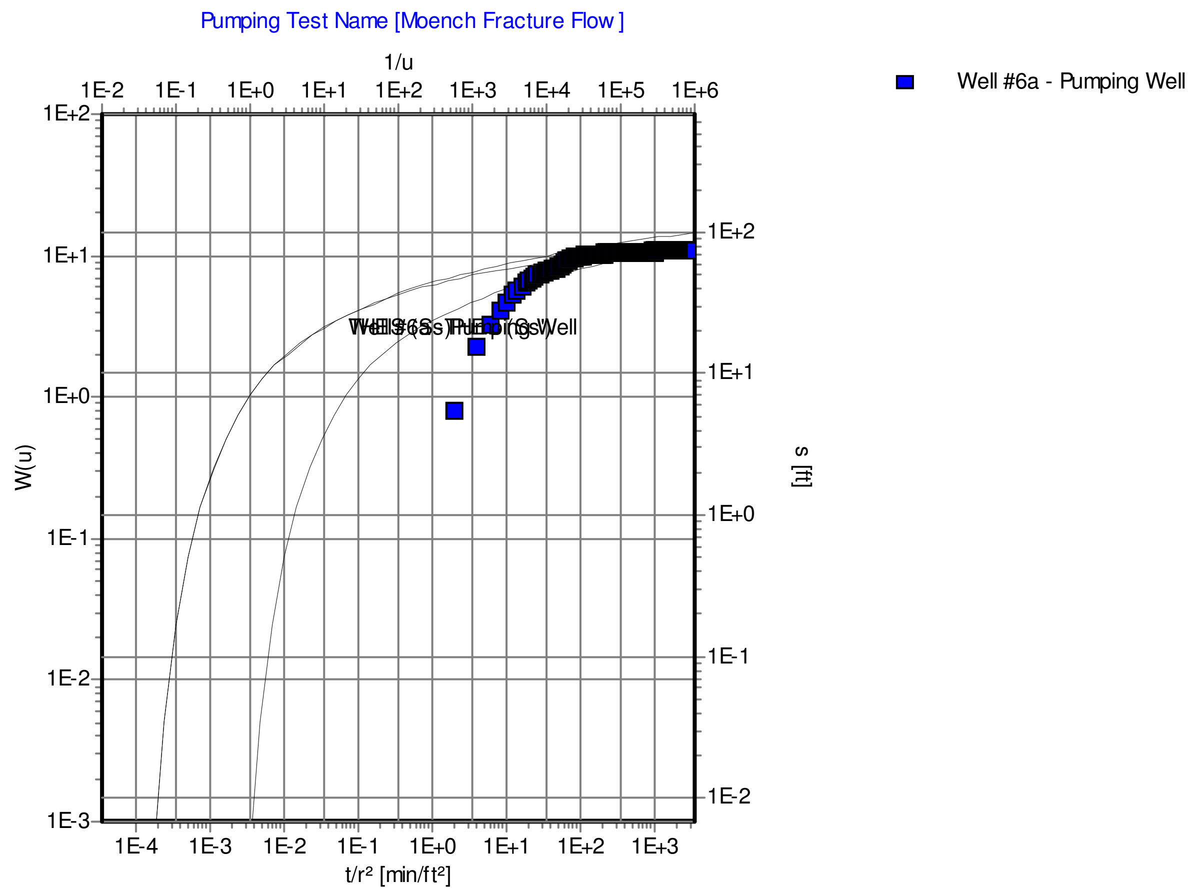
Waterloo Hydrogeologic, Inc.
460 Philip Street - Suite 101
Waterloo, Ontario, Canada
Phone: +1 519 746 1798

Pumping Test Analysis Report

Project: Rough Acres

Number:

Client:



Pumping Test: **Pumping Test Name**

Analysis Method: **Moench Fracture Flow**

Analysis Results:	Transmissivity:	1.12E+2 [ft²/d]	Conductivity:	2.25E-1 [ft/d]
	Storativity:	2.70E-4		

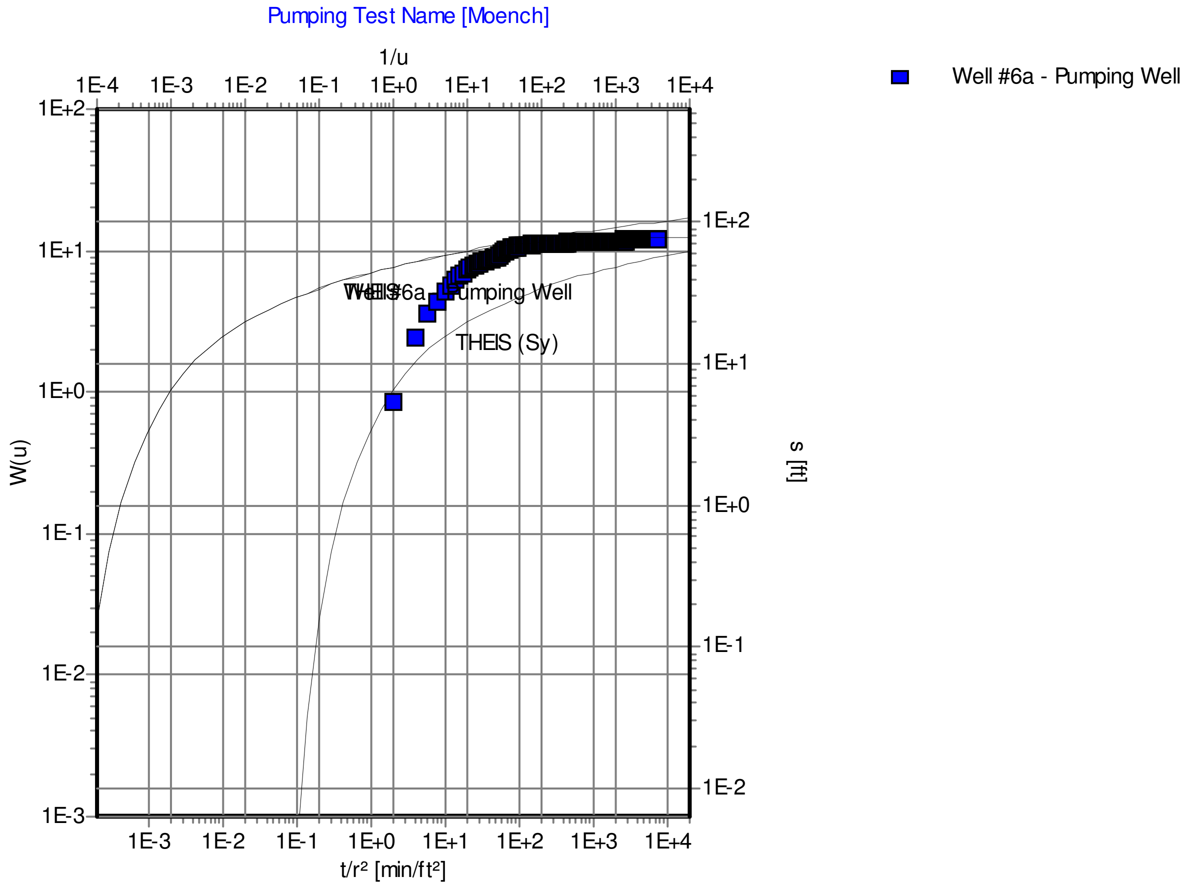
Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	b:	357 [ft]
	Screen length:	310 [ft]	Kv/Kh:	1
	Boring radius:	0.271 [ft]	C:	0.231
	Discharge Rate:	50 [U.S. gal/min]	K(block)/K(Skin):	0.1
	Ss(blk)/Ss(fract):	20	K(block)/K(fracture):	0.1

Comments: Match to late time data.

Evaluated by: MWV

Evaluation Date: 11/17/2010

Waterloo Hydrogeologic, Inc. 460 Philip Street - Suite 101 Waterloo, Ontario, Canada Phone: +1 519 746 1798	**Pumping Test Analysis Report** Project: Rough Acres Number: Client:



Pumping Test: **Pumping Test Name**

Analysis Method: **Moench**

Analysis Results:	Transmissivity:	1.21E+2 [ft²/d]	Conductivity:	2.43E-1 [ft/d]
	Storativity:	1.72E-1	Conductivity (vertical):	2.43E-1 [ft/d]
Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Unconfined Aquifer	
	Screen length:	310 [ft]	S/Sy:	0.001
	Boring radius:	0.271 [ft]	Kv/Kh:	1
	Discharge Rate:	50 [U.S. gal/min]	Gamma:	1E9
	b:	357 [ft]		

Comments:

Evaluated by:

Evaluation Date: 11/17/2010

Waterloo Hydrogeologic, Inc.
460 Philip Street - Suite 101
Waterloo, Ontario, Canada
Phone: +1 519 746 1798

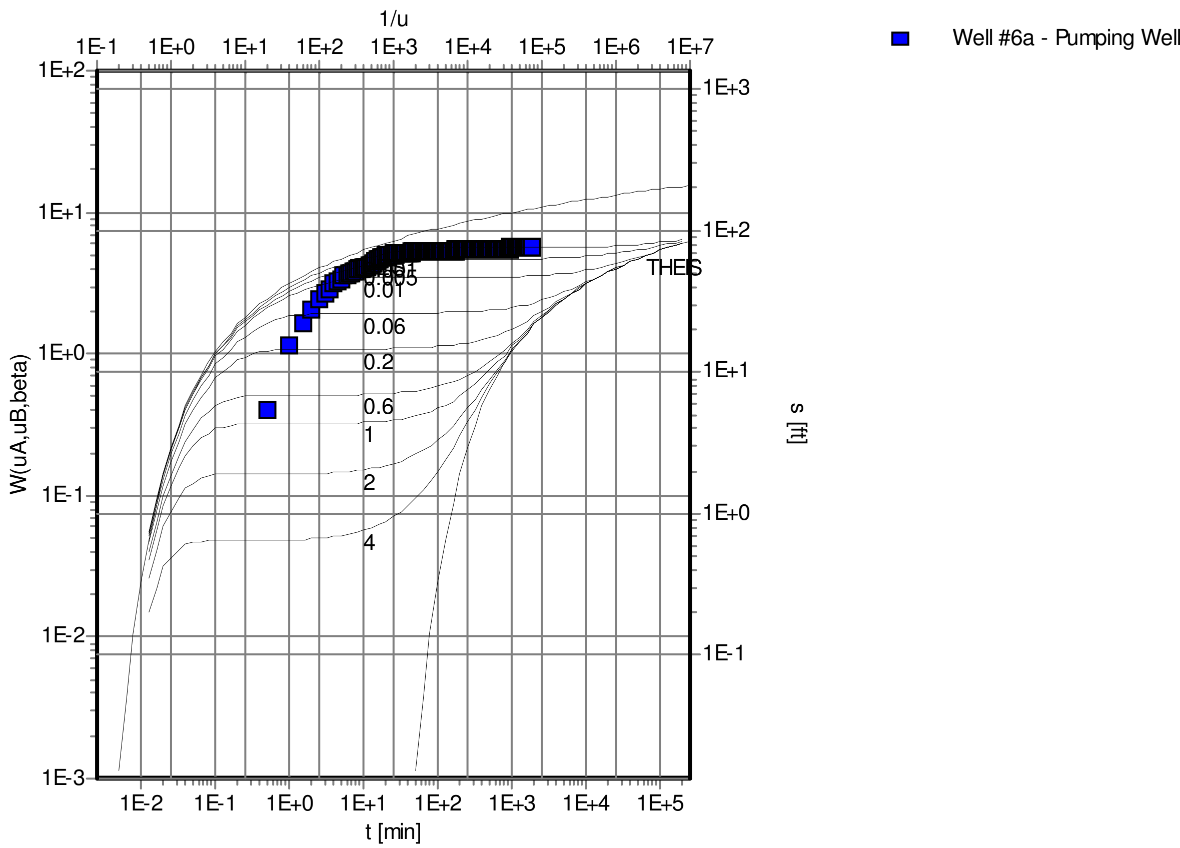
Pumping Test Analysis Report

Project: Rough Acres

Number:

Client:

Pumping Test Name [Neuman]



Pumping Test:	**Pumping Test Name**			
Analysis Method:	**Neuman**			
Analysis Results:	Transmissivity:	5.69E+1 [ft²/d]	Conductivity:	1.14E-1 [ft/d]
	Storativity:	1.62E-2	Specific Yield:	1.62E+2
Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Beta:	0.005
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		
	LOG(Sy/S):	4		
Comments:	Match to late time drawdown data.			

Evaluated by: MWV

Evaluation Date: 11/17/2010

Waterloo Hydrogeologic, Inc.

460 Philip Street - Suite 101

Waterloo, Ontario, Canada

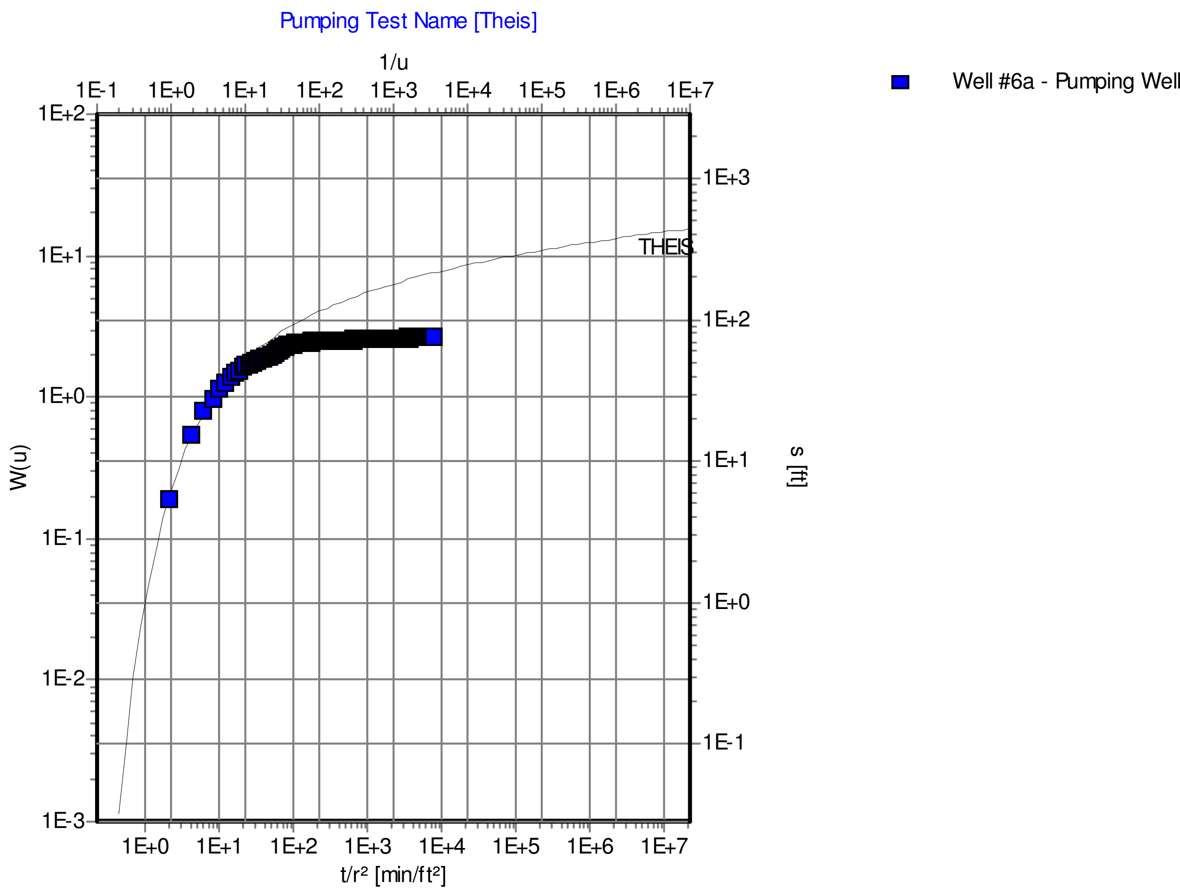
Phone: +1 519 746 1798

Pumping Test Analysis Report

Project: Rough Acres

Number:

Client:



Pumping Test: **Pumping Test Name**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	2.69E+1 [ft²/d]	Conductivity:	5.39E-2 [ft/d]
	Storativity:	1.64E-1		

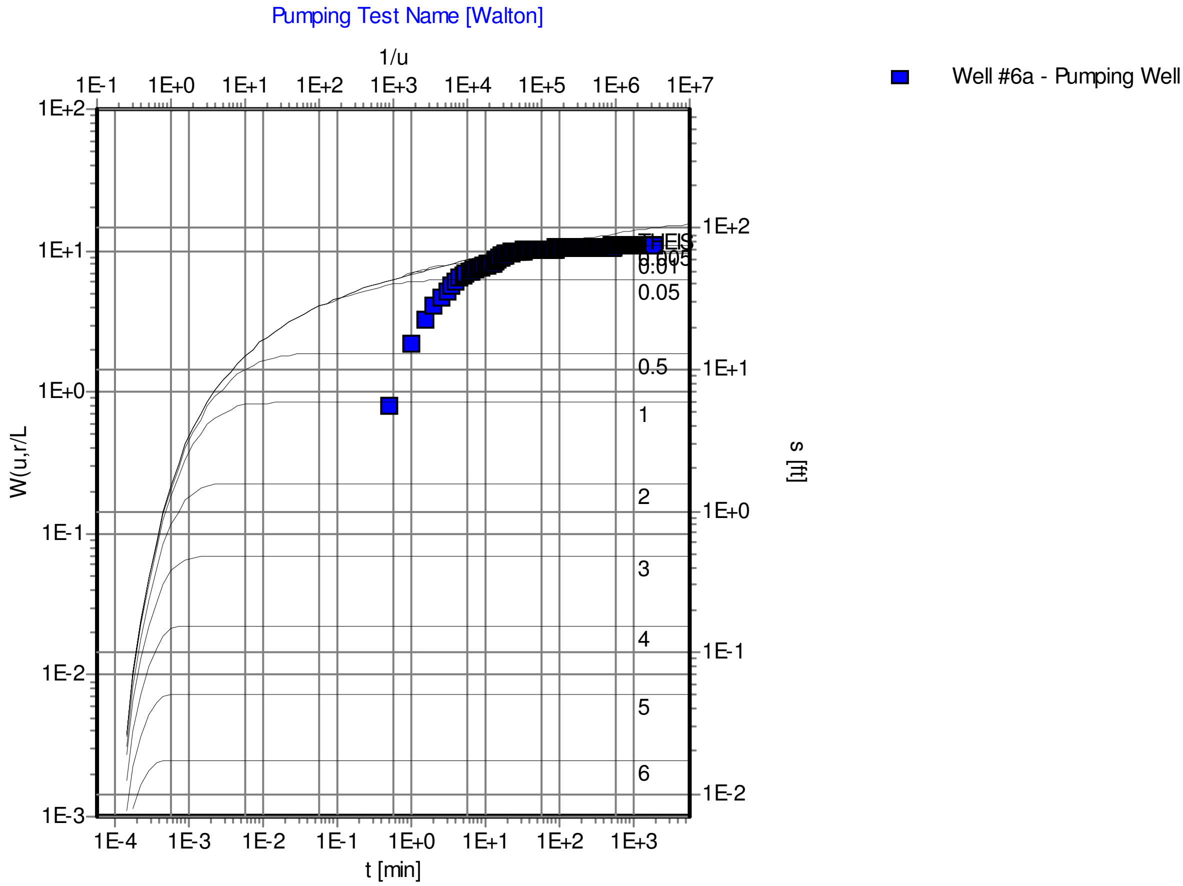
Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	Confined Aquifer	
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		

Comments: Match to early time data.

Evaluated by: MWV

Evaluation Date: 11/18/2010

Waterloo Hydrogeologic, Inc.	Pumping Test Analysis Report
460 Philip Street - Suite 101	Project: Rough Acres
Waterloo, Ontario, Canada	Number:
Phone: +1 519 746 1798	Client:



Pumping Test: **Pumping Test Name**

Analysis Method: **Walton**

Analysis Results:	Transmissivity:	1.11E+2 [ft²/d]	Conductivity:	2.21E-1 [ft/d]
	Storativity:	7.08E-4	c:	1.30E+5 [min]

Test parameters:	Pumping Well:	Well #6a	Aquifer Thickness:	500 [ft]
	Casing radius:	0.167 [ft]	r/L:	0.005
	Screen length:	310 [ft]		
	Boring radius:	0.271 [ft]		
	Discharge Rate:	50 [U.S. gal/min]		

Comments:

Evaluated by: MWV

Evaluation Date: 11/17/2010

Appendix B
Department of Water Resources Well Completion Reports

#4

Power at well

__NO__ pump

Across Road From Bathrooms in West Canyon

water was Discolored & hence quit using

COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH
1255 Imperial Ave
San Diego, CA 92101
619-338-2222

#4

INVOICE

ERMIT TYPE & NUMBER: LWEL 16226 INVOICE DATE: 16 SEP 2004
ERMIT OWNER: CONTACT:
ADEM ROBERT S&MARY O TRUST B1
553 OCEAN ST

92008

611-060-03
PN: ~~611-110-01-00~~ 611-070-01 APPLICANT:
FADEM ROBERT S&MARY O TRUST B1
ITE ADDRESS: ~~2533~~ MCCAIN VALLEY RD
OCATION DESCRIPTION: ~~2533~~ MCCAIN VALLEY RD,

ROJECT DESCRIPTION/SCOPE
umber of Wells on Permit Application:1
escription of Work:new
ype of Use for Each Well:private

EE/DEPOSIT DETAILS

FEE CODE	DESCRIPTION	TIME ACCT.	ACCT. CODE	AMOUNT
6LE01--EHO	WATER WELL PERMIT	429E01	9773-773	390.00
			09-16-04 11:30 9773 773 429E01 CHECK	
			TOTAL AMOUNT DUE	$390.00

275
6.15

COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH
WELL PERMIT APPLICATION

Parcel 1 600

DEH USE ONLY	
PERMIT # W	LWCL162
WELL COMPUTER #	
FEE:	
WATER DIST:	

1. Property Owner: Hamann Companies Phone: [illegible]
   [illegible] (Mailing Address) [illegible] (City) [illegible] (Zip)
2. Well Location - Assessors Parcel Number ~~611-110-01~~ 611-060-03 611-070-01
   [illegible] (Site Address) BOULEVARD (City) 91905 (Zip)
3. Well Contractor - Well Driller Jim Mayes Company Name: [illegible]
   [illegible] (Mailing Address) [illegible] (City) [illegible] (Zip)
   Phone#: [illegible] C-57#: [illegible] ☐ Cash Deposit ☐ Bond Posted
4. Use: ☒ Private ☐ Public ☐ Industrial ☐ Cathodic ☐ Other ____
5. Type of Work: ☐ New ☐ Reconstruction ☐ Destruction Time Extension: ☐ 1st ☐ 2nd
6. Type of Equipment: Air Rotary
7. Depth of Well: Proposed: [illegible] Existing: ____
8. Proposed:

Casing	Conductor Casing	Filter/Filler Material	Perforations
Type: Steel	☐ Yes ☐ No	☐ Yes ☐ No	From: ____ To: ____
Depth: [illegible]	Depth: ____ ft.	From: ____ To: ____	From: ____ To: ____
Diameter [illegible] in.	Diameter ____ in.	Type: ____	From: ____ To: ____
Wall/Gauge: [illegible]	Wall/Gauge: ____	Wall/Gauge: ____	

9. Annular Seal: Depth: [illegible] ft. Sealing Material: [illegible]
   Borehole diameter: ____ in. Conductor diameter: ____ in. Annular Thickness ____ in.
10. Date of Work: Start: [illegible] Complete: [illegible]

On sites served by public water, contact the local water agency for meter protection requirements.

I hereby agree to comply with all regulations of the Department of Environmental Health, and with all ordinances and laws of the County of San Diego and the State of California pertaining to well construction, repair, modification and destruction. Immediately upon completion of work, I will furnish the Department of Environmental Health with a complete and accurate log of the well. I accept responsibility for all work done as part of this permit and all work will be performed under my direct supervision.

Contractor's Signature: [signature] Date: [illegible]

DISPOSITION OF APPLICATION (Department of Environmental Health Use only)

☒ Approved ☐ Denied Special Conditions: Grading and clearing associated with access to, or the construction, maintenance or destruction of water wells, may require additional permits from the County of San Diego and/or other agencies.

Specialist: [signature] Date: 4/16/04

DEH-LU-731a (Rev. 4/02) NCR

[illegible handwriting]

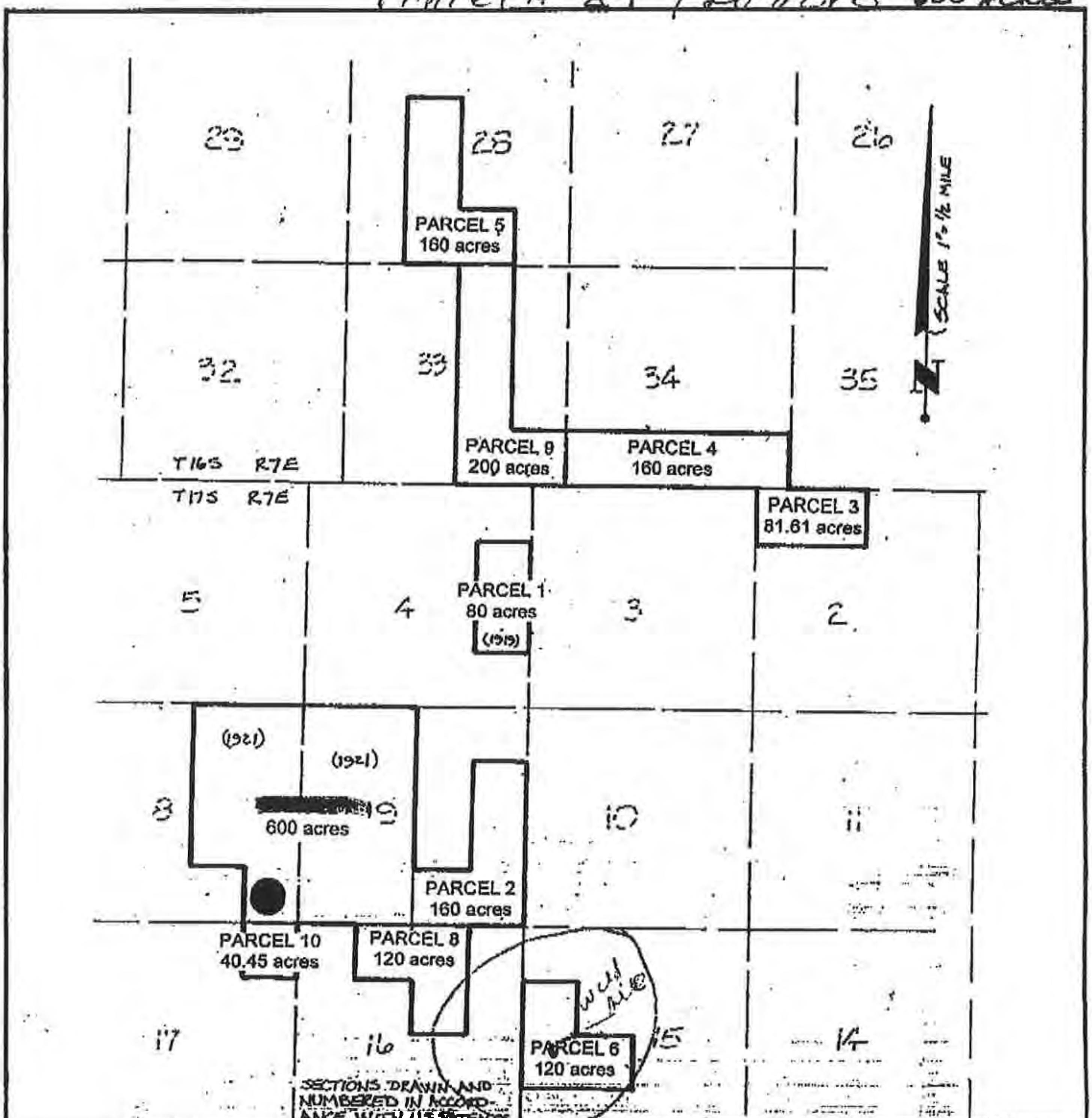
COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH

Control #: LWCL 16226
Assessor's Parcel Number: ~~[illegible]~~
611-060-03
611-070-01

LOCATION

Indicate below the vicinity and exact location of well with respect to the following items: Property lines, water bodies or water courses, drainage pattern, easements, roads, existing wells, sewers and private sewage disposal systems and other potential contamination sources, including dimensions.

Parcel # [illegible] ~~[illegible]~~ 600 ACRES



ACREAGE FROM U.S. PATENTS 2 of 2

County Mail Station – A-21

FIRST CARBON COPY

ASSESSORS PARCEL NUMBER: ______ ______ ______

COUNTY OF SAN DIEGO
DEPARTMENT OF HEALTH SERVICES
1700 PACIFIC HIGHWAY, SAN DIEGO, CA 92101-2417

WATER WELL DRILLERS REPORT
(INSERT under ORIGINAL PAGE w/carbon of State Form)

Notice of Intent No. ______
Local Permit No. or Date ______

State Well No. ______
Other Well No. ______

(1) OWNER: Name JOHN WELL NO 2
Address ROXY ACRES
City ______ Zip ______

(2) LOCATION OF WELL (See instructions):
County ______ Owner's Well Number ______
Well address if different from above ______
Township ______ Range ______ Section ______
Distance from cities, roads, railroads, fences, etc. ______

DEPARTMENT USE ONLY
Completed Well Construction:
Date ______
Date Inspected ______
Comments ______
Water Sample Taken? ______
Sanitarian's Approval: ______

Jeffrey #8

(3) TYPE OF WORK:
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item (12)

(4) PROPOSED USE:
Domestic ☒
Irrigation ☒
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

(12) WELL LOG: Total depth 260 ft. Depth of completed well 185 ft.
from ft. to ft. Formation (Describe by color, character, size or material)

0-91 – SANDY, D.G.
91-130 – SOFT, ORANGE, WHITE & BROWN
130-133 – GRAY SOFT (3 GPM)
133-185 – SOFT ORANGE, WHITE, BLACK
185-190 – LOOSE ROCKS (20 GPM)
190-260 – SOFT & HARD

(5) Equipment:
Rotary ☒ Reverse ☐
Cable ☐ Air ☒
Other ☐ Bucket ☐

(6) Gravel Pack: 3/8ths
Yes ☒ No ☐ Size ______
Diameter of above 9"
Packed from 0 to 185 ft.

(7) Casing Installed:
Steel ☒ Plastic ☐ Concrete ☐

(8) Perforations:
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot Size
0	91	6 5/8	.188	0	185	3/32nds

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 91' ft.
Were strata sealed against pollution? Yes ☐ No ☒ Interval ______ ft.
Method of sealing BENTONITE - CEMENT

(10) WATER LEVELS:
Depth of first water, if known 130 ft.
Standing level after well completion 85 ft.

(11) WELL TESTS:
Was well test made? Yes ☒ No ☐ If yes, by whom? DRILLER
Type of test Pump ☐ Bailer ☐ Air lift ☒
Depth to water at start of test – ft. At end of test – ft.
Discharge 15 gal/min after 1 hours Water temperature COOL
Chemical analysis made? Yes ☐ No ☒ If yes, by whom?
Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

Work Started 19 Completed 19

WELL DRILLERS STATEMENT: I hereby declare under penalty of perjury that the information provided in this report is true. This water well was installed in compliance with San Diego County Code and State of California, Department of Water Resources, Bulletin No. 74.

SIGNED [signature] (Well Driller)

NAME ______
(Person, firm, or Corporation) (Type or Print)

ADDRESS ______

CITY ______ ZIP ______

LICENSE NO. ______ DATE THIS REPORT ______

DHS:EHP-732 (83) CONFIDENTIAL – NOT FOR PUBLIC USE – WATER CODE SEC. 13752

DUPLICATE
Driller's Copy
Page 1 of 1
Owner's Well No. # 4
Date Work Began 9-25-04, Ended 9-27-04
Local Permit Agency San Diego E.H.S.
Permit No. LWEL16226 Permit Date 9-16-04

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 0909442

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

CONFIDENTIAL — NOT FOR PUBLIC USE — WATER CODE SEC. 13752

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD rotary FLUID air

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION Describe material, grain size, color, etc.
0 - 91	sandy, dg
91 - 130	soft, orange, white & brown
130 - 133	very soft
133 - 185	soft, orange, white & black
185 - 190	loose rocks
190 - 260	soft & hard

TOTAL DEPTH OF BORING 260 (Feet)
TOTAL DEPTH OF COMPLETED WELL 185 (Feet)

WELL OWNER

Name Hamann Companies
Mailing Address 1000 Pioneer Way
El Cajon, Ca. 92020
CITY STATE ZIP

WELL LOCATION

Address McCain Valley Rd
City Jacumba
County San Diego
APN Book 611 Page 110 Parcel 01
Township 17 Range 7 Section 1
Lat ___ N DEG. MIN. SEC. Long ___ W DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Send later

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. ***PLEASE BE ACCURATE & COMPLETE.***

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (*Describe Procedures and Materials Under "GEOLOGIC LOG"*)

USES (✓)

WATER SUPPLY
X Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 130 (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 35 (Ft.) & DATE MEASURED 9-27-04
ESTIMATED YIELD * 15 (GPM) & TEST TYPE airlift
TEST LENGTH 1 (Hrs.) TOTAL DRAWDOWN - (Ft.)
* *May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0 - 91	11	x				steel	5 5/8	.188	
0 - 185	6½		x			pvc	4	sch 40	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 - 91	x	x		
0 - 185			x	5/16 pea gravel

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME JIM MANOS DRILLING & PUMP
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

16052 LAWSON VLY RD, JAMUL, CA 91935
ADDRESS CITY STATE ZIP

Signed [signature] C-57 LICENSED WATER WELL CONTRACTOR
2-6-05 DATE SIGNED
360722 C-57 LICENSE NUMBER

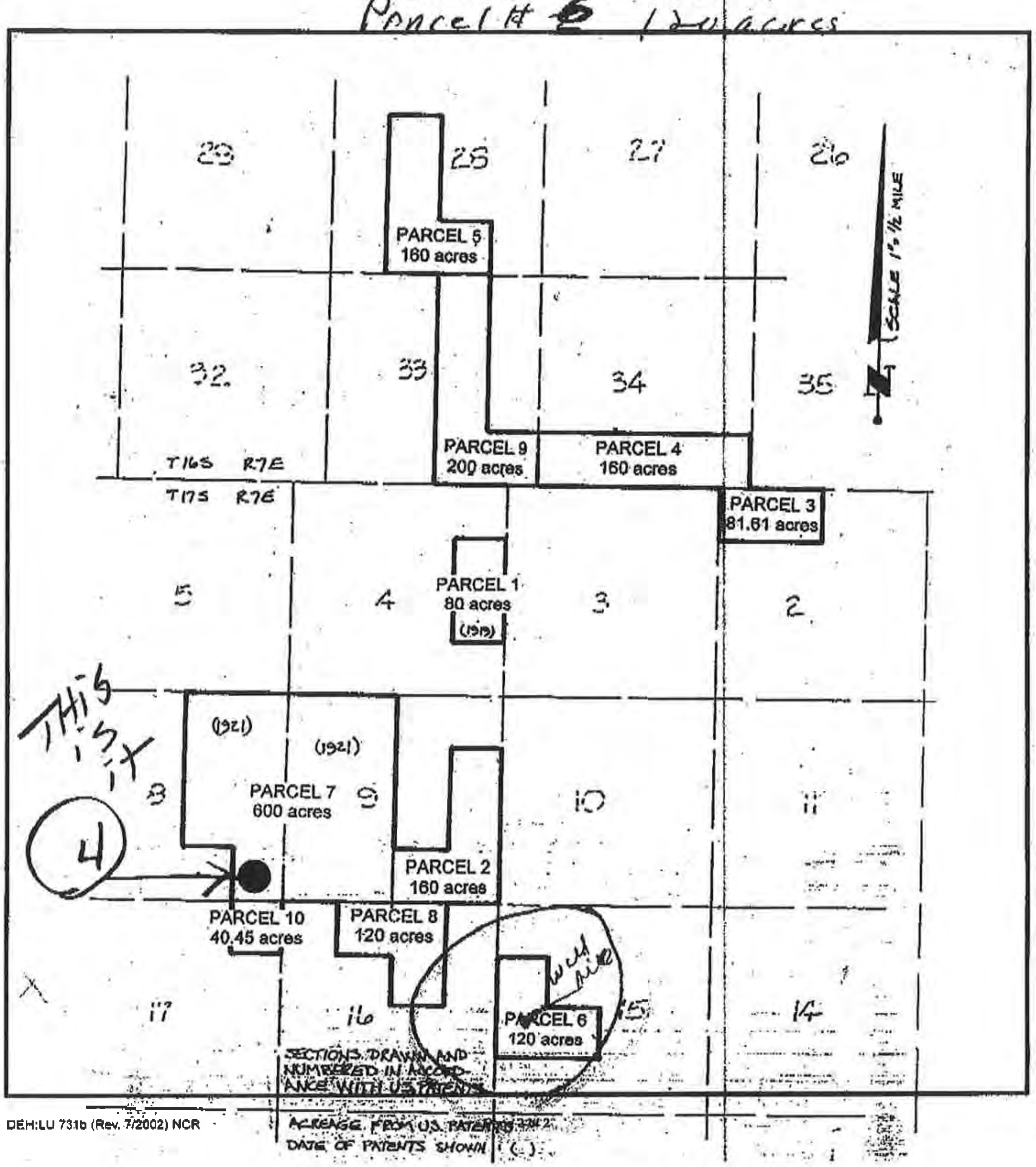
DWR 188 REV. 05-03
IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH

Control #: LWEL 16226
Assessor's Parcel Number: 611-110-01

LOCATION

Indicate below the vicinity and exact location of well with respect to the following items: Property lines, water bodies or water courses, drainage pattern, easements, roads, existing wells, sewers and private sewage disposal systems and other potential contamination sources, including dimensions.



Fully operational

#6 No Logs Available

origional well on Ranch

6A NEW
Public
Well

Fully operational

QUADRUPLICATE FEB 09 2010

For Local Requirements

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 1089956

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Page 1 of 1

County of San Diego
Dept. of Environmental Health
Land & Water Quality Div.

Owner's Well No. 1

Date Work Began 11-4-09, Ended 11-10-09

Local Permit Agency San Diego C.H.S.

Permit No. LWEC20420 Permit Date 11-13-09

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ROTARY FLUID AIR

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION Describe material, grain size, color, etc.
0 - 10	sandy-rocks
10 - 30	sandy-slightly firm
30 - 32	soft
32 - 70	sandy
70 - 85	harder
85 - 87	cracks
87 - 230	black & white rock, softer areas
230 - 233	softer, orange
233 - 330	black, white & orange
330 - 332	softer, orange
332 - 395	black & white rock, softer areas
395 - 395	sand
395 - 420	black & white rock

Completed Well Construction

Date 2/9/10

Date Inspected

Comments KIVA control at this date.

Water Sample Taken?

TOTAL DEPTH OF BORING 420 (Feet)

TOTAL DEPTH OF COMPLETED WELL 385 (Feet)

WELL OWNER

Name [illegible] Drive Partners

Mailing Address 1000 Pioneer Way

El Cajon, Ca 92020 CITY STATE ZIP

WELL LOCATION

Address Mc [illegible] Valley Road

City [illegible], Ca

County San Diego

APN Book 511 Page 090 Parcel 04

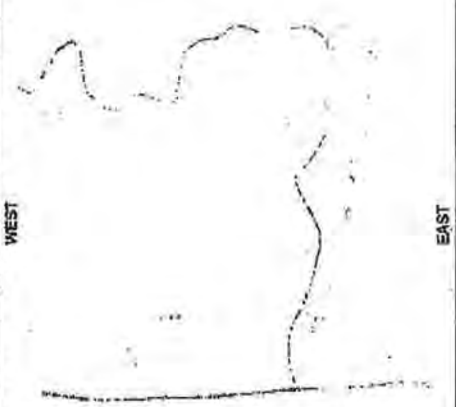
Township [illegible] Range [illegible] Section 17

Lat ___ DEG. MIN. SEC. N Long ___ DEG. MIN. SEC. W

LOCATION SKETCH

NORTH

WEST



EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ✓ Industrial

MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 30 (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL 30 (Ft.) & DATE MEASURED 11-10-09

ESTIMATED YIELD * 60 (GPM) & TEST TYPE airlift

TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN - (Ft.)

** May not be representative of a well's long-term yield.*

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	CASING TYPE: BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0 - 56	12	x				steel		.188	
0 - 75		x				steel	6 5/8	.188	
0 - 385	6½		x			pvc	4	CL200	

DEPTH FROM SURFACE Ft. to Ft.	ANNULAR MATERIAL TYPE: CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 - 56	x (cement was [illegible])			
0 - 75		x		
0 - 385			x	3/16 pea gravel

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other [illegible]

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME TIM MANOS DRILLING & PUMP
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

16052 LAWSON VALLEY ROAD, JAMUL, CA 91935
ADDRESS CITY STATE ZIP

Signed [illegible] C-57 LICENSED WATER WELL CONTRACTOR

DATE SIGNED 2-1-10 C-57 LICENSE NUMBER 3607

DWR 188 REV. 05-03

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

8

This WELL HAS
NO pump or power
NEEDS to be
relocated EAST
outside of
TRANSMISSION Line
power EASEMENT

Fain Drilling & Pump Co. Inc.

12029 Old Castle Rd.
Valley Center, CA 92082
Phone (760) 749-0701
Fax (760) 749-6380

#8

Invoice

Date	Invoice #
2/11/2005	8048

Bill To
THE HAMANN COMPANIES 1000 PIONEER WAY EL CAJON, CA 92020

P.O. No.	Terms	Project
	Due on receipt	

Description	Qty	Rate	Amount
DRILLING 970 FT DEEP WELL APN 611 110 01			
PARCEL 6 120 AC			
EQUIPMENT SET UP	1	500.00	500.00
DRILLING 6.5" DIA HOLE	400	12.00	4,800.00
DRILLING 400-800' 6.5" DIA HOLE	400	14.00	5,600.00
DRILLING 800 - 970' 6.5" DIA HOLE	170	16.00	2,720.00
REAMING 6" TO 10" DIA HOLE	226	12.00	2,712.00
FURNISH AND INSTALL 6" WELL CASING	228	13.00	2,964.00
INSTALL 50 FT. SURFACE SEAL	1	1,500.00	1,500.00
WELL PERMIT AND FILING FEES	1	490.00	490.00

Total	$21,286.00
Payments/Credits	$0.00
Balance Due	$21,286.00

TRIPLICATE
Owner's Copy
Page 1 of 1
Owner's Well No. Par. 6 -120
Date Work Began 2/1/05 , Ended 2/9/05
Local Permit Agency DEH
Permit No. 16456 Permit Date 2/1/05

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 0909549

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD Rotary FLUID Air

DEPTH FROM SURFACE Ft. to Ft.		DESCRIPTION *Describe material, grain size, color, etc.*
0	12	Slope wash - sandy decomposed granite - brown color
12	212	Weathered Granitic Rock
212	225	Broken Rock
226	310	Weathered granitic rock mostly white quartz
310		Water 8 gpm
310	961	Granitic rock large crystals of white quartz
961		Water 40+ gpm
961	970	Fractured granitic rock large quartz crystals

TOTAL DEPTH OF BORING 970 (Feet)
TOTAL DEPTH OF COMPLETED WELL 970 (Feet)

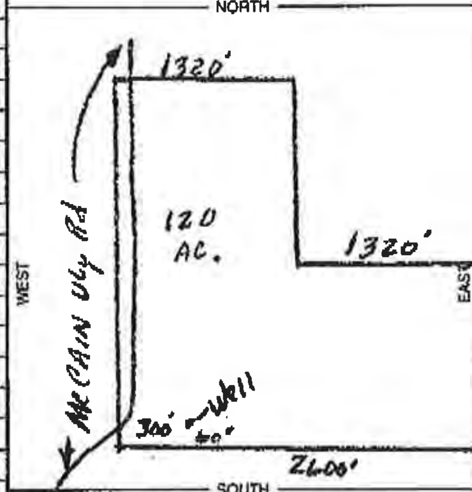
WELL OWNER

Name The Hamann Companies
Mailing Address 1000 Pioneer Way
El Cajon Ca 92020
CITY STATE ZIP

WELL LOCATION

Address Rough Acres Ranch McCain Valley Rd.
City Boulevard
County San Diego
APN Book 611 Page 110 Parcel 01
Township 17S Range 7E Section 15
Lat 36 16 772 N Long 115 69 465 W
DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH



Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. ***PLEASE BE ACCURATE & COMPLETE.***

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

USES (✓)

WATER SUPPLY
✓ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 30 (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 18 (Ft.) & DATE MEASURED
ESTIMATED YIELD * 50 (GPM) & TEST TYPE airlift
TEST LENGTH 8 (Hrs.) TOTAL DRAWDOWN 800 (Ft.)
** May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.		BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	226	10	X				Steel	6	.188	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.		CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	50	X			
50	226			X	

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other

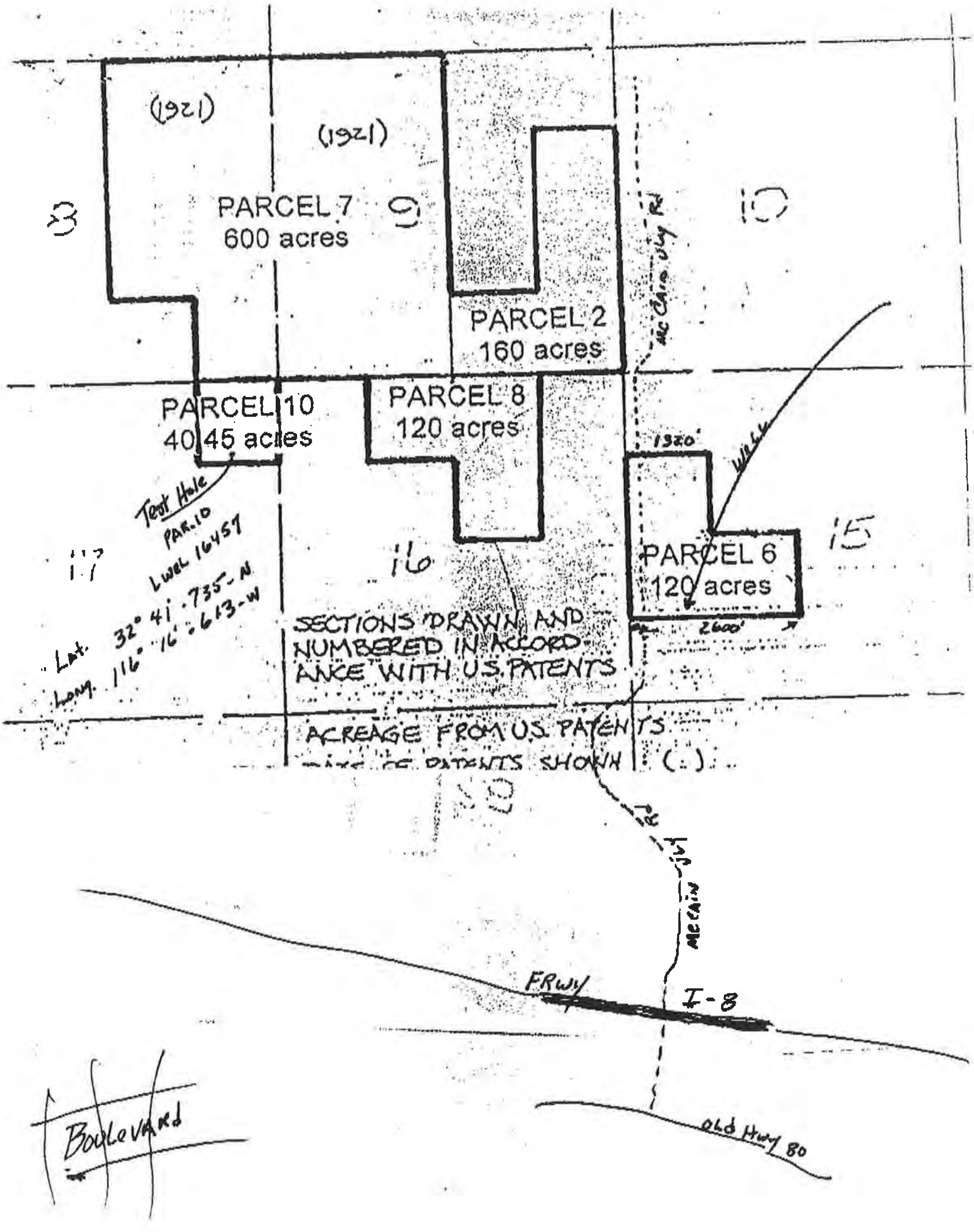
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Fain Drilling & Pump Co. Inc.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
12029 Old Castle Rd. Valley Center, Ca 92082
ADDRESS CITY STATE ZIP
Signed Joe R. Fain 2/11/05 328287
C-57 LICENSED WATER WELL CONTRACTOR DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 05-03 IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM


(1921)
(1921)
PARCEL 7
600 acres
9
10
8
PARCEL 2
160 acres
McCain Vly Rd
PARCEL 10
40 45 acres
PARCEL 8
120 acres
1320'
WELL
Test Hole
PAR.10
LWEL 16457
Lat. 32° 41' .735-N
Long. 116° 16' .613-W
17
16
15
PARCEL 6
120 acres
2600'
SECTIONS DRAWN AND
NUMBERED IN ACCORD-
ANCE WITH U.S. PATENTS
ACREAGE FROM U.S. PATENTS
( )
McCain Vly Rd
FRWY
I-8
Boulevard
Old Hwy 80

9

Fully operational
old well
No info
probably 5-10 GPM
& shallow

APPENDIX C

CUMULATIVE WATER QUANTITY IMPACTS ANALYSIS

ROUGH ACRES RANCH WATER PRODUCTION AREA

MCCAIN VALLEY, EAST SAN DIEGO COUNTY, CALIFORNIA

Table 1
Estimated Groundwater Demand - Rough Acres Ranch Water Production Area

Land Use Scenario	Land Use	Quantity	Water Demand per Unit (afy)	Total Demand (afy)
Existing Conditions	Single Family Residential	7	0.5	3.5
	Cattle/Livestock Free-Range Grazing (100 head)	1	2.13	2.13
	Poultry (500 hens)	1	0.11	0.11
	Total Water Demand (Existing Conditions)			5.74
Existing Conditions Plus 9-Month Construction at 50 gpm	Single Family Residential	7	0.5	3.5
	Cattle/Livestock Free-Range Grazing (100 head)	1	2.13	2.13
	Poultry (500 hens)	1	0.11	0.11
	Project 9-month Construction (50 gpm)	1	60	60
	Total Water Demand (Existing Conditions Plus 9-Month Construction at 50 gpm)			65.74
Existing Conditions Plus 9-Month Construction at 100 gpm	Single Family Residential	7	0.5	3.5
	Cattle/Livestock Free-Range Grazing (100 head)	1	2.13	2.13
	Poultry (500 hens)	1	0.11	0.11
	Project 9-month Construction (50 gpm)	1	120	120
	Total Water Demand (Existing Conditions Plus 9-Month Construction at 100 gpm)			125.74

Note: afy - acre feet per year; gpm - gallons per minute

Table 2
Groundwater in Storage Calculation - Effects of Pumping at 50 GPM
Rough Acres Ranch Water Production Area

Hydrogeologic Unit	Area (acres)	Specific Yield (%)	Saturated Thickness (ft)	GW in Storage (af)
Fractured Rock	502	0.10%	500	251
Residuum	502	5%	10	251
Alluvium	250	10%	20	500
Total				**1002**

Change in Groundwater in Storage (50 gpm)

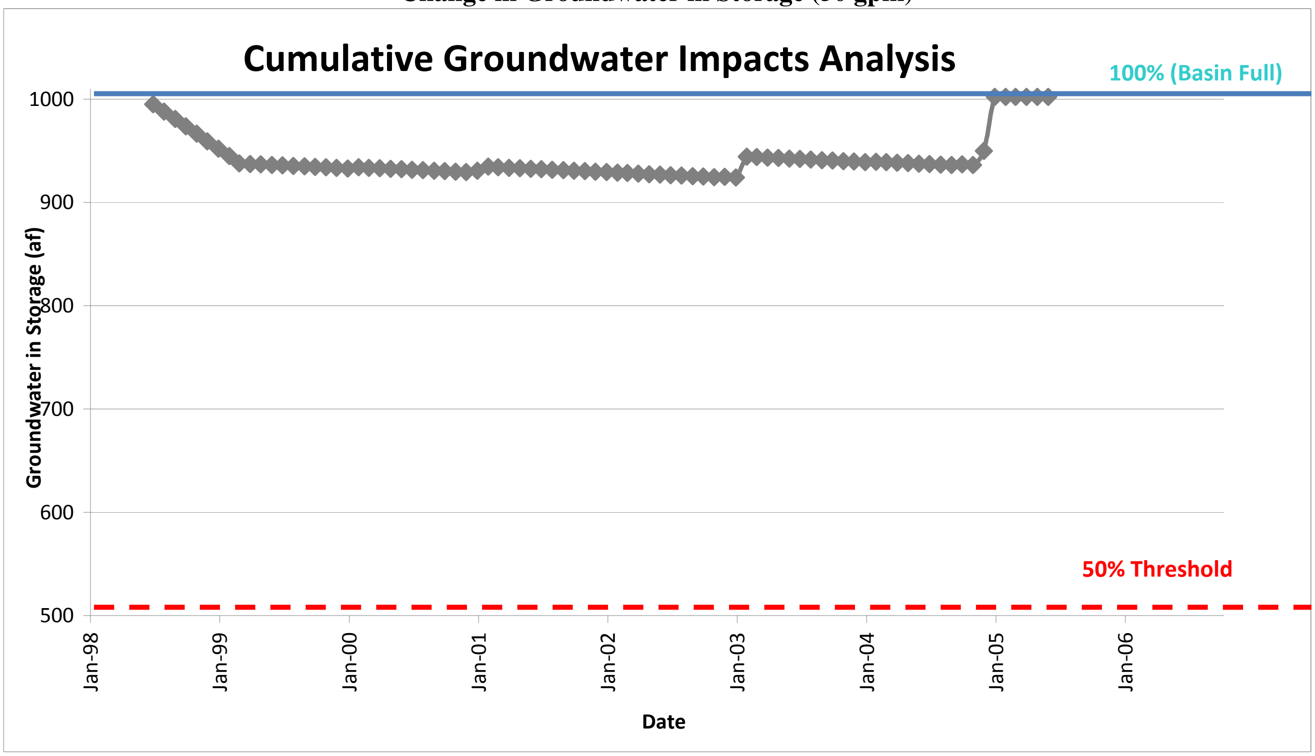


Table 3
Groundwater in Storage Calculation - Effects of Pumping at 100 GPM
Rough Acres Ranch Water Production Area

Hydrogeologic Unit	Area (acres)	Specific Yield (%)	Saturated Thickness (ft)	GW in Storage (af)
Fractured Rock	502	0.10%	500	251
Residuum	502	5%	10	251
Alluvium	250	10%	20	500
Total				**1002**

Change in Groundwater in Storage (100 gpm)

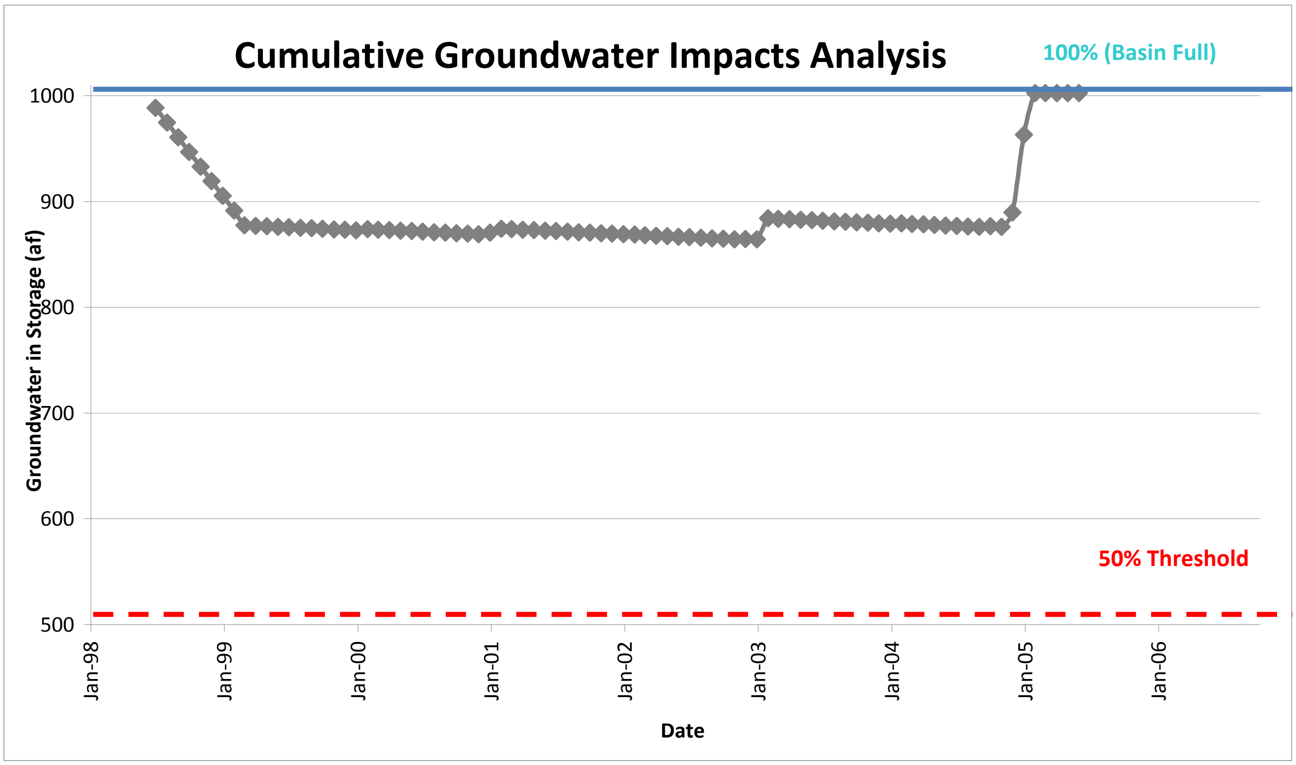
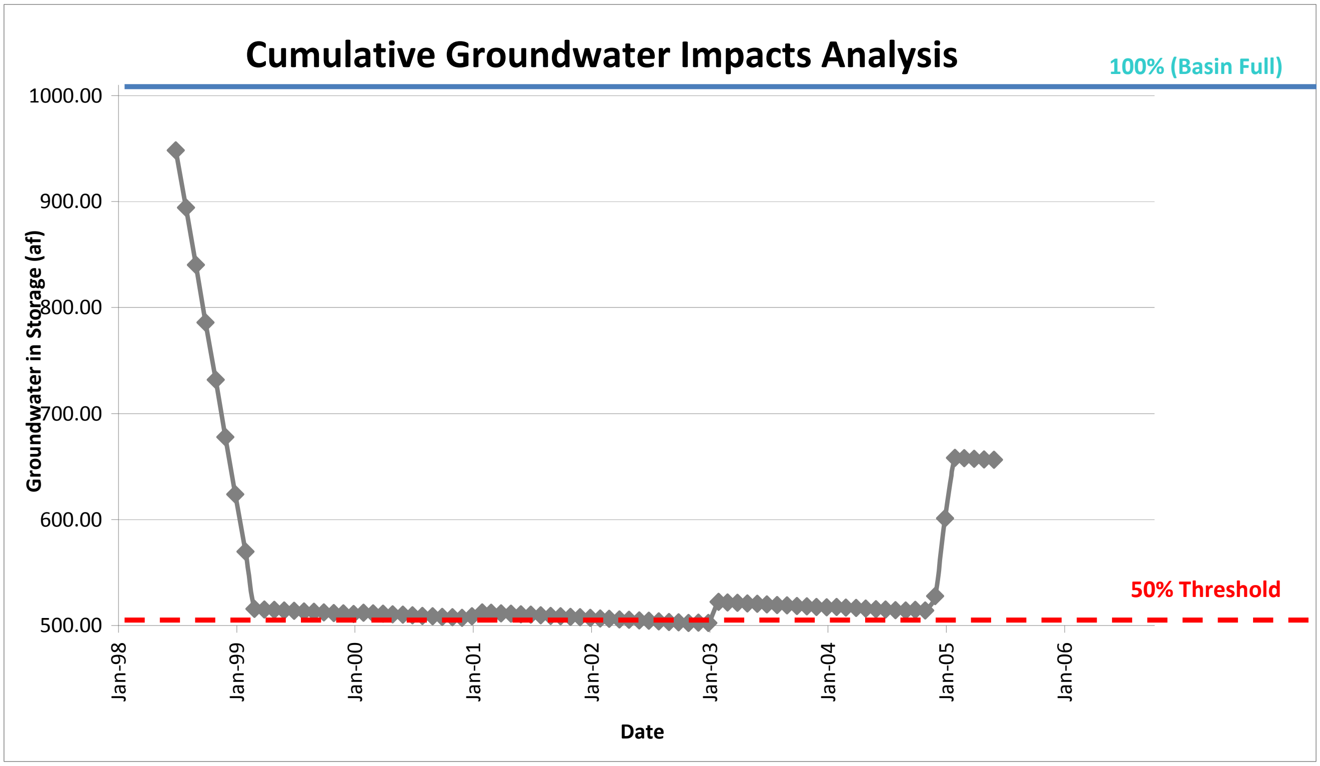


Table 4
Groundwater in Storage Calculation - Effects of Pumping at 400 GPM
Rough Acres Ranch Water Production Area

Hydrogeologic Unit	Area (acres)	Specific Yield (%)	Saturated Thickness (ft)	GW in Storage (af)
Fractured Rock	502	0.10%	500	251
Residuum	502	5%	10	251
Alluvium	250	10%	20	500
Total				**1002**

Change in Groundwater in Storage (400 gpm)



Geo-Logic ASSOCIATES
Geologists, Hydrogeologists and Engineers

MEMORANDUM

TO: Patrick O'Neill, HDR

FROM: Sarah J. Battelle, Geo-Logic Associates

DATE: February 28, 2011

SUBJECT: **MODIFIED CONSTRUCTION WATER SUPPLY EVALUATION**
TULE WIND PROJECT
EAST SAN DIEGO COUNTY, CALIFORNIA

At your request, this memorandum is being provided to supplement the Tule Wind Farm Groundwater Investigation Report (Geo-Logic, 2010), and to address the change in anticipated water needs for the Tule Wind Project construction based on recent revisions to the project description, which reduces the number of wind turbines from 134 to 128.

1. Water Capacity Analysis in Groundwater Investigation Report

The conclusions reached in the Groundwater Investigation (Geo-Logic 2010) remain valid. The groundwater investigation revealed that the combined groundwater resources on Tribal land and Rough Acres Ranch are sufficient to accommodate the maximum anticipated pumping rate of 130 gallons per minute (gpm) during the construction of the Tule Wind Project.

2. Water Supply Analysis

The purpose of our groundwater investigation was to evaluate the available groundwater resources in the area to support project construction based on initial gross water supply needs for various construction elements associated with a 134 wind turbine project as provided by Iberdrola Renewables, Inc. (IRI). The Groundwater Investigation Report assumed the total volume of extracted groundwater to support the construction of the 134-turbine Tule Wind Project conservatively could be approximately 65 to 125 acre-feet (approximately 21 to 41 million gallons). This analysis utilized a conservative estimate of the anticipated total volume of extracted groundwater to assess whether groundwater resources had sufficient capacity to support the maximum total required project water demand over the estimated nine (9) month construction period. The report concluded that there was sufficient groundwater to support the project water needs (Geo-Logic, 2010).

However, following additional discussions with project members, subsequent to the release of the Groundwater Investigation Report, as described below, the Tule Wind Project's anticipated construction water supply demand is significantly less than that estimated in the Groundwater Investigation Report, and in line with the 17.5 million gallon estimate included in the Draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS).

2.1. Calculating the Tule Wind Project's Water Supply Demand

Based on information provided by IRI (2010) the estimated water demand has been refined. Table A (below) summarizes the project construction activities that require water (IRI, 2010). The table provides estimated water use totals for the original 134 wind turbine project, and the more recently proposed 128 wind turbine project, during the construction period. Analysis of groundwater resources in the area available for construction activity is provided in the Groundwater Investigation Report (Geo-Logic, 2010).

As provided by IRI, construction activities include turbine foundation construction, new and modified access road construction, and associated dust suppression. The construction period for these activities is anticipated to be approximately nine (9) months in length. Table A identifies the estimated water demand based on IRI's construction experience. In addition, the water demand estimates provided in the table include filling four (4) 10,000 gallon water tanks one time for fire suppression. The San Diego Rural Fire Protection District will be responsible for maintaining water tank levels for the life of the Project.

2.2. Project Construction Activities – Estimated Water Demand

1. ***Road Construction*** – Up to 120,000 gallons per day (gpd) will be required over an approximate 72-day construction period, or approximately 8,640,000 gallons of water for road construction. This amount is not anticipated to change for the 128 turbine project.

2. ***Turbine Foundation Concrete Mixing*** – Turbine foundation construction is estimated to require 7,500 to 15,000 gallons of water per foundation, depending on the size of the wind turbine selected (larger turbines require more water for their foundations). Assuming construction of two foundations per day, water demand will be approximately 15,000 to 30,000 gpd. However, if larger turbines are used (such as a 3.0 MW turbine), then less turbines would be built to create a 201 MW project. For purposes of estimating total water demand for this construction activity, 15,000 gpd (67 days for 134 turbine foundations), or approximately 1,005,000 gallons is estimated for turbine foundation concrete mixing. This amount would decrease slightly by approximately 45,000 gallons (6 turbines x 7,500 gallons per foundation) for the 128 turbine project.

3. ***Dust Suppression During Turbine Foundation Construction*** **–** Dust suppression activities during turbine foundation construction is estimated to require 100,000 gpd for a maximum of 67 days for 134 turbines, or approximately 6,700,000 gallons. This amount would decrease slightly by approximately 300,000 gallons (2 foundations per day, 6 less foundations x 100,000 gpd) for the 128 turbine project.

4. ***Dust Suppression During Turbine Erection*** – An estimated sixty (60) days for turbine erection will be required. During this period of turbine erection, approximately 50,000 gpd will be required for dust control on project roads, or approximately 3,000,000 gallons. This amount would decrease slightly by approximately 100,000 gallons (2-3 turbines erected per day x 50,000 gpd).

5. ***Fire Protection (Four 10,000 gallon tanks)*** – 40,000 gallons total, which constitutes a one-time filling of all four (4) 10,000 gallon tanks. There would be no change in this water supply estimate under either the 134 or 128 turbine project.

Table A (below) summarizes the anticipated water demand for the 134 and 128 wind turbine projects.

Table A
Estimated Project Construction Water Supply
for 134 Wind Turbines versus 128 Wind Turbines

134 Turbines	Daily rate (gpd)	Days	Gallons	128 Turbines	Daily rate (gpd)	Days	Gallons
Road construction	120,000	72	8,640,000	Road construction	120,000	72	8,640,000
Turbine Foundations	15,000	67	1,005,000	Turbine Foundations	15,000	64	960,000
Dust Suppression During Foundation Construction	100,000	67	6,700,000	Dust Suppression During Foundation Construction	100,000	64	6,400,000
Dust Suppression During Turbine Erection	50,000	60	3,000,000	Dust Suppression During Turbine Erection	50,000	58	2,900,000
Fire Protection - 4 tanks		1	40,000	Fire Protection - 4 tanks		1	40,000
		Total (gals)	**19,385,000**			**Total (gals)**	**18,940,000**
		Total (acre-feet)	**59.5**			**Total (acre-feet)**	**58.0**

2.3. Analysis of Construction Water Demand Reduction with 128 Turbine Project
As presented in the table above, a reduction of six turbines will reduce construction water demand during turbine foundation construction by approximately 45,000 gallons (at 7,500 gallons per turbine foundation), dust suppression during foundation construction by approximately 300,000 gallons (3 days at 100,000 gpd), and dust suppression during turbine erection by approximately 100,000 gallons (2 days at 50,000 gpd), for a total reduction of approximately 445,000 gallons (approximately 1.4 acre-feet).

The Draft EIR estimates that the construction of the Tule Wind Project would require approximately 17.5 million gallons of water (approximately 53.7 acre-feet). (Draft EIR/EIS, 2010). The modified 128 turbine project would exceed this estimate by approximately 8%, or 1,440,000 gallons (approximately 4.4 acre-feet).

The Groundwater Investigation Report conservatively assumed that construction water supply required would be 65 to 125 acre-feet and concluded that there would be a sufficient water supply available to serve this demand. Based on the revised analysis presented above, the identified groundwater supply will be sufficient to serve either the 134 or 128 turbine projects.

3. Operations

Future operational needs for the project associated with the turbine operations and maintenance (O&M) have been estimated at 2,500 gallons per day, equivalent to about two (2) gallons per minute supplied by a well to be drilled in the vicinity of the O&M building. No change in water demand associated with operation of the wind project is anticipated due to the reduction of six wind turbines.

4. Conclusion

Based on the assumptions used for the project water needs, as provided by IRI (2010) and presented herein, when comparing the 134 turbine project (analyzed in the Draft EIR/EIS) to the 128 turbine project, the reduction in wind turbines will result in an estimated reduction of approximately 445,000 gallons. The existing analysis included in our Groundwater Investigation Report dated December 2010, which evaluated a more conservative, higher water demand, supplemented by the analysis herein associated with a lesser demand and smaller impact to the local groundwater resource, demonstrates that there is a sufficient water supply available to serve the 128 turbine project. Accordingly, the conclusions reached in the Groundwater Investigation (Geo-Logic 2010) remain valid, as supplemented by the information and analysis provided herein. If you have any questions, please call me at (858) 451-1136.

Attachment D – Comments on the Kamperman and James Paper: "How to" Guide to Siting Wind Turbines to Prevent Health Risks from Sound

Exhibit 22

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Comments on the Kamperman and James Paper: "How to" Guide to Siting Wind Turbines to Prevent Health Risks from Sound

Comments by Geoff Leventhall.

1. This document by Kamperman and James (K&J), entitled "The "How to" Guide to Siting Wind Turbines to Prevent Health Risks from Sound," places undue emphasis on infrasound and low frequency noise[1] and too much reliance on the usefulness of the C - A difference which, as will be shown below, is not a good or reliable predictor of annoyance due to low frequency sound, although it has uses as an indicator.

UNDUE EMPHASIS ON LOW FREQUENCY NOISE

2. Much of K&J's paper is based on their Fig 1, which appears to use a maximum wind turbine sound from a large 2.5MW turbine at a setback of 305m and a lowest L90 background level from a rural location.

3. The 10% threshold in their Fig 1, labelled "Threshold ISO 226 Young 10%" is not a standardised level. It is the approximate level, about 7 or 8dB lower than the standard threshold, for which 10% of the test population were more sensitive. However, the test population for threshold investigations is routinely composed of young adults, otologically selected for normal hearing. Other work has shown that, in the low frequency region up to 200Hz, an unselected middle aged population is about 7dB less sensitive than the young adults at the average threshold and about 3dB less sensitive at the 10% threshold level. (N S G, 1999; van den Berg and Passchier-Vermeer, 1999) This is clearly a fuzzy area and it would be preferable to work with the standard threshold and make any allowances later.

[1] A word search shows 68 occurrences of "low frequency" in the paper.

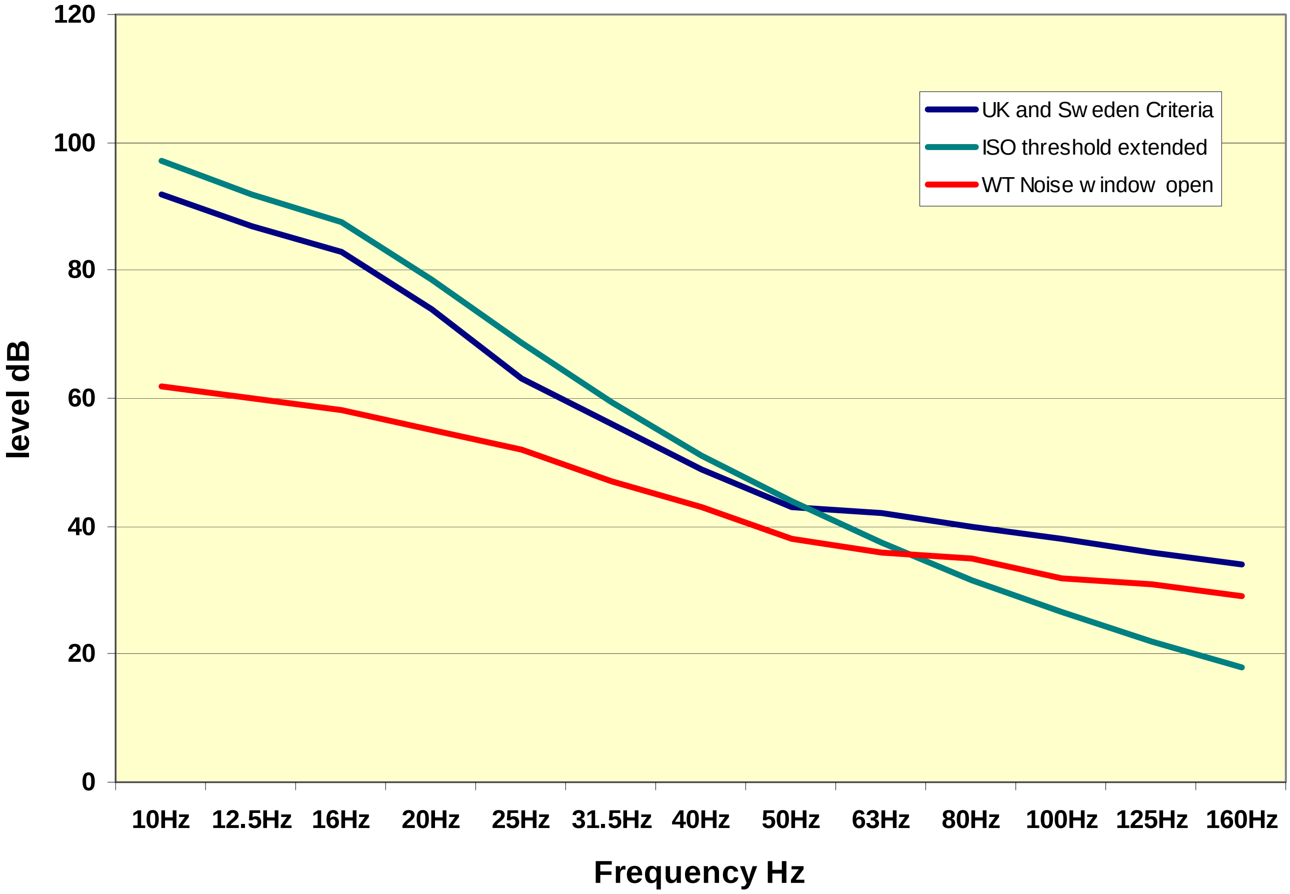

Fig 1. Comparison of WT internal spectrum – window open, with ISO 226 threshold and the UK/Sweden criterion for LF noise. (One 2.5MW wind turbine at 305m)

4. Consider K&J's references to low frequency noise. On page 2 they claim "We also cite standard international criteria for community noise levels and allowances for low frequency noise." This implies that they quote international standards for low frequency noise, but it is difficult to find these allowances for low frequencies in their paper. Only their own suggestions are given. However, if they had gone directly to criteria for low frequency noise (Moorhouse et al., 2004), they would have obtained a comparison as in our Fig 1. Our Fig 1 shows the hearing threshold from ISO 226 (the international standard equal loudness contour), extended to low frequencies, the UK and Swedish criterion for low frequency noise limits and the internal sound with window open, taken from their Fig 3, which is for a single 2.5MW turbine at 305m. It is clear that the wind turbine levels are below the well established and tested Swedish and UK criteria.[2] (Socialstyrelsen-Sweden, 2006) The levels are also below the average hearing threshold at frequencies below 63Hz. Of course, the internal sound with windows closed is even lower. Thus, this

[2] The UK criterion is developed from the Swedish one, extending the range to both lower and higher frequencies.

2.5MW wind turbine meets accepted low frequency noise limits at the 305m (1000ft) setback.

5. On page 4 K&J criticize developers because “There is no disclosure of the considerable low frequency content of the WT sound.” And on page 5 they discuss “sounds which contain a strong low frequency component, which is typical of wind turbines…" But wind turbines do not radiate strong low frequency sound. Where is the basis for this? Perhaps they are referring to their Fig 2, about which they write (page 9) “Note the dominance of sound energy in the lower frequency range.” K&J’s Fig 2 is reproduced here as our Fig 2. The spectrum depicted is a linear measurement, which means that all frequencies are equally weighted and there is no attenuation of low frequencies in the measurement. The red diagonal line has been added to show the approximate hearing threshold. The so called “dominant” low frequency sound energy is below hearing threshold. Indeed the infrasound levels of 50 to 60dB are so common in the environment that they may not even be from the wind turbine.

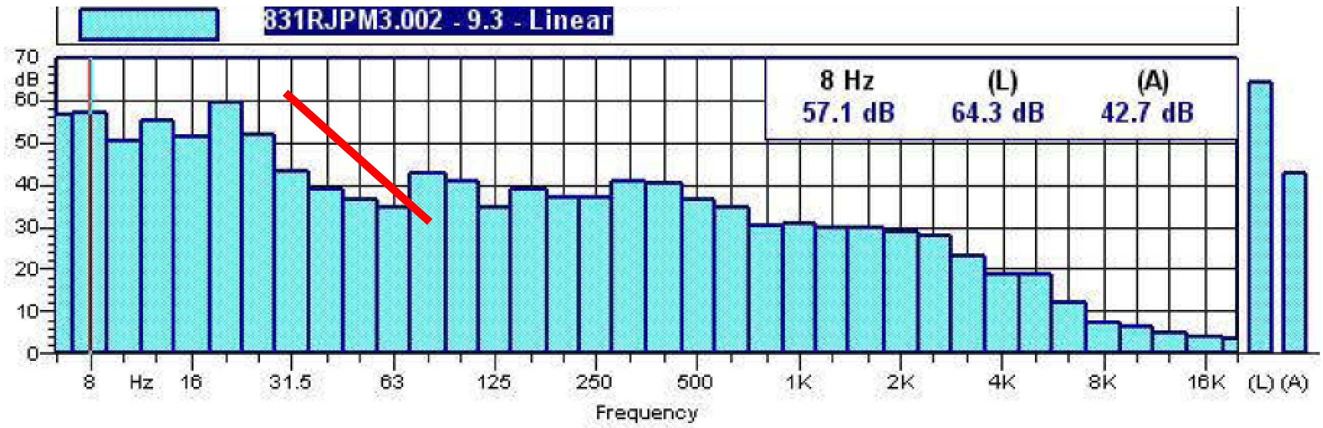

Fig 2. K&J spectrum – their Fig 2. The red line is the approximate hearing threshold

Above the hearing threshold – that part of the sound with which we interact – the level in Fig 2 is fairly uniform. There is simply no dominance of low frequency noise.[3]

6. K&J’s proposed solution to this “problem” of “dominant” low frequency noise is to use both the C-weighted and A-weighted spectra for analyzing wind turbine noise. On page 15, after considering use of C-weighting in addition to A-weighting, they make the

[3] Kamperman and James treatment of Fig 2 is so puzzling as to lead me to wonder whether they may have come to this work with the initial mindset that low frequency noise from wind turbines was a big problem, which it is not.

surprising statement: "Use of multiple metrics will address the audible and inaudible low frequency portions of wind turbine sound". Why is it necessary to address inaudible sound? [4]

7. K&J refer periodically to the World Health Organisation report on Community Noise. It is worth looking in more detail at what the WHO does say about low frequency noise sources.

> Various industrial sources emit continuous low-frequency noise (compressors, pumps, diesel engines, fans, public works); and large aircraft, heavy-duty vehicles and railway traffic produce intermittent low-frequency noise. Low-frequency noise may also produce vibrations and rattles as secondary effects. (WHO Community Noise - Section 3.9)

The sources described in this excerpt produce tonal components (separate frequencies) and are typical environmental low frequency noise sources. It is possible that the WHO experts had tonal sources in mind when writing this section, as many of the environmental low frequency problems are tonal. The WHO does not include wind turbines as a low frequency noise source.

8. On Page 11 K&J write "With just one turbine at 1000 ft there is a significant amount of low frequency noise above hearing threshold. . ."[5] This reference to low frequency noise exposes another facet of their thinking. They are working on the assumption that any audible low frequency noise is a problem noise. This is not so. Work with low frequencies has shown that an audible low frequency tonal noise does not normally become objectionable until it is 10-15dB above hearing threshold. (Inukai et al., 2000; Yamada, 1980) An exception is when a listener has developed hostility to the noise source, so that annoyance commences at a lower level. Much of the work of the prominent objectors to wind turbines has been directed towards developing such hostility in residents, deliberately fostering their fears, and possibly causing them harm by this.

9. On page 14 K&J write "The simple fact that so many residents complain of low frequency noise from wind turbines…" And on page 9 "Affected residents complain of the

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[4] This tends to support the "mindset" suspicion.

[5] There is some uncertainty in comparing a third octave noise level with a tonal threshold, as in their Fig 1, although it is often done. This is because the level of a band of noise depends on its bandwidth. For example, if the measurements had been made in a one twelfth octave band, instead of one-third octave, they would have all been 6dB lower, except for any band which contained a prominent tone.

middle to high frequency repetitive swooshing sounds of the rotating turbine blades at a constant rate of about 1Hz, plus low frequency noise." However, the main complaints are not from low frequency noise, but from the periodic "swoosh – swish," if this should occur.[6] Residents have been told that this is low frequency noise, and even, by Nina Pierpont,[7] that it is infrasound. (Leventhall, 2006) It is neither low frequency nor infrasound, but a modulation of aerodynamic noise, typically in the region of 500Hz to 1000Hz, which is catered for by the dBA. K&J's statement reproduced at the beginning of this paragraph is "media speak" not science. They have already given their opinion that swish sounds are the main problem. This marks an unfortunate lack of clarity on the part of K&J about what the true nature of the problem might be.

10. K&J are aware of the uncertainty in residents' descriptions. On page 6 they write: "The residents who are annoyed by wind turbine noise complain of the repetitive, approximately once-per-second (1 Hz) "swoosh-boom-swoosh-boom" sound of the turbine blades and of "low frequency" noise. It is not clear to us whether the complaints about "low frequency" noise are about the audible low frequency part of the "swoosh boom" sound, the once-per-second amplitude modulation (amplitude modulation means that the sound varies in loudness and other characteristics in a rhythmic pattern) of the "swoosh-boom" sound, or some combination of the two." Here they express their own doubts about what is actually the source of complaint, but continue to focus on low frequency noise (and infrasound) throughout their paper

11. On page 12, in Fig 5, K&J show a plot of the swoosh sounds and then say, in reference to this, "It also demonstrates the primary reason why relying on dBA alone will not work for community noise criteria." This is a surprising statement to be linked with swoosh sounds, since the plot they refer to, as demonstrating these effects, is entirely A-weighted, showing that A-weighting is adequate to show the swoosh sounds.

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[6] Work in the UK has shown that only four out of 130 wind farms had this problem. (Moorhouse, A., Hayes, M., Hunerbein, v., Piper, B., and Adams, M. (2007): Research into aerodynamic modulation of wind turbine noise. *Report: Department of Business Enterprise and Regulatory Reform www.berr.gov.uk/files/file40570.pdf*.

[7] Pierpont. Advert in Malone Telegram February 26 2005. "Wind turbines and infrasound: what the latest research says." Pierpont is, of course, completely mistaken in her interpretation of this research.

12. In conclusion, there is little low frequency noise in the “swoosh-boom” aerodynamic modulation, which is typically in the 500Hz to 1000Hz range. Low frequency noise from wind turbines is not normally a problem, but may increase to problem level under unusual conditions, for example, for high wind speeds which might bring highly turbulent inflow air. K&J’s focus on infrasound and low frequency sound is unfounded, as modern turbines do not typically produce either at problematic levels.

UNDUE EMPHASIS ON DIFFERENCE BETWEEN C- AND A-WEIGHTING

13. K&J propose including a C-A difference in the criteria for wind turbine noise, specifically to take account of low frequency noise. As has been shown above, low frequency noise is not normally a problem, but in any case, the C-A difference is not sufficiently established and tested to be safe to use as a criterion.

14. For example, on page 15 K&J say, “The World Health Organisation and others have determined that if a noise has a measured difference between dBC and dBA more than 20dB, the noise is highly likely to create an annoyance because of the low frequency content.” What the World Health Organisation actually says, in Section 4.3 of Community Noise, is:

> “…the difference between dB(C) and dB(A) will give crude information about the presence of low frequency components in the noise, but if the difference is more than 10dB it is recommended to that a low frequency analysis of the noise be performed.” (Berglund et al., 2000)

The WHO does not make any reference to 20dB. I am very familiar with the C - A difference. A colleague and I may have been the first to propose this as a quick, initial look at the issue of low frequency noise. (Broner and Leventhall, 1983b) When I first read the section from the WHO report quoted above, my reaction was that 10dB was probably a typing error. I based this on the fact that if you measure the C-A difference in any quiet location, the difference is invariably greater than 10dB, whilst fluctuating differences between 20 and 30dB are not uncommon. However, I did not follow up the 10dB difference until I found statements in self-published Internet articles containing gross misrepresentations like

> “A difference of 10 dB between A and C weighting represents a significant amount of low-frequency sound by World Health Organization standards.” (Nina Pierpont - Health Effects of Wind Turbine Noise)

I then took this up with Birgitta Berglund, the primary author of the WHO Guide, receiving the response that the WHO does not make any recommendations for C-A difference but, as a precautionary measure, suggests taking a closer look if the difference is greater than 10dB.

15. As I write this, I am in a very quiet office in a suburban area, periodically pausing to look at a sound level meter, which is displaying the running C-A difference every second. The average level is about 27dBA and C-A differences are fluctuating from 18 to 28dB. When I type, the A-weighting rises to around 50dBA and the difference drops to 6 to 8dB, due to the increased A-weighted level from the keyboard noise. There is most definitely not a low frequency noise problem, even though the C-A difference is greater than 20dB.

16. I believe it likely that the C-A difference for a noise to be annoying depends on the level of the noise in addition to the difference. The C-A difference for a noise of fixed spectrum does not change with overall level. This means that a given frequency spectrum which is almost inaudible will have the same C-A difference as the same spectrum when it is uncomfortably loud. There is clearly a problem in using the C-A difference, when what we really wish to know is the effect of the noise on loudness or annoyance.

As shown in the Appendix, the subjective effect associated with a particular C-A difference depends on the overall sound level in addition to the difference, and high differences at low levels are not a problem. This confirms the experience described in paragraph 15.

A limiting level of C-A = 20dB is too small for a criterion difference at low sound levels, such as those from wind turbines in homes. The C-A difference has not been used successfully as a criterion and should remain as an indicator.

17. There are other reasons why it is not safe to use the C-A difference as a criterion, rather than just as an indication for further investigation.

It has been shown by Blazier that, for sounds in office buildings, a negative slope of 5dB/octave from high to low frequencies is a bland, unobtrusive and characterless sound.

(Blazier, 1997)   A 5dB/octave falling spectrum slope has a C-A difference of 19dB, close to the limit which K&J suggest, but it is clearly not a problem sound.

Work which has been done on evaluation of the C-A difference with more than 700 persons, showed that inclusion of C-A in the annoyance estimate detected only 2.4% more of the people annoyed. (Kjellberg et al., 1997)

18. For the reasons above, it is clear that the C-A difference is not sufficiently robust or reliable to use as a component of a criterion. It should remain simply as an indicator for further investigations, which is what previous authors have suggested.

19. K&J have presented an unsatisfactory account of low frequency noise from wind turbines, whilst their proposal to use a C-A difference as a component of a criterion is not valid.

20. Beginning on page 21, K&J suggest a model ordinance relating to siting based on their findings on sound. We have the following criticisms of that model ordinance relating to the points made above.

Immission spectra imbalance (K&J page 23) It has been shown above that K&J's   C-A limit of 20dB is not valid. Therefore any ordinance which includes this as a compliance test is also not valid.

Infrasound (K&J page 23) It is now recognised that there is negligible infrasound from modern wind turbines (Jakobsen, 2004; van den Berg, 2004), whilst it is also recognised that the ear is the most sensitive body receptor of infrasound (Møller and Pedersen, 2004). For two experienced consultants to say that "perception is not limited to stimulation of the auditory senses," when referring to the low level infrasound from wind turbines, is disappointingly misleading, and an indication that they need to make further study of infrasound.

Sound from modern wind turbines is unlikely to cause rattles in buildings, although some of the earlier downwind ones did. The most recent work on criteria for onset of rattle is from Japan (where many domestic buildings are of lightweight construction), and are as follows. (Japan, 2006)

Freq Hz	5	6.3	8	10	12.5	16	20	25	31.5	40	50
Level dB	70	71	72	73	75	77	80	83	87	93	99

The Table shows that all rattle onset levels, due to building vibration, are higher than the sound levels from a 2.5MW wind turbine at 305m, as reflected in K&J's Fig 1.

The suggestion (K&J page 23) that infrasound may cause resonance in cavities in the human body is not supported by evidence. Infrasound wavelengths, 34m at 10Hz, are too long to resonate in body cavities.

Low Frequency Noise (K&J page 23) As shown earlier, the C-A limit of 20dB is unsafe to use in a criterion.

21. Final conclusions. Kamperman and James have

- failed to show that there is a general problem from infrasound and low frequency noise from wind turbines, requiring control criteria.
- failed to show that a C-A difference of less than 20dB would be an appropriate criterion limit at the low levels of wind turbine noise.
- failed to give any indication of what proportion of residents they believe to be adversely affected.

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Appendix

On the significance of the C – A difference for assessment of potential problems from low frequency noise.

A1. There is a well known proposal that, if the C-A difference in a noise measurement exceeds 20dB, then there may be a problem from environmental low frequency noise. (Broner and Leventhall, 1983a) (DIN:45680, 1997) Many of the environmental low frequency noise problems which have caused complaint contain tonal components, such as from diesel engines, compressors, fans and general industrial sources. The WHO report Community Noise (Berglund et al., 2000) lists low frequency noise sources as

> Various industrial sources emit continuous low-frequency noise (compressors, pumps, diesel engines, fans, public works); and large aircraft, heavy-duty vehicles and railway traffic produce intermittent low-frequency noise.
> (WHO Community Noise - Section 3.9)

These are all tonal sources, with the exception of large aircraft, which emit a band of noise with a centre frequency depending on the engine outlet size and jet velocity, but which might typically be around 100Hz.

A2. The C-A difference has not been investigated for either spectrum content or A-weighted level. A given spectrum shape will have the same C-A difference, irrespective of its overall level, but relying on this ignores non-linearity in the hearing contours, particularly at lower frequencies.

A3. As an indication of how the C-A difference changes with spectrum, consider the value of this difference for specific continuous spectra, which fall in level as the frequency increases. The spectra considered are:

- Level with frequency
- Falling at 3dB/octave

- Falling at 6dB/octave
- Falling at 9dB/octave

The spectra are shown in Fig 1A, where they commence at 10Hz 100dB and fall off into higher frequencies. There are 10 octaves between 10Hz and 10,000Hz

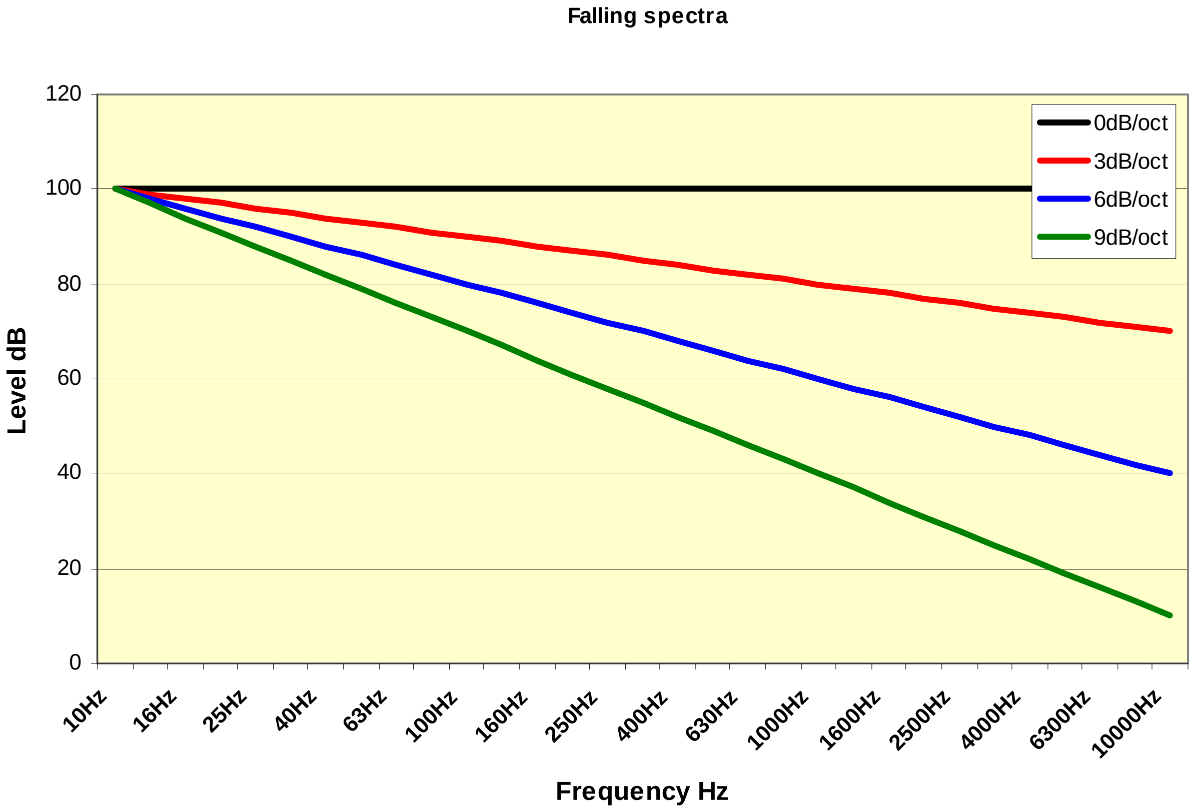

Fig 1A. Spectra with different rates of fall into high frequencies

The rates of fall and the calculated C-A differences are in Table 1:

Spectrum	1	2	3	4
Fall dB/oct	0	3	6	9
C-A difference	2	12	23	32

Table 1A Rate of spectral fall and C-A difference

Thus, a fall of 6dB/octave has a C-A difference of 23dB and, according to the 20dB criterion, is in a potential problem area, whilst a fall of 9dB/octave, with 32dB difference, might be a severe problem. Table 1A is independent of the actual level of the noise, since the same weightings are applied at all levels.

A4. Fig 2A shows the 9dB/octave falling spectrum plotted at different levels on the equal loudness contours. The top line, which passes through 60dB at 1000Hz is at 81dBA, which is contributed to mainly by the levels in the 125Hz region. The middle line is at 61dBA and the bottom line at 41dBA

The C-A difference necessary for a noise to become annoying depends on the level of the noise, in addition to the difference. The C-A difference for a noise of fixed spectrum does not change with overall level, whilst what we really wish to know is the effect of the noise on loudness or annoyance.

Consider the equal loudness contours. (Fig 2A). The equal loudness contours are in phons (the unit of loudness), where a contour line gives the levels at different frequencies which experiments have shown to have equal loudness to a 1000Hz tone on that contour line. For example, for the 30dB contour line, a tone of 125Hz at about 53dB has equal loudness with a 1000Hz tone of 30dB.

Fig 2A also shows the 9dB/octave falling spectrum plotted at different levels on the equal loudness contours. The top line, which passes through 60dB at 1000Hz, is at 81dBA. The middle line is at 61dBA and the bottom line at 41dBA. The A-weighted levels are contributed to mainly by the levels in the 125Hz region.

Although the C-A difference is the same for each line, if the line is at higher levels on the contours, it gradually intercepts relatively higher contours at the low frequencies. For example, a 9dB/octave slope, which has a very high C-A difference of 32dB, has the following properties.

Intersection with equal loudness contours at 1kHz i.e. Phon level at 1kHz	20dB	40dB	60dB
Highest contour reached	26phon	50phon	78phon
Approx frequency at highest contour intersection	315Hz	125Hz	63Hz
A-weighted level	41dBA	61dBA	81dBA

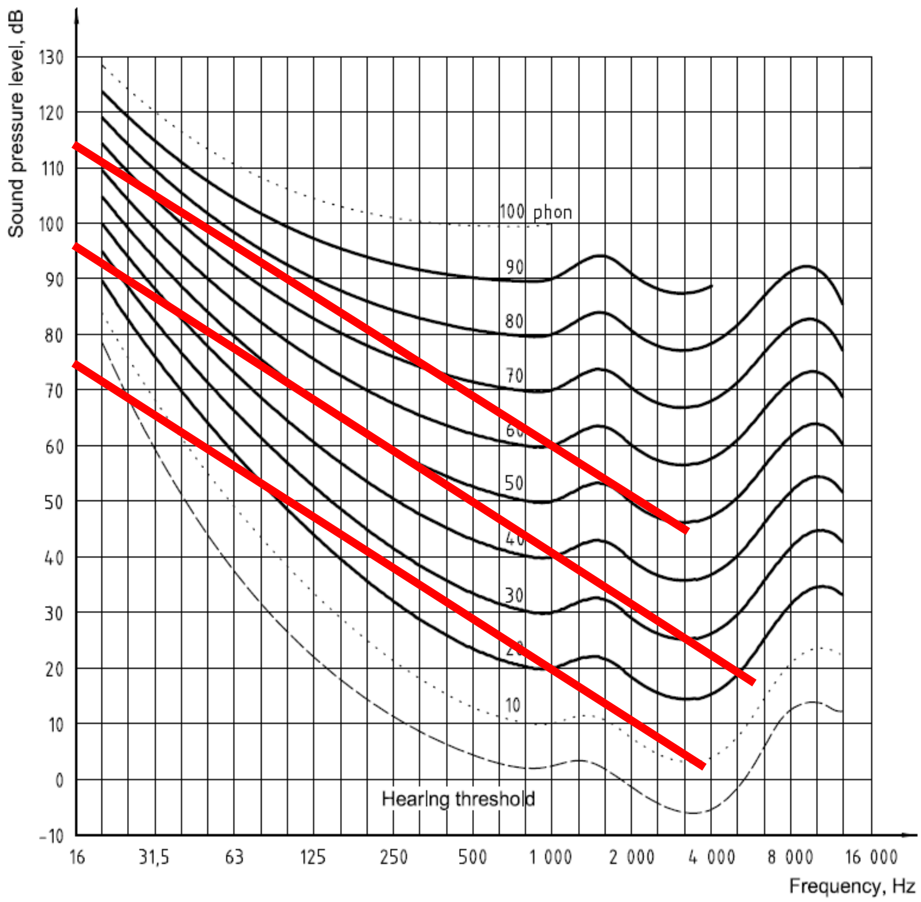

Fig 2A. Lines of approx 9dB/octave slope on the equal loudness contours

This shows that even for a high slope spectrum, which has a very large C-A difference of 32dB, the level of 41dBA does not rise above the 26phon contour and is not expected to be intrusive or objectionable. At higher levels such as 81dBA, the 78 phon contour is reached. Although the line has stepped up by only 40dB at 1000Hz, the highest phon contour reached is 78 phon, an increase of 52 phon. Additionally, the frequency at which the maximum phon contour is intercepted, reduces for the higher levels, as in the Table above.

A limiting level of C-A = 20dB is too small for a criterion difference at low sound levels, such as those from wind turbines in homes.

25 August 2009

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